ISPEC 17th INTERNATIONAL CONFERENCE ON AGRICULTURE, ANIMAL SCIENCE & RURAL DEVELOPMENT

April 25-27, 2025 / Kırşehir, Türkiye

CONFERENCE PROCEEDINGS BOOK

EDITORS

Prof. Dr. Selahattin ÇINAR

Assoc. Prof. Dr. Seyithan SEYDOŞOĞLU

ISPEC 17th INTERNATIONAL CONFERENCE ON AGRICULTURE, ANIMAL SCIENCE & RURAL DEVELOPMENT

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PROCEEDINGS BOOK
(Abstracts & Full Texts)

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EVALUATION PROCESS and POLICIES

All applications have undergone double blind peer review process. In addition, each paper was accepted and the process of publishing in the book was carried out through editorial oversight. The published papers were presented and discussed at the meeting.

Full texts and abstracts published in accordance with the Symposium Policy have been prepared in accordance with ethical rules and APA standards. Authors of all papers are both ethically and legally responsible.

PARTICIPANTS COUNTRIES

Türkiye, Algeria, Azerbaijan, Croatia, Hungarian, India, Indonesia, Iran, Iraq, Kazakhstan, Kenya, Kyrgyzstan, Morocco, Nigeria, Pakistan, Romania, Uzbekistan,

TOTAL ACCEPTED ARTICLES: 204

The Number of Accepted Papers from Türkiye: 192
The Number of Accepted Full Papers from Other Countries: 222
The Number of Total Papers: 414

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April 25 - 27, 2025

Kırşehir, TÜRKİYE

SYMPOSIUM SCHEDULE

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Face-to-face and Online

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FACE TO FACE SESSION / 25.04.2025	
HALL-1 / SESSION-1	Ahi Evran Kongre ve Kültür Merkezi
Ankara Time: 10:30-11:50	

HEAD OF SESSION: Prof. Dr. Sabri GÖKMEN

Authors	Affiliation	Presentation title
Rüştü HATİPOĞLU	*Kırşehir Ahi Evran University*	Growing genetically modified crops in the world and Türkiye
Metin TÜRKER Selma Nur TÜRKER AYDIN	*Ministry Of Agriculture and Forestry*	Historical development of land consolidation inheritance management and land banking practices in Türkiye
Selma Nur TÜRKER AYDIN Metin TÜRKER	*Ministry Of Agriculture and Forestry*	The effects of climate change on water and food crisis and measures to be taken
Selahattin ÇINAR	*Kırşehir Ahi Evran University*	Plant production planning and support in Türkiye
Bekir ENGÜRÜLÜ Oktay Nazmi ALKAN Mustafa KOPARAN Sevda YAZICI Hasan Cumhur SARISU	*Agricultural Insurance Pool Operation General Directorate Inc.*	The importance of agricultural insurance in climate change
Veysel GÜL Abdullah BEYAZ	*Kırşehir Ahi Evran Üniversitesi*	The strategic role of precision agricultural practices in climate change and their contribution to sustainable agricultural production

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

FACE TO FACE SESSION / 25.04.2025	
HALL-2 / SESSION-1	**Ahi Evran Kongre ve Kültür Merkezi**
	Ankara Time: 10:30-12:30

HEAD OF SESSION: Prof. Dr. Yaşar KARADAĞ

Authors	Affiliation	Presentation title
Melek KURT Rüştü HATİPOĞLU	*Kırşehir Ahi Evran University*	Effects of climate change on vegetation of grasslands
Mehmet ÖTEN Melike KÖSE Semih TOKAT	*Sakarya University of Applied Sciences*	Determination of allelopathic effects of sorghum (*Sorghum bicolor* L.) extract on common vetch (*Vicia sativa* L.)
Hasan Beytullah DÖNMEZ	*Çukurova University*	The effect of different salt concentrations on germination and seedling growth of perennial forage grasses
Osman YÜKSEL Hüseyin PALAZ	*Uşak University*	A study on determining some morphological and agricultural characteristics of scented grass (*Chrysopogon gryllus* (L.) Trin.)
Mustafa YILMAZ Mehmet ÖTEN Rahime CENGİZ Ferzat TURAN Melike KÖSE	*Sakarya University of Applied Sciences*	Determination of quality characteristics of corn (*Zea mays* L.) silage with different additives
Fazlı COŞKUN Yaşar KARADAĞ	*Necmettin Erbakan University*	Determination of weed and quality characteristics of some sorghum genotypes in Muş ecological conditions
Rahime CENGİZ Zehra YILDIZ	*Sakarya University of Applied Sciences*	Plant extraction methods: traditional and innovative techniques
Mustafa Alper SAVAŞ Selahattin ÇINAR	*Kırşehir Ahi Evran University*	Forage crop breeding studies in Turkey
Zahide Gül GÜRKAN Erdem GÜLÜMSER Uğur BAŞARAN	*Bilecik Şeyh Edebali University*	The effect of forage turnip leaf extracts on germination and seedling development of forage cowpea
Uğur BAŞARAN Erdem GÜLÜMSER	*Bilecik Şeyh Edebali University*	Reduction of greenhouse gas emissions in field crops production systems

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FACE TO FACE SESSION / 25.04.2025

HALL-3 / SESSION-1 Ahi Evran Kongre ve Kültür Merkezi

Ankara Time: 10:30-12:30

HEAD OF SESSION: Prof. Dr. İsa TELCİ

Authors	Affiliation	Presentation title
İsa TELCİ Erman BEYZİ Biyolog YALÇIN Erdal KAYA Mustafa ER Ahu ALTINKUT UNCUOĞLU	*Isparta University of Applied Sciences*	Investigation of the yield and essential oil properties of menthol mint grown in different ecologies
Nimet KATAR Emine BİLGİNOĞLU Rabia GÜNDÜZ Duran KATAR	*Kırşehir Ahi Evran University*	Effects of different nitrogen doses on yield and quality characteristics of sage (*Salvia officinalis* L.) under the ecological conditions of Eskişehir
Nimet KATAR Emine BİLGİNOĞLU Rabia GÜNDÜZ Duran KATAR	*Kırşehir Ahi Evran University*	Effect of different nitrogen doses on yield and quality parameters of rosemary (*Rosmarinus officinalis* L.) plant in Eskişehir ecological conditions
Buşra ÖZDEMIR Sibel ULCAY Bahadır ALTUN	*Kırşehir Ahi Evran University*	A study on the investigation of morphological and anatomical characteristics of some ornamental plants geophysics distributed in Kırşehir region
Aysun ÖRÇÜN Lifer DOĞAN Ferzat TURAN	*Sakarya University of Applied Sciences*	Effect of glycine betaine priming application on germination and seedling development in safflower seeds under drought stress
Elanur DURSUN Aysun ÖRÇÜN Ferzat TURAN	*Sakarya University of Applied Sciences*	Investigation of the effects of chitosan priming on soybean (*Glycine max* L.) Seeds against salt stress
Ali ONARAN Mehmet Emin ÇALIŞKAN	*Niğde Ömer Halisdemir University*	Selection of drought tolerant potato (*Solanum tuberosum* L.) breeding lines in vitro conditions by morphological and multi-criteria analysis methods

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FACE TO FACE SESSION / 25.04.2025

HALL-4 / SESSION-1 | **Ahi Evran Kongre ve Kültür Merkezi**

Ankara Time: 10:30-12:30

HEAD OF SESSION: Prof. Dr. Yaşar ERTÜRK

Authors	Affiliation	Presentation title
Sevil SAĞLAM YILMAZ	*Kırşehir Ahi Evran University*	Problems and solution suggestions encountered in micropropagation of walnut (*Juglans regia* L.)
Sevil SAĞLAM YILMAZ	*Kırşehir Ahi Evran University*	Agrobacterium-based transformation of cry 1c and cry 1cst genes into common bean (*Phaseolus vulgaris* L.)
Funda ÖZDEMİR DEĞİRMENCİ Asiye ULUĞ Uzuk KASYMOVA	*Kırşehir Ahi Evran University*	Genetic distinction between morphologically similar hexaploid and tetraploid wheat species
Tuana AKSOY Khalid Mahmood KHAVAR	*Yozgat Bozok University*	Genome dynamics of *Cannabis sativa* L. species
Tuana AKSOY Khalid Mahmood KHAVAR	*Yozgat Bozok University*	Identification of XY and XX sex chromosomes in Cannabis sativa L.
Betül Ayça DÖNMEZ Salih KAFKAS N. Ebru KAFKAS	*Kırşehir Ahi Evran University*	Use of anther culture in haploid plants production in strawberry
Betül Ayça DÖNMEZ Salih KAFKAS N. Ebru KAFKAS	*Kırşehir Ahi Evran University*	Physiological responses of strawberry plants to drought stress
Emre ŞİRİN Mehmet KURAN	*Kırşehir Ahi Evran University*	Determination of parthenogenetic activation capacity of bovine oocytes matured in vitro in culture media using royal jelly as a protein source
Ümmü TUĞLU Hasan BAYDAR	*Isparta University of Applied Sciences*	Development of sage varieties with tetraploid genome (tetra sage) by polyploidy breeding in medicinal and anatolian sage
Can ASLAN Ayşe Gül FİLİK	*Kırşehir Ahi Evran University*	The effect of *lactobacillus brevis* (MF098783) strain on the quality and aerobic stability of wheat forage silage
Ayşe Gül FİLİK Esin KIRAY Esra ŞİŞMAN	*Kırşehir Ahi Evran University*	Effectiveness of *lactobacillus plantarum* (MF098786) as a microbial inoculant in barley straw silages
Tareq HAMIJO Ilbilge OĞUZ N. Ebru KAFKAS	*Çukurova University*	Genetic basis of volatile compound production in strawberries: insights from QTL mapping and GWAS
Mikail YENİÇERİ Sena KARAKUŞ Gökhan FİLİK	*Kırşehir Ahi Evran University*	Efficacy of microbial inoculants in improving silage quality : millet (*Panicum miliaceum* L.)
Tuba TAŞ Esin KIRAY Gökhan FİLİK	*Kırşehir Ahi Evran University*	The effect of microbial inoculants on the silage quality and stability of unshredded Italian ryegrass (*Lolium multiflorum*)

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FACE TO FACE SESSION / 25.04.2025

HALL-1 / SESSION-2 | **Ahi Evran Kongre ve Kültür Merkezi**

Ankara Time: 14:30-17:00

HEAD OF SESSION: Prof. Dr. Sultan KIYMAZ

Authors	Affiliation	Presentation title
Sultan KIYMAZ Serdar GENÇ Ebru ŞIRIN	*Kırşehir Ahi Evran University*	Determination of nitrate levels in well water: the case of Kirsehir province
Çayan ALKAN Mecit ÖZTÜRK	*Bilecik Şeyh Edebali University*	Agricultural water management planning: the case of Bilecik province
Cevat FİLİKCİ Tamer MARAKOĞLU	*Kırşehir Ahi Evran University*	Evaluation of reduced tillage practices in terms of conservation tillage technique
Ali BOLAT	*Adıyaman University*	Technical and economic comparison of spraying with unmanned aerial vehicles (UAVS) and field sprayers
Alper BOLAT Ergün ERTUĞRUL	*Türk Traktör*	The effect of combine harvester speed on grain loss during wheat harvest
Ismet Furkan GEZGIN	*Kırşehir Ahi Evran University*	Integration of artificial intelligence and agricultural machinery in plant protection technologies
Tamer YAVUZ Veysel GÜL Ömer ERTUĞRUL	*Kırşehir Ahi Evran University*	Monitoring early-stage crop emergence in oat fields using multispectral uav-based vegetation indices
Ahu Alev ABACI BAYAR	*Kırşehir Ahi Evran University*	An investigation of nutrition status in olive (*Olea europaea* L.) Gardens in Onikişubat (Kahramanmaraş) county based on soil and leaf analysis
Halil ERDEM Ibrahim SAYGILI Mazlum ERDEM	*Tokat Gaziosmanpasa University*	Heterosis effects on uptake and accumulation of zinc in barley
Fevziye Şüheda HEPŞEN TÜRKAY Murat ARSLAN	*Kırşehir Ahi Evran University*	From organic waste to fish feed: eisenia fetida biomass in biogas residue and olive mill wastewater by vermicomposting for agriculture and aquaculture nutrient integration
Mehmet OZTURK Anna CATES Lindsay PEASE	*University of Minnesota, USA*	Enhancing soil health and reducing wind erosion: cover crop strategies for sugarbeet systems in minnesota's fertile black soils

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FACE TO FACE SESSION / 25.04.2025

HALL-2 / SESSION-2 | **Ahi Evran Kongre ve Kültür Merkezi**

Ankara Time: 14:30-17:00

HEAD OF SESSION: Prof. Dr. Rüştü HATİPOĞLU

Authors	Affiliation	Presentation title
Melek GÜMÜŞBAŞ Selma BOYACI	*Kırşehir Ahi Evran University*	Rooting of different chokeberry cultivars with hardwood cuttings
Selma BOYACI	*Kırşehir Ahi Evran University*	A significant problem in apple growing: pre-harvest fruit dropping
Ebru ŞİRİN Yaşar ERTÜRK	*Kırşehir Ahi Evran University*	Soil suitability map for walnut cultivation in Kırşehir: evaluation using the AHP method based on soilgrids data
Ebru ŞİRİN Yaşar ERTÜRK	*Kırşehir Ahi Evran University*	Carbon sequestration of fruit orchards and their role in sustainable agriculture
Fadimana ÖZEL Beyza HAFÇI Yaşar ERTÜRK	*Kırşehir Ahi Evran University*	Dwarfing mechanisms in temperate fruit trees
Sebahattin YILMAZ Yaşar AKÇA	*Kırşehir Ahi Evran University*	Tips for top-working of walnut trees
Beyza HAFÇI Yaşar ERTÜRK	*Kırşehir Ahi Evran University*	Evaluations on in vitro micropropagation of walnut
Yassir Ahmed HASSAN Josephine BIRUNGI	*Animal Production Research Centre, SUDAN*	Overview on genetic variability of casein protein genes in sudanese nubian goats
Yassir Ahmed HASSAN Josephine BIRUNGI Morris AGABA	*Animal Production Research Centre, SUDAN*	Phylogenetics of goat populations in Sudan
Yassir Ahmed HASSAN Mohammed Tageldin Iibrahim	*Animal Production Research Centre, SUDAN*	Conservation modelling of biodiversity for three sudanese cattle breeds (Butana, Ariashy and Nuba)
Cemal KURT Ömer Afşin ÇIL Hatice CANKESEN	*Çukurova University*	Peanut (*Arachis hypogaea* L.) cultivation and its importance in Türkiye

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FACE TO FACE SESSION / 25.04.2025

HALL-3 / SESSION-2	Ahi Evran Kongre ve Kültür Merkezi
Ankara Time: 14:30-17:00	

HEAD OF SESSION: Prof. Dr. Mustafa KAN

Authors	Affiliation	Presentation title
Semiha ÇETINKAYA Cuma AKBAY Hasan Hüseyin AKGÜL Aynur BELVEREN	*Kahramanmaraş Sütçü İmam University*	An investigation of the current situation of forest villagers: the case of Göksun district in Kahramanmaraş province
Cuma AKBAY Yeşim AYTOP Semiha ÇETINKAYA Aynur BELVEREN	*Kahramanmaraş Sütçü İmam University*	Analysis of the structural characteristics of broiler farms in Balıkesir province
Rıza Umut GÜNGÖR Hakan KIR	*Kırşehir Ahi Evran University*	Plant production and agricultural structure in the province of Kırşehir
Ertuğrul GÜREŞCİ	*Kırşehir Ahi Evran University*	The higher organization in cooperatives in Türkiye
Hüseyin ATAŞ	*Adıyaman University*	A proposed method to measure the impact of the geographic registration mark for Kaman nuts on production: nominal group technique
Figen ÇUKUR Tayfun ÇUKUR	*Muğla Sıtkı Koçman University*	Evaluation of geographically indication products in terms of rural tourism: recommendations on Milas district of Muğla province
Remziye Nur ÖZDEMIR İsmail DEMIR	*Kırşehir Ahi Evran University*	Determination of factors influencing the choice of agricultural faculty: a case study of Kırşehir Ahi Evran University
Remziye Nur ÖZDEMIR İsmail DEMIR	*Kırşehir Ahi Evran University*	Determining the perspectives of agricultural faculty students on their profession: a case study of Kırşehir Ahi Evran university
Isroilova Dildora Muxtorovna Jumaboyeva Mubina Javlinbek Jumaboyeva Mavluda Javlonbek	*Kukon University*	Importance of soft skills in professional communication of engineering students

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FACE TO FACE SESSION / 25.04.2025

HALL-4 / SESSION-2 | **Ahi Evran Kongre ve Kültür Merkezi**

Ankara Time: 14:30-17:00

HEAD OF SESSION: Assoc. Prof. Dr. Gökhan FİLİK

Authors	Affiliation	Presentation title
Emre ŞİRİN	*Kırşehir Ahi Evran University*	Determination of growth performance of lambs and fertility characteristics of Karayaka sheep raised in Tokat
Ertuğrul KUL	*Kırşehir Ahi Evran University*	Passive immunity and its importance in calves
Yasin UYANIK Hayrettin ÇAYIROĞLU	*Kırşehir Ahi Evran University*	Factors affecting meat quality in ruminant animals: red meat quality from farm to table
Abdullah AYDOĞAN Isa COŞKUN	*Kırşehir Ahi Evran University*	The effects of dietary tarhana supplementation to quail ration on egg production and egg quality criteria
Derya DURAN GÖKALP	*Kırşehir Ahi Evran University*	Examination of the landscape potential of within the scope of rural tourism activities in Savcılı Büyükoba (Kırşehir/Kaman) village
İlker TÜRKAY Lokman ÖZTÜRK	*Kırşehir Ahi Evran University*	Glandular trichomes as model structures in phytochemical biosynthesis research
Miraç KILIÇ Hikmet GÜNAL Nurullah ACİR	*Harran University*	Assessment of land degradation vulnerability in semi-arid areas using fuzzy logic approach and geospatial data: a case study from Kırşehir, Türkiye
Hikmet GÜNAL Miraç KILIÇ İsmail ÇELIK Mesut BUDAK	*Harran University*	Development and opportunities of carbon markets in Türkiye: current status and future perspectives
Tuğba GÜNGÖR ERTUĞRAL Işıl ERZİNCAN		Preparation and characterization of edible films based on corn zein
Büşra AVCI YURTDAŞ M. Akif IRMAK	*Kırşehir Ahi Evran University*	Evaluation of different surface textures in urban parks in terms of micro thermal comfort; case study of Erzurum olympic park

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FACE TO FACE SESSION / 25.04.2025

HALL-5 / SESSION-2 | **Ahi Evran Kongre ve Kültür Merkezi**

Ankara Time: 14:30-17:00

HEAD OF SESSION: Prof. Dr. Sedat BOYACI

Authors	Affiliation	Presentation title
Gülten KAÇAR AVCI Halil TOKTAY Ramazan CANHİLAL	*Potato Research Institute*	Morphological diagnosis of golden cyst nematode (*Globodera rostochiensis* L.) populations in Niğde province
Gökhan DOĞAN Makbule ERDOĞDU Zeki AYTAÇ	*Kırşehir Ahi Evran University*	The powdery mildews of Yedigöller national park, Bolu province, Türkiye
Ali ENDES Bekir AKTAŞ Sevim ATMACA	*Yozgat Bozok University*	The symptomatology, epidemiology, ecology and management practices of *Rhynchosporium graminicola* as barley leaf blotch/scald pathogen
Ali ENDES Bekir AKTAŞ Sevim ATMACA	*Yozgat Bozok University*	Fusarium wilt and root rot on chickpea
Yusuf BAYAR Abdurrahman ONARAN Özlem BAHAR	*Kırşehir Ahi Evran University*	Comparative antifungal activity of methanol and hexane extracts of *Pteridium aquilinum* against *Monilinia fructigena*
Yusuf BAYAR Fatma KISA Melih Yılar Özlem BAHAR Abdurrahman ONARAN	*Kırşehir Ahi Evran University*	Comparative evaluation of leaf, flower, and seed extracts of vitex agnus-castus for antifungal activity against *fusarium oxysporum* species
Yasin Nazım ALPKENT Sibel ERTÜRK Selçuk ULUSOY Sait ERTÜRK	*Directorate of Plant Protection Central Research Institute*	Bioefficacy and chemical profiling of two essential oils against *Sitophilus granarius* L. (Coleoptera: Curculionidae)
Ahmet Emin YILDIRIM Erdal SERTKAYA Ibrahim Halil ELEKÇIOĞLU	*Hatay Mustafa Kemal University*	Determining plant parasitic nematodes and their population densities in important crop plants in Hatay province, Türkiye
Ahmet Emin YILDIRIM Erdal SERTKAYA Ibrahim Halil ELEKÇIOĞLU	*Hatay Mustafa Kemal University*	Survey studies on comparison of *tylenchulus semipenetrans* (cobb, 1913) (tylenchida: tylenchulidae) population levels according to rootstock, rootstock age and soil texture in Hatay, Türkiye
Sedat BOYACI	*Kırşehir Ahi University*	Evaluation of the effect of natural ventilation and cooling applications on indoor climate in a high tunnel greenhouse
Sedat BOYACI	*Kırşehir Ahi University*	Evaluation of the effects of insect nets used in ventilation openings in greenhouses on ventilation

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ONLINE SESSION / 26.04.2025

HALL - 1 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Mustafa KAN

Authors	Affiliation	Presentation title
Gülden Özgünaltay Ertuğrul Erkan Urkan Ikbal Aygün	*Kırşehir Ahi Evran University*	Innovative approaches in ergonomic risk assessment methods and occupational safety in agriculture
Gülden Özgünaltay Ertuğrul Erkan Urkan Ikbal Aygün	*Kırşehir Ahi Evran University*	Applicability and advantages of the 6s method in agriculture
Fatih Çalişkan Halil Özcan Özdemir Başar Altuntaş	*Kırşehir Ahi Evran University*	Knowledge and attitude levels of female consumers in Nevşehir province about the storage of bee products
Lütfi Eren Volkan Mehmet Çinar Aydın Ünay	*Aydın Adnan Menderes University*	Heat stress in cotton
Selcen Babaoğlu Aydaş Ayhan İbrahim Aysal Hikmet Türk Katırcıoğlu Kübra Erkan Türkmen Pınar Mursaloğlu Kaynar Orhan Canbolat	*Gazi University*	Investigation of existence of biogenic amin in siderophore-producing *Bacillus* sp.
Ece B. Kasapoğlu Uludamar Ali Endes Perihan Tuğçe Altiparmak I. Halil Elekcioğlu	*Çukurova University*	Effects of root rot fungus (*Fusarium oxysporum* f. sp. *ciceris*) and root lesion nematode (*Pratylenchus thornei*) on some chickpea varieties at different application times
Mehmet Selim Yildiz Abdulbaki Bilgiç Nuray Demir Adem Aksoy	*Ataturk University*	Green energy, sweet results: the impact of wind farms on honey production
Harun Furuncuoğlu Mehmet Öten	*Sakarya University of Applied Sciences*	The effect of fertiliser and bacteria applications on nitrogen and protein ratios in grass pea
Sümeyya Vuslat Dişkaya Salim Avcıoğlu Ece Börteçine Kasapoğlu Uludamar İbrahim Halil Elekcioğlu	*Çukurova University*	Investigation of biodiversity of nematodes (nematoda) in ali nihat gökyiğit botanical garden of Çukurova University
Sena Özbay	*Kırşehir Ahi Evran University*	Plant protein revolution for sustainable agriculture and rural development: opportunities and challenges
Ömer Şengül	*Bursa Uludag University*	Structural characteristics and problems of fattening sheep farms in Karacabey district

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ONLINE SESSION / 26.04.2025

HALL - 2 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Makbule ERDOĞDU

Authors	Affiliation	Presentation title
Hacer Tüfekci Ibrahim Can Temur	*Yozgat Bozok University*	Factors affecting the survival of lambs and kids
Hacer Tüfekci Ibrahim Can Temur	*Yozgat Bozok University*	Sheep milk production and importance
Hassan Mohamud Hassan Serdar Kamanli	*Kırşehir Ahi Evran University*	The impact of global warming and climate change on the poultry industry
Melek Derya Nitelik Mehmet Ali Çullu Bilal Enüştekin	*Harran University*	Spatial analysis of the impact of fertilizer use practices on nitrate pollution in cotton farming using remote sensing techniques: the case of Harran plain
Sinan Akbal	*Pamukkale University*	Potential use of probiotic spore-forming bacteria in dairy technology
Ihsan Gür Ayşe Yeşilayer	*Tokat Gaziosmanpaşa University*	Pesticide applications and residue problems in greenhouse agriculture
Damla Balaban Göçmen Ismet Başer	*Tekirdağ Namık Kemal University*	Evaluation of stability for some yield components of triticale (*x Triticosecale* wittmack) elite lines
Ceyda Dadali Arda Nur Çimen	*Ege University*	Alternative approches to cheese: plant- based cheeses
Arda Nur Çimen Ceyda Dadali	*Ege University*	Applications of intelligent packaging technology in foods
Bünyamin Bildik Abdurrahman Sami Koca	*Bolu Abant İzzet Baysal University*	Adult population development and damage rates of the codling moth *Cydia pomonella* L. (Lepidoptera: Tortricidae) in pear orchards of Kocaeli province

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ONLINE SESSION / 26.04.2025

HALL - 3 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Ramazan BEYAZ

Authors	Affiliation	Presentation title
Stepheny J. Rusli Denny Satria Hafid Syahputra Syukur Berkat Waruwu	*Universitas Sumatera Utara*	Box-behnken design optimization of brotowali stem extraction conditions and its anticervical cancer potential: an in silico and experimental approach
Putri Widyanti Harlina Havilah Jemima Dahlan	*Universitas Padjadjaran*	Optimizing glycerol monostearate (gms) and sorbitan monostearate (sms) ratios on lipid profiles in low-saturated shortening: a lipidomic and chemometric approach
Soukaina El Bourachdi Abdelhay El Amri Amal Lahkimi	*Sidi Mohamed Ben Abdellah University*	Hydrochar from fish waste as an efficient adsorbent for pollutant removal: synthesis, characterization, and adsorption mechanisms analyzed through DFT calculations
Jesslyn Frederica Denny Satria Poppy Anjelisa Zaitun Hasibuan Syukur Berkat Waruwu	*Universitas Sumatera Utara*	Anticancer potential of extract and fraction from brotowali (*Tinospora crispa*) stem against breast cancer: cytotoxicity, network pharmacology, molecular docking
Moula Bux Peerzado Muhammad Usman Nawab ul Deen	*University of Sargodha,*	Agricultural land and Pakistan
Siti Nurmilah Andri Frediansyah Yana Cahyana Roostita L. Balia Bibin Bintang Andriana Gemilang Lara Utama	*Universitas Padjadjaran*	Exploring microbial dynamics and metabolomic profiling of isoflavone transformation in black and yellow soybean tempe for sustainable functional foods
Ogunde A. A. Adefolarin D. A. Phillips S. A. Ajayi B. Adeleye N. A.	*University of Ibadan*	Modeling of dairy animal milk production using nadarajah–haghighi bur type-x distribution
Syarifah Huswatun Miswar	*Central China Norma Universuty*	The impact of renewable energy implementation on rural economic growth
Kanat Galymbek Serik Bakirov Aigul Madenova Kadir Akan Dinara Amanbekova	*Abai Kazakh National Pedagogical University*	Reactions to wheat leaf rust (*Puccinia triticina*) and its effect on grain quality
Serik Bakirov Kanat Galymbek Aigul Madenova Kadir Akan Aqerke Tuimebay	*Abai Kazakh National Pedagogical University*	The effect of experimental yield trial materials on bunt reactions and wheat yield

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ONLINE SESSION / 26.04.2025

HALL - 4 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Sultan KIYMAZ

Authors	Affiliation	Presentation title
Ajayi B., Phillips S. A., Adeleye N. A., Adefolarin D. A., Ogunde A. A	*Federal Polytechnic Ado-Ekiti*	Statistical modeling of wind data using type i half-logistic exponentiated inverse lomax distribution
Ahmed Osmane Khadija Zidan Moustapha Belmouden	*Agadir University Ibn Zohr*	Health and disease implications of sorghum irrigated with trickling filter-treated wastewater in North Africa's semi-arid regions
Muhamad Syaifudin Tangcheng Li Hong Du	*Shantou University*	Effect of environmental factors on heavy metal in seaweed: a bibliometric analysis of 20 years of research publications
Udoye, Charles Ekene Ezeogu Chisimdi Franklin	*University of Nigeria*	Crop farmers' knowledge of e-banking in enugu east senatorialzone of enugu state, Nigeria
Aliyu Nana Aisha Ado A. Datti Kazeem Ibraheem Ajadi Bakare Abdulakeem Oyesode Olotu Johu Suleiman Zuleihat Ozohu	*Ahmadu Bello University Zaria*	Heavy metal removal from textile effluent using activated carbon prepared from coconut shell-orange peel
Ramsha Rashid Aqeela Saghir Muhammad Iftikhar Ghazanfar Ali Khan Babar Shahbaz	*University of Agriculture Faisalabad*	Identifying constraints in the adoption of pulses cultivation: challenges and policy interventions
Maria Marcella Rianita Pramitasari	*Atma Jaya Catholic University of Indonesia*	Formulation of vegetarian ice cream from maja fruit (*Aegle Marmelos*) as a cow's milk substitute and antioxidant source

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ONLINE SESSION / 26.04.2025

HALL - 5 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Yaşar ERTÜRK

Authors	Affiliation	Presentation title
Okoro, John Chukwuma	*University of Nigeria*	Adaptation strategies to fuel subsidy removal among farmers in Nsukka agricultural zone, Enugu State, Nigeria
Okoro, John Chukwuma	*University of Nigeria*	Effects of fuel subsidy removal on household food consumption and dietary patterns of farmers in Enugu Ezike agricultural zone, Enugu Etate, Nigeria
Yassir Ahmed Hassan Galal Mustafa Yousif Mohammed Tageldin Iibrahim George Erhardt	*Animal Production Research Centre*	Genetic polymorphisms and diversity characteristics at milk protein genes for the Hamari desert sheep in Sudan
Muyiwa Abiodun Okusanya Oke O. Adedamola Idowu Tolulope	*The Federal Polytechnic Ilaro*	Comparison of rice husk as a planting media in urban agriculture to conventional farming
Mohammad Mehdi Pakdel Zahra Tahmasebi Sarvestani Mohammad Amini Feridun Esmaielzadeh	*Shiraz University*	The effect of CO_2 and H_2O removal from top gas fuel stream upon its heating value at goharzamin company
Zahra Tahmasebi Sarvestani Mohammad Mehdi Pakdel Mohsen Khojasteh Nezhad Kazem Askarifar Feridun Esmaielzadeh	*Shiraz University*	Substitution of beach well intake technology for open intake technology as seawater intake for reverse osmosis desalination plant
Anwar Rovik Laelatul Afifah Vania Uly Andyra	*The Graduate School of Universitas Gadjah Mada*	Exploring the anticancer potential of agriculturally relevant mimosa pudica (*Linn.):* a network pharmacology perspective
Abdullah Hammad Asghar Ali Hassan Zulfiqar	*The University of Faisalabad*	Marketing of agriculture business, its impact on the earnings ofa diagnostic analysis of role of middlemen in financing and farmers and consumer price: a case study of potato farmers
Muhammad Ashfaq Mahreen Alam	*The University of Faisalabad*	Impact of raps based adaptation package on agriculture in Punjab-Pakistan

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ONLINE SESSION / 26.04.2025

HALL - 1 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assoc. Prof. Dr. Gökhan FİLİK

Authors	Affiliation	Presentation title
Irfan Kadioğlu Ismail Bülent Gürbüz	*Bursa Uludağ University*	From farm to fork: next-generation development through circular economy
Irfan Kadioğlu Ismail Bülent Gürbüz	*Bursa Uludağ University*	Digital transformation and sustainable mobility in agriculture
Hasan Gökhan Doğan Derya Malkoç	*Kırşehir Ahi Evran University*	Evaluation of development trend of breeding activities: the case of Kırşehir province
Hasan Gökhan Doğan Kahraman Eldek	*Kırşehir Ahi Evran University*	Relationship between urban spreading and the agricultural sector: a conceptual assessment
Selin Ceren Balsak	*Kahramanmaraş Sütçü İmam University*	Genetic diversity and population structure of lettuce mosaic virus based on coat protein gene region
Ümit Acay Behiye Tuba Biçer	*Bingöl University*	Effect of plant density and shading treatments on broad bean (*Vicia faba* l.) yield
Ümit Acay Behiye Tuba Biçer	*Bingöl University*	Investigation of growth and development of bean (*Vicia faba* l.) in different plant densities and shade treatments
Hasan Gökhan Doğan Ahmet Doğanli	*Kırşehir Ahi Evran University*	Study of Turkish sugar industry and sugar policies between 1923-1956
Bekir Aktaş Ali Endes Sevim Atmaca	*Yozgat Bozok University*	Effects of legislative changes in the registration of plant varieties on cool season cereals
Bekir Aktaş Ali Endes Sevim Atmaca	*Yozgat Bozok University*	Changing climatic conditions and black point disease in cool season cereals
Tolga ARABACI Murat OLGUN Savaş BELEN	*Eskişehir Osmangazi Üniversitesi,*	Comparaitive usability of diffretent image processing techniques and yield components in wheat (T. *Avestium* L.) Breeding

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ONLINE SESSION / 26.04.2025

HALL - 2 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assist. Prof. dr. Funda ÖZDEMİR DEĞİRMENCİ

Authors	Affiliation	Presentation title
Gülay Özkan	*Nottingham Trent University*	Embracing circularity: transforming agriculture through sustainable practices
Levent Yazici Muhammed Batuhan Erbay	*Yozgat Bozok University*	The effect of organic fertilizer use on yield and quality in field
Mehmet Ali Kargicak Sebahattin Yilmaz	*Fig Research Institute Directorate*	Geographically indicated figs of Türkiye
Mehmet Ali Kargicak	*Fig Research Institute Directorate*	The effects of iba and ostiol stimulation treatments on parthenocarpic fruit formation in “sarilop” and “bursa siyahi” fig (*Ficus carica*) cultivars
Emrullah Culpan Burhan Arslan	*Tekirdağ Namık Kemal University*	The effects of seed size on germination and seedling growth of safflower
H. Güran Ünal	*Kastamonu University*	An evaluation on Kastamonu garlic
Tuba Batur Zübeyde Filiz Arslan	*Düzce University*	Studies on the effect of allelopathic plants to weeds in Türkiye
Seydanur Sevim Kavunluk Taki Karsli	*Eskisehir Osmangazi University*	Determination of hsp90aa1 gene polymorphism in Ile de France x Anatolian Merino crossbred sheep
Ayşenur Işbilen Zübeyde Filiz Arslan	*Düzce University*	A harmless method in agricultural production: Allelopathy
Osman Inanç Güney Levent Sangün	*Çukurova University*	A study on social determinants of food consumption behavior
Osman Inanç Güney Levent Sangün	*Çukurova University*	Online food purchasing trends in turkey after the pandemic: an evaluation based on socio-demographic factors

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ONLINE SESSION / 26.04.2025

HALL - 3 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assoc. Prof. Dr. Ertuğrul KUL

Authors	Affiliation	Presentation title
Youssef Arif Mohamed Bouhrim Ahmed Arif Mustapha Boulghallat Fatiha Chigr Ahmed Ait Chaoui	*Sulatan Moulay Slimane University*	Molecular docking analysis of bioactive compounds from asparagus officinalis reveals potential antidiabetic interactions with human proteins
El Hassania El Hamzaoui Mohamed El Baghdadi Maria El Harram Ayoub Outalleb Jamila Zouhri Atika Mouaddine Abdessamad Hilali Hind Elhamzaoui	*Sultan Moulay Slimane University*	Assessment of trace element pollution and potential health hazards in agricultural soils of the beni moussa sub-perimeter, Morocco
Arockia Allfer Nathan T. R. Poorani	*Rajalakshmi Engineering College*	Evaluation on the therapeutic efficacy of green synthesised copper oxide nanoparticles from gracilaria sp
Margaret Toluwalope Omoleye Fiyinfoluwa Tijesunimi Laoye Bobinihi Maria Olufunke Yetunde O. Oladigbolu Samuel Abiodun Ayanwole Amos Adegbala	*Cocoa Research Institute of Nigeria,*	Precision agriculture: a possible bedrock on which Nigeria past glory in cashew production can be rebuilt/restored
Bellil Zahra Meyer Sylvain Tilloy Valentin Bellil Dassine Mairi Assia De Champs Christophe Barraud Olivier Touati Abdelaziz	*Université de Bejaia*	Occurrence and characterization of antibiotic-resistant *Salmonella* isolates from fresh produce in agricultural environments
Alireza Mohammadi Sheyda Hosseinzadeh Amin Abbbasi	*Tarbiat Modares University*	Different protein hydrolysates derived from animal and plant sources: an overview on their nutraceutical properties
Amrouche Zoheir Fauconnier Marie-Laure Laribi Habchi Hassiba	*University of Khemis Miliana*	Biological activity & Bioactive molecules of Essential *Oil:Origanum vulgare, Rosmarinus officinalis* from Algerian region
Paul Abiodun Babarinde Adetunji Olusegun Adeyinka Amao Oyetoun Dunmola Aishatu Shettima Atibioke Oluwatoyin Adeola Adetoro Gbenga Opeyemi Owolabi Gbenga	*Nigeria stored products Research Institute*	Econimic analysis of oil palm fruits marketing among women in edo state, Nigeria
Fouzia Benoudjit Amina Sebhi Samia Medjdouba Hania Guechetouli Lylia Naili	*M'hamed Bougara University*	Comparative investigation of volatile oils extracted from two cupressus species
Jegede, R.O. Coker, A.A.A. Baba, K. M. Ojo, A. O.	*Federal University of Technology*	Trends and growth rates in fish import and export in Nigeria for the period 1970 – 2022

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ONLINE SESSION / 26.04.2025

HALL - 4 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Dr. Ayşe ÇANDAR

Authors	Affiliation	Presentation title
G.A. Ubandoma B.A. Sule S. Abubakar K.C. Baba D.H. Yakubu A. Bello	*Ibrahim Badamasi Babangida University Lapai*	Assessment of climate change effects and adaptation practices among cereals crop farmers in bwari area council fct, Abuja, Nigeria
M. Thenmozhi	*School of Sciences - Life Sciences*	Investigation of extraction method and physicochemical properties of emilia sonchifolia
Ariona Lubishtani Blerona Gavazi Miribane Dërmaku-Sopjani Arleta Rifati-Nixha	*University of Prishtina*	Analysis of organic molecules and physicochemical parameters as indicators of authenticity and quality of acacia honey samples
Alejna Rashiti Malsore Hysenaj Arleta Rifati-Nixha	*University of Prishtina*	Evaluation of fruit juice quality through chemical and physical analysis
Salma Makdouf Karima El Bouqdaoui Abdelhakim El Makssoudi Mounia Cherki	*University Hassan II*	Study of the chemical composition of *Fumaria parviflora* from three regions of Morocco
Soumaya Atouife Jamila Elbiyad Halima Belaoufi Abdellah El Habazi Rekia Belahsen	*Chouaïb Doukkali University*	Awareness and understanding of organic food among the Moroccan population
Yakubu Ibrahim Usman Ahmed Usman	*Yobe State University*	A spatial attention-enhanced CNN for early detection of NPK deficiencies in rice crops
Adeboye, Muhammed Mustapha. Manga, Shaibu Bala. Maryam Lamin Riskuwa-Shehu. Asiya Umar Imam	*Confluence University of Science and Technology*	Plasmid curing potential of nigella sativa on multidrug resistant *Staphylococcus Aureus*

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ONLINE SESSION / 26.04.2025

HALL - 5 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assoc. Prof. Dr. Hakan KIR

Authors	Affiliation	Presentation title
Mohammad Mehdi Pakdel Zahra Tahmasebi Sarvestani Mohammad Amini Feridun Esmailzadeh	*Shiraz University*	Simulation and evaluation of the impact of removing carbon dioxide and water from the top gas fuel stream exiting the top gas scrubber in midrex unit of the gohar zamin mining and industrial company
Zahra Tahmasebi Sarvestani Mohammad Mehdi Pakdel Mohsen Khojasteh Nezhad Kazem Askarifar Feridun Esmaielzadeh	*Shiraz University*	Substitution of beach well intake technology for open intake technology as seawater intake for reverse osmosis desalination plant
Alireza Mohammadi Sheyda Hosseinzadeh Amin Abbbasi	*Tarbiat Modares University*	Different Protein hydrolysates derived from animal and plant sources: an overview on their nutraceutical properties
Babayemi, A.W, G. I. Onwuka, Musa Abdulrahman Sumayya Jibril B. Shehu	*Kebbi State University Of Science And Technology*	Price volatility of rice production in Nigeria (an appraisal of rice production In Kebbi state)
Udoye, Charles Ekene Ezeogu Chisimdi Franklin	*University of Nigeria*	Crop farmers' knowledge of e-banking in enugu east senatorial zone of Enugu State, Nigeria
Heni Radiani Arifin Tri Yuliana Yana Cahyana Ali Wangsa Jayakusuma	*Universitas Padjadjaran*	Enhance the properties of rice paper by incorporating citronella essential oil (*Cymbopogon nardus* (L.) Rendle)
Mohsin Raza Muhammad Ali Imran	*Department of Agricultural Management and Entrepreneurship Development*	Investigating young consumers attitudes towards food waste reduction: key insights and lessons learned

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ONLINE SESSION / 26.04.2025

HALL - 1 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assoc. Prof. Dr. Selma BOYACI

Authors	Affiliation	Presentation title
Turan Yaman	*Van Yuzuncu Yıl University*	Pathological findings of lamb mortality due to high dose drug usage
Murat Uztimür	*Bingöl University*	Evaluation of the relationship between blood ph, anion gap and blood electrolyte concentration in calves with hypoglycemic diarrhea
Mehmet Öncü Mustafa Kan Asli Akilli	*Kırşehir Ahi Evran University*	Factors affecting consumer' green product preferences: the case of Kırşehir province
Yusuf Yanar Mevlüde Beyza Bayhan	*Tokat Gaziosmanpaşa University*	In vitro compatibility of the entomopathogenic fungi *Beauveria bassiana* (bals.) vuill. and *Metarhizium bruneumu* with different fungicides
Aysun Cavusoglu Mehmet Erhan Göre	*Kocaeli University*	A critical review of symptomatology and isolation techniques of *Alternaria* spp. in solanaceous crops
Saber Delpasand Khabbazi	*Yozgat Bozok University*	Microsatellite analysis of the clpp gene in cannabis sativa plant
Sabri Yurtseven Özlem Durğun Veysel Gökmen	*Harran University*	A study on the effectiveness of modifications in reducing anti-nutritional factors in barley
Mustafa Kan Bülent Gülçubuk	*Kırşehir Ahi Evran University*	New era in rural development in Türkiye: Digitalisation
Miray Kalaycı	*Akdeniz University*	The relationship between cultural routes and rural development in Türkiye
Ömer Aydoğmuş Levent Yazici	*Yozgat Bozok University*	The effect of seed coating application on yield and quality in field crops
Ilbilge Oğuz N. Ebru Kafkas Salih Kafkas	*Cukurova University*	A review of genomic breeding strategies in the case of strawberry yield and fruit quality traits

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ONLINE SESSION / 26.04.2025

HALL - 2 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Prof. Dr. Meral AYDENİZÖZ

Authors	Affiliation	Presentation title
Levent Sangün Osman Inanç Güney	*Çukurova University*	A comparative analysis of the relationship between social media use and food purchasing and consumption based on demographic characteristics
Şenol Köse	*Van Yüzüncü Yıl University*	Microplastic contamination in food and its effects on human health
Levent Sangün Osman Inanç Güney	*Çukurova University*	Consumer's food consumption preferences and concerns during the covid-19 period
Yağmur Kaya Rasim Koçyiğit	*Tokat Gaziosmanpaşa University*	The effect of use of phosphorus fertilizers with organic materials on the phosphorus content of corn plant growing in different soils ph
Mehmet Başbağ Erdal Çaçan	*Bingöl University*	Evaluation of some cota species in terms of herbage quality characteristics
Çiğdem Özkan Kahraman Ayşe Çandar	*Kırşehir Ahi Evran University*	Research on the effect of some biofungicides on plant virus diseases
Ayşe Çandar	*Kırşehir Ahi Evran University*	Phytopathological problems observed in tomato plants in Kırşehir Ahi Evran University r'd greenhouse during the cultivation season
Müberra Erdoğan Karaağaçlı Mehmet Murat Cömert	*Tokat Gaziosmanpaşa University*	Determination of solar radiation variation in some central black sea region provinces by şen's innovative and mann-kendall methods
Caner Kövmen Hilal Erdoğan	*Bursa Uludağ University*	Balers in the transformation of agriculture: a historical review from past to present
Meral Aydenizöz	*Kırıkkale University*	A general overview of the stinger structure and poison secretion in honeybees

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ONLINE SESSION / 26.04.2025

HALL - 3 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assist. Prof. Dr. Ömer ERTUĞRUL

Authors	Affiliation	Presentation title
Khadija Syed Irfan Ahamd Baig Mubashir Mehdi	*MNS-University of Agriculture*	Determinants of compliance behavior of farmers towards agricultural taxation in Punjab
Hamza Belkhodja Abderrahmane Remil Fatima Zohra Labbaci Djilali Bouhadi Asmaa Belmimoun Khadidja Sidelarbi	*University of Mustapha Stambouli*	Evaluation of the anti-inflammatory and anti-hemolytic potential of polyphenolic components of common mallow (*Malva sylvestris*)
Hussaini, A. S. Oladimeji, Y. U Sani, A. A Umar, M Udeh, B. E	*Ahamdu Bello University*	Effects of fuel subsidy removal on price trend of staple food crops in kaduna Municipal, Nigeria
Subhashish Dey	*Gudlavalleru Engineering College*	Analysis and design of G + 5 floors apartment building
Mohammed Cheurfa Abdallah Noui	*University of Djillali*	In vitro antioxidant and antibacterial effect of Thymus hirtus subsp. algeriensis (*Boiss. & Reut.*) leaves extracts.
Alexander Idoko Parker Joshua Elijah Njoku Obioma Uzoma	*Caritas University Enugu*	Assessments of phytopharmaceuticals with therapeutic potentials in health management
Hebat-Allah S. Tohamy	*National Research Centre*	Novel intelligent naked-eye food packaging ph-sensitive and fluorescent sulfur, nitrogen-carbon dots biosensors for tomato spoilage detection including DFT and molecular docking characterization
Salami Mercy Funke Akinola Abdulbaaki Bolaji Adepoju Rukayat Adekemi Onuche Sandra Ikoojo	*University of Ilorin*	Waste to wealth: insights from the cassava peel value chain management in Southwestern Nigeria
AJIWE, S.T. ILUYEMI, C. A., OBISESAN, B. A. AFOLABI, I.D.	*Ajayi Crowther University*	Fusarium wilt of A tomato: A review

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ONLINE SESSION / 26.04.2025

HALL - 4 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assist. Prof. Dr. Sebahattin YILMAZ

Authors	Affiliation	Presentation title
BOUKHALFA Hassina Hafida BENOUAMANE Ourida FAFI Amira	*University Mohamed Khider of Biskra*	Nutritional value of some rare varieties of dates from Southern Algeria
Dio Samudra	*UIN KH. Abdurrahman Wahid*	Contemporary approaches in animal breeding and their impact on sustainable agriculture
Mizanur Rahman	*Gopalganj Science and Technology University*	Land, water and borders: the geopolitical contest over agricultural resources in South Asia
Muhammad Tayyab	*University of Veterinary and Animal Sciences*	Recombinant DNA technology as tool for the production of poultry feed enzymes
Muhammad Faisal Anam Hameed	*MNS-University of Agriculture*	Investigating the role of *Bacillus Subtilis* biopriming to enhances salt-stress tolerance in soybean varieties
Akbar Soliemanzadeh	*Hormozgan Agricultural and Natural Resources Research and Education Center*	Silicon-Mediated mitigation of climate change impacts on wheat production in MENA: physiological and agronomic insights
Dhivya C Arunkumar R	*Tamil Nadu Agricultural University*	Youth as catalysts for agricultural transformation in the digital era
Cristina Raluca Gh. Popescu	*University of Bucharest*	Agricultural biotechnology for sustainable development goals: a holistic approach for ecosystem restoration, environmental conservation, and sustainable resource management
Aman Ullah Malik	The University of Faisalabad	Mango Industry Development in Pakistan Through Research for Development Approach
Satish Kumar Singh	*Central University of Punjab*	A critical analysis of the role of women in agriculture and animal welfare in relation to the sustainability of rural food systems

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ONLINE SESSION / 26.04.2025

HALL - 5 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assist. Prof. Dr. Hayriye Didem SAĞLAM ALTINKÖY

Authors	Affiliation	Presentation title
Rotimi-Williams Bello Pius A. Owolawi Chunling Tu Etienne A. van Wyk Mojisola Abosede Oladipo	*Tshwane University of Technology*	Real-Time plant pest monitoring in agrivoltaic farms using deep learning-based pest image generation models for sustainable pest management
Fahima NABI Meriem CHEBAANI Lamia BOUDELLA Mohamed Zadi et Dahbia KECHAD	*Université Dr Yahia Farès de Médéa*	Effect of green and hay alfalfa on milk quality and quantity
Rimsha Zaheer Mubashir Mehndi	*University of Agriculture*	Social capital and entrepreneurial intentions among women farmers in Punjab, Pakistan
Sándor Földvári	*Debrecen University*	Potatoes, pepper, lamb, tomato: Türkiye components of hungarian gastronomy as parts of the multicultural heritage
Anas Hamdani Rachid Razouk Said Bouda Atman Adiba	*National Institute of Agricultural Research*	Agro-physiological and biochemical responses of the 'Angelino' cultivar (*Prunus salicina L*) under conditions of drought and heat stress
Izuogu, C.U Okonwe, P.N Njoku, L.C Olaolu, M.O Ibrahim-Olesin, S Umeh, N.E Agou, G.D Iroegbu, S.C	*Alex Ekwueme Federal University*	Access and use of information and communication technology among rice farmers in ishielu, Ebonyi State, Nigeria
Shahid Adeel Shumaila Kiran Muhammad Aamir Muhammad Kamran Farwa Khalid	*Government College University Faisalabad*	Dyeing of cotton with reactive dyes using microwave treatments
Oladimeji, Y. U Hussaini, A. S. Magaji, B. D. Suleiman, R. Owolabi, M, O. Abdulrahman, S. Tijjani, H.	*Ahamdu Bello University*	Emergency of wheat production among small-scale farmers and its effect on poverty reduction in Jigawa State, Nigeria
Satish Kumar Singh	*Central University of Punjab*	The legal dimensions of food security in the context of agricultural development policy: a critical analysis of regulatory approaches and governance mechanisms

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ONLINE SESSION / 27.04.2025

HALL - 1 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Pınar AYVAZOĞLU DEMİR

Authors	Affiliation	Presentation title
Büşra Görgülü Yeşim Sıla Tekin Hande Eser Seda Kaçar Serkan Benli Ahmet Cemil Eken	*Central Anatolian Chemical Industry Production Marketing Inc.*	Environmentally sustainable pest management strategies against *Frankliniella occidentalis* (western flower thrips)
Çiğdem Ürer Halil Özcan Özdemir	*Kırşehir Ahi Evran University*	Evaluation of Kırşehir province Mucur district 2024 agriculture and livestock supports
Şerife Nur Ekici Kadir Saltali Bedriye Bilir Ömer Faruk Demir	*Kahramanmaraş Sütçü İmam University*	Effect of raw phosphate and elemental sulfur applications on available phosphorus content of soils
Seray Bilir Ali Yiğit	*Aydın Adnan Menderes University*	Impacts of drought stress on bread making quality of wheat: a review
Oktay Yavuz Ali Yiğit Osman Erekul	*Aydın Adnan Menderes University*	Current situation, problems and development potential of maize cultivation in the aegean region
Emre Akbulut Selçuk Arslan	*Bursa Uludağ University*	Sensor technologies and control structures in hydroponic systems
Filiz Haykir Halil Özcan Özdemir	*Kırşehir Ahi Evran University*	A study on the use of canned and frozen agricultural products
Murat Özocak A. Ilker Esin	*İstanbul University – Cerrahpaşa*	Determining the manageability of irrigation systems with lora communication technologies in greenhouses
Pınar Ayvazoğlu Demir	*Kırıkkale University*	Risk perception in livestock production
Özcan Ateş Selçuk Arslan	*Bursa Uludağ University*	A structurally reinforced vineyard post design suitable for mass production by roll forming line

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ONLINE SESSION / 27.04.2025

HALL - 2 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Assoc. Prof. Dr. Koray KIRIKÇI

Authors	Affiliation	Presentation title
Osman Albayrak Alper Güngör	*Kırşehir Ahi Evran University*	Effect of mycorrhizal inoculation of aspir (*Carthamus tinctorius* L.) seeds on germination under different irrigation water salinity conditions
Alper Güngör	*Kırşehir Ahi Evran University*	Effect of growth regulators on the leaf morphology of spinach (Spinacia oleracea L.) grown under salt stress
Neslihan Yonca Şatir Erkan Işik	*Van Agricultural Research Institute-Soil and Water Resource*	Negative effects of incorrect storage and application of barn manure
Mehmet Ilhan Odabaşioğlu Mehmet Koç	*Adıyaman University*	Drought tolerance mechanism in commonly used grapevine rootstocks
Selin Taşyonar Nur Okur	*Ege University*	Effect of microplastic pollution on physico-chemical and microbiological properties of soil
Tuğçe Varazli Yavuz Gamze Bayram	*Tokat Gaziosmanpaşa University*	Determination of herbage yield and quality characteristics of some soybean varieties in main crop conditions under Tokat conditions
Hüseyin Çayan Kadir Çakir	*Kırşehir Ahi Evran University*	The use of black cumin seed in poultry nutrition
Ahu Alev ABACI BAYAR Aslı AKILLI	*Kırşehir Ahi Evran University*	Assessment of soil quality in vineyard areas using a fuzzy logic-based decision support system: a case study from Kırşehir
Kenan Çiftçi Mustafa Terin Melike Ceylan Ibrahim Yildirim	*Van Yüzüncü Yıl University*	Analysis of milk marketing preferences of dairy cattle producers in van province by analytical hierarchy process
Asel Amanova Tair Esenali Uulu	*Kırgızistan-Türkiye Manas University*	Fall armyworm (*Spodoptera frugiperda*) in central Asia: an emerging threat
Ahmet Cengiz Yildirim Havva Eylem Polat	*Ankara University*	Spatial analysis of Konya–Cihanbeyli livestock enterprises and determination of environmental pollution potential

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ONLINE SESSION / 27.04.2025

HALL - 3 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Assoc. Prof. Dr. Gökhan FİLİK

Authors	Affiliation	Presentation title
Ayoub LAMTITA Bahija MOUNIR Fathallaah BAZI	*Hassan II University of Casablanca*	Nouveaux catalyseurs stables et régénérables à base de Schistes bitumineux marocains pour la réaction de protection des aldéhydes
Chourouk Nebatti Chergui Nadjia Saidi Ouahrani	*University of Science and Technology of Oran*	Earthworms biodiversity in agricultural fields in Temouchent (Western Algeria)
Mohcin Elkhatir Ismail Louragli Abdechahid Loukili Youssef Aboussaleh	*Ibn Tofail University*	Relationship between Organic food consumption and attention performance in a sample of Moroccan primary school students from Khemisset
Afaq Ahmad Samir Al Busaidi Wadhah Al Mandhari Hothefa Shaker	*Sultan Qaboos University*	Productive and effectively sustainable agriculture through Ai
Aicha ROSSAFI Sana EL MOUTAOUAKIL Soukaina NJILI Mohamed ROSSAFI Mohammed OUHSSINE	*Faculty of Sciences. B.P*	The conduit of the chia (*Salvia Hispanica*) growth cycle duration by varying sowing date In North Morocco
Sana EL MOUTAOUAKİL Aicha ROSSAFI Nabil SBAI Youssef EL MADHI Mohammed OUHSSINE Fathalah ELWAHAB	*Ibn Tofail University*	Factors influencing strawberry flavor: the role of variety and ripeness
El Hassania EL HAMZAOUI Mohamed EL BAGHDADI Abdessamad HILALI Atika MOUADDINE Hind ELHAMZAOUI	*Sultan Moulay Slimane University*	Assessment of trace element pollution and potential health hazards in agricultural soils of the beni moussa sub-perimeter, Morocco
Mohanapriya. P Chamundeeswari. M	*St. Joseph's College of Engineering*	Microplastics in agricultural soil- a growing ecological challenge
Sejal Porwal Rishabha Malviya	*Galgotias University*	Enhancing food safety and sustainability: ai-powered innovations in smart packaging
Muhammad Rizwan Muhammad Ali Imran Mohsin Raza Ayesha Sarwar	*MNS University of Agriculture*	Economic analysis of potato production through contract farming In Multan

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ONLINE SESSION / 27.04.2025

HALL - 4 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Prof. Dr. Mustafa KAN

Authors	Affiliation	Presentation title
Rimsha Arooj Muhammad Haseeb Raza Mubashir Mehdi Muhammad Sibt-e-Abbas Shoaib Akhtar Muhammad Faisal	*MNS University of Agriculture,*	Appraising food waste reduction behavior in university students: an application of extended norm activation model
Umair Sultan Alamgir Akhtar Khan	*Muhammad Nawaz Shareef University of Agriculture*	A synergistic modeling and experimental approach for self-propelled seeders design
Sadiq, M.S. Singh, I.P Ahmad, M.M. Buhari, B. Sani, B.S. Zakari, F.S.	*Department of Agricultural Economics and Agribusiness*	Output supply and inputs demand elasticities of small-scale onion production in nigeria's kano state
Sara Shokrpoor Sakineh Khanamani Falahatipour Zahra Harsini	*University of Tehran*	Basal cell carcinoma in a rabbit
Mohammad Hossein Banakar Amir Parnian Mohammad Javad Babaie Zarch Rostam Yazdani Biuki	*National Salinity Research Center*	The feasibility study of replacing Haloxylon with Nitrebush in desertification operations
Minahil Tanveer Sami Ullah	*MNS -University Of Agriculture,*	Exploring the relation between farm size and technical efficiency in Pakistan: a directional distance function approach
Daniela Trifan Alexandre Moreau Marian Brăilă Victoria Amelia Anghel Nicoleta Axinti Vlad Dumitru Mihăilă	*Agricultural Research and Development Station of Braila,*	Research on the influence of foliar clean fertilizers applied to maize and sunflowers under current climate change conditions
Zainab Khan Sami Ullah	*Muhammad Nawaz University of Agriculture*	Impact of farm services and agronomic practices on cotton yield
Beckley IKHAJIAGBE	*University of Benin*	Safe science in the age of biotech advancements and ai: imperatives for effective biorisk management
AMROUCHE Zoheir El Hadi Djamel Laribi Habchi Hassiba	*University of Khemis Miliana*	Valorization of a whey by-product and research into lactic acid bacteria isolated from whey

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ONLINE SESSION / 27.04.2025

HALL - 5 / SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Assoc. Prof. Dr. Hakan KIR

Authors	Affiliation	Presentation title
Nermin Yaraşir Ali Yiğit Osman Erekul	*Aydın Adnan Menderes University*	Changes in some quality characteristics of soybean (*Glycine max*. L. Merr) under full and deficit irrigation
Sinem Zere Taşkin Fikret Yönter Uğur Bilgili	*Bursa Uludağ University*	Effects of different nitrogen doses on forage yield and yield components in sweet sorghum [*sorghum bicolor var. Saccharatum (l.) Moench*] genotypes
Berat Ceylan Zeynep Ünal	*Ömer Halis Demir University*	Effectiveness of yolo algorithm model in agricultural applications
Arif Çam Mehmet Metin Özgüven	*Çukurova University*	Machine learning applications in agriculture
Ismail Terzi Mehmet Metin Özgüven	*Çukurova University*	The latest point in ampelography: digital ampelography
Muhammad Zulqarnain Uğur Bilgili	*Bursa Uludag University*	Promoting sustainable agriculture practices through wheat-pea intercropping: determining ideal ratios and harvest stages for enhanced yield
Fahreddin Ataman Engin Takil Nihal Kayan	*Eskişehir Osmangazi University*	Determination of the effect of amino acid application on some morphological characteristics in beans (*Phaseolus vulgaris* L.) applied with different doses of herbicide
Dilara Aslan Bakkalbaşi	*Van Yüzüncü Yıl University*	Buckwheat: its origin, composition and health importance
Dilara Aslan Bakkalbaşi İsa Cavidoğlu	*Van Yüzüncü Yıl University*	Total phenolic content and antioxidant activity of pomegranate seed pomace

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ONLINE SESSION / 27.04.2025

HALL - 6/ SESSION - 1 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 10:00-12:00

HEAD OF SESSION: Dr. Ayşe ÇANDAR

Authors	Affiliation	Presentation title
Saikal BOBUSHOVA	*Kyrgyz Turkish Unıversıty Manas*	Vegetable seed diseases in Kyrgyzstan and their control
Abdulwaheed Adeyemi Bello	*College of Agriculture,*	Water consumption pattern of konkan kanyal goats fed finger millet straw supplemented with varying levels of dried poultry dropping based diets
“Miqdad Raza Asghar Ali”,	*University of Agriculture,*	Economic returns of rabi crops in Punjab: strategies for enhancing farm income
Ananya Khatun,	*Hajee Mohammad Danesh Science and Technology University,*	Influence of on-tree nutrient sprays and bagging on the quality and postharvest physiology of mango cv. amrapali under ambient conditions
Ghanshyam Barman	*Vidhyadeep University,*	Engineering the future of farming: chemical innovations for sustainable agriculture
"Sadiq, Mohammed Sanusi Grema, Isiyaku Jawa"	*Department of Agricultural Economics and Agribusiness,*	The role of neazdp on social mobility of poverty in yobe state of Nigeria
"Saba Shaheen Rakshanda Kousar Javaria Nasir Aqeela Saghir"	*University of agriculture,*	Impacts of climate change on citrus production in district Sargodha
"Chokri BAYOUDH Malek BEN ALI Afifa MAJDOUB Taoufik BETTAIEB "	*Regional Research Centre on Horticulture and Organic Agriculture*	Study of in vitro propagation and selection for salt tolerance of local Opuntia cactus
"Mohsin Raza Irfan Ahmad Baig Umar Ijaz Ahmed"	*Muhammad Nawaz University of Agriculture Multan*	Role of social support for sustainable rural food security in covid-19 pandemic
"Hasan Zulfiqar Neelam Rana"	*University of Agriculture Faisalabad,*	The linkage between living standard of small farmer and agricultural poverty in rural Punjab, Pakistan

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ONLINE SESSION / 27.04.2025

HALL - 1 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assoc. Prof. Dr. Ertuğrul KUL

Authors	Affiliation	Presentation title
Ramazan Beyaz Başar Altuntaş Merve Meşe	*Kırşehir Ahi Evran University*	Determining the attitudes of young consumers towards genetically modified organism (GMO) products: the case of Ahi Evran University in Kırşehir
Nurten Iştar Ahmet Kinay	*Tokat Gaziosmanpaşa University*	Performance of some anise genotypes under Tokat ecological conditions
Efe Berkay Serçe Zeynep Ünal	*Niğde Ömer Halisdemir University*	Unmanned ground vehicles in smart farming: challenges and applications
Muhammed Temel Mustafa Boğa	*Niğde Ömer Halisdemir University*	Non-protein nitrogen sources in dairy cattle nutrition
Sevim Atmaca Ali Endes Bekir Aktaş	*Yozgat Bozok University*	Wilt and crown rot disease on lentil: *Fusarium oxysporum* f. sp. *lentis*
Sevim Atmaca Ali Endes Bekir Aktaş	*Yozgat Bozok University*	Methods of fighting against wilt and root disease in lentil
Sezai Gökalp Celal Kalebaş Salih Yilmaz Saadet Tosunoğlu Gamze Bayram Ebubekir Paşazade Mustafa Bozdağ	*Central Black Sea Transitional Zone Agricultural Research Institute*	Effects of row spacing and seeding rate application on seed yield and some yield components in crested wheatgrass (*Agropyron cristatum* L. Gaertn.) In the Tokat zone of the Türkiye
Ceyhun Yücel	*Yozgat Bozok University*	Effects of bee pollen and propolis as alternative feed additives in sustainable sheep nutrition
Cihad Said Alp Ramazan Güngör Hakan Başak Alim Aydin	*Kırşehir Ahi Evran University*	Effect of solid fertilizer tea derived from biogas plants combined with reduced nutrient solution on lettuce growth in hydroponic culture
Ramazan Güngör Cihad Said Alp Hakan Başak Alim Aydin	*Kırşehir Ahi Evran University*	Determination of the effects of vermicompost and reduced nutrient solution applications on plant growth in hydroponic lettuce cultivation

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ONLINE SESSION / 27.04.2025

HALL - 2 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Prof. Dr. Ahmet ŞAHİN

Authors	Affiliation	Presentation title
M. N. H. Perera P. C. D. Perera A. J. D. Perera Nilanthi Dahanayake	*University of Ruhuna*	Influence of plant growth regulators on in-vitro shoot regeneration in ginger (*Zingiber officinale* Rosc.)
Roman Truskavetsky Zubkovska Viktoriia Khyzhniak Iryna	*National Scientific Center "Institute for Soil Science and Agrochemistry Research named after A. N. Sokolovsky*	Peatland resources of Ukraine: Problems and challenges
Ahmed Attahiru Abubakar Umar Birnin-Yauri Bashar Attahiru	*Kebbi State University of Science and Technology*	Studies on medicinal applications of tannins
Aqeela Saghir Shoukat Ali Ramsha Rashid Muhammad Usama Saeed Saima Sadaf	*University of Agriculture Faisalabad*	Exploring alternative solutions to rice growers' challenges through mixed-method approaches
LADOUALI Zeyneb BENHOULA Mohammed BOUCHEMAL Amina INOURI Ahlam MECHIAH Fahima	*Campus Universitaire*	Impact of animal nutrition on milk production efficiency in Algeria
DEGHICHE DIAB N BOUCIF A ABBAS S	*Mohamed Khider University*	Poisonous spontaneous plants as sources of traditional and modern medicines In Biskra, South Algeria-Noth Africa
MOKHNANE Tarek ADJLANE Sabah KHIARI Reguia	*Scientific and Technical Research Center on Arid Regions*	The Role Of Agricultural Policies In Developing Livestock In Desert Areas Oued Souf (Algeria) As A Model
Saloni Sharma Suhani Sharma	*Manav Rachna International Institute of Research Studies*	Gastronomy beyond the plate: A multisensory experience
Kavindya ABEYSINGHE Mahesha MADUMALI Peliyagodage Chathura Dineth PERERA	*University of Ruhuna*	Comparative impact of monocot and dicot invasive plant species on wildlife: Assessing habitat disruptions and biodiversity loss

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ONLINE SESSION / 27.04.2025

HALL - 3 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Prof. Dr. Mustafa KAN

Authors	Affiliation	Presentation title
Edita Abalikstiene Daiva Gudritiene Vilma Salkauskiene Darius Pupka	*Lietuvos Inzinerijos Kolegija Higher Education Institution*	Real-Time herd monitoring with unmanned aerial vehicles: A thermal imaging approach
Onyekwelu, Chinyere Nkemakonam Alagbu Ogochukwu Philomina	*Federal Polytechnic, Oko, Anambra State*	Evaluation of proximate and sensory properties of breakfast cereals from blends of oat, sweet potato and malted African yam bean
Tasawar Iqbal	*University of Agriculture*	Pharmacological evaluation of *Ficus Benghalensis* latex in rheumatoid arthritis management
Ali Ahmad	*University of Agriculture*	Role of horticulture in promoting environmental sustainability
Aloui Mourad Menana Elhalaoui	*Sidi Mohamed Ben Abdellah University*	Novel MX-106 hydroxyquinoline derivatives: 2D-QSAR modeling, molecular docking, molecular dynamics simulations, and admet predictions for potent selective survivin inhibitors
Husnain Riaz *Zarrish Rafique* *Ali Ahmad"*	*University of Agriculture*	Entrepreneurship in floriculture: Turning passion into profit
Zarrish Rafique Husnain Riaz Ali Ahmad	*University of Agriculture*	Exploring the horticultural significance of tuberose
Skender DEMAKU Arbnorë ALIU Donika SYLEJMANI Bahrije DOBRA	*University of Prishtina*	Nitrate Ion (NO3-) levels in fruits and vegetables in the cities of prishtina and graçanica were measured using the "green test eco 5 f -anmez" equipment
Aminu ıbrahim Bello Salihu salisu	*Umaru Musa Yaradua Unıversıty*	Probiotics in livestock production: Enhancing growth, immunity, and meat quality
Amel ZITOUNI Nassira GHEMBAZA Nabila BELYAGOUBI-BENHAMMOU Faiza ILYAS	*University of Ain Temouchent*	Identification analysis of bioactive constituents of a medicinal plant “Sedum Villosum L” By UHPLC-DAD-HRSM.

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ONLINE SESSION / 27.04.2025

HALL - 4 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assoc. Prof. Dr. Koray KIRIKÇI

Authors	Affiliation	Presentation title
Khalid Doumi Miloud Chakit Adil Doumi Jalal Taki Thami Hraira Driss Belghyti	*Ibn Tofail University*	First inventory of the biodiversity of aquatic macroinvertebrates of Lake Sidi Boudaroua Ouazzane, Morocco
Khalid Doumi Miloud Chakit Adil Doumi Younes Yassine Driss Belghyti	*Ibn Tofail University*	Physicochemical characterization of the water of Sidi Boudaroua Lake, Ouezzane, Morocco: towards explanation of biodiversity of lake
Ananda Majumdar	*University of Alberta*	The role of rural development in achieving the united nations sustainable development goals
Abdelilah MECHNINE Ahmed AARAB	*Abdelmalek Essaadi University*	Biotechnology and genomics study of a SARS-CoV-2 protein
Amadi Oko Amadi Nwachi_Ikpor Juliana Ogeri Onuoha Raymond Udochukwu Okpo Charles Nnanna Ibiam Nzeogu Inya Nwokocha Victory Chigozirim Patience James Oden Oruruo Ogechukwu Nsude	*Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state*	5G and edge computing for real-time monitoring of soil and crop health
Khizar Ilyas Nasir Nadeem Mubashir Mehdi Abd-ur-Rehman	*Muhammad Nawaz University of Agriculture Multan*	Consumer preferences and willingness to pay for value-added fish products In Muzafargarh
Nabiha Arshad Irfan Ahmad Baig Umar Ijaz Ahmed Muhammad Ali Imran	*Muhammad Nawaz University of Agriculture*	Assessing farmers' willingness to adopt and future demand for hybrid wheat varities in Punjab, Pakistan
C.Vijai V. Uma Maheswari	*Institute of Science and Technology*	Smart farming using iot and ai for precision agriculture
C.Vijai Sindhuja S	*Institute of Science and Technology*	Adoption of sustainable agricultural practices and their impact on food security

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ONLINE SESSION / 27.04.2025

HALL - 5 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Prof. Dr. Yaşar ERTÜRK

Authors	Affiliation	Presentation title
Shahid Adeel Tahsin Gulzar Huma Hira Rehman Mehboob Afzal Esha Zia	*Government College University Faisalabad*	Microwave assisted dyeing of cotton fabric using reactive green 6 dye
Felicia KING-AGBOTO Chizoma Catherine OKPARA	*Captain Elechi-Amadi Polytechnic*	Analyzing student performance in continous assessment through the application of artificial intelligence driven tools among higher insitutions in rivers state
Latefa SAIL	*Aboubekr Belkaid University*	Different modes of plant extraction and their use as corrosion inhibitors
Rostam Yazdani Biouki Hossein Kari Dolatabad Mohammad Hossein Banakar Hossein Beyrami Amir Parnian	*National Salinity Research Center*	Fungal biostimulants improve growth and salinity stress tolerance in licorice: A focus on *Trichoderma Harzianum* and *Epicoccum Nigrum*
Rostam Yazdani Biouki Mohammad Hadi Rad Hossein Beyrami Amir Parnian Vali Soltani Gardfaramarzi	*National Salinity Research Center*	*Licorice* farming in challenging environments: sustainable methods for saline regions
Rostam Yazdani Biouki Mohammad Hadi Rad	*National Salinity Research Center*	Constraints, capacities, and strategies for developing the cultivation of medicinal plants using saline water and soil resources
M.K. Atouailaa A. Arif M. Boulghallat M. El idrissi	*Sultan Moulay Slimane University*	Computational investigation of photovoltaic energy in agriculture: DFT/TD-DFT investigations
Mzia Kokhia Oleg Gorgadze David Nebieridze Manana Lortkipanidze Madona Kuchava	*Ilia State University*	Soil invertebrate role in the forest litter decomposition

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ONLINE SESSION / 27.04.2025

HALL - 6 / SESSION - 2 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 12:30-14:30

HEAD OF SESSION: Assist. Prof. Dr. Funda ÖZDEMİR DEĞİRMENCİ

Authors	Affiliation	Presentation title
József Horváth András Tóth Ádám Varga Nguyễn Ngọc Quyến Türker Bodur Hüseyin Sevgili Tamás Müller	*Hungarian University of Agriculture and Life Sciences,*	Induced fish propagation method development in African Catfish (*clarias gariepinus*) (preliminary results)
Muhammad Imran	*Government College University*	Health benefits and nutritional composition of green peas
Qaiser Javed Mohammed Bouhadi Danko Cvitan Nikola Major Smiljana Goreta Ban Dean Ban Marko Černe	*Institute of Agriculture and Tourism,*	Bioconversion of olive mill residues: composting performance and environmental benefits
Mohammed Bouhadi Qaiser Javed Tvrtko Karlo Kovačević Mirela Uzelac Božac Danijela Poljuha Nikola Major Smiljana Goreta Ban Dean Ban David Heath Marko Černe	*Institute of Agriculture and Tourism,*	Genotoxic, morpho-physiological, and biochemical impacts of olive pomace on broad bean plant
Pooja Kapoor Pooja Joshi Vipin Parkash Manoj Pal	*(Deemed to be University),*	Screening of rhizospheric actinobacteria from pine forest, chakrata, uttarakhand for plant growth promotion and fungal pathogen biocontrol potential
ZOUBIR Souad ILIAS Faiza ZITOUNI Amel	*University of Ain Temouchent*	Scale insect infestation in citrus orchards: A case study from aïn témouchent
BENHOULA Mohammed MECHIAH Fahima LADOUALI Zeyneb INOURI Ahlam BOUCHEMAL Amina MAGHLAOUI Zobeida BOUCHERBA Nawel MADI Nassim	*Campus Universitaire*	Pesticides and the global economy: agricultural and environmental challenges and sustainable perspectives
A. MEZERKET M.HAMMACHE C.CANTALAPIEDRA-NAVARRETE P.CASTILLO J.E. PALOMARES-RIUS	*Ecole Normale Supérieure*	Molecular analysis of cyst nematode species in the main potato production areas of Blida province, Northern Algeria
Soukaina NJILI Aicha ROSSAFI Mohammed OUHSSINE	*Laboratory of Natural Resources and Sustainable Development,*	Agro-morphological characterization of 17 lentil varieties (*Lens culinaris medik*) grown in north morocco.
Retem Chahira Derbal Sara Djouini Amina Bairi Abdel Madjid	*Badji Mokhtar University*	Sensitivity of the immune system in users of tobacco and psychoactive substances: A study conducted at Cisa-Boukhadra, Algeria

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ONLINE SESSION / 27.04.2025

HALL - 1 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assist. Prof. Dr. Sebahattin YILMAZ

Authors	Affiliation	Presentation title
Mechiah Fahima Inouri Ahlam Bourenine Kahina Benhoula Mohammed Bouchemal Amina Ladouali Zeyneb Meghlaoui Zoubeida	*Campus Universitaire*	Diversity and valorization of citrus fruits in Algeria: towards responsible growth
Hawraa Abdulameer Ali Al-Dahhan Zahraa Ghaleb Taleb Muhamed Hussain Hasan Slim Zarir	*University of Kufa*	Bacterial and serological survey study on Patients with tonsilitis Introduction
Inouri Ahlam Mechiah Fahima Benhoula Mohammed Bouchemal Amina Ladouali Zeyneb	*Research Center for Agri-Food Technologies*	Role of essential oils in improving the quality of beehive products: towards sustainable beekeeping in support of agriculture
Svitlana Krylach Yevhen Skrylnyk Angela Kutova Maxim Popirny	*Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky*	Stimulating the development of the spring wheat root system as a way to eliminate the negative impact of overdensity soil
Awobona E.O. Olatunji H.T. Adebayo R.A.	*Federal University of Technology Minna*	Phytochemical composition, nutritional significance and utilization of various leaves in poultry nurition; a review
Olatunji H.T. Awobona E.O.	*Federal University of Technology Minna*	Nanoparticle (*Nanocurcumin*) and curcumin; a review on their effect on poultry, rabbit and swine production
Hari Lama	*Om Sterling Global University*	Effects of plant based supplement diets on growth performance of rainbow trout fish: a review
Adulsamiu Inuwa Bello Tela, Aminu H. Maryam Muhammad Sodangi	*University Putra Malaysia.*	Determination of the level of some fat-soluble vitamins and water-soluble vitamins in farm chicken, turkey, and duck eggs
Bourenine Kahina Nait Kaci-Boudiaf Malika Saadoun Noria	*Mouloud Mammeri University*	Valorization of local pomegranate: A strategic path to efficient resilience

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ONLINE SESSION / 27.04.2025

HALL - 2 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assist. Prof. Dr. Ömer ERTUĞRUL

Authors	Affiliation	Presentation title
Badamasi Suleiman Muhammad Halliru Gabriel Ternege Ahungwa Ibrahim Muhammad Abdul Jamilu Suraja Ya'u	*Sule Lamido University Kafin Hausa*	Comparative analysis of profitability of irrigated rice production in kano river and hadejia valley irrigation schemes, Nigeria
Ajiwe, S.T. Lawal, I.T. Ganiyu, C.P. Adeniyi, R. Oluwasanmi, F.A.	*Ajayi Crowther University*	Efficacy of iron micronutrient on fusarium wilt (*Fusarium oxysporium F.* sp. *lycopersici*) and yield of tomato (*Solanum lycopersicum L*)
Ayoub LAMTITA Bahija. MOUNIR Fathallaah. BAZI	*Ben M'Sik. Hassan II University*	Knoevenagel reaction catalyzed by apatite and sodium-modified apatite: a fast, efficient, and sustainable approach
Melik Sami Khelil Sara Tallal Abdel Karim Bouzir	*Mohamed Khider Biskra University*	Agri-architecture-for-the-21st-century-innovations-in-rural-built-environments
Melik Sami Khelil Sara Tallal Abdel Karim Bouzir	*Mohamed Khider Biskra University*	Agricultural hubs: Designing spaces for food processing, storage, and distribution
Melik Sami Khelil Sara Tallal Abdel Karim Bouzir	*Mohamed Khider Biskra University*	Architecture for agricultural justice: Spatial equity in the design of food-producing communities
Melik Sami Khelil Sara Tallal Abdel Karim Bouzir	*Mohamed Khider Biskra University*	Designing the productive countryside: Architectural approaches to sustainable agriculture
Melik Sami Khelil Sara Tallal Abdel Karim Bouzir	*Mohamed Khider Biskra University*	Hybrid landscapes: Architecture at the intersection of farming, ecology, and community
Melik Sami Khelil Sara Tallal Abdel Karim Bouzir	*Mohamed Khider Biskra University*	Living landscapes: Integrating agriculture, housing, and infrastructure through design

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ONLINE SESSION / 27.04.2025

HALL - 3 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assist. Prof Gülden ÖZGÜNALTAY ERTUĞRUL

Authors	Affiliation	Presentation title
Oluwadamilola Peace AGOI Moses Adeolu AGOI Oluwanifemi Opeyemi AGOI	*Federal University of Agriculture Abeokuta*	An assessment on the efficacy of nanotechnology as a modern agricultural application
Boussak Hassina Loucif Seiad Linda Demim Soraya Berrouane Naoual	*University M'hamed Bougara - Boumerdes*	Development of new hybrid membranes applied to the treatment of oil effluents from H'assi Rmel
Abdul Rehman Arqam Iqbal Mudassar Yasin, Sami ullah Abd-Ur-Rehman	*MNS University of Agriculture,*	Impact of technology adoption on cotton production in district Sibbi
Anisa Abdul Rehman Arqam Iqbal Mudassar Yasin Sami Ullah Ali Imran	*MNS University of Agriculture,*	Economic and sustainability analysis of cotton; a comparison of climate resilient practices and convetional practices in Multan
Bouchemal Amina Inouri Ahlem Ladouali Zeyneb Mechiah Fahima Benhoula Mohamed	*Campus Universitaire*	Fermented foods as functional tools in resilient agri-food systems
Bate, Garba Barde	*Federal University Dutse*	Pesticidal efficacy of nerium oleander leaf extract on the survival of pachnoda interrupta (*Sorghum Chafer)* under field and laboratory conditions
Mohbobeh Sharifi Bahareh Rafiei Mohammad Taghi Mobasheri Saeideh Javar Daryoush Mansouri Razi Kourosh Ghaderi Ali Kianpour Fatemeh Sadat Hosseini	*Golestan Agricultural and Natural Resources Research Center*	Evaluation of soil management with various insecticides in controlling the overwintering stages of the mediterranean fruit fly
"Fernando MATA Meirielly JESUS Nuno BAPTISTA"	*Center for Research and Development in Agrifood Systems and Sustainability,*	Companion animals and farm animals: speciesism and welfare attitudes among european citizens – a sociodemographic perspective
Bouzidi Maryam Bouikhalene Belaid Madani Youness Farissi Mohamed	*Sultan Moulay Slimane University,*	Large-scale irrigation revolution: use of machine learning for sustainable water management

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ONLINE SESSION / 27.04.2025

HALL - 4 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assoc. Prof. Dr. Ertuğrul KUL

Authors	Affiliation	Presentation title
Saeed Ahmad Zaman Naima Nawaz Zain Nawaz Ijaz Ashraf Muhammad Idrees Nadia Idrees Lubna Anjum Shahzad Ayesha Riaz Abdul Rahman	*The University of Lahore*	Globalization impact on sustainable agriculture
Saeed Ahmad Zaman Naima Nawaz Zain Nawaz Ijaz Ashraf Muhammad Idrees Nadia Idrees Lubna Anjum Shahzad Ayesha Riaz Abdul Rahman	*The University of Lahore*	AI in agriculture — the future of farming
Saeed Ahmad Zaman Naima Nawaz Zain Nawaz Ijaz Ashraf Muhammad Idrees Nadia Idrees Lubna Anjum Shahzad Ayesha Riaz Abdul Rahman	*The University of Lahore*	Environment and natural resources
Saeed Ahmad Zaman Naima Nawaz Zain Nawaz Ijaz Ashraf Muhammad Idrees Nadia Idrees Lubna Anjum Shahzad Ayesha Riaz Abdul Rahman	*The University of Lahore*	What is smart farming? it's the future of agriculture
Saeed Ahmad Zaman Naima Nawaz Zain Nawaz Ijaz Ashraf Muhammad Idrees Nadia Idrees Lubna Anjum Shahzad Ayesha Riaz Abdul Rahman	*The University of Lahore*	Impact of globalization on sustainable land use and farming system in the rural development
Bohdan Romanovych Ivan Tymchuk	*Lviv Polytechnic National University*	Compost as a tool for enhancing nutrient bioavailability on degraded lands
Chayanika Uniyal Amna Mirza	*University of Delhi*	Questioning the gender narrative in agritech: a critical perspective on women's role in Viksit Bharat

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ONLINE SESSION / 27.04.2025

HALL - 5 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Prof. Dr. Emre ŞİRİN

Authors	Affiliation	Presentation title
Merve Karakoyun Mutluay Süleyman Avci Mustafa Erden Sinem Öztürk Erdem	*Bilecik Şeyh Edebali University*	Effect of iron oxide (Fe_3O_4) nanoparticles on the rooting of Blackberry (*Rubus fructicosus L.*) Cuttings
Fatih Şahan Ahmet Şahin	*Kırşehir Ahi Evran University*	Water footprint in animal farm
Ilker Ünal Tahsin Uygun Mesut Çoşlu Mete Yiğit	*Burdur Mehmet Akif Ersoy University*	Edge computing devices in digital agriculture and agricultural iot: core technologies, applications, and challenges
Zeynep Ekicioğlu Küzeci	*Kırşehir Ahi Evran University*	The role of artificial intelligence in the transformation of smart agriculture: Technological approaches and application areas
Yeliz Sakal Ümit Özyilmaz	*Aydın Adnan Menderes Üniversitesi,*	Biological control of bacterial speck of tomato (*Pseudomonas syringae* pv. *tomato*) using copper-tolerant antagonist bacteria
Fatih Şevki Erkuş Koray Tuncay	*Van Yüzüncü Yıl Üniversitesi,*	Determination of methane concentration in biogas using low-cost multiple methane sensors
Fatih Şahan Ahmet Şahin	*Kırşehir Ahi Evran University*	Use of molasses in animal nutrition
Muhammet Ekemen Çiğdem Ulubaş Serçe	*Niğde Ömer Halisdemir University*	Effect of chitosan-based nanocapsules on the aphid-mediated transmission of potato virus y

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ONLINE SESSION / 27.04.2025

HALL - 6 / SESSION - 3 | **ZOOM ID: 833 1287 1999 / PASSCODE: 252627**

Ankara Local Time: 15:00-17:00

HEAD OF SESSION: Assoc. Prof. Dr. Koray KIRIKÇI

Authors	Affiliation	Presentation title
Lyazzat Mukanova Koray KIRIKÇI Tuleukhan Sadykulov Yerlik Baimazhi Gulsad Zhumagaliyeva	*Kazakh National Agrarian Research University*	Dgat1 gene polymorphism in coarse-haird fat tailed lambs of different genotypes
Bibigul Sansyzbayeva Sholpan Adylkanova Toleukhan Sadykulov Koray KIRIKÇI	*Kazakh National Agrarian Research University*	Determination of cast/mspi gene polymorphism and its effects on 180-day weight in meat production line of Kazakh saryarka lambs
N.J. Khodjayeva Q. Jurakulov S. Khojiakhmatov S. Eliboyeva	*Samarkand State University of Veterinary Medicine*	Nutrient media developed for cultivation and multiplication of epiphytic microorganisms
Jurabek Nayimovich Xujamov Ruxsora Normumin Kızı Hamidova	*Samarkand State University of Veterinary Medicine*	Location, status and statistical analysis of livestock in the republic of Uzbekistan
Kh. Juraqulov Ch. Sattorov	*Samarkand State University of Veterinary Medicine*	Obtaining polyhydroxyalkanoate by concentration of butanols of the resistant strain pseudomonas helmanticensis P1
N. Zh. Khuzhaeva A. H. Nurmukhammadov K. H. Jorakulov	*Samarkand State University of Veterinary Medicine*	Effect of gibberellic acid-producing lactic acid bacteria on the development of grapes.
Tursunaliyev Bobur	*Samarkand State University of Veterinary Medicine*	Effectiveness of using micronutrient and vitamin supplements in dairy cows
Nurniyozov Akhtam Yunusov Khudaynazar Tashpulatov Yigitali Eshonkulova Nozliya	*Samarkand State University of Veterinary Medicine*	Biological treatment of wastewater from intensive fishing ponds
N. Khodjaeva O. N. Khujaeva P. K. Dzhurakulov G. Akbarova	*Samarkand State University of Veterinary Medicine*	Use of chlorella in livestock (the case of cattle)
Ainur Orakbayeva Sholpan Adylkanova Koray Kirikci	*Samarkand State University of Veterinary Medicine*	The development of meat qualities in lambs of the coarse-wool fat-tailed saryarka sheep breed (interbreed zhanaarka
Boulhaia Imene Moulai-Mostefa Nadji Hadjsadok Abdelkader Aouabed Ali	*University of Blida*	Preparation of bionanomaterials as reinforcing phase in polymeric matrices to form nanocomposites.

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SYMPOSIUM PHOTOS


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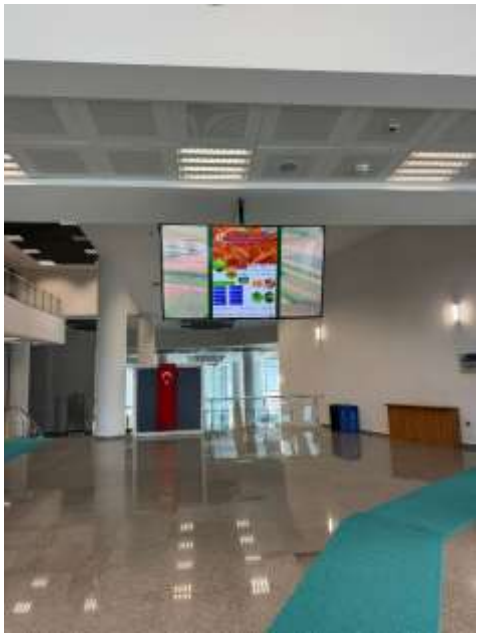


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VELİ


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ABSTRACTS

BOX-BEHNKEN DESIGN OPTIMIZATION OF BROTOWALI STEM EXTRACTION CONDITIONS AND ITS ANTICERVICAL CANCER POTENTIAL: AN IN SILICO AND EXPERIMENTAL APPROACH

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ABSTRACT

Cervical cancer remains a major global health concern with high morbidity and mortality rates. Natural products like brotowali (*Tinospora crispae* L.) offer promising alternatives due to their multi-targeted mechanisms and lower toxicity. This study integrates computational and experimental approaches to evaluate the anticancer potential of brotowali stem extracts. Network pharmacology and molecular docking were used to identify key bioactive compounds and predict their interactions with target proteins, revealing common targets between the disease and the compounds, particularly EGFR and ESR1, which play crucial roles in cervical cancer inhibition. The extraction process was optimized using the Box-Behnken Design (BBD), determining optimal conditions of 5.383 minutes extraction time, a 23.792 mL/g solvent-to-sample ratio, and 180.001 W microwave power. These conditions yielded a cytotoxic activity of 230.434 µg/mL and a total flavonoid content of 20.274 mg QE/g, with a desirability of 0.726. Response surface methodology (RSM) analysis was conducted on the BBD results using 3D visualization and contour plots, confirming that the applied equation followed a quadratic model with valid values. By combining in silico analysis with experimental validation, this study highlights the therapeutic potential of brotowali in cervical cancer treatment, underscores the importance of optimized extraction techniques, and suggests that its bioactive compounds have promising potential in combating cervical cancer.

Keywords: cervical cancer, Box-Behnken Design, *Tinospora crispae* L., in silico, optimization

OPTIMIZING GLYCEROL MONOSTEARATE (GMS) AND SORBITAN MONOSTEARATE (SMS) RATIOS ON LIPID PROFILES IN LOW-SATURATED SHORTENING: A LIPIDOMIC AND CHEMOMETRIC APPROACH

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ABSTRACT

Cardiovascular disease (CVD) remains a leading global health concern, often associated with excessive intake of saturated fatty acids (SFA), which contribute to elevated cholesterol levels and vascular obstruction. This study explores the role of Glycerol Monostearate (GMS) and Sorbitan Monostearate (SMS) in optimizing the lipid profile of low-saturated shortening, leveraging lipidomic and chemometric approaches. Experimental formulations included 5% and 10% GMS:SMS treatments with six ratio variations (100:0, 80:20, 60:40, 40:60, 20:80, and 0:100), each replicated three times. Lipid profiling was conducted using lipidomic analysis, free fatty acid quantification, peroxide value determination, and Gas Chromatography-Mass Spectrometry (GC-MS) for fatty acid composition. Chemometric techniques, including Principal Component Analysis (PCA) and Partial Least Squares-Discriminant Analysis (PLS-DA), facilitated data interpretation. Results indicated that in the 5% GMS:SMS treatment, the 100:0, 80:20, and 60:40 formulations exhibited superior stability based on free fatty acid and peroxide value assessments. Notably, lipidomic profiling identified the 80:20 ratio within the 5% treatment as the most favorable, featuring an increased proportion of unsaturated fatty acids and reduced SFA content. These findings suggest that GMS and SMS ratios can enhance the lipid profile of shortening, offering potential health benefits and improved product stability.

Keywords: Shortening, lipidomic analysis, low saturated fat, chemometric analysis.

HYDROCHAR FROM FISH WASTE AS AN EFFICIENT ADSORBENT FOR POLLUTANT REMOVAL: SYNTHESIS, CHARACTERIZATION, AND ADSORPTION MECHANISMS ANALYZED THROUGH DFT CALCULATIONS

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ABSTRACT

This study explores the potential of hydrochar derived from fish waste as an efficient adsorbent for the removal of pollutants from aqueous solutions. Hydrochar, produced via hydrothermal carbonization (HTC) of fish waste, was characterized using various techniques such as FTIR, SEM, and BET surface area analysis to understand its structural properties and surface characteristics. Adsorption experiments were conducted to evaluate the efficiency of the hydrochar in removing heavy metals, organic dyes, and other contaminants. The results revealed that the hydrochar exhibited significant adsorption capacity, with optimal conditions determined for pollutant removal, including pH, contact time, and adsorbent dosage. The adsorption process followed the Langmuir isotherm model, indicating monolayer adsorption on a surface with a finite number of identical sites. Additionally, Density Functional Theory (DFT) calculations were employed to investigate the molecular interactions between the pollutants and the hydrochar surface. The DFT results provided a deeper understanding of the adsorption mechanisms, revealing the key role of functional groups in binding the pollutants. Thermodynamic studies showed that the adsorption process was spontaneous and exothermic, further supporting the viability of hydrochar as a cost-effective and sustainable material for environmental remediation. This study demonstrates the promising application of fish waste-derived hydrochar in water treatment, highlighting its potential as a green material for pollution control.

Keywords: Hydrochar, Fish Waste, Adsorption, Pollutant Removal, DFT Calculations, Water Treatment, Environmental Remediation.

ANTICANCER POTENTIAL OF EXTRACT AND FRACTION FROM BROTOWALI (TINOSPORA CRISPA) STEM AGAINST BREAST CANCER: CYTOTOXICITY, NETWORK PHARMACOLOGY, MOLECULAR DOCKING

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ABSTRACT

Breast cancer continues to be a major health concern, requiring the exploration of alternative treatment strategies. Berberine, a bioactive alkaloid found in *Tinospora crispa*, has shown promising anticancer properties with previous studies reporting its cytotoxic activity against various cancer cell lines. This study aims to evaluate cytotoxic effects, network pharmacology, moleculaqr docking analysis, and antioxidant activity of extract and fraction from *T. crispa* against T47D breast cancer cells. The fractions were obtained through maceration using methanol, followed by acid-base fractionation. Cytotoxic activity was assessed using the MTT assay on the T47D cell, while antioxidant activity was evaluated using the radical DPPH scavenging activity and the IC_{50} values were determined. The results showed that the pH 9 fraction exhibited the strongest anticancer activity against T47D cells, with an IC_{50} of 172.27 ± 8.30 µg/mL, and the highest antioxidant activity, with an IC_{50} of 43.36 ± 0.08 µg/mL. To further explore its anticancer potential, a network pharmacology approach was employed to identify key molecular targets of brotowali-derived compounds. Network analysis revealed AKT1 as a critical target associated with breast cancer. Additionally, molecular docking studies demonstrated strong interactions between brotowali-derived compounds and AKT1, supporting their potential role in breast cancer inhibition. These findings provide insights into the anticancer mechanisms of brotowali and establish a foundation for future research on its therapeutic applications.

Keywords: *Tinospora crispa*, breast cancer, cytotoxic activity, antioxidant activity, bioinformatics

THE IMPORTANCE OF AGRICULTURAL INSURANCE IN CLIMATE CHANGE

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ABSTRACT

Agricultural production is a sector that can be carried out under suitable climatic conditions. Due to climate change, fluctuations in temperature, irregularities in precipitation patterns, and increased incidence of extreme weather events are among the most significant global challenges facing agricultural production. Research indicates that natural events affecting production are expected to increase in both intensity and frequency. It is anticipated that natural events that restrict agricultural production due to climate change will directly or indirectly cause a decrease in income and a serious increase in production costs. Farmers need to take measures to prevent or mitigate risk factors that reduce production and cause income loss. For this reason, it is expected that producers' awareness of risks will increase every year and interest in agricultural insurance will increase .As of 2024, the ratio of Insurance Amount to Agricultural Gross Domestic Product (GDP) is 44.5%. The Turkiye Agricultural Insurance (TARSİM) system plays a critical role in protecting farmers against climate change risks and in ensuring the sustainability of production.

Keywords: Tarsim, Climate Change, Agricultural Insurance, Risk

İKLİM DEĞİŞİKLİĞİNDE TARIM SİGORTASININ ÖNEMİ

ÖZET

Tarımsal üretim uygun iklim koşullarında gerçekleştirilebilen bir sektördür. İklim değişikliği nedeniyle sıcaklık dalgalanmaları, yağış rejiminde düzensizlikler ve ekstrem hava olaylarındaki artışlar; tarımsal üretimde, karşılaşılan en önemli küresel zorluklar arasında yer almaktadır. Yapılan araştırmalarda üretimi etkileyen doğa olaylarının, şiddetinde ve frekansında artış olacağı öngörülmektedir. İklim değişikliğine bağlı tarımsal üretimi kısıtlayıcı doğa olayları, doğrudan veya dolaylı olarak gelirlerin azalmasına ve üretim maliyetlerinde ciddi şekilde artışa neden olacağı öngörülmektedir. Çiftçilerin, üretimi azaltan ve gelir kaybına neden olan risk faktörlerini engelleyici veya azaltıcı tedbirler alması gerekmektedir. Bu nedenle üreticilerin her yıl risklere karşı farkındalığının artması ve tarım sigortasına olan ilginin yükselmesi beklenmektedir. 2024 yılı itibariyle Sigorta Bedelinin/ Tarımsal Gayri Safi Yurt İçi Hasılaya (TGSYH) oranı %44,5 dir. Türkiye'deki Tarım Sigortaları (TARSİM) sistemi, çiftçilerin iklim değişikliği risklerine karşı korunmasında ve üretimin sürdürülebilirliğinde kritik bir rol oynamaktadır.

Anahtar Kelimeler: Tarsim, İklim Değişikliği, Tarım Sigortası, Risk

THE STRATEGIC ROLE OF PRECISION AGRICULTURAL PRACTICES IN CLIMATE CHANGE AND THEIR CONTRIBUTION TO SUSTAINABLE AGRICULTURAL PRODUCTION

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ABSTRACT

Climate change has become one of the most critical factors affecting agricultural production. Extreme weather events, such as rising temperatures and irregular rainfall regimes, seriously threaten the sustainability of the agricultural sector. The agricultural sector accounts for approximately 24% of global greenhouse gas emissions, increasing the global carbon footprint. Precision agriculture practices reduce the adverse effects of climate change on agricultural production processes, increasing productivity and sustainability. This study examined the role of precision agriculture practices in combating climate change in terms of efficiency and sustainability.

Precision agriculture practices play a significant role not only in conserving water and energy but also in reducing greenhouse gas emissions. Studies have shown that precision irrigation systems reduce water use by up to 30%. Similarly, it has been determined that variable rate fertilization (VRA) practices reduce nitrogen oxide (N_2O) emissions by 20-30%. Recently, with the widespread use of artificial intelligence applications in agriculture, data analytics and optimizing planting processes have reduced yield losses by 25% and pesticide use by 40%. In terms of energy efficiency, GPS-supported tractor steering systems reduce fuel consumption by 10-15%, reducing fossil fuel use. Monitoring agricultural areas at the micro level with remote sensing technologies and unmanned aerial vehicles (UAVs) can optimize fertilizer and water consumption by up to 25%. Despite these benefits, various factors prevent precision agriculture practices from becoming widespread. High investment costs stand out as a significant limiting factor in accessing these technologies. The installation costs of precision agriculture equipment are, on average, 30% higher than traditional agriculture. In addition, the complexity of data collection and analysis processes makes it challenging to adopt these technologies, especially in small-scale agricultural enterprises.

As a result, precision agriculture technologies increase water and energy efficiency, reduce greenhouse gas emissions, and stand out as an effective tool in combating climate change by optimizing agricultural production processes. However, for these technologies to be adopted more widely, incentive mechanisms need to be strengthened, digital infrastructure needs to be developed, and raising farmers' awareness is essential. The acceleration of digital

transformation in agricultural production will increase the capacity and adaptation ability to produce sustainable solutions against the climate crisis.

Keywords: Precision agriculture, climate change, greenhouse gas emissions, water management, carbon footprint, sustainable agricultural production

HASSAS TARIM UYGULAMALARININ İKLİM DEĞİŞİKLİĞİNDEKİ STRATEJİK ROLÜ VE SÜRDÜRÜLEBİLİR TARIMSAL ÜRETİME KATKISI

ÖZET

İklim değişikliği tarımsal üretimi doğrudan etkileyen en önemli faktörlerden biri haline gelmiştir. Artan sıcaklıklar ve düzensiz yağış rejimleri gibi ekstrem hava olayları, tarım sektörünün sürdürülebilirliğini ciddi şekilde tehdit etmektedir. Tarım sektörü dünya genelindeki sera gazı emisyonlarının yaklaşık %24'ünü oluşturarak, küresel karbon ayak izinin artmasına neden olmaktadır. Hassas tarım uygulamaları iklim değişikliğinin tarımsal üretim süreci üzerindeki olumsuz etkilerini azaltarak verimliliği ve sürdürülebilirlik artırmaktadır. Bu çalışmada verimlilik ve sürdürülebilirlik bakımından hassas tarım uygulamalarının iklim değişikliğiyle mücadeledeki rolü incelenmiştir.

Hassas tarım uygulamaları, su ve enerji tasarrufunun yanı sıra sera gazı emisyonlarının azaltılmasında önemli rol oynar. Yapılan araştırmalar hassas sulama sistemlerinin su kullanımını %30'a kadar azalttığını ortaya koymaktadır. Benzer şekilde, değişken oranlı gübreleme (VRA) uygulamalarının azot oksit (N_2O) emisyonlarını %20-30 oranında azalttığı belirlenmiştir. Son zamanlarda tarımda yapay zeka uygulamalarının kullanımının yaygınlaşmasıyla birlikte veri analitiği ve ekim süreçlerini optimize ederek verim kayıplarını %25, pestisit kullanımını ise %40 oranında düşürmüştür. Enerji verimliliği açısından, GPS destekli traktör direksiyon sistemleri yakıt tüketimini %10-15 oranında azaltarak fosil yakıt kullanımını azaltır. Uzaktan algılama teknolojileri ve insansız hava araçları (İHA) ile tarımsal alanların mikro düzeyde izlenmesi gübre ve su tüketimini %25'e kadar optimize edebilir. Hassas tarım uygulamalarının bu faydalarına karşın yaygınlaşmasını engelleyen çeşitli faktörler bulunmaktadır. Yüksek yatırım maliyetleri bu teknolojilere erişimde önemli bir sınırlayıcı unsur olarak öne çıkmaktadır. Hassas tarım ekipmanlarının kurulum maliyetleri, geleneksel tarıma kıyasla ortalama %30 daha fazladır. Ayrıca veri toplama ve analiz süreçlerinin karmaşıklığı özellikle küçük ölçekli tarım işletmelerde bu teknolojilerin benimsenmesini zorlaştırmaktadır.

Sonuç olarak, hassas tarım teknolojileri su ve enerji verimliliğini artırırken, sera gazı emisyonlarını azaltmakta ve tarımsal üretim süreçlerini optimize ederek iklim değişikliğiyle mücadelede etkili bir araç olarak öne çıkmaktadır. Bununla birlikte bu teknolojilerin daha geniş çapta benimsenebilmesi için teşvik mekanizmalarının güçlendirilmesi, dijital altyapının geliştirilmesi ve çiftçilerin bilinçlendirilmesi gerekmektedir. Tarımsal üretimde dijital dönüşümün ivme kazanması, iklim krizine karşı sürdürülebilir çözümler üretme kapasitesini ve adaptasyon yeteneğini artıracaktır.

Anahtar Kelimeler: Hassas tarım, iklim değişikliği, sera gazı emisyonları, su yönetimi, karbon ayak izi, sürdürülebilir tarımsal üretim

A STUDY ON DETERMINING SOME MORPHOLOGICAL AND AGRICULTURAL CHARACTERISTICS OF SCENTED GRASS (Chrysopogon gryllus (L.) Trin.)

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ABSTRACT

This study was conducted in 2024 in Uşak to determine some morphological and agricultural characteristics of the perennial, warm-climate grass species, *Chrysopogon gryllus* (L.) Trin., which naturally occurs in the rangelands of Uşak. As part of the study, measurements and observations were made on 15 plants, two years old and in the flowering stage, which were collected from the Budaklar Village rangeland in Uşak and planted in plots with a spacing of 70 x 50 cm.

According to the results determined in the study, the plant height of *Chrysopogon gryllus* ranged between 78.00 cm and 144.00 cm, the number of nodes ranged from 3.00 to 5.00 nodes/stem, and the internode length varied between 12.00 cm and 25.00 cm. The average stem thickness of the plants was 3.01 mm, while the number of stems per plant varied from 1 to 15 stems/plant. The average plant spread diameter was determined to be 36.51 cm. In the study, the green forage yield per plant ranged from 54.00 g to 148.80 g/plant, while hay yields ranged from 15.71 g to 48.29 g/plant. Regarding quality characteristics, the crude protein content ranged from 7.45% to 12.68%, while the NDF and ADF contents were found to be in the ranges of 66.20%-72.46% and 32.13%-35.81%, respectively. The average RFV of the plant was determined to be 83.97.

Keywords: *Chrysopogon gryllus* (L.) Trin., plant height, crude protein content, NDF, RFV

BUZAĞI OTUNUN (*Chrysopogon gryllus* (L.) Trin.) BAZI MORFOLOJİK VE TANIMSAL ÖZELLİKLERİNİN BELİRLENMESİ ÜZERİNE BİR ARAŞTIRMA

ÖZET

Bu çalışma, Uşak meralarında doğal halde yayılış gösteren, çok yıllık bir sıcak iklim buğdaygili olan buzağı otunun (*Chrysopogon gryllus* (L.) Trin.) bazı morfolojik ve tarımsal özelliklerinin belirlenmesi amacıyla 2024 yılında Uşak'ta yürütülmüştür. Çalışma kapsamında Uşak Merkez Budaklar Köyü merasından toplanarak 70 x 50 cm aralığındaki ocaklara dikilen, iki yaşında ve çiçeklenme dönemindeki 15 bitki üzerinde ölçüm ve gözlemler yapılmıştır.

Araştırmada belirlenen sonuçlara göre buzağı otunda bitki boyu 78.00 cm ile 144.00 cm arasında, boğum sayısı 3.00 ile 5.00 adet/sap arasında ve boğum uzunluğu 12.00 ile 25.00 cm arasında değişim göstermiştir. Bitkide ortalama sap kalınlığı 3.01 mm iken, bitki başına sap sayısı 1 ile 15 adet/bitki arasında farklılık göstermiştir. Buzağı otunda ortalama bitki yayılma çapı ise 36.51 cm olarak belirlenmiştir. Çalışmada buzağı otunun bitki başına yeşil ot verimi değerleri 54.00 g ile 148.80 g/bitki arasında değişirken kuru ot verimleri 15.71 g ile 48.29 g/bitki arasında değişim göstermiştir. Kalite özelliklerinden ham protein oranı %7.45 ile %12.68 arasında değişiklik gösterirken, NDF ve ADF oranları sırasıyla %66.20-%72.46 ve %32.13-%35.81 aralığında tespit edilmiş, bitkide ortalama RFV değeri ise 83.97 olarak tespit edilmiştir.

Anahtar Kelimeler: *Chrysopogon gryllus* (L.) Trin., bitki boyu, ham protein oranı, NDF, RFV

DETERMINATION OF QUALITY CHARACTERISTICS OF CORN (*Zea mays* L.) SILAGE WITH DIFFERENT ADDITIVES

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ABSTRACT

This study was conducted in 2023 at the Sakarya University of Applied Sciences, Agricultural Sciences and Technologies Education Application and Research Center, to determine the effects of different additives added to cobbed and cobless corn silage on their quality characteristics. The FAO 700 hybrid Kale corn variety was used in the study. The cobbed and cobless plants were prepared for silage, and these materials were silaged with four different additives: urea, barley chop, whey, and molasses. The research was conducted using a randomized complete block design with three replications. After the fermentation period, silages were evaluated using dry matter content and pH values to calculate Flieg scores, and physical analysis was performed using color, odor, and structure data, with DLG (Deutsche Landwirtschafts Gesellschaft) scoring to assess the silages' quality parameters. According to the findings, the lowest dry matter content of 32.5% was observed in the silages with cobless plants and whey, while the highest content of 45.5% was found in the cobbed silage with molasses. In terms of pH, the cobbed molasses mixture had the lowest value of 3.82, while the highest value of 5.59 was detected in the cobless urea mixture. According to the physical analysis and DLG scoring, all samples, except for the cobbed urea mixture, were generally

classified as medium to good, while according to Flieg scores, all applications, except for the cobbed urea and cobless urea mixtures, were classified as very good.

In the physical analysis, no positive effect of the additives added to the silages made from cobless plants was observed, whereas the findings derived from pH and dry matter values calculated using Flieg scoring revealed that additives such as molasses and urea had a significant positive effect on the pH value and dry matter content of corn silage. Additionally, all silages were observed to be of high quality, as indicated by Flieg scores.

Considering all these results, it can be said that, except for the urea application, additives had a positive effect on both cobbed and cobless silage quality.

Keywords: Corn, Silage, Additive, Silage quality

FARKLI KATKI MADDELERİ İLE YAPILAN MISIR (*Zea mays* L.) SİLAJININ KALİTE ÖZELLİKLERİNİN BELİRLENMESİ

ÖZET

Bu çalışma, koçanlı ve koçansız mısır silajına ilave edilen farklı katkı maddelerinin kalite özellikleri üzerindeki etkilerini belirlemek amacıyla, Sakarya Uygulamalı Bilimler Üniversitesi Tarım Bilimleri ve Teknolojileri Eğitimi Uygulama ve Araştırma Merkezi arazisinde 2023 yılında yürütülmüştür. Çalışmada, FAO 700 olum grubuna ait Kale mısır çeşidi kullanılmıştır. Koçanlı ve koçansız bitkiler, silaj yapılmak üzere hazırlanmış ve bu materyaller; üre, arpa kırması, peyniraltı suyu ve melâs gibi dört farklı katkı maddesi eklenerek silaj yapılmıştır. Araştırma, Tesadüf Blokları Deneme Deseni'ne göre üç tekerrürlü olarak yürütülmüştür. Fermantasyon süresi sonunda açılan silajlarda kuru madde oranı ve pH değerinden yararlanılarak Flieg puanları, renk, koku ve strüktür verilerinden yararlanılarak fiziksel analiz değerlendirmesi DLG (Deutsche Landwirtschafts Gesellschaft) puanlaması ile hesaplanarak, silajların kalite parametreleri ortaya konulmuştur. Elde edilen bulgulara göre, en düşük kuru madde oranı %32.5 ile koçansız peyniraltı suyu ilave edilen silajlarda, en yüksek ise %45.5 ile koçanlı melâs katkı maddeli silajlarda gözlemlenmiştir. pH değeri açısından ise; 3.82 ile koçanlı melas karışımı en düşük değere sahip olurken, koçansız üre karışımında en yüksek değer olan 5.59 tespit edilmiştir. Fiziksel analiz sonucu DLG puanlamasına göre, koçanlı üre karışımlı silaj hariç tüm örnekler genel olarak orta ve iyi sınıfta yer alırken, Flieg puanlarına göre, koçanlı üre katkılı ve koçansız üre katkılı silajlar hariç tüm uygulamalar çok iyi sınıfında değerlendirilmiştir.

Silaj fiziksel analiz sonucu yapılan değerlendirmede koçansız bitkilerden yapılan silajlara ilave edilen katkı maddelerinin olumlu etkisi görülmezken, pH ve kuru madde değerleri üzerinden hesaplanan ve silaj kalitesini belirlemede yararlanılan Flieg puanlamasında ise bulgular, melâs ve üre gibi katkı maddelerinin mısır silajının pH değeri ve kuru madde oranı üzerinde önemli olumlu etkiler sağladığını ortaya koymuştur. Ayrıca, Flieg puanları açısından tüm silajların yüksek kaliteli olduğu gözlemlenmiştir.

Tüm bu sonuçlar değerlendirildiğinde; katkı maddelerinden üre uygulaması hariç koçanlı ve koçansız silaj kalitesi üzerinde olumlu etki gösterdeği söylenebilir.

Anahtar Kelimeler: Mısır, Silaj, Katkı Maddesi, Silaj kalitesi

DETERMINATION OF WEED AND QUALITY CHARACTERISTICS OF SOME SORGHUM GENOTYPES IN MUŞ ECOLOGICAL CONDITIONS

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ABSTRACT

The research was carried out in Muş province in 2022. The aim of the research was to determine the grass yield and quality of the genotypes of 14 Sorghum and Sorghum Sudan grass hybrids and 4 candidate varieties (Akdarı, 26, Mataco, Talisman, Karaca Melez, 305, Uzun, Hulk, Gözde 80, E.Sumac, Rox, 310, Aldarı, Öğretmen Oğlu, 314, Leoti, Erdurmuş, Beydarı) in Muş Ecological conditions. The desaduff blocks were used in 3 replications according to the experimental design.

Plants; height 96.33-243.66 cm, single plant weight 868.33-2418.33 gr, dry matter yield 345.95-1057.18 kg per decare, crude protein ratio % 6.08-10.02

According to the research results in this study, while Leoti, Uzun and Beydarı varieties stand out in terms of quality; Gözde 80, Uzun and Mataco varieties stand out in terms of yield. In order to obtain a good yield in Muş and similar ecological conditions, it can be recommended to grow one of the Gözde 80, Uzun or Mataco varieties. When evaluated in terms of both yield and quality, it would be appropriate to use the Uzun variety, which is in high statistical groups.

Keywords: Grass yield, Silage, Sorghum

MUŞ EKOLOJİK KOŞULLARINDA BAZI SORGUM GENOTİPLERİNİN OT VE KALİTE ÖZELLİKLERİNİN BELİRLENMESİ

ÖZET

Araştırma 2022 yılında Muş ilinde yürütülmüştür. Araştırmada amaç Muş Ekolojik koşullarına bazı 14 Sorgum ve Sorgum Sudan otu melezi ile 4 adet çeşit adayında (Akdarı, 26, Mataco, Talisman, Karaca Melez, 305, Uzun, Hulk, Gözde 80, E.Sumac, Rox, 310, Aldarı, Öğretmen Oğlu, 314, Leoti, Erdurmuş, Beydarı) genotiplerinin ot verim ve kalitesi belirlenmesi amacıyla desadüf blokları deneme desenine göre 3 tekrarlı olarak yapılmıştır.

Bitkilerin; boyu 96,33-243,66 cm, tek bitki ağırlığı 868,33-2418,33 gr, kuru madde verimi dekara 345,95-1057,18 kg, ham protein oranı % 6,08-10,02

Bu çalışmada araştırma sonucuna göre kalite bakımından Leoti, Uzun ve Beydarı çeşitleri ön plana çıkarken; verim bakımından ise Gözde 80, Uzun ve Mataco çeşitleri ön plana çıkmıştır. Muş ve benzeri ekolojik koşullarda iyi bir verim elde etmek için Gözde 80, Uzun veya Mataco çeşitlerinden birinin yetiştirilmesi önerilebilir. Hem verim hem de kalite bakımından değerlendirildiğinde ise yüksek istatistiki gruplar içinde olan Uzun çeşidinin kullanılması elverişli olacaktır.

Anahtar Kelimeler: Ot verimi, Silaj, Sorgum

PLANT EXTRACTION METHODS: TRADITIONAL AND INNOVATIVE TECHNIQUES

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ABSTRACT

Plant extracts contain natural compounds widely used in the food, pharmaceutical, and cosmetic industries. The effective extraction of these compounds depends on the selected extraction method. Traditional methods include maceration, percolation, and Soxhlet extraction, while in recent years, environmentally friendly and high-efficiency techniques have been developed.

Modern extraction methods reduce solvent consumption while obtaining compounds with higher purity and biological activity. Supercritical fluid extraction (SFE) operates at low temperatures, preventing thermal degradation and preserving volatile compounds. Ultrasonic-assisted extraction (UAE) enhances solvent penetration by breaking down cell structures through sound waves, accelerating the process. Microwave-assisted extraction (MAE) helps selectively extract target compounds while providing energy savings. In recent years, innovative solvents such as deep eutectic solvents (DES) and ionic liquids (IL) have been introduced as alternatives to toxic organic solvents. These solvents are biodegradable and environmentally friendly, making them a crucial part of sustainable extraction processes. Additionally, enzyme-assisted extraction techniques allow for the natural breakdown of cell walls, leading to higher yields.

In our study, plant extraction was performed using the fruits and leaves of the chinaberry tree (*Melia azedarach*). The fruits were separated from their seeds and dried in an oven for 24 hours along with the leaves, followed by a grinding process. The leaf extract was prepared using ethanol, while the fruit extract was obtained using methanol. The extraction process was carried out in 50 mL Falcon tubes, with 10 parts plant material and 40 parts solvent. The mixtures were subjected to orbital shaking for 48 hours, and the solvents were evaporated at room temperature to obtain dried extracts. Finally, the dried extracts were dissolved in distilled water to form solutions.

The extraction method used in this study is a traditional solvent-based technique, which can be integrated with widely adopted modern approaches to enhance efficiency. This paper will examine the traditional and modern extraction methods used for obtaining bioactive compounds from plants.

Keywords: Extraction, Bioactive Compounds, Solvent, Sustainability

BİTKİSEL EKSTRAKSİYON YÖNTEMLERİ: GELENEKSEL VE YENİLİKÇİ TEKNİKLER

ÖZET

Bitkisel ekstraktlar, gıda, ilaç ve kozmetik endüstrisinde yaygın olarak kullanılan doğal bileşikler içerir. Bu bileşiklerin etkin bir şekilde elde edilmesi, seçilen ekstraksiyon yöntemine bağlıdır. Geleneksel yöntemler arasında maserasyon, perkolasyon ve soxhlet ekstraksiyonu bulunurken, son yıllarda çevre dostu ve yüksek verimli yeni teknikler geliştirilmiştir.

Modern ekstraksiyon yöntemleri, çözgen tüketimini azaltarak daha yüksek saflıkta ve biyolojik aktiviteye sahip bileşiklerin elde edilmesini sağlamaktadır. Süperkritik akışkan ekstraksiyonu (SFE), düşük sıcaklıkta çalışarak termal bozulmayı önler ve özellikle uçucu bileşiklerin korunmasını sağlar. Ultrasonik destekli ekstraksiyon (UAE), ses dalgalarının hücre yapısını parçalama etkisiyle çözgen penetrasyonunu artırarak süreci hızlandırır. Mikrodalga destekli ekstraksiyon (MAE) ise hedef bileşiklerin seçici olarak elde edilmesine yardımcı olurken enerji tasarrufu da sağlar. Son yıllarda derin ötektik çözücüler (DES) ve iyonik sıvılar (IL) gibi yenilikçi çözücüler kullanılarak, toksik organik çözücülere alternatif geliştirilmiştir. Bu çözücüler biyolojik olarak parçalanabilir ve çevre dostu olmaları nedeniyle sürdürülebilir ekstraksiyon süreçlerinde önemli bir yer edinmektedir. Ayrıca, enzim destekli ekstraksiyon teknikleri, hücre duvarlarının doğal yollarla parçalanmasını sağlayarak daha yüksek verim elde edilmesini mümkün kılmaktadır.

Yapmış olduğumuz bir çalışmada, tesbih ağacı meyveleri ve yaprakları kullanılarak bitkisel ekstraksiyon işlemi gerçekleştirilmiştir. Meyveler, çekirdeklerinden ayrılarak yapraklarla birlikte 24 saat etüvde kurutulmuş, ardından öğütme işlemi uygulanmıştır. Yaprak ekstraktı, etanol ile; meyve ekstraktı ise metanol ile hazırlanmış olup, 50 ml'lik Falcon tüplerinde 10 birim bitki materyali ve 40 birim çözücü oranında ekstrakte edilmiştir. Karışımlar 48 saat orbital shaker cihazında çalkalanarak ekstraksiyon süreci tamamlanmış, ardından çözücüler oda sıcaklığında uçurularak ekstraktlar kurutulmuştur. Son olarak, kuruyan ekstraktlar saf su ile çözelti haline getirilmiştir.

Bu çalışmada kullanılan ekstraksiyon yöntemi, geleneksel çözücü bazlı ekstraksiyon tekniklerinden biri olup, günümüzde yaygın olarak tercih edilen modern yaklaşımlarla entegre edilerek daha verimli hale getirilebilir. Bu bildiride, bitkisel biyoaktif bileşiklerin çıkarılmasında kullanılan geleneksel ve modern ekstraksiyon yöntemleri incelenecektir.

Anahtar Kelimeler: Ekstraksiyon, Biyoaktif Bileşikler, Çözücü, Sürdürülebilirlik

INVESTIGATION OF THE YIELD AND ESSENTIAL OIL PROPERTIES OF MENTHOL MINT GROWN IN DIFFERENT ECOLOGIES*

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ABSTRACT

This study aims to determine the herbage and essential oil yield potentials of high-menthol clones (YLV-M46, Abure, Arven-1, and Arven-2) in three different ecological regions (Isparta, Kayseri, and Yalova) and to evaluate the effects of ecological variations on these yields. The plants used in the study were selected from clones with high menthol content based on previous research. Field studies in different ecological regions were carried out using a randomized block design. After planting, the water needs of the plants were met through a drip irrigation system, and weed control was performed manually. The plants were harvested at the flowering stage. In the study, fresh and dry herbage yields as well as essential oil ratios were determined depending on ecological conditions. Essential oils were isolated using the hydro-distillation method with a Clevenger apparatus. According to the research results, the highest yields were obtained in the Yalova due to the vegetation period. The highest yield was recorded for the YLV-M46 clone in Yalova, with fresh and dry herbage yields of 3,170 kg/da and 396 kg/da, respectively. Due to its high leaf proportion, the highest dry leaf yield was obtained from the Abure. The highest essential oil content with 6% was from Arven-1, which also had the highest essential oil yield with 25.98 L/da. Based on the first-year results, it was determined that the

Yalova ecology is more suitable for the cultivation of menthol mint. Additionally, among the clones examined, Arven-1 was found to be promising for national essential oil production to meet Turkey's demand.

Keywords: Mint, *Mentha arvensis*, menthol yield, essential oil

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FARKLI EKOLOJILERDE YETIŞTIRILEN MENTOL NANESININ VERIM VE UÇUCU YAĞ ÖZELLIKLERININ ARAŞTIRILMASI*

ÖZET

Bu çalışmada, mentol oranı yüksek klonların (YLV-M46, Abure, Arven-1 ve Arven-2) üç farklı ekolojide (Isparta, Kayseri ve Yalova) herba ve uçucu yağ verim potansiyelleri ile ekolojik farklılıkların bu verimler üzerindeki etkilerinin belirlenmesi amaçlanmıştır. Çalışmada kullanılan bitkiler, önceki araştırmalardan seçilmiş, yüksek mentol oranına sahip klonlardan oluşmaktadır. Ekolojilerde yürütülen tarla denemeleri, tesadüf blokları deneme desenine göre planlanmıştır. Bitkilerin su ihtiyacı damla sulama sistemiyle karşılanmış, yabancı ot mücadelesi ise elle yapılmıştır. Bitkiler çiçeklenme dönemine ulaştığında hasat edilmiştir. Çalışma kapsamında, ekolojik koşullara bağlı olarak taze ve kuru herba verimleri ile uçucu yağ oranları belirlenmiştir. Uçucu yağ oranları hidro-distilasyon yöntemiyle analiz edilmiştir. Araştırma sonuçlarına göre, uzun vejetasyon süresi nedeniyle en yüksek verimler Yalova lokasyonunda elde edilmiştir. En yüksek verim, Yalova ikliminde YLV-M46 klonundan alınmış olup, bu klonda taze ve kuru herba verimleri sırasıyla 3.170 kg/da ve 396 kg/da olarak belirlenmiştir. Yaprak oranının yüksek olması nedeniyle, en yüksek kuru yaprak verimi Abure klonunda kaydedilmiştir. Çalışmada, uçucu yağ oranının en yüksek değeri %6 ile Arven-1 klonunda tespit edilmiş olup, aynı klonda 25,98 L/da ile en yüksek uçucu yağ verimi elde edilmiştir. Çalışmanın ilk yılı verilerine göre, sıcak iklime sahip Yalova ekolojisinin mentol nanesi yetiştiriciliği için daha uygun olduğu belirlenmiştir. Ayrıca, incelenen klonlar arasında Arven-1 klonunun, Türkiye'nin ihtiyaç duyduğu uçucu yağın yerli üretimi açısından ümit vaat ettiği sonucuna ulaşılmıştır.

Anahtar Kelimeler: Nane, *Mentha arvensis*, mentol verimi, uçucu yağ

SELECTION OF DROUGHT TOLERANT POTATO (SOLANUM TUBEROSUM *L.*) BREEDING LINES *IN VITRO* CONDITIONS BY MORPHOLOGICAL AND MULTI-CRITERIA ANALYSIS METHODS

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ABSTRACT

Potato (*Solanum tuberosum* L.) is a major field crop highly susceptible to drought stress and is anticipated to be significantly affected by the increasing threat of drought associated with climate change. In this context, the present study aimed to evaluate the morphological responses of 17 different potato genotypes under in vitro drought conditions simulated by adding PEG-6000 (Polyethylene Glycol) to the standard MS-0 (Murashige and Skoog) medium. The drought tolerance levels of these genotypes were compared using various analytical approaches.

The experimental material consisted of breeding lines and commercial cultivars developed by Niğde Ömer Halisdemir University and the Potato Research Institute Directorate, along with breeding lines obtained from the International Potato Center (CIP). The study was carried out in the Tissue Culture Laboratory of the Potato Research Institute, following a factorial experimental design with four replications. The evaluated morphological parameters included root length, shoot length, total fresh weight (TFW), and total dry weight (TDW) of the plants.

Based on TDW values, classical drought stress indices such as the Drought Tolerance Index (DTI) and the Drought Susceptibility Index (DSI) were calculated. In addition, modern decision support methodologies offering multi dimensional assessment namely, Multi-Criteria Decision Making (MCDM) methods TOPSIS and VIKOR were also employed. According to the DTI results, genotypes exhibiting the least biomass reduction under drought stress and maintaining high performance were identified. Specifically, CIP37, KONSUL, and NAHITA stood out with high DTI scores, suggesting strong drought tolerance. The findings from the VIKOR analysis were consistent with these results, with CIP37 being identified as the closest genotype to the ideal solution, having the lowest VIKOR score. Similarly, KONSUL and NAHITA ranked second and third, respectively, due to their robust drought tolerance and balanced stress response profiles.

Overall, the integration of classical indices (DTI, DSI) with modern MCDM methods (TOPSIS, VIKOR) provided a more comprehensive and reliable approach for genotype evaluation in

breeding programs. Based on the combined results of all analyses, CIP37, KONSUL, NAHITA, and MUT655 were recommended as promising genetic materials for further selection studies.

Keywords: Potato, PEG-6000, Drought Stress, Morphological Traits, Selection, DTI, DSI, TOPSIS, VIKOR

KURAKLIĞA TOLERANSLI PATATES (SOLANUM TUBEROSUM *L.*) ISLAH HATLARININ *IN VITRO* KOŞULLARDA MORFOFİZYOLOJİK VE ÇOK KRİTERLİ ANALİZ YÖNTEMLERİYLE SELEKSİYONU

ÖZET

Patates (*Solanum tuberosum* L.), kuraklık stresine karşı duyarlılığı yüksek olan önemli bir tarla bitkisidir ve iklim değişikliğine bağlı olarak artan kuraklık tehdidinden ciddi şekilde etkilenmesi beklenmektedir. Bu bağlamda yapılan çalışmada, standart MS-0 (Murashige and Skoog) ortamına PEG-6000 (Polietilen Glikol) eklenerek oluşturulan in vitro kuraklık koşullarında, 17 farklı patates genotipinin morfolojik tepkileri değerlendirilmiş ve kuraklığa tolerans düzeyleri farklı analiz yöntemleriyle karşılaştırılmıştır.

Denemede, Niğde Ömer Halisdemir Üniversitesi ve Patates Araştırma Enstitüsü Müdürlüğü tarafından geliştirilen ıslah hatları ve ticari çeşitler kullanılmıştır. Ayrıca International Potato Center (CIP)'dan temin edilen ıslah hatları da kullanılmıştır. Çalışma, dört tekerrürlü olarak faktöriyel deneme desenine göre Patates Araştırma Enstitüsü Müdürlüğü Doku Kültürü Laboratuvarı'nda yürütülmüştür. Değerlendirilen morfolojik parametreler; kök uzunluğu, sürgün uzunluğu, bitki toplam yaş ağırlığı (BTYA) ve bitki toplam kuru ağırlığı (BTKA) olmuştur.

Çalışmada, bitki toplam kuru ağırlığı (BTKA) verileri esas alınarak klasik stres indekslerinden Kuraklık Tolerans İndeksi (KTI) ve Kuraklık Hassasiyet İndeksi (KHI) hesaplanmıştır. Bunun yanı sıra, karar destek süreçlerinde çok boyutlu değerlendirme imkânı sunan modern yaklaşımlar kapsamında Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden TOPSIS ve VIKOR analizleri de uygulanmıştır. KTI analizleri doğrultusunda, kuraklık uygulaması altında ağırlık kaybı minimum düzeyde kalan ve stres koşullarında iyi sonuç veren genotipler ön plana çıkmıştır. Bu bağlamda, özellikle CIP37, KONSUL ve NAHİTA genotipleri yüksek KTI değerleri ile dikkat çekmiş ve kuraklık stresine karşı en toleranslı materyaller arasında yer almıştır. VIKOR analizi sonuçları da bu bulguları destekler nitelikte olup, tüm kriterler dikkate alındığında CIP37 genotipi en düşük VIKOR skoruna sahip olarak ideal çözüme en yakın genotip olarak belirlenmiştir. Aynı analizde, KONSUL ve NAHİTA genotipleri sırasıyla ikinci ve üçüncü sırada yer alarak güçlü kuraklık toleransı ve dengeli stres yanıt profilleri ile öne çıkmıştır.

Sonuçlar, klasik indeksler (KTI, KHI) ile Çok Kriterli Karar Verme (TOPSIS, VIKOR) yöntemlerinin birlikte kullanılmasının, ıslah programlarında daha güvenilir ve çok boyutlu seleksiyon stratejileri geliştirilmesine olanak sunduğunu göstermektedir. Yürütülen tüm analizler neticesinde CIP37, KONSUL, NAHİTA ve MUT655 genotipleri, ileri seleksiyon çalışmaları için umut vaat eden materyaller olarak önerilmektedir.

Anahtar Kelimeler: Patates, PEG6000, Kuraklık, Morfoloji, Seleksiyon, KTI, KHI, TOPSIS, VIKOR

AGROBACTERIUM-BASED TRANSFORMATION OF CRY 1C AND CRY 1CST GENES INTO COMMON BEAN (*Phaseolus vulgaris* L.)

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ABSTRACT

Common bean (*Phaseolus vulgaris* L.), a major food and plant protein source worldwide, is an important food grain legume plant that is used for both human and animal consumption and also enriches the soil with nitrogen. However, the bean seed beetle, *Acanthoscelides obtectus* Say., is a species that causes devastating damage to beans, chickpeas, black-eyed peas and beans in Türkiye and worldwide. Therefore, it causes significant annual losses in bean yield and economic burden. Therefore, this study aimed to investigate the introduction and integration of Cry 1C and Cry 1CST genes from the synthetic Cry gene family into the bean genome and to evaluate their effects on bean seed beetle infestation by producing and characterizing stable transgenic beans expressing Cry 1C and Cry 1CST genes. Transgenic bean plants containing the Cry 1C gene were treated with bean seed beetle under controlled field conditions and it was observed that all insects that ate the plants died. In addition, bean seed beetle larvae were given transgenic leaves in petri dishes, and all larvae that fed on the leaves died and their survival rates were found to be zero. These findings show that the transgenic lines demonstrated their resistance to bean seed beetle pests. In addition to bioassay analyses, histochemical GUS analysis, classical PCR, real time PCR and ELISA analyses proved that T-DNA integration occurred in both bean varieties. These results, together with possible changes to be made in the Biosafety Law in Türkiye, will enable the commercial use of transgenic bean varieties carrying the Cry 1C and Cry 1CST genes in the fight against Coleoptera.

Keywords: Common bean, *Agrobacterium tumefaciens*, bean seed beetle, Cry 1C gene, Cry1CST gene

FASULYE (*Phaseolus vulgaris* L.) BİTKİSİNE AGROBACTERİUMA DAYALI CRY 1C ve CRY 1CST GENLERİNİN TRANSFORMASYONU

ÖZET

Dünya çapında temel bir gıda ve bitkisel protein kaynağı olan fasulye (*Phaseolus vulgaris*), hem insan hem de hayvan tüketiminde kullanılmasının yanında ayrıca toprağı azotça zenginleştiren önemli bir yemeklik tane baklagil bitkisidir. Ancak, fasulye tohum böceği, *Acanthoscelides obtectus* Say., dünya genelinde ve Türkiye'de başta fasulye olmak üzere nohut, mürdümük ve börülcede yıkıcı zararlara sebep olan bir türdür. Bu sebeple de fasulye veriminde ve ekonomik yükte önemli yıllık kayıplara yol açmaktadır. Bu nedenle, bu çalışma, sentetik Cry gen ailesinden olan Cry 1C ve Cry 1CST genlerinin fasulye genomuna girişi ve entegrasyonunu araştırmayı ve Cry 1C ve Cry 1CST genlerini ifade eden stabil transgenik fasulyeleri üreterek ve karakterize ederek fasulye tohum böceği istilası üzerindeki etkisini değerlendirmeyi amaçlamıştır. Cry 1C geni aktarılmış transgenik fasulye bitkileri kontrollü tarla koşullarında fasulye tohum böceği ile muamele edilmiş ve bitkileri yiyen tüm böceklerin öldüğü gözlemlenmiştir. Ayrıca fasulye tohum böceği larvalarına petri kabı içinde transgenik yapraklar verilmiş, yapraklarla beslenen larvaların da tamamının öldüğü, hayatta kalma oranlarının sıfır olduğu sonucuna varılmıştır. Bu bulgular, transgenik hatların fasulye tohum böceği zararlılarına karşı dayanıklılıklarını ortaya koyduğunu göstermektedir. Biyoassay analizlerinin yanısıra Histokimyasal GUS analizi, Klasik PCR, Real Time PCR ve ELISA analizleri ile de T-DNA entegrasyonunun, heriki fasulye çeşidinde de gerçekleştiği kanıtlanmıştır. Bu sonuçlar, Türkiye'de Biyogüvenlik Kanununda yapılacak olası değişikliklerle birlikte Cry 1C ve Cry 1CST genlerini taşıyan transgenik fasulye çeşitlerinin Coleoptera zararlılarıyla mücadelesinde ticari kullanıma olanak sunacaktır.

Anahtar Kelimeler: Fasulye, *Agrobacterium tumefaciens,* fasulye tohum böceği, Cry 1C geni, Cry1CST geni

PROBLEMS AND SOLUTION SUGGESTIONS ENCOUNTERED IN MICROPROPAGATION OF WALNUT (*Juglans regia* L.)

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ABSTRACT

Walnut (*Juglans regia* L.) is an important hard-shelled fruit species with economic importance. It originates from Central Asia and Iran, but is currently grown in many countries such as Europe, America, Türkiye and China. Türkiye is one of the leading countries in the world in terms of production. Its use in the nuts and food industry is quite common. Its wood is also used in furniture, coatings and works of art. Due to its omega-3 content, it supports heart and brain health and is a food with an antioxidant effect that helps balance blood sugar and cholesterol levels. The walnut plant is one of the stubborn species in *in vitro* microculture. Plant tissue culture is an extremely advantageous method in mass-scale plant propagation. There is increasing interest in the application of tissue culture techniques in areas such as breeding, propagation, production of disease-free plants, rejuvenation of old varieties, development of clones suitable for abiotic and biotic stresses, production of disease-free plants, protection of genetic resources, genetic transformation, etc. *In vitro* micropropagation is now a tissue culture method used in many plants, including walnut, to develop new varieties on a large scale in a relatively short time. Despite the many advantages of the micropropagation technique in walnut, it has not reached the desired popularity due to many application difficulties/problems. There are various limitations such as microbial contamination, secretion of phenolics from cultured explants, accumulation of toxic compounds in the medium, low regeneration rate, necessity/difficulty and long time to develop genotype-specific micropropagation protocols, vitrification in shoots, thin shoots in tissue cultured products, reduced productivity in subcultures, *in vitro* rooting, high production cost, difficulties encountered in acclimatization and emergence of some variants in micropropagated populations. There are many reasons behind these problems that still await solutions. This study aims to explain some of the problems encountered during commercial scale *in vitro* micropropagation of walnut plants and solution proposals to overcome these problems. Although some problems have been largely solved by some researchers in some laboratories and countries, some limitations still prevent this technique from being used safely and efficiently in clonal rootstock production programs for walnut. This situation necessitates the continuation of intensive research on what these obstacles are and how they can be solved.

Keywords: Walnut, clonal propagation, contamination, darkening, vitrification

CEVİZ (*Juglans regia* L.)'İN MİKROÇOĞALTIMINDA KARŞILAŞILAN SORUNLAR ve ÇÖZÜM ÖNERİLERİ

ÖZET

Ceviz (*Juglans regia* L.) ekonomik öneme sahip önemli bir sert kabuklu meyve türüdür. Orta Asya ve İran kökenlidir, ancak günümüzde Avrupa, Amerika, Türkiye ve Çin gibi birçok ülkede yetiştirilmektedir. Türkiye; üretim açısından dünyada önde gelen ülkelerden biridir. Kuruyemiş ve gıda sanayisinde kullanımı oldukça yaygındır. Ayrıca ahşabı da mobilya, kaplama ve sanat eserlerinde kullanılmaktadır. Omega-3 içeriğinden dolayı kalp ve beyin sağlığını desteklemekte, kan şekeri ve kolesterol seviyelerini dengelemeye yardımcı olan antioksidan etkisine sahip bir besindir. Ceviz bitkisi *in vitro* mikroğaltımlarda inatçı türlerden biridir. Bitki doku kültürü, kitlesel ölçekte bitki çoğaltımlarında son derece avantajlı bir yöntemdir. Doku kültürü tekniklerine ıslah, çoğaltma, hastalıksız bitkilerin üretimi, eski çeşitlerin gençleştirilmesi, abiyotik ve biyotik streslere uygun klonların geliştirilmesi, hastalıksız bitkilerin üretimi, genetik kaynakların korunması, genetik transformasyon vb. alanlarda uygulanmasına yönelik ilgi artmaktadır. *In vitro* mikroçoğaltım artık ceviz de dahil olmak üzere birçok bitkide nispeten daha kısa sürede büyük ölçekte yeni çeşitlerin geliştirilmesi amacıyla kullanılan bir doku kültürü yöntemidir. Cevizde mikroçoğaltım tekniğinin pekçok avantajlarına rağmen, pekçok da uygulama zorluklarından/problemlerden dolayı istenilen popülerliğe ulaşamamıştır. Mikrobiyal kontaminasyon, kültürlenmiş eksplantlardan fenoliklerin salgılanması, toksik bileşiklerin ortamda birikmesi, düşük rejenerasyon oranı, genotipe özel mikroçoğaltım protokollerinin geliştirilmesinin zorunluluğu/zorluğu ve uzun zaman alması, sürgünlerde camlaşma (vitrifikasyon), doku kültüründe yetiştirilen ürünlerde ince sürgünler, alt kültürlerde azalan verimlilik, *in vitro* köklenme, yüksek üretim maliyeti, aklimatizasyonda karşılaşılan zorluklar ve mikroçoğaltılmış popülasyonda bazı varyantların ortaya çıkması gibi çeşitli kısıtlamalar vardır. Bu sorunların arkasında hala çözüm bekleyen birçok neden vardır. Bu çalışma, ceviz bitkisinin ticari ölçekte *in vitro* mikroçoğaltılması sırasında karşılaşılan bazı sorunları ve bu sorunları aşmaya yönelik çözüm önerilerini açıklamayı amaçlamıştır. Bazı sorunlar artık önemli ölçüde kimi araştırıcılarca kimi laboratuvar ve ülkelerde çözülmüşse de, bazı kısıtlamalar hala bu tekniğin cevizin klonal anaç üretim programında güvenli ve verimli bir şekilde kullanılmasına engel olmaktadır. Bu durum, bu engellerin neler olduğu ve nasıl çözülebileceklerine dair yoğun araştırmaların devamını zorunlu kılmaktadır.

Anahtar Kelimeler: Ceviz, klonal çoğaltım, kontaminasyon, kararma, vitrifikasyon

GENETIC DISTINCTION BETWEEN MORPHOLOGICALLY SIMILAR HEXAPLOID AND TETRAPLOID WHEAT SPECIES

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ABSTRACT

Wheat is one of the most widely cultivated and economically significant agricultural crops worldwide. Although *Triticum aestivum* (bread wheat) has a hexaploid chromosome structure and *Triticum durum* (durum wheat) is tetraploid, distinguishing these two species based on morphological characteristics is challenging. In this study, we examined the genetic differences between *Triticum aestivum* and *Triticum durum* by analyzing nuclear gene regions, including 26S rDNA, the intergenic spacer (IGS), the XDuPw167 microsatellite locus, and the *Glu-1* gene regions. Our findings revealed distinct variations in the IGS region, confirming the hexaploid nature of *Triticum aestivum* and the tetraploid structure of *Triticum durum*. The analysis of 26S rDNA and the *Glu-1* gene regions identified species-specific nucleotide differences. The XDuPw167 microsatellite locus exhibited significant polymorphism in terms of repeat number for hekzaploid and tetaploid wheat species. This study highlights the role of genetic analysis in accurately distinguishing morphologically similar wheat species and underscores the importance of understanding wheat genetics to support sustainable agricultural practices.

Keywords: *Triticum aestivum*, *Triticum durum*, Hexaploid, Polymorphism, Tetraploid

MORFOLOJİK OLARAK BENZER HEKZAPLOİD VE TETRAPLOİD BUĞDAY TÜRLERİNİN GENETİK AYRIMI

ÖZET

Buğday, dünya genelinde en yaygın yetiştirilen ve ekonomik açıdan en önemli tarım ürünlerinden biridir. *Triticum aestivum* (ekmeklik buğday) hekzaploid, *Triticum durum* (makarnalık buğday) ise tetraploid kromozom yapısına sahip olmasına rağmen, bu iki türü morfolojik olarak ayırt etmek oldukça güçtür. Bu çalışmada, *Triticum aestivu*m ve *Triticum durum* türleri arasındaki genetik farklılıklar, 26S rDNA, intergenik spacer (IGS), XDuPw167 mikrosatellit lokusu ve Glu-1 gen bölgeleri analiz edilerek incelenmiştir. Elde edilen veriler, IGS bölgesindeki belirgin farklılıkların *Triticum aestivum*'un hekzaploid, *Triticum durum*'un ise tetraploid yapısını doğruladığını göstermiştir. 26S rDNA ve Glu-1 gen bölgelerinin analizinde türler arasında spesifik nükleotid farklılıkları tespit edilmiştir. XDuPw167 mikrosatellit lokusu ise tekrar sayıları açısından hekzaploid ve tetraploid buğday türleri açısından önemli düzeyde polimorfizm sergilemiştir. Bu çalışma, morfolojik olarak benzerlik gösteren buğday türlerinin genetik analiz yoluyla güvenilir şekilde ayrılabileceğini ortaya koymakta ve tarımsal sürdürülebilirliği desteklemek amacıyla buğday genetiğinin daha iyi anlaşılmasının önemini vurgulamaktadır.

Anahtar Kelimeler: *Triticum aestivum*, *Triticum durum*, Hekzaploid, Polimorfizm, Tetraploid

DEVELOPMENT OF SAGE VARIETIES WITH TETRAPLOID GENOME (TETRA SAGE) BY POLYPLOIDY BREEDING IN MEDICINAL AND ANATOLIAN SAGE

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ABSTRACT

Sage (Salvia spp.) is a medicinal and aromatic plant of high economic value due to the secondary metabolites it contains. All of the wild collected and cultivated sage species and cultivars are diploid and there is no polyploid species and cultivars obtained naturally or artificially and commercialised yet. In this study, it was aimed to obtain autotetraploid (2n = 4x = 28) plants by applying different concentrations (0, 125, 250 and 500 ppm) of colchicine, a mitotic spindle strand inhibitor, to the seeds and cotyledonal growth tips of common sage (Salvia officinalis L. var. Elif, 2n = 2x = 14) and Anatolian sage (Salvia fruticosa L. var. Karık, 2n = 2x = 14).

Autotetraploid plants produced by colchicine induction are very important breeding materials as well as providing opportunities to obtain higher amounts of medicine, pharmacy, cosmetics and functional food raw materials. With polyploidy, organs such as leaves, flowers, fruits and seeds become larger, the number of stomata and chloroplasts and the amount of secondary metabolites increase. These results indicate that autotetraploid plants are of great economic importance with their potential to produce larger plants and more secondary metabolites compared to diploids.

In this study, phenological, morphological, anatomical (epidermis, trichome, stomata, chloroplast, pollen counts and measurements), cytological (chromosome counts and nuclear DNA content), agricultural (herb and leaf yields), quality (essential oil content) of diploid and tetraploid genotypes of both species, phenolic matter content, GC/MS essential oil components, HPLC phenolic matter components) and antiradical and antioxidant activities (ABST, β-carotene linoleic acid, CUPRAC, DPPH, Phosphomolybdanium and FRAP) were determined and in vitro micropropagation of the diploids were started.

Keywords: *Salvia*, Polyploidy Breeding, Colchicine, Diploid, Autotetraploid.

TIBBİ VE ANADOLU ADAÇAYINDA POLİPLOİDİ ISLAHI İLE TETRAPLOİD GENOMLU ADAÇAYI ÇEŞİTLERİNİN (TETRA SAGE) GELİŞTİRİLMESİ

ÖZET

Adaçayı (*Salvia* spp.), içerdiği sekonder metabolitler nedeniyle ekonomik değeri oldukça yüksek olan bir tıbbi ve aromatik bitkidir. Yabani olarak toplanan ve kültürü yapılan adaçayı tür ve çeşitlerinin tamamı diploid olup, henüz doğal veya yapay olarak elde edilerek ticarileştirilmiş bir poliploid türü ve çeşidi yoktur. Bu araştırmada, tıbbi adaçayı (*Salvia officinalis* L. var. Elif, 2n = 2x = 14) ve Anadolu adaçayının (*Salvia fruticosa* L. var. Karık, 2n = 2x = 14) tohumlarına ve kotiledonal büyüme uçlarına mitoz iğ iplikçiği inhibitörü olan kolhisinin farklı konsantrasyonları (0, 125, 250 ve 500 ppm) uygulanarak autotetraploid (2n = 4x = 28) seviyede bitkiler elde etmek hedeflenmiştir.

Kolhisin indüksiyonu ile meydana getirilmiş olan autotetraploid formdaki bitkiler oldukça önemli ıslah materyalleri olmalarının yanı sıra tıp, eczacılık, kozmetik ve fonksiyonel gıda hammaddelerinin daha yüksek miktarlarda elde edilme olanakları da sunmaktadır. Poliploidy ile birlikte yaprak, çiçek, meyve ve tohum gibi organlarda irileşme, stoma ve kloroplast sayılarında ve sekonder metabolitlerin miktarında artışlar olmaktadır. Bu sonuçlar, diploidlerle kıyaslandıklarında autotetraploid bitkilerin, daha büyük bitkiler ve daha fazla sekonder metabolit üretimini mümkün kılma potansiyelleri ile ekonomik açıdan büyük önem taşıdıklarını göstermektedir**.**

Bu araştırmada her iki türe ait diploid ve tetraploid genomlu genotiplerin fenolojik, morfolojik anatomik (epidermis, trikom, stoma, kloroplast, polen sayımları ve ölçümleri), sitolojik (kromozom sayımı ve çekirdek DNA miktarı), tarımsal (drog herba ve yaprak verimleri), kalite (uçucu yağ içeriği, fenolik madde içeriği, GC/MS uçucu yağ bileşenleri, HPLC fenolik madde bileşenleri) ile antiradikal ve antioksidan aktiviteleri (ABST, β-karoten linoleik asit, CUPRAC, DPPH, Fosfomolibdanyum ve FRAP) belirlenmiş, diploidlerinden üstün bulunanların *in vitro* mikroçoğaltımlarına başlanmıştır.

Anahtar Kelimeler: *Salvia*, Poliploidi Islahı, Kolhisin, Diploid, Autotetraploid.

THE EFFECT OF *LACTOBACILLUS BREVIS* (MF098783) STRAIN ON THE QUALITY AND AEROBIC STABILITY OF WHEAT FORAGE SILAGE

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ABSTRACT

This study aimed to investigate the potential use of the *Lactobacillus brevis* (LB) MF098783 strain, isolated from natural sources, as a microbial inoculant in wheat (*Triticum aestivum*) forage silage. The main objectives were to evaluate whether this lactic acid bacterium could enhance silage fermentation when applied at appropriate population densities, and to assess its effects on the chemical and microbiological quality of silage, as well as its contribution to aerobic stability. The experimental design consisted of four groups: a control group (TA) and three treatment groups inoculated with *L. brevis* strains (TALB10^6, TALB10^8, and TALB10^9). Wheat forage was harvested during the milk stage of maturity, packed into 2-liter vacuum-sealed polyethylene bags in eight replicates per group, and allowed to ferment under laboratory conditions for 60 days. Upon completion of the fermentation period, physical, chemical, microbiological, and aerobic stability analyses were performed. Statistically significant differences in pH values were observed among the groups (60.56, 4.73, 4.90, and 4.86, respectively). Increasing bacterial inoculant levels resulted in a notable reduction in yeast populations during the aerobic exposure period, and no mold development was detected in the treated silages. In conclusion, inoculation with the *Lactobacillus brevis* strain contributed to the suppression of undesirable microorganisms and yeasts, thereby improving both the quality and aerobic stability of wheat forage silage. These results suggest that *L. brevis* may offer a promising biotechnological approach for enhancing silage preservation.

Keywords: Aerobic stability, silage microbiology, *Lactobacillus brevis*, *Triticum aestivum* forage

LACTOBACILLUS BREVIS (MF098783) SUŞUNUN BUĞDAY HASILI SILAJININ KALITESI VE AEORBIK STABILITESI ÜZERINE ETKISI

ÖZET

Bu çalışma, buğday (*Triticum aestivum*) hasılında *Lactobacillus brevis* (LB) MF098783 suşunun mikrobiyel inokulant olarak kullanım olanaklarını araştırmayı amaçlamaktadır. Araştırmada, bu laktik asit bakterisinin uygun popülasyon yoğunluğunda silaj fermantasyonunu olumlu yönde etkileyip etkilemediği, silajın kimyasal ve mikrobiyolojik kalitesine olan etkisi ile aerobik stabilite süresine katkısı değerlendirilmiştir. Çalışma dört farklı gruptan meydana gelmektedir. Gruplar kontrol grubu (TA), *Lactobacillus brevis* TALB10^{6}, TALB10^{8} ve TALB10^{9}'dir. Süt olum döneminde hasat edilen buğday hasılı, 8 tekerrürlü olarak 2 litrelik vakumlu torbalara konulmuş ve laboratuvar koşullarında 60 gün süreyle fermentasyona bırakılmıştır. Fermentasyon süreci sonunda fiziksel, kimyasal, mikrobiyolojik ve aerobik stabilite analizleri gerçekleştirilmiştir. pH değerleri gruplar arasında istatistiksel olarak anlamlı farklılık göstermiştir (sırasıyla: 60.56, 4.73, 4.90 ve 4.86). Kullanılan bakteri dozunun artışıyla birlikte aerobik stabilite sürecinde maya popülasyonlarında azalma gözlenmiş, silaj örneklerinde küf gelişimi saptanmamıştır. Sonuç olarak, *Lactobacillus brevis* suşunun buğday hasılı silajına inokulasyonu, istenmeyen mikroorganizma ve maya gelişimini sınırlayarak silaj kalitesinin ve aerobik stabilitenin artırılmasında potansiyel bir biyolojik katkı sunmaktadır.

Anahtar Kelimeler: Aerobik stabilite, silaj mikrobiyolojisi, *Lactobacillus brevis*, *Triticum aestivum hasılı*

DETERMINATION OF NITRATE LEVELS IN WELL WATER: THE CASE OF KIRSEHIR PROVINCE

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ABSTRACT

Water is essential to survive and groundwater plays an important role in supplying water to rural areas. Over time, however, groundwater quality has deteriorated due to anthropogenic activities such as agricultural run-off, excessive fertiliser use and industrial pollution. In particular, high nitrate levels in groundwater raise concerns about whether the water is safe to drink. The aim of this research is to determine the nitrate content of well water used for irrigation purposes in the agricultural areas of Kırşehir region, to evaluate the suitability of this well water for agricultural irrigation, and to analyse the effect of precipitation and evaporation patterns and nitrate pollution levels. Well water was sampled seasonally in January, April, July and October from 2015-2019. The analysis results were evaluated within the framework of the Regulation on protection of waters against nitrate pollution from agricultural sources. In addition, Geographic Information Systems and Inverse Weighted Distance interpolation were used to model the spatial distribution of nitrate pollution at different points in the region. The study integrated multi-site groundwater nitrate data with meteorological data including annual precipitation and evapotranspiration. The study identifies areas at risk of groundwater quality degradation. It also highlights the importance of sustainable water management practices. It also highlights the importance of the consideration of climatic factors such as rainfall and evaporation in water quality assessments.

Keywords: Groundwater, Nitrate Pollution, GIS, IDW Interpolation, Precipitation, Evaporation, Spatial Distribution

KUYU SULARINDAKI NITRAT DEĞERLERININ BELIRLENMESI: KIRŞEHIR İLI ÖRNEĞI

ÖZET

Su, yaşamı sürdürebilmek için hayati öneme sahip bir kaynaktır ve yer altı suyu, kırsal bölgelerdeki su temini için önemli bir rol oynamaktadır. Ancak zamanla tarımsal akış, aşırı gübre kullanımı ve endüstriyel kirlilik gibi insan kaynaklı faaliyetler yer altı suyu kalitesinin düşmesine neden olmuştur. Özellikle, yer altı suyunda yüksek nitrat seviyeleri, suyun tüketim için güvenli olup olmadığı konusunda endişelere yol açmaktadır. Bu araştırma, Kırşehir bölgesinde tarımsal faaliyetlerin yapıldığı bölgelerde, sulama amaçlı kullanılan kuyu sularındaki nitrat içeriklerinin belirlenmesi, bu kuyu sularının tarımsal sulama açısından uygun olup olmadığının değerlendirilmesi, nitrat kirliliği seviyelerinin yanı sıra yağış ve buharlaşma desenlerinin etkisini analiz etmeyi amaçlamaktadır. Kuyu su örnekleri 2015-2019 yılları arasında, her yıl mevsimsel olarak Ocak, Nisan, Temmuz, Ekim aylarında alınmıştır. Analiz sonuçları, Tarımsal Kaynaklı Nitrat Kirliliğine Karşı Suların Korunması Yönetmeliği kapsamında değerlendirilmiştir. Ayrıca, Coğrafi Bilgi Sistemleri (CBS) ve Ters Ağırlıklı Mesafe (IDW) enterpolasyonu kullanılarak bölgedeki farklı noktalarda nitrat kirliliğinin mekansal dağılımı modellenmiştir. Çalışma, birden fazla izleme noktasından elde edilen yer altı suyu nitrat verilerini, yıllık yağış ve buharlaşma oranları gibi meteorolojik verilerle entegre etmiştir. Bu çalışma, yer altı suyu kalitesinin bozulma riski taşıyan bölgeleri vurgulayarak sürdürülebilir su yönetimi uygulamalarının önemini ortaya koymaktadır. Ayrıca, su kalitesi değerlendirmelerinde yağış ve buharlaşma gibi iklimsel faktörlerin dikkate alınmasının önemini vurgulamaktadır.

Anahtar Kelimeler: Yer Altı Suyu, Nitrat Kirliliği, CBS, IDW Enterpolasyonu, Yağış, Buharlaşma, Mekansal Dağılım

THE EFFECT OF COMBINE HARVESTER SPEED ON GRAIN LOSS DURING WHEAT HARVEST

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ABSTRACT

This study was conducted to determine the effects of operating combine harvesters at different forward speeds on grain losses during wheat harvesting. Reducing harvest losses is of great importance in increasing efficiency in agricultural production. Operating combine harvesters at inappropriate speeds may lead to overloading of the threshing and cleaning systems, which in turn can significantly increase grain losses. In this context, field trials were carried out during the 2024 wheat harvest season at the Aksu Research Farm of Akdeniz University, Faculty of Agriculture, located in Antalya, Türkiye. The trials were conducted on a 3-hectare wheat field where the combine harvester was operated at three different forward speeds: 4.4 km/h, 5.5 km/h, and 6.4 km/h. At each speed level, grains lose through the sieves, and from the straw walkers were collected and weighed to calculate the grain loss percentage. The data obtained indicated that grain loss increased significantly with increasing forward speed. The lowest loss was observed at 4.4 km/h, while the highest was recorded at 6.4 km/h. These findings highlight the importance of operating combine harvesters at optimal speeds to enhance harvesting efficiency and minimize economic losses.

Keywords: Combine Harvester, Wheat Harvesting, Grain Loss, Harvesting Efficiency

BİÇERDÖVER İLERLEME HIZININ, BUĞDAY HASADINDA DANE KAYBI ÜZERİNE ETKİSİ

ÖZET

Bu çalışmada, biçerdöverlerin farklı ilerleme hızlarında çalıştırılmasının buğday hasadında meydana gelen dane kayıpları üzerindeki etkilerini belirlemek amacıyla gerçekleştirilmiştir. Tarımsal üretimde hasat kayıplarının azaltılması, verimliliğin artırılması açısından büyük önem arzetmektedir. Biçerdöverlerin uygun olmayan hızda çalıştırlması, özellikle harmanlama ve temizleme sistemlerinin kapasitesinin üzerine çıkmasına neden olmakta bu da dane kaybını artırabilmektedir. Bu kapsamda, 2024 yılı buğday hasat sezonunda Antalya Akdeniz Üniversitesi, Ziraat Fakültesi Aksu Çiftliğinde 3 ha alanda buğday hasadında, biçerdöver üç farklı ilerleme hızında (4.4 km/h, 5.5 km/h ve 6.4 km/h) çalıştırılmıştır. Her hız seviyesinde, tabla arkasında, eleklerden ve sarsaklardan yere düşen daneler toplanarak tartılmış ve dane kaybı oranları hesaplanmıştır. Elde edilen veriler, hasat hızı arttıkça dane kaybının da anlamlı bir şekilde yüseldiğini göstermiştir. En düşük kayıp oranı 4.4 km/h hızda, en yüksek kayıp ise 6.4 km/h hızda gözlemlenmiştir. Bu bulgular, biçerdöverin optimum hızda çalıştırılmasının hem hasat verimliliğini artırmak hem de ekonomik kayıpları en aza indirmek açısından öneme sahip olduğunu ortaya koymaktadır.

Anahtar Kelimeler: Biçerdöver, Buğday Hasadı, Dane Kaybı, Hasat Verimliliği

HETEROSIS EFFECTS ON UPTAKE VE ACCUMULATION OF ZINC IN BARLEY

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ABSTRACT

Increasing zinc content of crops has attracted plant breeders only to produce more nutritious food but also to develop high yielding plants for zinc-deficient soils. The most convenient and environmentally friendly way to increase zinc content in zinc-deficient and zinc-sufficient agricultural soils is genetic improvement.

The present study investigated the effect of heterosis on Zn uptake, Zn accumulation and zinc deficiency tolerance in barley. Cultivars Tokak 157/37 and Baronesse, which differed in tolerance to zinc deficiency, zinc uptake and zinc accumulation in grain, and F1 derived from these cultivars were used as plant material. Genotypes were cultured hydroponically in zinc-deficient and zinc-sufficient conditions until two different stages, spike appearance and physiological maturity. Shoot, root and grain yields, zinc concentration, zinc content, plant height and zinc deficiency symptom were determined in the genotypes.

Zinc deficiency caused a decrease in all other characters except root yield. Under zinc deficient conditions, F1 produced 27% more shoot and 25% more roots, 54% less root zinc concentration, 25% less grains and 6% weaker grains than the high parent. In other characters, F1 had similar values to the high parent.

Under zinc-sufficient conditions, F1 produced 35% more shoots, 18% more shoot zinc content and 52% more grain than the high parent. However, root zinc concentration decreased by 54%, root zinc content by 47%, shoot zinc concentration by 13%, grain weight by 11%, grain zinc concentration by 12% and grain zinc content by 21% in F1 compared to high parent. Other traits of F1 showed similar values with the higher parent.

The results show that heterosis improves the translocation of zinc. The increased grain numbers due to higher performance by heterosis resulted in a slight decrease in grain zinc content compared to the high parent due to the dilution effect. Finally, the tolerance to zinc deficiency, zinc uptake and zinc accumulation in the grain can be improved by heterosis.

Key words: Grain zinc content, *Hordeum vulgare*, Hybrid, Zn,

ARPADA HETEROSİSİN ÇİNKO ALIMI VE BİRİKİMİNE ETKİSİ

ÖZET

Kültür bitkilerinin çinko içeriğini artırmak daha besleyici gıdalar üretmek yanında çinko eksik tarım alanları için yüksek verimli bitkiler geliştirmek için bitki ıslahçılarının fazlasıyla dikkatini çekmektedir. Çinko eksik ve yeterli tarım topraklarında çinko içeriğini artırmanın en pratik ve çevre dostu yolu genetik kazanımlardır.

Bu araştırmada arpada heterosisin Zn alımına, Zn birikimine ve çinko eksikliği toleransına etkisi incelenmiştir. Çinko eksikliğine tolerans ve çinko alımı ve tanede çinko birikimi bakımından farklılıklar gösteren Tokak 157/37 ve Baronesse çeşitleri ve bunlardan üretilen F1 bitki materyali olarak kullanılmıştır. Genotipler başaklanma ve olgunlaşma olmak üzere iki farklı döneme kadar çinko eksik ve çinko yeterli su kültüründe incelenmiştir. Genotiplerde yeşil aksam, kök ve tane verimleri, çinko içeriği, çinko konsantrasyonu, bitki boyu ve çinko eksikliği semptomu belirlenmiştir.

Çinko eksikliği kök verimi dışında diğer incelenen bütün karakterlerin azalmasına neden olmuştur. Çinko eksik şartlarda F1 yüksek ebeveyne göre %27 daha fazla yeşil aksam ve %25 daha fazla kök üretirken, %54 daha az kök çinko konsantrasyonu, %25 daha az tane ve %6 daha hafif taneler üretmiştir. Diğer karakterlerde F1'de yüksek ebeveyne benzer değerler belirlenmiştir.

Çinko yeterli koşullarda, F1 bitkileri, yüksek ebeveynine göre %35 daha fazla yeşil aksam, %18 daha fazla yeşil aksam çinko içeriği ve %52 daha fazla tane üretmiştir. Ancak, kök çinko konsantrasyonu %54, kök çinko içeriği %47, yeşil aksam çinko konsantrasyonu %13, tane ağırlığı %11, tane çinko konsantrasyonu %12 ve tane çinko içeriği %21 oranında azalma göstermiştir. F1'in diğer özellikleri ise yüksek ebeveynle benzer değerler sergilemiştir.

Sonuçlar heterosis çinkonun translokasyonunu geliştirdiğini göstermektedir. Heterosis ile ortaya çıkan daha yüksek performans sayesinde artan tane sayıları, seyrelme etkisinden dolayı tane çinko içeriğinin yüksek ebeveyne göre bir miktar düşmesine neden olmuştur. Son olarak çinko eksikliğine toleransı, çinko alımı ve tanede çinko birikiminin heterosis sayesinde geliştirilebileceğini göstermektedir.

Anahtar kelimeler: Hibrit, *Hordeum vulgare*, Tane çinko içeriği Zn,

ENHANCING SOIL HEALTH AND REDUCING WIND EROSION: COVER CROP STRATEGIES FOR SUGARBEET SYSTEMS IN MINNESOTA'S FERTILE BLACK SOILS

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ABSTRACT

Maintaining the sustainability of Minnesota's black soils (United States) is crucial, especially given the significant economic role of the sugar beet industry and the negative effects of intensive heavy machinery use, which degrades soil and increases erosion. This study, conducted through both station and on-farm trials from 2022 to 2024, evaluated the impact of cover crops on wind erosion, sugar beet yield, and overall soil health.

The station experiment, conducted in Crookston, MN, tested four treatments on 7 m x 12 m plots with six replications each: interseeded mustard and rye, a control treatment, and fall-planted rye. In contrast, the on-farm trials were carried out in Polk and Renville counties—areas with differing weather patterns and erosion conditions—and each site was divided into rye and control treatments. Monthly sediment collection was performed using nine BSNE samplers per treatment, while soil samples were taken from the 0–20 cm depth before planting the next crop in the on-farm experiments.

Results from the station experiment showed that interseeded cover crops did not significantly affect sugar beet yield or quality and no statistical difference between treatments for soil health metrics was observed. However, the on-farm trials revealed that winter rye had a more pronounced effect on soil health. Principal Component Analysis of soil properties indicated no significant treatment differences in the station experiment, suggesting that factors such as soil pH at the Renville site and temperature fluctuations across both sites had a more substantial influence on soil health.

Furthermore, rye proved effective in reducing horizontal mass flux, particularly when well-established. Increased temperature was correlated with higher erosion rates, and over 80% of the total sediment flux occurred under the no cover crop treatment. Notably, approximately 75% of the sediment flux was measured at heights between 0 and 15 cm, indicating that rye is especially effective at preventing wind erosion when it fully covers the soil surface and reaches a height of 15 cm.

Keywords: Sugar beet, black soil, wind erosion, soil health, sugar beet yield and quality

TOPRAK SAĞLIĞINI ARTIRMA VE RÜZGAR EROZYONUNU AZALTMA: MINNESOTA'NIN VERİMLİ SİYAH TOPRAKLARINDA ŞEKER PANCARI SİSTEMLERİ İÇİN ÖRTÜ BİTKİSİ STRATEJİLERİ

ÖZET

Minnesota'nın siyah topraklarının (Birleşik Devletler) sürdürülebilirliğinin korunması, özellikle şeker pancarı endüstrisinin önemli ekonomik rolü ve ağır makinelerin yoğun kullanımının toprak bozunmasına ve erozyonun artmasına yol açan olumsuz etkileri göz önüne alındığında kritik öneme sahiptir. Bu çalışma, 2022'den 2024'e kadar gerçekleştirilen istasyon ve arazi denemeleri yoluyla, örtü bitkilerinin rüzgar erozyonu, şeker pancarı verimi ve genel toprak sağlığı üzerindeki etkisini değerlendirmiştir.

Crookston, MN'de gerçekleştirilen istasyon çalışmasında, 6 tekrarlı 7 m x 12 m parseller üzerinde; şeker pancarı sıraları arasına hardal ve çavdar, ve şeker pancarı hasadı sonrası sonbaharda ekilen çavdar olmak üzere, control ile birlikte dört farklı uygulama gerçekleştirilmiştir. Buna karşın, farklı hava koşulları ve erozyon durumlarına sahip olan Polk ve Renville bölgelerinde arazi denemeleri yapılmış ve her bölge çavdar ve kontrol uygulamaları olarak ayrılmıştır. Her bir uygulama için dokuz sediment toplayıcı kullanılarak aylık sediment örnekleri toplanmış, aynı zamanda saha denemelerinde takip eden ekim öncesi 0–20 cm derinliğinden toprak numuneleri alınmıştır.

İstasyon deneyinden elde edilen sonuçlar, sıra arası örtü bitkilerinin şeker pancarı verimi ya da kalitesi üzerinde anlamlı bir etkisi olmadığını ve toprak sağlığı metrikleri açısından uygulamalar arasında istatistiksel bir farkın gözlenmediğini göstermiştir. Ancak, arazi denemeleri, kış çavdarının toprak sağlığı üzerinde daha belirgin bir etki yarattığını ortaya koymuştur. Toprak özelliklerinin Temel Bileşen Analizi ile incelenmesi, istasyon deneyinde anlamlı bir uygulama farkı olmadığına işaret etmiş olup, Renville bölgesinde toprak pH'ı ve her iki alanda da sıcaklık dalgalanmalarının toprak sağlığı üzerinde daha belirgin bir etkiye sahip olduğunu göstermiştir.

Ayrıca, toprak üzerinde iyi bir çavdar örtüsü, yatay sediment akışını azaltmada etkili olmuştur. Artan sıcaklık, daha yüksek erozyon oranları ile ilişkili bulunmuş ve toplam sediment taşınımının %80'inden fazlası örtü bitkisi kullanılmayan uygulamalar altında gerçekleşmiştir. Özellikle, sediment taşınımının yaklaşık %75'i yerden 0 ila 15 cm yükseklik arasında ölçülmüş olup, bu durum çavdarın toprak yüzeyini tamamen kaplayıp 15 cm yüksekliğe ulaştığında rüzgar erozyonunu önlemede özellikle etkili olduğunu göstermektedir.

Anahtar Kelimeler: Şeker pancarı, siyah toprak, rüzgar erozyonu, toprak sağlığı, şeker pancarı verimi ve kalitesi

ROOTING OF DIFFERENT CHOKEBERRY CULTIVARS WITH HARDWOOD CUTTINGS

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ABSTRACT

This study was carried out in the Department of Horticulture, Faculty of Agriculture, Kırşehir Ahi Evran University, in order to determine the effects of different IBA doses on rooting of different aronia cultivars with hardwood cuttings. Hardwood cuttings of chokeberry cultivars; Nero, Viking, Aron, Galicjanka and Katya were used in the study. The cuttings were dipped in control, 1500 and 3000 ppm IBA solution and planted in bottom-heated perlite: peat medium with three replications. In the cuttings taken on November 24, 2024 and kept in the medium for ninety days; live cutting rate (number), callus formation rate (%), rooting rate (%), average root number (number), average root thickness (mm) and average root length (cm) were evaluated. At the end of the study, the highest rooting rate was found in the Katya cultivar, and the lowest rooting rate was found in the Galicjanka cultivar.

Keywords: chokeberry, propagation by cuttings, IBA

FARKLI ARONYA ÇEŞİTLERİNİN ODUN ÇELİKLERİ İLE KÖKLENDİRİLMESİ

ÖZET

Bu çalışma, farklı IBA dozlarının, farklı aronya çeşitlerinin odun çelikleri ile köklenmeleri üzerine etkilerini belirlemek amacıyla Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümünde yürütülmüştür. Çalışmada Aronyanın; Nero, Viking, Aron, Galicjanka ve Katya çeşitlerine ait odun çelikleri kullanılmıştır. Alınan çelikler, kontrol, 1500 ve 3000 ppm IBA solüsyonuna batırılıp, alttan ısıtmalı perlit:torf ortamına üç tekerrürlü olarak dikilmiştir. 24 Kasım 2024 tarihinde alınan ve ortamda doksan gün süreyle bekletilen çeliklerde; canlı çelik oranı (adet), kallus oluşum oranı (%), köklenme oranı (%), ortalama kök sayısı (adet), ortalama kök kalınlığı (mm) ve ortalama kök uzunluğu (cm) değerlendirilmiştir. Çalışma sonunda en yüksek köklenme oranı Katya çeşidinde, en düşük köklenme oranı Galicjanka çeşidinde bulunmuştur.

Anahtar Kelimeler: aronya, çelikle çoğaltma, IBA

TIPS FOR TOP-WORKING OF WALNUT TREES

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ABSTRACT

Top-working can be used in fruit trees to replace varieties that exhibit undesirable characteristics during their productive period and to repair damaged trees. In Türkiye, top-working is widely used to convert walnut trees from seedling origin and former cultivars that yield low and frequently damaged by spring frosts in their growing locations into new productive, late-leafing, and early harvest cultivars with superior nut quality. In recent years, the topworking of walnut trees has become common in many other countries with similar walnut production facilities and growing risks. Topworking of walnut trees by using new cultivars has increased the yield and quality of unproductive trees, thereby improving the profitability of orchards and making significant contributions to the incomes of orchard owners. Besides, existing walnut trees have facilitated the development of new skilled labor capable of grafting, generated additional employment in the fruit sector, and, most importantly, led to a rapid increase in walnut production quantity at the national level.

Topworking in walnuts dates back many years and has been chiefly carried out by applying the cleft grafting technique on the main branches of the trees. Recent research and experiments with different grafting techniques have revealed that the most suitable grafting technique for the topworking of walnuts is the bark grafting technique, which is applied with various modifications. In top-working practices, not only the grafting technique but also the preparatory steps before grafting, post-grafting maintenance, and other complementary applications are crucial to achieving the desired consequences. During the top-working process of walnut trees, performers may encounter many unexpected situations and must make numerous decisions following the grafting.

In this study, valuable information and practical tips have been provided based on the results of applied research, the experiences of grafting experts, and our own experiences. The main topics covered include the proper preparation of trees before grafting, the possible ways of applying grafts on trees, the collection and appropriate storage of graft scions, the implementation of the grafting technique, the maintenance of the graft union, and the emerging shoots from buds, the management of suckers from limbs, trunk, and base, and additional practices that may be applied in subsequent years. It is considered that the information presented will help meet the informational needs of those planning to perform top-working in walnut trees, enabling them to act more consciously and systematically, gain a long-term perspective, reduce potential

uncertainties, and develop realistic expectations about the outcomes they may achieve. Furthermore, it is also expected to reduce misinformation on the subject.

Keywords: Walnut, Top-working, bark grafting, cleft grafting, Chandler

CEVİZ AĞAÇLARINDA ÇEŞİT DEĞİŞTİRME AŞILARI İÇİN İPUÇLARI

ÖZET

Çeşit değiştirme, meyve ağaçlarında, verim döneminde istenmeyen özellikler gösteren çeşitlerin değiştirilmesi ve zararlanmış ağaçların onarılması için kullanılabilmektedir. Türkiye'de, büyük çoğunlukla düşük verim veren ve yetiştirildikleri ekolojilerde ilkbahar donlarından sıklıkla zarar gören eski ceviz çeşitlerinin verimli, geç uyanan, erken hasat edilen ve yüksek meyve kalitesine sahip yeni yabancı çeşitlere dönüştürülmesi için yaygın olarak uygulanmaktadır. Günümüzde, dünyanın benzer ceviz üretim geçmişine ve üretim risklerine sahip birçok ülkesinde de yaygın olarak ceviz ağaçlarında çeşit değişimi yapılmaktadır. Cevizlerde yapılan çeşit değiştirme aşıları, eski verimsiz ağaçlardan elde edilen verimin ve ürün kalitesinin artmasını sağlayarak bahçelerin karlılığını artırmış ve ceviz üreticilerinin ekonomilerine ciddi katkılarda bulunmuştur. Öte yandan, mevcut ceviz ağaçlarımız aşılama yapabilen yeni bir işgücü kitlesinin yetişmesine imkân sağlamış, meyvecilik sektöründe ilave istihdam oluşturmuş ve en önemlisi ceviz üretimimizin ülke düzeyinde hızlı bir şekilde artmasına neden olmuştur.

Çeşit değiştirme aşılarının cevizlerde kullanımı uzun yıllar öncesine dayanmakta olup büyük çoğunlukla ağaçların ana dallarına yarma aşı tekniğinin uygulanması şeklinde yapılagelmiştir. Son yıllarda yürütülen araştırmalar ve farklı aşı tekniklerinin denenmesi sonucunda, cevizlerde çeşit değişimi için en iyi aşılama metodunun çeşitli modifikasyonlarla yapılan kabuk altı aşı tekniği olduğu ortaya çıkarılmıştır. Çeşit değiştirme uygulamalarında sadece aşılama tekniği değil aşılama öncesi hazırlık ve sonrasındaki bakım işlemleri ile diğer tamamlayıcı uygulamalar da istenen sonuca ulaşmak açısından önemlidir. Ceviz ağaçlarının çeşit değiştirilmesi sürecinde uygulayıcılar çok farklı beklenmedik durumlarla karşılaşabilmekte ve aşılama sonrasında farklı konularla ilgili çok sayıda karar verilmesi gerekmektedir.

Bu çalışmada; yürütülen uygulamalı araştırmaların sonuçlarına, aşı ustalarının tecrübelerine ve tarafımızdan yapılan çeşit değiştirme aşılarından elde edilen tecrübeye dayalı olarak faydalı olabilecek bilgiler ve kullanışlı ipuçları verilmiştir. Aşı öncesi ağaçların uygun şekilde hazırlanması, aşıların ağaçlarda uygulanabileceği şekiller, aşı kalemlerinin alınması ve uygun koşullarda muhafazası, aşı tekniğinin uygulanması, aşı bölgesinin ve aşılardan gelişen sürgünlerin bakımı, ağaçlardan çıkan dal, gövde ve dip sürgünlerinin yönetilmesi ve ilerleyen yıllarda ağaçlarda yapılabilecek ilave uygulamalar bilgi verilen ana konulardır. Sunulan bu bilgilerin, cevizlerde çeşit değiştirme aşısı yapacak kişilerin uygulama öncesi bilgi ihtiyaçlarını karşılayarak daha bilinçli ve planlı hareket etmelerini sağlayacağı, uzun vadeli bakış açısı kazandıracağı, yaşayabilecekleri tereddütleri azaltacağı ve elde edilebilecekleri sonuçlar hakkında öngörü sahibi olmalarına yardımcı olacağı değerlendirilmektedir. Ayrıca, konu hakkındaki bilgi kirliliğinin azaltılmasında katkı sağlayacağı beklenmektedir.

Anahtar Kelimeler: Ceviz, Çeşit değiştirme aşısı, kabuk altı aşı, yarma aşı, Chandler

GENETIC POLYMORPHISMS AND DIVERSITY CHARACTERISTICS AT MILK PROTEIN GENES FOR THE *HAMARI* DESERT SHEEP IN SUDAN

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ABSTRACT

The aim of this study was to determine allele and genotype frequencies and shed light on diversity characteristics at five milk protein loci namely, α-Lactalbumin (*LAA*), αS1-Casein (*CSN1S1*), β-Casein (*CSN2*), β-Lactaglobulin (*LGB*) and αS2-Casein (*CSN1S2)*, in *Hamari* Desert sheep ecotype of Western Sudan. The study was carried out on 63 (sixty-three) milk samples taken at random. The milk proteins genes under the study were genotyped with polyacrylamide gel electrophoresis (PAGE) under acidic conditions and using isoelectric focusing (IEF) techniques to extract the genotypes. The *Hamari* sheep is a protype export sheep to Middle East and Gulf livestock markets. It has been kept for their combined efficiency (meat and milk). The Hamari sheep population studied were monomorphic with one genetic variant (A = 1.000) for *LAA* locus. In particular, the genetic variant C at the *CSN1S1* locus occurred with high frequency (C=0.905) in Hamari sheep. Variant A is 'absent' in Hamari (A = 0) and D presents with a very low frequency (D = 0.007). A new varied termed X has been exhibited by *CSN1S1*, with minor frequency of 0.064.Phenotyping using Polyacrylamide Gel Electrophoresis-Isoelectric Focussing (PAGE-IEF) technique of the CSN2 locus showed that the genetic variant B were predominant, had high frequency (B = 0.429) than did variant A (0.365) and C (0.206). The *LGB* locus showed two alleles, A with high frequency of (0.857) and B with frequency of (0.143). *CSN1S2* locus for Hamari sheep in this study codifying three variants (A = 0.183), (B = 0.444) and (C = 0.373). According to Hardy-Weinberg equilibrium, Hamari sheep was in genetic equilibrium at the locus *CSN2* and *LAA* ($P < 0.05$).

The overall mean of diversity characteristics (Observed (H_o) and Expected (H_E) of homozygosity and heterozygosity were reported as: (H_o = 0.806 ± 0.240 and H_E = 0.653 ± 0.279) with *CSN1S1* and *LGB* loci scored the highest homozygoity .For heterozygosity (H_o = 0.194 ± 0.240 and H_E = 0.347 ± 0.279) with *CSN1S2* scored the highest heterozygosity

The information on the genotypic structure and diversity characteristics in Hamari sheep Desert ecotype could be exploited in future using specific breeding programme aimed at conserving biodiversity or select animals for the production of both meat and typical milk products in the Sudan.

OVERVIEW ON GENETIC VARIABILITY of CASEIN PROTEIN GENES in SUDANESE NUBIAN GOATS

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ABSTRACT

MILK and dairy products are very important in African diet because of their health promoting and organoleptic properties. In many developing countries, goat breeding has a key role in livestock production. What makes goat so popular is their ability to provide high quality food under diverse climatic conditions and resilience to extreme and capricious environments. In the last years, the interest concerning caprine milk has been increasing; also to find a new exploitation for local goats to contribute to food security and human health worldwide in order promote the goat dairy products as well. That being so, the purpose of this study was to genetically characterize goat milk caseins protein genes in Sudanese Nubian dairy goats. The electrophoretic pattern of milk samples of Sudanese Nubian goats revealed the presence of four major of caseins variants, i.e. as1-casein (CSN1S1), as2-casein (CSN1S2), B-casein (CSN2) and kappa-casein (CSN3). Five αs1-casein alleles: CSN1S1A, CSN1S1B, CSN1S1E, CSN1S1F, CSN1S1O were identified in this study. The predominant allele of as1-casein locus was CSN1S1B, with a frequency of 0.662 whereas the frequency of CSN1S1F and CSN1S1O allele was 0.050 for both. The αs2-casein and β-casein loci shows a new electrophoretic pattern termed (X) with a frequency of 0.013 and 0.002 on for both loci.

The production of quality goat milk through professional breeding programs can be rewarding, profitable, pleasant and successful. Human had to give more importance to their health and nutritional situation with increasing environmental pollution and stress in their life. So, recently goat is watched as being genetic resources demand for functional food i.e. food that has positive effects on the health.

PHYLOGENETICS of GOAT POPULATIONS IN SUDAN

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ABSTRACT

Molecular Analysis of mitochondrial DNA (mtDNA) was carried out using 125 (Taggar), 38 (Desert), 38 (Boer), 27 (Nubian) and 23 (Kalahari Red) goats randomly sampled from population bred in Sudan. As an initial step, to investigate the genetic structure of the five population s mentioned, for the first time in country. Apart from estimating genetic diversities, phylogenetic analysis, to elucidate, maternal lineages, relationships with Asiatic goats. The hypervariable (D-Loop) region of mtDNA (1200 bp) sequenced from 71 individuals, represented 61 haplotypes (40 for Taggar, 10 for Kalahari Red, 8 for Desert, 7 for Boer and 3 from the Nubian. Polymorphism of D-Loop fragment was high with haplotype diversities of 0.994 ± 0.04. Maximum-likehood tree constructed with 68 haplotypes and 22 reference haplotypes representing 6 haplogroups Worldwide, revealed that: 7 individuals that from the Taggar population belong to haplogroup B, 4 individuals that from Desert population belong to haplogroup G, whereas the remaining 67 individuals are belong to haplogroup A. So goats found in Sudan are only from A, B and G haplogroups.

We find evidence for population structure and novel lineages in goats bred in Sudan and cannot reconcile the genetic diversity found within the major lineage with domestication starting 10,000 years ago from a single mtDNA ancestor. Thus, the information obtained is strategic to sustainable utilization and conservation of the goat genetic resources at the national level.

CONSERVATION MODELLING of BIODIVERSITY for THREE SUDANESE CATTLE BREEDS (BUTANA, ARIASHY and NUBA)

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ABSTRACT

Methods of biodiversity conservation are reported and a applied to three major Sudanese cattle breeds (Araishy, Butana and Nuba Mountain). It was estimated that about half of the breeds and half of today's genetic diversity between breeds would be lost within 50 years. Based on a survey and literature review, costs and effects of four conservation models were assed: Herd Books with promotion of the breed (HB), in situ conservation with sire rotation (IS), Cryoconservation of semen (CC) and in situ plus Cryoconservation (IC). Conservation modeling involving strongly breeders and giving them part of the responsibility for the conservation of the breed reduce endangerment. In this case breeders were not just potential sellers of animals for a conservation programme, but they participated actively in the program (e.g. take decisions) and took over part of the responsibility for the success of the program. It was shown that allocation of resources to only a subset of breeds is optimal.

AN INVESTIGATION OF THE CURRENT SITUATION OF FOREST VILLAGERS: THE CASE OF GÖKSUN DISTRICT IN KAHRAMANMARAŞ PROVINCE

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ABSTRACT

This study was conducted to reveal the socio-economic structure and current situation of forest villagers living in the Kahramanmaraş province. The research was carried out in the Göksun district of Kahramanmaraş with 62 forest villagers through face-to-face surveys in April and May 2023. The study analyzed the villagers' demographic characteristics, sources of income, income level derived from forest products, participation in agricultural and livestock activities, social security status, and the main economic and social issues they face. Descriptive statistics were used in the data analysis. The results of the study showed that the forest villagers have an average of 10.23 cattle, 17.44 small ruminants, 55.55 poultry, and 13.87 beehives. It was found that 53.2% of the villagers were very satisfied with being forest villagers, 53.2% were moderately satisfied with the state's forestry policies, and 51.6% were moderately satisfied with the state's attention to the problems of forest villagers. 79% of the surveyed villagers occasionally went hunting, with wild boar (95.2%), rabbit (90.3%), and partridge (75.8%) being the most commonly hunted animals. 54.3% of the forest villagers reported having problems with the Forestry Operations Directorate regarding firewood procurement, 24.3% with grazing, 20% with land ownership, and 1.4% with hunting. 46.8% of the villagers stated that their relationship with the Forestry Operations Directorate was normal, while 24.2% reported it was bad. The villagers strongly agreed that when laws and regulations are being prepared, the demands of the villagers should be considered (4.65), that the forest-village relationship should be improved (4.56), that villagers should be provided with information about forestry (4.56), and that the staff's relations with the public should be improved (4.56). This study will

contribute to the development of policy suggestions aimed at improving the living standards of forest villagers. It is particularly recommended to encourage cooperatives, education, and support programs to increase income diversification.

Keywords: Forest villagers, socio-economic structure, income sources, forestry activities, Kahramanmaraş

ORMAN KÖYLÜLERİNİN MEVCUT DURUMLARININ İNCELENMESİ: KAHRAMANAMARAŞ İLİ GÖKSUN İLÇESİ ÖRNEĞİ

ÖZET

Bu çalışma, Kahramanmaraş ilinde yaşayan orman köylülerinin sosyo-ekonomik yapılarını ve mevcut durumlarını ortaya koymak amacıyla gerçekleştirilmiştir. Çalışma, Kahramanmaraş ilinin Göksun ilçesinde yaşayan 62 orman köylüsü ile 2023 yılı Nisan – Mayıs aylarında yüz yüze anket yöntemi kullanılarak yürütülmüştür. Çalışmada, köylülerin demografik özellikleri, gelir kaynakları, orman ürünlerinden elde edilen gelir düzeyi, tarım ve hayvancılık faaliyetlerine katılımı, sosyal güvence durumları ve karşılaştıkları temel ekonomik ve sosyal sorunlar analiz edilmiştir. Verilerin analizinde tanımlayıcı istatistiklerden yararlanılmıştır. Çalışma sonucunda orman köylülerinin ortalama 10.23 adet büyükbaş hayvanının, 17.44 adet küçükbaş hayvanının, 55.55 adet kanatlı hayvanının, 13.87 adet arılı kovanının bulunduğu belirlenmiştir. Köylülerin %53.2'si orman köylüsü olmaktan çok memnun olduğunu, %53.2'si devletin ormancılık politikalarından, %51.6'sı ise devletin orman köylülerinin sorunlarıyla ilgilenme durumundan orta derecede memnun olduklarını bildirmişlerdir. Anket yapılan orman köylülerinin %79'u ara sıra ava gittiklerini, en çok domuz (%95.2), tavşan (%90,3) ve keklik (%75,8) avladıklarını belirtmişlerdir. Orman köylülerinin %54,3'ü odun temini, %24.3'ü otlatma, %20'si mülkiyet, %1.4'ü ise avlanma konusunda Orman İşletme Müdürlüğü ile sorun yaşadığını bildirmiştir. Köylülerin %46,8'i Orman İşletme Müdürlüğü ile ilişkisinin normal olduğunu, %24.2'si ise ilişkisinin kötü olduğunu bildirmiştir. Köylüler, Orman İşletme Müdürlüğü ile sorun yaşanmaması için kanun ve yasalar hazırlanırken köylülerin isteklerinin dikkate alınması gerektiğine (4.65), orman – köylü ilişkilerinin iyileştirilmesi gerektiğine (4.56), köylülere ormancılık ile ilgili bilgi verilmesi gerektiğine (4.56) ve personelin halk ile ilişkilerinin iyileştirilmesi gerektiğine (4.56) kesinlikle katıldıklarını bildirmişlerdir. Bu çalışma, orman köylülerinin yaşam standartlarını yükseltmeye yönelik politika önerilerinin geliştirilmesine katkı sağlayacaktır. Özellikle gelir çeşitliliğini artırmaya yönelik kooperatifleşme, eğitim ve destek programlarının teşvik edilmesi önerilmektedir.

Anahtar Kelimeler: Orman köylüleri, sosyo-ekonomik yapı, gelir kaynakları, ormancılık faaliyetleri, Kahramanmaraş

ANALYSIS OF THE STRUCTURAL CHARACTERISTICS OF BROILER FARMS IN BALIKESIR PROVINCE

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ABSTRACT

Broiler farming makes significant contributions to the livestock sector due to advantages such as the rapid growth of animals, low production costs, reduced need for breeding space, and continuous market demand. This study aims to determine the socio-demographic characteristics of broiler producers and reveal the structural features of broiler farms in Balıkesir province. For this purpose, a survey was conducted with 71 broiler producers in Balıkesir in August 2023. Descriptive statistics and frequency tables were used in the analysis of the data. According to the results, the producers carry out an average of 5.88 production cycles per year. The average live weight per bird sent for slaughter in the past year was 2.73 kg, the feed conversion ratio was 1.62, and the mortality rate was found to be 3.94%. At the beginning of a production cycle, an average of 16.84 chicks per square meter are placed in a poultry house. Producers reported that they send their chickens for slaughter at an average of 43.93 days old and that they have an average of 18.83 days between two production cycles. In the surveyed region, the average size of a farm was determined to be 1,570.98 m². The average pad area of the poultry houses was 45.83 m², with an average of 4.61 fans, 8.61 tunnel fans, and 98.79 shutters. On average, the farms had 3.44 rows of feeders and 5.19 rows of drinkers. Nearly all broiler producers (97.18%) reported using nipple drinkers with drippers, and 92.96% stated that they used rice husk as bedding material. Among the producers, 85.92% preferred stoves for heating, 50.70% used coal as a fuel type, 97.18% utilized pad ventilation systems, and 90.14% used well water. Additionally, 76.06% of the producers reported not insulating their poultry houses, 46.48% used sandwich panels and another 46.48% used asbestos cement sheets as roofing material, and 73.24% used bricks as the wall material. This study is expected to serve as a resource for

strategic decisions aimed at effectively guiding broiler production potential, improving existing practices in the sector, and enhancing animal health and production processes.

Keywords: Balıkesir, broiler chicken, broiler production, poultry farming, feed conversion ratio

BALIKESİR İLİNDEKİ BROYLER İŞLETMELERİNİN YAPISAL ÖZELLİKLERİNİN ANALİZİ

ÖZET

Broyler yetiştiriciliği, hayvanların hızlı büyümesi, düşük maliyetli olması, daha az yetiştirme alanına ihtiyaç duyulması ve sürekli pazar talebinin olması gibi avantajlardan dolayı hayvancılık sektörüne önemli katkılar sağlamaktadır. Bu çalışmada Balıkesir ilinde broyler üretimi yapan işletmelerin sosyo-demografik özelliklerinin belirlenmesi ve işletmelerin yapısal özelliklerinin ortaya konulması amaçlanmıştır. Bu amaç doğrultusunda 2023 yılının ağustos ayında Balıkesir ilinde 71 broyler üreticisi ile anket çalışması yapılmıştır. Verilerin analizinde tanımlayıcı istatistikler ve frekans tablolarından yararlanılmıştır. Analiz sonucunda üreticilerin yıllık ortalama 5.88 devre üretim yaptıkları, son bir yıl içerisinde kesime gönderilen hayvan başı ortalama canlı ağırlığın 2.73 kg olduğu, yem dönüşüm oranının 1.62, ölüm oranının ise %3.94 olduğu belirlenmiştir. Dönem başında bir kümeste m^2'ye ortalama 16.84 adet civciv bırakılmaktadır. Üreticiler, yetiştirdiği tavukları kesime ortalama 43.93 günlükken gönderdiklerini, iki üretim dönemi arasında ortalama 18.83 gün devre arası verdiklerini bildirmişlerdir. Anket yapılan bölgede işletme genişliği ortalama 1570.98 m^2 olarak belirlenmiştir. Kümeslerin ped alanı genişliği ortalama 45.83 m^2, minimum fan sayısı 4.61 adet, tünel fan sayısı 8.61 adet, klape sayısı ise ortalama 98.79 adettir. Anket yapılan bölgedeki işletmelerde ortalama 3.44 sıra yemlik ve 5.19 sıra suluk bulunmaktadır. Broyler üreticilerinin tamamına yakını (%97.18) damlalıklı nipel suluk kullandığını, altlık materyali olarak çeltik kavuzu (%92.96) kullandıklarını bildirmişlerdir. Üreticilerin %85.92'si işletmelerinde ısıtma yöntemi olarak soba tercih ettiğini, %50.70'i yakıt türü olarak kömür kullandığını, %97.18'i havalandırma olarak ped kullandığını ve %90.14'ü kuyu suyu kullandığını bildirmişlerdir. Üreticilerin %76.06'sı kümeslerde mantolama yapmadığını, %46.48'i çatı malzemesi olarak sandeviç panel, %46.48'i ise atermit kullandığını, %73.24'ü duvar malzemesi olarak tuğla kullandığını ifade etmiştir. Bu çalışma ile broyler üretim potansiyelinin etkin bir şekilde yönlendirilmesi, sektördeki mevcut uygulamaların daha verimli hale getirilmesi, hayvan sağlığı ve üretim süreçlerinin iyileştirilmesi gibi stratejik kararlar için kaynak teşkil edeceği düşünülmektedir.

Anahtar kelimeler: Balıkesir, etlik piliç, broyler üretimi, kümes hayvancılığı, yem dönüşüm oranı

THE HIGHER ORGANIZATION IN COOPERATIVES IN TÜRKIYE

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ABSTRACT

Cooperatives have played an important role in the economic and social development of societies, especially after the Industrial Revolution. Many socio-economic conditions such as the monopolization of capital, the disruption of the production and supply chain, excessive profit expectations and imperfect competition conditions are effective in the emergence and development of cooperatives. This movement, which was founded in 1844 under the leadership of Robert Owen and is, considered the beginning of modern cooperatives, spread to Western Europe in a short time and later manifested itself in various ways all over the world. The Homeland Funds, founded in 1863 under the leadership of Mithat Pasha during the Ottoman period, is considered the first cooperative in the western sense in Turkey. The Homeland Funds was established as a type of agricultural credit cooperative, but Turkish cooperatives experienced their original and important development after the Republic. It was an expected and desired application that the first development efforts of Turkey, a country where approximately 75% of the population lived in agriculture in the early years of the Republic, were also aimed at the agricultural sector. It is accepted that the agricultural sector has some of its own characteristics, that this sector is special and important, and that the approaches to solving its problems have some of its own characteristics. It can be said that cooperatives, which establish a commercial partnership system based on mutual assistance, solidarity and cooperation, are quite suitable for the agricultural sector due to their sociological structure and are an effective organization in solving the problems of this sector. One of the areas where cooperatives are most widespread and effective in Turkey is the agricultural sector, and the existence of agricultural producer unions and chambers in this sector supports the organized structure in the agricultural sector. Cooperatives in the agricultural sector in Turkey continue their activities within the scope of the Cooperatives Law No. 1163, the law on agricultural credit cooperatives and the laws on agricultural sales cooperatives. These laws create a legal infrastructure for a higher organization in the form of the Union, Central Union and the Turkish National Cooperatives Association (TURKEY COOP). The higher organization is evaluated both as a strong structure for Turkish cooperatives and as a very positive aspect for a democratic cooperative management. In this study, it is aimed to evaluate and compare the current situation of the upper organization of agricultural cooperatives in Turkey within the framework of the specified cooperative legislation.

Keywords: Union, cooperative, central union organization, agriculture.

TÜRKİYE'DE TARIMSAL AMAÇLI KOOPERATİFLERDE ÜST ÖRGÜTLENME

ÖZET

Kooperatifler özellikle Sanayi Devrimi sonrası toplumların, ekonomik ve sosyal kalkınmalarında önemli bir role sahip olmuştur. Sermayenin tekelleşmesi, üretim ve tedarik zincirinin bozulması, aşırı kar beklentisi ve aksak rekabet koşulları gibi birçok sosyo-ekonomik koşul, kooperatifleşmenin ortaya çıkması ve gelişmesinde etkili olmaktadır. 1844 yılında Robert Owen'in öncülüğünde kurulan ve modern kooperatifçiliğinde başlangıcı sayılan bu hareket, kısa sürede özelikle batı Avrupa'ya yayılmış ve sonradan tüm dünyada çeşitli şekillerde kendisini göstermiştir. Osmanlı döneminde 1863 yılında Mithat Paşa'nın öncülüğünde kurulan Memleket Sandıkları Türkiye'deki batılı anlamdaki ilk kooperatif olarak kabul edilmektedir. Memleket Sandıkları, bir tür tarımsal kredi kooperatifi olarak tesis edilmiş ancak Türk kooperatifçiliği aslı ve önemli gelişmesini Cumhuriyet sonrası yaşamıştır. Cumhuriyetin ilk yıllarında nüfusun yaklaşık %75'inin tarımda yaşadığı bir ülke olan Türkiye'nin ilk kalkınma çabalarının da tarımsal kesime yönelik olması beklenen ve istenen bir uygulama olmuştur. Tarım sektörünün kendisine has bir takım özellikleri, bu sektörün özel ve önemli olduğunu ve sorunlarının çözümündeki yaklaşımların da kendisine özgü bir takım özellikler taşıdığı kabul edilmektedir. Karşılıklı yardımlaşma, dayanışma ve işbirliğine dayalı ticari bir ortaklık sistem kuran kooperatiflerin, sosyolojik yapısı itibari ile tarım sektörü için oldukça uygun ve bu sektörün sorunlarının çözümünde de etkili bir organizasyon olduğu söylenebilir. Türkiye'de kooperatifleşmenin en yaygın ve etkin olduğu alanlardan birisi de tarım sektörü olup bu sektörde tarımsal üretici birlikleri ve odaların da varlığı, tarım sektöründe ki örgütlü yapıyı destekler niteliktedir. Türkiye'de tarım sektöründe ki kooperatifler, 1163 sayılı Kooperatifler Kanunu, tarım kredi kooperatifleri ile ilgili kanun ve tarım satış kooperatifleri ile ilgili kanunlar kapsamında faaliyetlerine devam etmektedir. Bu yasalar, kooperatifler için Birlik, Merkez Birliği ve Türkiye Millî Kooperatifler Bilirliği (TÜRKİYE KOOP) şeklinde bir üst örgütlenmeye yasal altyapı oluşturmaktadır. Üst örgütlenme, Türk kooperatifçiliği için hem güçlü bir yapılanma hem de demokratik bir kooperatifçilik yönetimi için de oldukça olumlu yönde değerlendirilmektedir. Bu çalışmada, Türkiye'de ki tarımsal amaçlı kooperatiflerin üst örgütlenmesinin mevcut durumu belirtilen kooperatif mevzuatları çerçevesinde değerlendirilmesi ve mukayese edilmesi amaçlanmıştır.

Anahtar Kelimeler: Birlik, kooperatif, merkez birliği örgüt, tarım.

A PROPOSED METHOD TO MEASURE THE IMPACT OF THE GEOGRAPHIC REGISTRATION MARK FOR KAMAN NUTS ON PRODUCTION: NOMINAL GROUP TECHNIQUE

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ABSTRACT

Kırşehir is one of the most important centers of grain production in the Central Anatolia Region, known as the "breadbasket" of Türkiye. While the share of agriculture, forestry and fisheries in Türkiye's total GDP is 5% according to data from 2021, this share was around 16% in Kırşehir. Agricultural activities in Kırşehir such as plant and animal production have an important share in the city's economy. Although Kırşehir is an important center of grain production, the Kaman walnut, the only product with a geographical registration mark, also contributes significantly to the city's economy.

An application was submitted to the Turkish Patent and Trademark Office in 2019 for the Kaman walnut, one of Kırşehir's most important agricultural production resources, and the application for registration as a “designation of origin” was accepted in 2020. Kaman walnut, the only agricultural product of Kırşehir with a geographical registration mark, was registered as a geographical indication of the ”designation of origin" type, all or the most important characteristics of which are due to natural and human elements belonging to a specific geographical area. The suitability of Kaman district for walnut production is cited as one of the factors that make investment in agriculture in Kırşehir attractive by the Agricultural Investor Consultancy Office, which is affiliated to the Ministry of Agriculture and Forestry.

Taking the data on walnut trees and walnut production in Kaman district as a reference, it is noticeable that there was a radical change in 2019, when the application for GI registration was made. In Kaman, the number of walnut trees of fruiting age in 2018 was 63,250, the number of walnut trees of non-fruiting age was 161,854 and the total walnut production was 468 tons. In 2019, the number of trees of fruit-bearing age rose to 199,207, while the number of trees of non-fruit-bearing age fell to 45,460. The production volume was 468 tons in 2018, 1,296 tons in 2019 and 2,431 tons in 2024. The ratio between the number of trees of fruit-bearing age, which indicates productivity, and the production volume was as follows 2018: 7, 2019: 7, 2020: 9, 2021: 9, 2022: 10, 2023: 11, 2024: 11.

In this study, the contribution of Kaman walnut to the city's economy after obtaining the geographical indication, the impact on production volume and new production investment, the adequacy of agricultural support and the problems in the production processes are analyzed using the Nominal Group Technique (NGT) method conducted with producers and industry experts. NGT can also be defined as ‘an ad hoc group process for identifying the elements of a problem situation, defining the elements of a solution program, and establishing priorities’ (Scott & Deadrick, 1982). NGT has been widely used in agricultural research in recent years. Jeffreys (2006) argues that NGT is a proven method for evaluating organic farming and agri-environmental policy. Some of the studies in which NGT has been used in agricultural research

are as follows: (Bammer et al, 2022; Hugé et al, 2022; Santiago-Brown et al, 2015; Jeffreys, 2006; Motsenbocker & Hinson, 2003). The use of NGT is also quite common in the fields of ecology and conservation. Some of the studies that have been conducted using NGT in this field are as follows: (Hugé and Mukherjee, 2018; Waas et al, 2014; Robinson and Shepard, 2011; Strager and Rosenberger, 2006; Jacobson, Gape, Sweeting and Stein, 2005); (Motsenbocker and Hinson, 2003).

It is expected that the results of the study will highlight the problems in the production processes of Kaman walnut, which is an important production item for the urban economy, offer suggestions for solutions and can serve as data for determining the economic impact of registering a geographical indication and determining the appropriate agricultural policy.

Keywords: Kaman nut, geographical indication, nominal group technique, agricultural production

KAMAN CEVİZİ COĞRAFİ TESCİL İŞARETİNİN ÜRETİME ETKİSİNİN ÖLÇÜMÜ ÜZERİNE BİR YÖNTEM ÖNERİSİ: NOMİNAL GRUP TEKNİĞİ

ÖZET

Türkiye'nin "tahıl ambarı" olarak anılan İç Anadolu Bölgesi'nin önemli tahıl üretim merkezlerinden birisi Kırşehir'dir. 2021 verilerine göre Türkiye'nin toplam GSYİH değeri içerisinde tarım, ormancılık ve balıkçılık sektörünün payı %5 iken Kırşehir'de bu oran %16 dolaylarında gerçekleşmiştir. Bitkisel ve hayvansal üretim olarak Kırşehir'de tarımsal faaliyetler kent ekonomisi içerisinde önemli bir paya sahiptir. Kırşehir önemli bir tahıl üretim merkezi olsa da coğrafi tescil işaretine sahip tek ürünü olan Kaman cevizinin de kent ekonomisine katkısı toplam içerisinde önemli bir oranda yer almaktadır.

Kırşehir'in en önemli tarımsal üretim kalemlerinden birisi olan Kaman Cevizi için Türk Patent ve Marka Kurumu'na 2019'da başvurulmuş, 2020'de "menşe adı" olarak tescil başvurusu kabul edilmiştir. Kırşehir'in coğrafi tescil işaretine sahip tek tarımsal ürünü olan Kaman Cevizi, tüm veya esas nitelikleri belirli bir coğrafi alana ait doğal ve beşeri unsurlardan kaynaklanan coğrafi işaret türü "menşe adı" olarak tescil almıştır. Kaman ilçesinin ceviz üretimine uygunluğu, Tarım ve Orman Bakanlığı'na bağlı Tarımsal Yatırımcı Danışma Ofisi tarafından Kırşehir'de tarıma yatırım yapmayı cazip kılan unsurlardan birisi olarak ifade edilmektedir.

Kaman ilçesindeki ceviz ağaçları ve ceviz üretim verileri referans alındığında coğrafi işaret tescil başvurusunun yapıldığı 2019'da radikal bir değişim olduğu dikkat çekmektedir. Kaman'da 2018'de meyve veren yaşta ceviz ağacı sayısı 63.250, meyve vermeyen yaşta ceviz ağacı sayısı 161.854 ve toplam ceviz üretimi de 468 ton olarak gerçekleşmiştir. 2019'da meyve veren yaşta ağaç sayısı 199.207'ye yükselirken, meyve vermeyen yaşta ağaç sayısı ise 45.460'a düşmüştür. Üretim miktarı da 2018'de 468 ton iken 2019'da 1.296 ton, 2024'te 2.431 tona ulaşmıştır. Verimliliği ifade eden meyve veren yaşta ağaç sayısının üretim miktarına oranı ise yıllara göre şu şekilde gerçekleşmiştir; 2018:7, 2019:7, 2020:9, 2021:9, 2022:10, 2023:11, 2024:11.

Bu çalışmada; Kaman Cevizi'nin coğrafi işaret aldıktan sonra kent ekonomisine katkısı, üretim miktarına ve yapılan yeni üretim yatırımlarına etkisi, tarımsal desteklemelerin yeterliliği, üretim süreçlerinde yaşanan problemler üreticiler ve sektörel uzmanlarla gerçekleştirilecek olan Nominal Grup Tekniği (NGT) yöntemiyle analiz edilecektir. NGT *'bir problem durumunun unsurlarını tanımlamak, bir çözüm programının unsurlarını tanımlamak ve öncelikleri belirlemek için özel amaçlı bir grup süreci'* olarak da tanımlanabilmektedir (Scott & Deadrick, 1982). NGT son yıllarda tarımsal araştırmalarda sıkça kullanılmaktadır. Jeffreys (2006), NGT'nin organik tarım ve tarım-çevre politikalarının değerlendirilmesinde etkinliği kanıtlanmış bir yöntem olduğunu savunmaktadır. NGT'nin tarımsal araştırmalardaki kullanımını içeren çalışmalardan bazıları şu şekildedir; (Bammer vd., 2022; Hugé vd., 2022; Santiago-Brown vd., 2015; Jeffreys, 2006; Motsenbocker & Hinson, 2003). NGT'nin ekoloji ve koruma alanlarında kullanımı da oldukça yaygındır.. Bu alanda NGT ile gerçekleştirilen bazı çalışmalar şu şekildedir; (Hugé ve Mukherjee, 2018; Waas vd., 2014; Robinson ve Shepard, 2011; Strager ve Rosenberger, 2006; Jacobson, Gape, Sweeting ve Stein, 2005); (Motsenbocker ve Hinson, 2003).

Çalışmanın sonuçlarının, kent ekonomisi için önemli bir üretim kalemi olan Kaman cevizine yönelik üretim süreçlerinde yaşanan problemleri ortaya koyması, çözüm önerileri sunabilmesi

ve coğrafi işaret tescilinin ekonomik etkilerinin tespit edilerek ilgili tarımsal politikaların belirlenmesi için veri niteliği taşıyabileceği değerlendirilmektedir.

Anahtar Kelimeler: Kaman cevizi, coğrafi işaret, nominal grup tekniği, tarımsal üretim

EVALUATION OF GEOGRAPHICALLY INDICATION PRODUCTS IN TERMS OF RURAL TOURISM: RECOMMENDATIONS ON MİLAS DISTRICT OF MUĞLA PROVINCE

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ABSTRACT

Geographically indicated products are among the most important tools in the development of rural tourism. Geographically indicated products play an important role in terms of preserving local values on site, sustainability of cultural heritage and transferring them from generation to generation. Geographically indicated products can also be considered as a strategic step towards cities becoming brands. Geographically indicated products for food have significant contributions to the development of gastronomy tourism, which is a part of rural tourism. Indeed, it is seen that the development of rural tourism is faster in places that are rich in gastronomy. Rural tourism provides employment to the region where it is located and has an important income diversification feature. It is also an important driving force in terms of increasing the tendency of young people to stay in rural areas.

Muğla province has 36 geographical indications, 14 of which belong to Milas district. Milas has the first Turkish olive oil, Milas olive oil and Milas oil olives, which are among Turkey's 31 products with EU geographical indications. Muğla province's EU geographical indication products are produced in Milas. With all these features, Milas is among the leading places in terms of geographical indications both in Turkey and in Muğla province. With this feature, it creates significant added value in the promotion and economy of the country. At the same time, the successful examples of rural tourism in Milas allow for the inclusion of geographically indicated products in rural tourism. Milas's geographically indicated products, olives and olive oil, local dishes and hand-woven carpets, as well as having a wide range of products, enable the diversification of rural tourism activities. In this study, the current status of geographically indicated products in Milas' rural tourism will be revealed first, and then a roadmap will be determined by considering suggestions for increasing the future contributions of geographically indicated products. The results obtained from the study are considered important in terms of setting an example and providing guidance for places that want to take steps and progress in this direction.

Keywords: geographical indication, rural, tourism, economy, Milas, Muğla

COĞRAFİ İŞARETLİ ÜRÜNLERİN KIRSAL TURİZM AÇISINDAN DEĞERLENDİRİLMESİ: MUĞLA İLİ MİLAS İLÇESİ ÜZERİNE ÖNERİLER

ÖZET

Kırsal turizmin geliştirilmesinde coğrafi işaretli ürünler en önemli araçlar arasında yer almaktadır. Coğrafi işaretli ürünler yerel değerlerin yerinde korunması, kültürel mirasın sürdürülebilirliği ve nesilden nesile aktarımı açısından önemli roller üstlenmektedir. Coğrafi işaretli ürünler aynı zamanda şehirlerin marka olma yolunda stratejik bir adım olarak nitelendirilebilir. Gıdaya yönelik olan coğrafi işaretli ürünlerin kırsal turizmin bir parçası olan gastronomi turizmin gelişimine önemli katkıları bulunmaktadır. Nitekim gastronomik açıdan zengin olan yerlerde kırsal turizmin gelişiminin daha hızlı olduğu görülmektedir. Kırsal turizm bulunduğu yöreye istihdam sağlamasının yanında önemli bir gelir çeşitlendirici özelliğine sahiptir. Ayrıca özellikle kırsal alanda gençlerin kalma eğilimini artırması açısından önemli bir itici güçtür.

Muğla ili 36 adet coğrafi işarete sahip olup bunun 14 adeti Milas ilçesine aittir. Milas Türkiye'nin AB coğrafi işaretli 31 ürünü arasında yer alan ilk Türk zeytinyağı olan Milas zeytinyağı ve Milas yağlı zeytinine sahiptir. Muğla ilinin AB coğrafi işaretli ürünleri Milas'ta üretilmektedir. Tüm bu özellikleri ile Milas coğrafi işaret konusunda gerek Türkiye'de gerekse Muğla ilinde önde gelen yerler arasındadır. Bu özelliği ile ülke tanıtımı ve ekonomisinde önemli bir katma değer yaratmaktadır. Aynı zamanda Milas'ta kırsal turizmin başarılı örneklerinin görülmesi coğrafi işaretli ürünlerin kırsal turizm içinde yer almasına olanak sağlamaktadır. Milas'ın coğrafi işaretli ürünleri olan zeytin ve zeytinyağı, yöresel yemekler ve el dokuması halıları ile geniş bir ürün yelpazesine sahip olması kırsal turizm faaliyetlerinin çeşitlendirilmesine olanak sağlamaktadır. Bu çalışmada Milas'ın kırsal turizmine coğrafi işaretli ürünlerin öncelikle mevcut durumu ortaya konacak, daha sonra coğrafi işaretli ürünlerin gelecekteki katkılarının artırılmasına ilişkin öneriler ele alınarak bir yol haritası belirlenecektir. Ele alınan çalışmadan elde edilen sonuçların bu yönde adım atıp ilerlemek isteyen yerlere örnek teşkil edip rehber olabilmesi açısından önemli görülmektedir.

Anahtar kelimeler: coğrafi işaret, kırsal, turizm, ekonomi, Milas, Muğla.

IMPORTANCE OF SOFT SKILLS IN PROFESSIONAL COMMUNICATION OF ENGINEERING STUDENTS

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ABSTRACT

Since the language learning is relatively connected with the study of culture, a language learner should develop intercultural competence skills in order to use the target language appropriately in different contexts. Developing learners' soft skills improves their cross cultural and professional communication, specifically in the field of ESP. The purpose of this presentation is to provide the guidelines for developing soft skills through language learning for engineering students.

Summary

Technology has already become a part of our life and its influence is much more than ever. However, having extensive knowledge of technology and technical skills is not adequate for engineering professionals. Soft skills are also equally vital as technical abilities. They help engineering professionals to maintain an interpersonal connection with their employers, colleagues and clients. These professionals should interact with others in the course of work, which requires collaboration and communication skills. Having soft skills and intercultural competence facilitates a good collaboration and performance. Acquiring soft skills requires making accurate judgments, paying attentive attention on the issue. However, digital technology is making it challenging to decide accurately on the issue. On the other hand, it helps learners to develop their critical thinking skills because of accessibility of huge amount of information. This has led to new approach to language learning and teaching and new beliefs about pedagogies. To achieve the goal the presenter will suggest and explain the manual "English for cross cultural and professional communication" in the following steps: a) the overview of the manual; b) the subject areas and methods to apply CLIL methods for engineering students; c) the main topic covered in the manual; d) analysis of the principles of engineering psychology and language teaching; e) some illustrations and examples from the manual. Attendees will have clear perception on the guidelines to develop intercultural competence and soft skills of engineering students through language teaching.

THE EFFECTS OF DIETARY TARHANA SUPPLEMENTATION TO QUAIL RATION ON EGG PRODUCTION AND EGG QUALITY CRITERIA

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ABSTRACT

The aim of this study was to determine the effects of dietary tarhana supplementation as a probiotic source at different doses on egg yield parameters and egg quality characteristics in Japanese quails. Japanese quails were used at the age of 10 weeks. The experiment lasted 56 days. The quails were divided into 3 groups and 8 replicates and 96 Japanese quails were used in the study. Treatment groups; 1) The control group, 2) T1 (0.25% Tarhana added feed), 3) T2 (0.50% Tarhana added feed). The experiment was conducted in cimuka brand laying quail cages with 60 x 35 x 97 cm dimensions. Feed consumption and feed conversion ratio were calculated by weekly. The eggs were collected daily and weighed. Egg analyzes were performed on Tuesdays and eggs collected every Monday were weighed and kept for one day and internal and external quality characteristics were determined. At the end of the study, it was determined that dietary tarhana suplementation in different doses did not affect the egg yield, feed consumption and feed utilization rate, internal and external quality characteristics of the eggs. It was determined that adding 0.5% tarhana supplementation increased the roche color scale value (Yellow value) compared to the control group and adding 1% tarhana decreased the fracture resistance. As a result, it was determined that addition of 0.5% tarhana can be used to increase egg yellow color without affecting egg performance.

Keywords: Quail, tarhana, egg quality

YUMURTACI BILDIRCIN RASYONUNA TARHANA İLAVESİNİN YUMURTA VERİMİ VE KALİTE KRİTERLERİ ÜZERİNE ETKİLERİ

ÖZET

Bu çalışmanın amacı, büyütme yemine probiyotik kaynağı olarak farklı dozlarda tarhana ilavesinin Japon bıldırcınlarında yumurta verim parametreleri ve yumurta kalite özellikleri üzerine etkilerini belirlemektir. Denemede 10 haftalık yaşta yumurtacı Japon bıldırcınları kullanılmıştır. Deneme 56 gün sürmüştür. Denemede bıldırcınlar 3 gruba ayrılarak her grupta 8 tekerrür olacak şekilde yerleştirilmişlerdir. Çalışmada 96 adet Japon bıldırcını kullanılmıştır. Muamele grupları; 1) Kontrol grubu, 2) T1 (%0.25 Tarhana ilaveli yem), 3) T2 (%0.50 Tarhana ilaveli yem) olarak ayarlanmıştır. Deneme 60 x 35 x 97 cm boyutlarında nipel suluklu cimuka marka yumurtacı bıldırcın kafeslerinde yürütülmüştür. Yem tüketimleri ve yemden yararlanma oranları haftalık tartımlarla hesaplanmıştır. Yumurtalar günlük toplanmış ve tartılmıştır. Yumurta analizleri Salı günleri yapılmış ve her pazartesi toplanan yumurtalar tartılarak 1 gün süreyle bekletilmiş ve iç dış kalite özellikleri belirlenmiştir. Çalışma sonunda yeme farklı dozlarda tarhana ilavesinin % yumurta verimi, yem tüketimi ve yemden yararlanma oranını, yumurta iç ve dış kalite özelliklerini etkilemediği belirlenmiştir. % 0,5 tarhana ilavesinin roche renk skala değerini (Sarı değeri) kontrol grubuna göre arttırdığı %1 düzeyinde tarhana ilavesinin kırılma direncini düşürdüğü belirlenmiştir. Sonuç olarak %0,5 tarhana ilavesinin yumurta performansını etkilemeksizin yumurta sarı rengini arttırmak için kullanılabileceği belirlenmiştir

Anahtar Kelimeler: Bıldırcın, tarhana, yumurta kalitesi

PREPARATION AND CHARACTERIZATION OF EDIBLE FILMS BASED ON CORN ZEIN

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ABSTRACT

In terms of evaluating food waste and producing healthy packaging materials, zein protein-based edible coating materials have become popular in recent years. According to 2020 data, 1.102.164 tons of corn are produced in the world. Protein-based films and coatings are better than polysaccharide-based films and coatings in terms of being a barrier against oxygen, carbon dioxide and lipids and mechanical properties. Zein, one of the four different groups of corn protein fractions, can be used in food packaging, drug coatings and biomedical applications with its hydrophobic structure and biodegradability. Edible films and coatings can provide barrier properties against moisture, gas and oil migration in food preservation. This structure, which can retain volatile compounds, can be made functional by adding antioxidants, food additives and antimicrobial substances. While hydrocolloids (protein and polysaccharide) and lipids are mainly used in the preparation of edible films, it is also possible to benefit from composite films obtained from their combinations. In addition to sensory properties (transparent, tasteless and odorless), a good quality edible film is expected to have barrier properties (moisture and oxygen permeability), be stable against physical and biochemical reactions that may occur between the food and the film and/or the atmosphere and the film, be reliable in terms of health, environmentally friendly and low cost. Protein molecules during the formation of zein films determine the mechanical, water resistance and barrier properties of the film. Glycerol, a hydroscopic molecule, is frequently used in edible film production to eliminate film brittleness. In this study, protein films were produced from %85 pure corn zein in ethyl alcohol medium for the preparation of edible food packaging material and 99% pure glycerol was added to give the film a flexible structure. The films were characterized by SEM (Scanning Electron Microscopy) and TGA (Thermogravimetric analysis) and the obtained films were applied to food examples such as candy and dried figs.

Keywords: Zein, film, edible packaging, food safety

MISIR ZEİNİ ESASLI YENİLEBİLİR FİLMLERİN HAZIRLANMASI VE KARAKTERİZASYONU

ÖZET

Gıda atıklarının değerlendirmesi ve sağlıklı ambalaj materyali üretiminde zein proteini esaslı yenilebilir kaplama malzemeleri son yıllarda popüler hale gelmiştir. 2020 verilerine göre dünyada 1.102.164 ton mısır üretilmektedir. Protein bazlı film ve kaplamalar ise oksijen, karbondioksit ve lipitlere karşı bariyer olma ve mekanik özellikler bakımından polisakkarit bazlı film ve kaplamalara kıyasla daha iyidir. Mısır protein fraksiyonlarının dört farklı grubundan biri olan zein hidrofobik yapısı ve biyobozunurluk özelliği ile gıda ambalajı, ilaç kaplamaları ve biyomedikal uygulamalarda kullanılabilir. Yenilebilir film ve kaplamalar gıda muhafazasında nem, gaz ve yağ migrasyonuna karşı bariyer özellik gösterebilmektedir. Uçucu bileşiklerin tutulmasını sağlayabilen bu yapı antioksidan, gıda katkı maddesi ve antimikrobiyal madde eklenerek fonksiyonel hale getirilebilir. Yenilebilir filmlerin hazırlanmasında temelde hidrokolloidler (protein ve polisakkarit) ve lipitler kullanılırken, bunların kombinasyonlarından elde edilen kompozit filmlerden de yararlanmak mümkündür. İyi kaliteye sahip yenilebilir bir filmin; duyusal özellikleri (şeffaf, tatsız ve kokusuz) yanında bariyer özellikleri (nem, oksijen geçirgenlikleri), gıda ile film ve/veya atmosfer ile film arasında gerçekleşebilecek fiziksel ve biyokimyasal reaksiyonlara karşı kararlı yapıda olması, sağlık açısından güvenilir, çevreyle dost ve düşük maliyetli olması beklenen özellikleridir. Zein filmlerinin oluşumu sırasında protein molekülleri filmin mekanik, suya dayanıklılık ve bariyer özelliklerini belirler. Hidroskopik bir molekül olan gliserol ise yenilebilir film üretiminde film kırılganlığını gidermek için sıkça kullanılır. Bu çalışmada, yenilebilir gıda ambalaj malzemesi hazırlanması amacıyla etil alkol ortamında %85 saflıkta mısır zeininden protein film üretildi ve filmin esnek yapı kazanması için %99 saflıkta gliserol eklendi. Elde edilen fimler SEM (Taramalı Elektron Mikroskobu) ve TGA (Thermogravimetrik analiz) ile karakterize edilerek şeker ve kuru incir gibi gıda örneklerine uygulandı.

Anahtar kelimeler: Zein, film, yenilebilir ambalaj, gıda güvenliği

EVALUATION OF DIFFERENT SURFACE TEXTURES IN URBAN PARKS IN TERMS OF MICRO THERMAL COMFORT; CASE STUDY OF ERZURUM OLYMPIC PARK

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ABSTRACT

Climate change is considered one of the biggest problems our world faces, and today, this change is occurring much more rapidly compared to natural processes. Cities around the world are combating the negative effects that arise due to increasing temperatures. Green areas are of great importance in terms of their quantity, size and characteristics in combating the urban heat island effect that results from intensive urbanization. Urban parks, which are a part of green areas and an important microclimate zone, influence temperature formation, thermal comfort and urban life quality through the plant and structural materials they contain, surface coatings and area usage decisions.

In this study, the Olympic Park, located on an area of approximately 25 ha in Erzurum, was examined. The park, which has a closed area of 2200 m², includes entertainment and recreation areas, an amusement park, an artificial pond, cafes, children's playgrounds, walking paths, seating areas, sports facilities and picnic areas. The park, which is intensively used in terms of accessibility and size, has different surface textures (water, asphalt, concrete, wood, travertine, grass, woodland, soil, rubber, etc.). The aim of the study is to examine the effects of these surface textures on micro thermal comfort in response to climate changes, which are one of the most significant problems of our time. At the same time, the study aims to collect data that can serve as a resource for design studies within the scope of the landscape architecture discipline. In this context, the development and changes in the usage areas of Olympic Park over time have been examined. In this process, Landsat satellite data from July, when the park was most intensively used and temperatures reached the highest levels, were used. To examine the effects of the change in ground surface temperatures of the usage areas over the years on micro thermal comfort values, July data from the years 2009, 2013 and 2024 were utilized. These data were obtained from Landsat 5 and Landsat 8 satellite images provided by the USGS (United States Geological Survey). Using ArcMap 10.5 software, Land Surface Temperature (LST) maps were created through various transformations applied to the thermal bands of the satellite images, and the micro thermal comfort values, which change over the years, were determined for the park’s usage areas and its surrounding environment.

As a result of the study, data from 2009 were compared with those from 2013 and 2024. The effects of structural and surface changes within the park on micro thermal comfort were examined. The results indicate that these structural and surface modifications significantly affect land surface temperatures, and that water elements, particularly large water bodies such as artificial ponds, play a crucial role in regulating environmental temperatures.

Keywords: Micro Thermal Comfort, Thermal Satellite Bands, Urban Parks.

KENT PARKI İÇERİSİNDEKİ FARKLI YÜZEY DOKULARININ MİKRO TERMAL KONFOR AÇISINDAN DEĞERLENDİRİLMESİ; ERZURUM OLİMPİYAT PARKI ÖRNEĞİ

ÖZET

İklim değişikliği dünyamızın karşılaştığı en büyük sorunlardan biri olarak kabul edilmektedir ve günümüzde bu değişim doğal süreçlere kıyasla çok hızlı gerçekleşmektedir. Tüm dünyada kentler artan sıcaklıklar sonucunda meydana gelen olumsuzluklarla mücadele etmektedir. Yoğun kentleşme sonucu meydana gelen kentsel ısı adası ile mücadele konusunda yeşil alanlar; miktarı, büyüklüğü ve özellikleri açısından büyük öneme sahiptir. Yeşil alanların bir parçası ve önemli bir mikro iklim alanı olan kent parkları bulundurdukları bitkisel ve yapısal materyaller ile yüzey kaplamaları ve alan kullanım kararları sayesinde sıcaklık oluşumu, termal konfor ve kentsel yaşam kalitesi üzerinde etkili olmaktadır.

Bu çalışmada, Erzurum'da bulunan yaklaşık 25 ha alan üzerinde yer alan Olimpiyat Parkı incelenmiştir. Park, 2200 m² kapalı alana sahip olup; eğlence ve dinlenme alanları, lunapark, yapay gölet, kafeler, çocuk oyun alanları, gezinti alanları, oturma bölgeleri, spor ve piknik alanlarını içermektedir. Erişilebilirlik ve büyüklük açısından rekreasyonel kullanımın yoğun olduğu parkta, farklı yüzey dokuları (su, asfalt, beton, ahşap, traverten, çim, ağaçlık, toprak, kauçuk vb.) bulunmaktadır. Çalışmanın amacı, bu yüzey dokularının, günümüzün en önemli sorunlarından biri olan iklimsel değişikliklere karşı mikro termal konfor üzerindeki etkilerini incelemektir. Aynı zamanda peyzaj mimarlığı meslek disiplini kapsamında tasarım çalışmalarına kaynak oluşturabilecek verilerin elde edilmesi hedeflenmiştir. Bu doğrultuda, Olimpiyat Parkı'ndaki kullanım alanlarının zaman içerisindeki gelişimi ve değişimi ele alınmıştır. Bu süreçte, parkın kullanım açısından en yoğun olduğu ve sıcaklıkların en yüksek seviyeye ulaştığı Temmuz ayına ait Landsat uydu verileri kullanılmıştır. Kullanım alanlarının yer yüzey sıcaklıklarının yıllara göre değişiminin mikro termal konfor değerlerine etkisini incelemek amacıyla, 2009, 2013 ve 2024 yıllarına ait Temmuz ayı verileri kullanılmıştır. Bu veriler USGS (United States Geological Survey)'den alınan Landsat 5 ve Landsat 8 uydu görüntülerinden elde edilmiştir. ArcMap10.5 yazılımında, uydu görüntülerinin termal bantlarından yapılan çeşitli dönüşümlerle Yer Yüzey Sıcaklık Haritaları oluşturulmuş ve parkın kullanım alanlarında ve çevresinde, yıllara göre değişen mikro termal konfor değerleri belirlenmiştir.

Çalışma sonucunda, 2009 yılına ait veriler ile 2013 ve 2024 yılına ait veriler karşılaştırılmış, parktaki yapısal ve yüzey kaplama değişikliklerinin mikro termal konfor üzerindeki etkileri incelenmiştir. Elde edilen veriler, parkın yapısal ve yüzeysel değişikliklerinin yer yüzey sıcaklıkları üzerinde önemli bir etkisi olduğunu ve su öğelerinin, özellikle yapay gölet gibi büyük su yüzeylerinin, çevresel sıcaklıkları dengelemede önemli bir rol oynadığını göstermektedir.

Anahtar Kelimeler: Mikro Termal Konfor, Termal Uydu Bantları, Kent Parkları.

DETERMINING PLANT PARASITIC NEMATODES AND THEIR POPULATION DENSITIES IN IMPORTANT CROP PLANTS IN HATAY PROVINCE, TÜRKİYE

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ABSTRACT

Surveys were carried out between 2017-2021 in areas where important cultivated plants were grown in Hatay province. Soil samples (104) were taken in vineyard, pepper, wheat, tomato, corn, cotton, stone fruit and olive areas relating the production pattern of Hatay province. Motile nematodes in the soil samples were isolated by the modified Baermann method. The isolated nematodes were fixed in glycerin and 11 species of plant parasitic nematodes belonging to 3 orders, 10 families and 11 genera were identified. Aphelenchoides sp. and *Aphelenchus avenae* from the order Aphelenchida; *Ditylenchus* sp., *Heterodera latipons*, *Meloidogyne incognita*, *M. javanica*, *Merlinius brevidens*, *M. microdorus*, *Paratylenchus sp.*, *Pratylenchus neglectus*, *P. thornei*, *Rotylenchulus macrosomus* and *Tylenchulus semipenetrans* from the order Tylenchida; *Xiphinema pachtaicum* from the order Dorylaimida were identified. Further studies are needed to investigate pest status, economic threshold and alternative management strategies for these plant parasitic nematodes.

Keywords: Hatay, Plant Parasitic Nematode

HATAY İLİNDE ÖNEMLİ KÜLTÜR BİTKİLERİNDE BULUNAN BİTKİ PARAZİTİ NEMATODLARIN VE POPÜLASYON YOĞUNLUKLARININ BELİRLENMESİ

ÖZET

Hatay ilinin üretim desenini yansıtacak şekilde bağ, biber, buğday, domates, mısır, pamuk, taş çekirdekli ve zeytin alanlarından 2017-2021 yılları arasında gerçekleştirilen arazi çıkışlarında 104 toprak örneği alınmıştır. Alınan toprak örneklerindeki hareketli nematodlar modifiye Baermann yöntemi ile izole edilmiştir. İzole edilen nematodlar gliserin içine fikse edilmiş ve 3 takım, 10 familya, 11 cinse ait 11 tür bitki paraziti nematod belirlenmiştir. Aphelenchida takımına ait *Aphelenchoides* sp. ve *Aphelenchus avenae*; Tylenchida takımına ait *Ditylenchus* sp., *Heterodera latipons, Meloidogyne incognita, M. javanica, Merlinius brevidens, M. microdorus, Paratylenchus sp., Pratylenchus neglectus, P. thornei, Rotylenchulus macrosomus* ve *Tylenchulus semipenetrans*; Dorylaimida takımına ait *Xiphinema pachtaicum* türleri tespit edilmiştir. Teşhis edilen nematodların zarar düzeyleri, ekonomik zarar eşikleri, bu nematodlarla farklı mücadele yöntemlerin araştırılması hem Hatay hem de ülkemiz tarımı ve buna bağlı olarak ekonomisi açısından önem arz etmektedir.

Anahtar Kelimeler: Hatay, Bitki Paraziti Nematod

SURVEY STUDIES ON COMPARISON OF *TYLENCHULUS SEMIPENETRANS* (COBB, 1913) (TYLENCHIDA: TYLENCHULIDAE) POPULATION LEVELS ACCORDING TO ROOTSTOCK, ROOTSTOCK AGE AND SOIL TEXTURE IN HATAY, TÜRKİYE

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ABSTRACT

In previous studies, the presence of *Tylenchulus semipenetrans* in citrus fields of Hatay province was determined, and in this consecutive study, it was investigated whether the rootstock, rootstock age and soil texture had an effect on *T. semipenetrans* population levels. Field studies were carried out in April 2021 and 107 soil samples were taken. Sour orange and Volkameriana rootstocks were found to be supporting higher population levels, Carizzo rootstock was found to be having less and C35 rootstock was found to have intermediate population levels between these two groups. It was observed that as the rootstock age increased, the citrus nematode population also increased. It was also noted that the soil texture had no effect on the citrus nematode population.

Keywords: Hatay, Citrus Nematode, Rootstock, Soil

HATAY İLİNDE *TYLENCHULUS SEMIPENETRANS* (COBB, 1913) (TYLENCHIDA: TYLENCHULIDAE) POPÜLASYON SEVİYELERİNİN ANAÇ, ANAÇ YAŞI VE TOPRAK BÜNYESİNE GÖRE KARŞILAŞTIRILMASI ÜZERİNE SURVEY ÇALIŞMALARI

ÖZET

Daha önce yapılan çalışmalarda, Hatay ili turunçgil alanlarında *Tylenchulus semipenetrans* varlığı belirlenmiş, ardışık yapılan bu çalışma ile *T. semipenetrans* popülasyon seviyelerine anaç, anaç yaşı ve toprak bünyesinin etkisinin olup olmadığı araştırılmıştır. Arazi çalışmaları 2021 yılı Nisan ayında gerçekleştirilmiş ve 107 toprak örneği alınmıştır. Turunç ve Volkameriana anaçlarında turunçgil nematodu popülasyonlarının daha yüksek, Carizzo anacında ise bu iki anaca göre daha düşük seviyelerde, C35 anacında ise bu iki grup arasında kaldığı, anaç yaşı arttıkça turunçgil nematod popülasyonunun da arttığı gözlenmiştir. Toprak bünyesinin turunçgil nematod popülasyonuna bir etkisinin olmadığı gözlenmiştir.

Anahtar Kelimeler: Hatay, Turunçgil Nematodu, Anaç, Toprak

INNOVATIVE APPROACHES IN ERGONOMIC RISK ASSESSMENT METHODS AND OCCUPATIONAL SAFETY IN AGRICULTURE

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ABSTRACT

The agricultural sector is an area where workers are exposed to high levels of physical and mental stress, resulting in significant ergonomic risks. These risks contribute to musculoskeletal disorders (MSDs), which affect workers' health and reduce work efficiency. Identifying and mitigating ergonomic risks is essential both to protect workers' health and to improve agricultural productivity. In this context, ergonomic risk assessment methods, agricultural mechanisation and innovative engineering solutions play a critical role in ensuring occupational safety.

Traditional ergonomic assessment tools such as ALLA (Agricultural Lower Limb Assessment), REBA (Rapid Entire Body Assessment) and RULA (Rapid Upper Limb Assessment) analyse workers' postures to identify potential risks. Agricultural mechanisation is a key factor in reducing ergonomic risks, as modern agricultural machinery helps to minimise manual labour and physical strain on workers. However, existing agricultural equipment needs to be further optimised to improve ergonomic efficiency. This is where TRIZ (Theory of Inventive Problem Solving) offers a systematic approach to optimising agricultural machinery and developing innovative designs that reduce the physical workload of workers.

In addition, artificial intelligence (AI)-based ergonomic assessment systems provide faster and more accurate analysis than traditional methods, enabling real-time assessment of working conditions. Integrating TRIZ with AI technologies can lead to more innovative and ergonomic solutions in agricultural mechanisation.

This study is directly aligned with the United Nations Sustainable Development Goals (SDGs). Under Goal 3 (Health and well-being), reducing ergonomic risks helps protect the health of agricultural workers and prevent occupational diseases. In relation to Goal 8 (Decent work and economic growth), agricultural mechanisation, AI-assisted ergonomic analysis and the TRIZ approach contribute to improving occupational safety and promoting more sustainable and

efficient working environments. From the perspective of Goal 9 (Industry, Innovation and Infrastructure), TRIZ-driven innovative solutions support technological progress and efficiency in agricultural production.

In this context, the effective use of ergonomic assessment methods, the integration of agricultural mechanisation and innovative approaches such as TRIZ play a crucial role in protecting workers' health and increasing productivity. The combination of AI-based assessment tools with TRIZ-based solutions is expected to make a significant contribution to the development of sustainable and ergonomic working conditions in agriculture.

Keywords: Ergonomic Risk Assessment, Agricultural Occupational Safety, AI-Assisted Ergonomics, Agricultural Mechanization and Ergonomics

TARIMDA ERGONOMİK RİSK DEĞERLENDİRME YÖNTEMLERİNDE YENİLİKÇİ YAKLAŞIMLAR VE İŞ GÜVENLİĞİ

ÖZET

Tarım sektörü, çalışanların fiziksel ve psikolojik stres altında olduğu, ergonomik risklerin yüksek olduğu bir alandır. Bu riskler, kas-iskelet sistemi rahatsızlıklarına (MSD) yol açarak işçilerin sağlığını olumsuz etkilemekte ve iş verimliliğini düşürmektedir. Ergonomik risklerin belirlenmesi ve azaltılması, hem çalışan sağlığını korumak hem de tarımsal üretkenliği artırmak için kritik öneme sahiptir. Bu kapsamda, ergonomik risk değerlendirme yöntemleri, tarımsal mekanizasyon ve yenilikçi mühendislik çözümleri iş güvenliğini sağlamada önemli rol oynamaktadır.

ALLA (Agricultural Lower Limb Assessment), REBA (Rapid Entire Body Assessment) ve RULA (Rapid Upper Limb Assessment) gibi geleneksel ergonomik değerlendirme araçları, tarım işçilerinin vücut duruşlarını analiz ederek potansiyel riskleri tespit etmektedir. Tarımsal mekanizasyon, ergonomik risklerin azaltılmasında kritik bir faktördür; modern tarım makinelerinin kullanımı, manuel iş yükünü azaltarak çalışanların fiziksel zorlanmalarını en aza indirmektedir. Ancak, mevcut tarımsal ekipmanların ergonomik açıdan daha verimli hale getirilmesi gerekmektedir. Bu noktada, TRIZ (Yenilikçi Problem Çözme Teorisi), tarımsal makinelerin ergonomik olarak optimize edilmesi ve işçilerin fiziksel yükünü azaltan yenilikçi tasarımlar geliştirilmesi için önemli bir yaklaşım sunmaktadır.

Bununla birlikte, yapay zekâ (AI) tabanlı ergonomik değerlendirme sistemleri, geleneksel yöntemlere kıyasla daha hızlı ve doğru analizler sunarak işçilerin çalışma koşullarını gerçek zamanlı olarak değerlendirme imkânı sağlamaktadır. TRIZ ile yapay zekâ teknolojilerinin entegrasyonu, tarımsal mekanizasyonda daha inovatif ve ergonomik çözümler üretmeye olanak tanıyabilir.

Bu çalışma, BM Sürdürülebilir Kalkınma Hedefleri (SKH) ile doğrudan ilişkilendirilebilir. Hedef 3 (Sağlık ve Kaliteli Yaşam) kapsamında, ergonomik risklerin azaltılması, tarım işçilerinin sağlığını koruyarak meslek hastalıklarını önlemeye katkı sağlar. Hedef 8 (İnsana Yakışır İş ve Ekonomik Büyüme) ile bağlantılı olarak, tarımsal mekanizasyon, yapay zekâ destekli ergonomik analizler ve TRIZ yaklaşımı, iş güvenliğini artırarak daha sürdürülebilir ve verimli çalışma ortamları oluşturulmasına yardımcı olmaktadır. Hedef 9 (Sanayi, Yenilikçilik ve Altyapı) açısından ise, TRIZ odaklı yenilikçi çözümler, tarımsal üretimde teknolojik gelişimi ve verimliliği desteklemektedir.

Bu bağlamda, tarım sektöründe ergonomik değerlendirme yöntemlerinin etkin kullanımı, tarımsal mekanizasyonun entegrasyonu ve TRIZ gibi yenilikçi yaklaşımlar, çalışan sağlığını koruyarak iş verimliliğini artırmaktadır. Yapay zekâ destekli değerlendirme araçlarının TRIZ tabanlı çözümlerle birleştirilmesi, tarımda sürdürülebilir ve ergonomik çalışma koşullarının oluşturulmasına önemli katkılar sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Ergonomik Risk Değerlendirme, Tarım İş Güvenliği, Yapay Zekâ Destekli Ergonomi, Tarımsal Mekanizasyon ve Ergonomi

THE RELATIONSHIP BETWEEN CULTURAL ROUTES AND RURAL DEVELOPMENT IN TÜRKİYE

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ABSTRACT

Turkey, with its rich historical, cultural, and natural heritage, holds significant potential in terms of cultural routes. The Lycian Way, Turkey's first long-distance hiking trail, extends approximately 760 kilometers from Fethiye to Antalya. In addition to this, there are nearly 30 officially registered cultural routes across the country. These routes allow visitors the opportunity to explore various cultural and natural areas in different regions of Turkey. In recent years, due to urbanization, the COVID-19 pandemic, and changing holiday preferences, interest in nature and rural areas has increased significantly.

Although Turkey generates considerable income from tourism, the impact of this income on rural development remains limited. Alternative forms of tourism, such as cultural routes, hiking trails, and rural tourism, have the potential to enhance economic activity in rural areas. Cultural routes, particularly through hiking activities, promote rural tourism and stimulate local economies. Travelers who follow these routes contribute to regional development by staying in rural areas, consuming local products, and engaging with local communities. Furthermore, the development of cultural routes revitalizes sectors such as agriculture, handicrafts, and small-scale enterprises in rural areas, thus supporting regional development.

In order for rural tourism to contribute more effectively to sustainable development, it is essential to increase infrastructure investments, ensure the active involvement of local communities in the formation of cultural routes, and promote these routes more effectively to broader audiences. This study evaluates the impacts of cultural routes on rural development in Turkey and presents recommendations for sustainable tourism.

Keywords: Cultural Routes, Rural Development, Rural Tourism

TÜRKIYE'DE KÜLTÜR ROTALARI İLE KIRSAL KALKINMA ARASINDAKI İLİŞKİ

ÖZET

Türkiye, zengin tarihi, kültürel ve doğal mirasıyla, kültür rotaları açısından büyük bir potansiyele sahiptir. Türkiye'nin ilk doğa yürüyüşü rotası olan Likya Yolu, Fethiye'den Antalya'ya kadar uzanan ve yaklaşık 760 kilometreyi bulan bir rotadır. Bunun yanı sıra, ülkemizde 30'a yakın tescilli kültür rotası bulunmaktadır. Bu rotalar, ziyaretçilere ülkenin farklı bölgelerindeki kültürel ve doğal alanları keşfetme imkanı sunmaktadır. Son yıllarda kentleşme, COVID-19 pandemisi ve değişen tatil tercihleri nedeniyle doğa ve kırsal alanlara yönelik ilgi artmıştır.

Türkiye turizm açısından önemli bir gelir elde etmesine rağmen bu gelirin kırsal kalkınmaya etkisi sınırlıdır. Kültür rotaları, doğa yürüyüşleri ve kırsal turizm gibi alternatif turizm türleri, kırsal alanlardaki ekonomik hareketliliği artırma potansiyeline sahiptir Kültür rotaları, özellikle doğa yürüyüşü etkinlikleri aracılığıyla kırsal turizmi teşvik etmekte ve yerel ekonomiyi canlandırmaktadır. Bu rotaları takip eden gezginler, kırsal bölgelerde konaklayarak, yöresel ürünleri tüketerek ve yerel halkla etkileşime girerek bölgesel kalkınmaya katkı sunmaktadır. Ayrıca, kültür rotalarının gelişmesi, kırsal alanlarda tarım, el sanatları ve küçük ölçekli işletmeler gibi sektörleri canlandırarak bölgesel kalkınmaya katkı sağlamaktadır.

Kırsal turizmin sürdürülebilir kalkınmaya daha etkin katkı sağlayabilmesi için altyapı yatırımlarının artırılması, kültür rotalarının oluşum sürecinde, yerel halkın katkılarının önemli bir rol oynaması ve oluşturulan rotaların daha geniş kitlelere etkili bir şekilde tanıtılması gerekmektedir. Bu çalışmada, Türkiye'deki kültür rotalarının kırsal kalkınmaya etkileri değerlendirilerek, sürdürülebilir turizm için öneriler sunulmuştur.

Anahtar Kelimeler: Kültür Rotaları, Kırsal Kalkınma, Kırsal Turizm

INVESTIGATION OF EXISTENCE OF BIOGENIC AMIN IN SIDEROPHORE-PRODUCING *Bacillus sp.*

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ABSTRACT

Bacillus species can exhibit probiotic properties through their spores and metabolites (enzymes, antimicrobial substances, siderophores, etc.) they produce. Recently, soil isolate probiotics with high siderophore production and siderophore-producing probiotic applications have attracted considerable attention. The presence of biogenic amines is particularly important as an indicator of food spoilage as well as their toxic effects on human health. It is observed that the content of biogenic amines such as histamine, putrescine, cadaverine, and tyramine in probiotic products has increased. In this study, it was aimed to determine whether biogenic amine production, which is an important parameter in terms of GRAS criteria, is present in Bacillus subtilis subsp. inaquosorum DY5 strain and Bacillus pumilus 441 strain. In particular, biogenic

amine measurements were determined before and after the treatment of soil isolate strains with CuSO4, which is a widely used organic pesticide in agriculture, and whether there was any change in the investigated strains. For this purpose, measurements were carried out with LC-MS Q-TOF device, which is one of the most sensitive analysis methods and preferred for the determination of trace amounts of analytes. Tyramine, putrescine, cadaverine, histamine, phenylethylamine were studied in the samples with the analysis method created in the LC-MS Q-TOF system. MS operating mode was applied in the range of 30-1200 Dalton and 2 GHz Extended Dynamic Range. C18 (2.1 mm x 50 mm x 1.7 µm) column was used for chromatographic separation. Data evaluation was made via the software program of the device. LC-MS Q-TOF was preferred to analyze components at very low concentrations to verify molecular structure and to examine complex samples. As a result, no amount of biogenic amines was found within the detection limits in samples prepared under acidic and basic conditions. In the light of these data obtained, it was predicted that soil isolates found to have probiotic properties may have the potential to be used as probiotics, especially since they do not produce biogenic amines, which are not GRAS in terms of soil probiotics but are criteria for human health.

This study was supported by Gazi University BAP Unit with the project coded FGA-2023-7867.

Keywords: Biogenic amine, Siderophore, LC-MS

SİDEROFOR ÜRETEN PROBİYOTİK ÖZELLİKLİ *Bacillus sp.*'de BİYOJENİK AMİN VARLIĞININ ARAŞTIRILMASI

ÖZET

Bacillus türleri, sporları ve ürettikleri metabolitleri (enzim, antimikrobiyal madde, siderofor vs.) aracılığıyla probiyotik özellikler gösterebilmektedir. Son zamanlarda siderofor üretimi yüksek toprak izolatı probiyotikler, siderofor üreten probiyotik uygulamaları açısından oldukça dikkat çekicidir. Biyojen aminlerin varlığı özellikle gıda bozulmasının göstergesi olması yanında insan sağlığına toksik etkilerinin bulunması bakımından önemlidir. Probiyotik ürünlerdeki histamin, putresin, kadeverin, tiramin gibi biyojen aminlerin içeriğinin arttığı görülmektedir. Bu çalışmada, *Bacillus subtilis* subsp. *inaquosorum* DY5 suşu ve *Bacillus pumilus* 441 suşunda GRAS kriterleri açısından önemli bir parametre olan biyojenik amin üretiminin olup olmadığının tespiti hedeflenmiştir. Özellikle toprak izolatı suşlarının tarımda yaygın kullanılan organik pestisit bordo bulamacının içeriğinde yer alan $CuSO_4$'ın muamelesi öncesinde ve sonrasında biyojenik amin ölçümlerinin yapılarak araştırılan suşlarda herhangi bir değişimin olup olmadığı incelenmiştir. Bu amaçla eser miktardaki analitlerin tayini için tercih edilen ve en hassas analiz yöntemlerden biri olan LC-MS Q-TOF cihazı ile ölçümler gerçekleştirilmiştir. LC-MS Q-TOF sisteminde oluşturulan analiz metodu ile numunelerde tiramin, putresin, kadaverin, histamin, feniletilamin çalışılmıştır. MS çalışma modu olarak 30-1200 Dalton aralığında ve 2 GHz Extended Dynamic Range uygulanmıştır. Kromatografik ayrım için C18 (2.1mm x 50 mm x 1.7 µm) kolon kullanılmıştır. Veri değerlendirmesini cihazın yazılım programı üzerinden yapılmıştır. LC-MS Q-TOF, çok düşük konsantrasyonlardaki bileşenleri analiz ederek moleküler yapı doğrulaması yapmak ve kompleks numuneleri incelemek için tercih edilmiştir. Sonuç olarak asidik ve bazik koşullarda hazırlanan örneklerde tespit limitleri dahilinde biyojenik aminlere ilişkin bir miktar bulunamamıştır. Elde edilen bu veriler ışığında probiyotik özellikleri olduğu tespit edilen toprak izolatlarında, özellikle toprak probiyotiği kriterleri açısından GRAS olmayan ancak insan sağlığı için önemli bir kriter olan biyojen amin üretiminin bulunmamasıyla, probiyotik olarak kullanım potansiyelinin olabileceği öngörülmüştür.

Bu çalışmamız Gazi Üniversitesi BAP Birimi tarafından FGA-2023-7867 kodlu proje ile desteklenmiştir.

Anahtar Kelimeler: Biyojenik amin, Siderofor,LC-MS

INVESTIGATION OF BIODIVERSITY OF NEMATODES (NEMATODA) IN ALI NIHAT GÖKYIĞIT BOTANICAL GARDEN OF ÇUKUROVA UNIVERSITY

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ABSTRACT

Nematodes are organisms that have an important place among soil organisms as bioindicators in the ecosystem with their biodiversity and population densities. Nematodes interact with living and non-living factors in the soil and are one of the indicators of biodiversity in the soil ecosystem. Therefore, assessing nematode diversity in terrestrial habitats has been adopted as a common research method. In this purpose, the potential effects of plant species on soil nematode diversity were investigated by examining the nematode communities found in the rhizospheres of 24 different plant species from 14 families in different seasons in 2024-2025 at the Ali Nihat GÖKYİĞİT Botanical Garden of Çukurova University. This approach provides important contributions to habitat-based assessment of plant-nematode relationships. The nematode fauna identified in this study consisted of 21 families and 36 genera belonging to 8 orders. Plant parasites were represented by 9 families and 14 genera belonging to 2 orders (Tylenchida and Dorylaimida); bacterivores by 7 families and 17 genera belonging to 3 orders (Rhabditida, Monhysterida and Araeolaimida); fungivores by 3 genera belonging to 2 orders (Aphelenchida and Tylenchida); predators by 2 genera belonging to 1 order (Dorylaimida). The proportion of plant parasitic and free-living nematodes in the fauna was 29.62% and 70.37%, respectively. Among the free-living nematodes found in the soil samples, *Cephalobus* genus belonging to Cephalobidae family was found at the highest rate and the highest population density was found in Lavender (*Lavandula amustifolia*) plant with 506 individuals. Among the fungivorous nematodes, the genus *Aphelenchoides* was the most common genus and the highest population density with 265 individuals was found on Balkaymak (*Helichrysum italicum*).

Among the plant parasitic nematodes, *Paratylenchus* and *Tylenchus* were the most common genera and the highest population densities were found in the rhizosphere of calendula (*Calendula officinalis*) and safflower (*Carthamus tinctorius*) plants, respectively. Predatory nematodes had the lowest population in the sampling and constituted 6.5% of the total population. Among these nematodes, the genus *Dorylaimus* with 227 individuals was found in the highest population in yellow patience (*Aloe vera*) plant.

Keywords: Nematode fauna, biodiversity, Cephalobidae, plant parasitic nematodes

ÇUKUROVA ÜNİVERSİTESİ ALİ NİHAT GÖKYİĞİT BOTANİK BAHÇESİ'NDE NEMATODLARIN (NEMATODA) BİYOÇEŞİTLİLİĞİNİN ARAŞTIRILMASI

ÖZET

Nematodlar, biyolojik çeşitlilikleri ve popülasyon yoğunlukları ile bulundukları ekosistemde bioindikatör olarak toprak canlıları arasında önemli bir yere sahip olan organizmalardır. Nematodlar, topraktaki canlı ve cansız etkenlerle etkileşim halinde olup toprak ekosisteminde biyoçeşitliliğin göstergelerinden biri konumundadır. Bu nedenle karasal habitatlardaki nematod çeşitliliğini değerlendirmek yaygın bir araştırma yöntemi olarak benimsenmiştir. Bu amaçla, Çukurova üniversitesi Ali Nihat GÖKYİĞİT Botanik Bahçesi'nde 2024-2025 yıllarında farklı mevsimlerde, 14 familyadan 24 farklı bitki türünün rizosferlerinde bulunan nematod topluluklarını familya ve cins düzeyinde incelenerek, bitki türlerinin toprak nematod çeşitliliği üzerindeki potansiyel etkileri araştırılmıştır. Bu yaklaşım, bitki-nematod ilişkilerinin habitat bazlı değerlendirilmesine önemli katkılar sağlamaktadır. Bu çalışmada tespit edilen nematod faunası 8 takıma ait 21 familya ve 36 cinsten oluşmuştur. Bitki parazitleri 2 takıma (Tylenchida ve Dorylaimida) ait 9 familya 14 cins ile; bakterivorlar 3 takıma (Rhabditida, Monhysterida ve Araeolaimida) ait 7 familya ve 17 cins ile; fungivorlar 2 takıma ait (Aphelenchida ve Tylenchida) ait 3 cins ile; predatörler 1 takıma (Dorylaimida) ait 2 cins ile temsil edilmişlerdir. Faunada bitki paraziti ve serbest yaşayan nematodların oranı sırasıyla % 29,62 ve % 70,37 olarak gerçekleşmiştir. İncelenen toprak örneklerinde bulunan serbest yaşan nematodlar içerisinde Cephalobidae familyasına ait *Cephalobus* cinsi en yüksek oranda bulunmuş olup, popülasyon yoğunluğu da 506 birey ile en yüksek Lavanta (*Lavandula amustifolia*) bitkisinde saptanmıştır. Fungivor nematodlar içerisinde *Aphelenchoides* cinsinin en yaygın cins olduğu ve 265 birey ile en yüksek popülasyonu Balkaymak (*Helichrysum italicum*) bitkisinde oluşturduğu belirlenmiştir. Bitki paraziti nematodlarda en yüksek bulunma oranı ise sırasıyla *Paratylenchus* ve *Tylenchus* cinsine ait olup en yüksek popülasyon yoğunluklarına Aynısafa (*Calendula officinalis*) ve Aspir (*Carthamus tinctorius*) bitkilerinin rizosferinde rastlanmıştır. Predatör nematodlar ise örneklemelerde en düşük popülasyona sahip olup toplam popülasyonun %6,5' unu oluşturmuştur. Bu nematodlar içerisinde *Dorylaimus* cinsi 227 birey ile Sarı sabır (*Aloe vera*) bitkisinde en yüksek popülasyonda saptanmıştır.

Anahtar Kelimeler: Nematod faunası, biyoçeşitlilik, Cephalobidae, bitki paraziti nematodlar

EFFECTS OF ROOT ROT FUNGUS (*Fusarium oxysporum* f. sp. *ciceris*) AND ROOT LESION NEMATODE (*Pratylenchus thornei*) ON SOME CHICKPEA VARIETIES AT DIFFERENT APPLICATION TIMES

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ABSTRACT

Chickpeas (*Cicer arietinum* L.) are considered to be a nutritious cool season legume that plays a key role in global food security. This is due to the fact that they constitute a significant source of food protein. However, its production is significantly affected by several biotic agents, including the root lesion nematode (*Pratylenchus thornei*) and the crown rot fungus (*Fusarium oxysporum* f. sp. *ciceris*: Foc). These nematodes and diseases can have significant impacts either individually or synergistically through complex interactions. This study is designed to investigate the interaction between *P. thornei* and Foc in resistant and susceptible six different chickpea genotypes and how their simultaneous presence at different times may influence disease severity and nematode populations. Application of *P. thornei* prior to the inoculation of Foc isolate resulted in a considerable increase in disease severity in all varieties. This research has shown that the time of inoculation of Foc isolates is critical. The highest disease severity recorded was 92.9% in Akline 82 when Foc was applied one week after *P. thornei* inoculation. While the disease severity was 2.4% when only Foc was present, it increased to 92.9% in the Foc application 1 week after *P. thornei*. The MR value of the resistant Akline 82 variety was observed to be 2.2 in the absence of *P. thornei*, 7.7 when the disease was present, and 6.4 when the disease was applied one week later. In this application and simultaneous application an increase in MR values was generally observed on the varieties. The present study has shown that in order to develop effective integrated disease management strategies, it is essential to understand the etiology and epidemiology of complex disease interactions on chickpea. This study was supported by a project of Tübitak 122O889.

Keywords: *Cicer arietinum*, multiplication rate, simultaneous application, wilting

STRUCTURAL CHARACTERISTICS AND PROBLEMS OF FATTENING SHEEP FARMS IN KARACABEY DISTRICT

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ABSTRACT

This study aims to determine some structural features and breeding practices in fattening sheep farms in Karacabey district of Bursa province and to identify the problems encountered in these issues. The material of the study consists of survey data conducted with the owners of 76 fattening sheep farms in Karacabey district in 2025. In the surveyed farms, in addition to the socio-economic characteristics of the farm owners, breeds of sheep raised in the farms, number of mother sheep, care and feeding of mothers and lambs, feeding methods, lamb production, roughage supply, roughage used, silage production, grazing on pasture, fattening period, marketing and frequently encountered diseases were examined.

According to the results obtained; it was determined that the average age of the business owners was 49.26, 44.7% of them were primary school graduates and 15.8% of them were university graduates and they had been doing sheep breeding for an average of 25.6 years. It was determined that the average land size of the examined businesses was 169.36. In the businesses surveyed, the average number of mother rams and sheep was determined as 141.4. The vast majority of the sheep raised in the businesses were Karacabey Merino and the rate in all businesses was calculated as 79.9%. The average ages for disposal of mother rams and sheep in the businesses were found as 4.88 and 6.93 years, respectively. The business owners announced that they obtained an average of 173.75 lambs per year. The mortality rate of lambs from weaning to weaning was determined as 9.11%. The average weaning age of the lambs was 3.78 months and the average fattening period applied was determined as 4.82 months. At the end of fattening, the live weight of the lambs was calculated as 48.33 kg.

It was observed that 56.6% of the enterprises used concentrated feed and 43.4% did not. It was determined that 78.9% of the enterprise owners fed their animals twice a day. In terms of silage use, it was determined that 72.4% of the enterprises did not use silage and 27.6% used it. The rate of enterprises that made silage was found to be 15.8%. It was determined that 93.5% of the enterprise owners took their sheep to pasture and 57.9% kept their animals in pasture all year round. The rate of those receiving feed support in the examined enterprises was determined to be 15.8%. The enterprise owners stated that they saw high feed costs, shepherd problem, high medicine-treatment expenses, roughage problem, insufficient support and pasture problem as the most important problems.

As a result, it is important to carry out studies to solve these problems in the examined fattening sheep farms in terms of care-feeding, utilization of feed support, silage production and use, lamb deaths and diseases.

Keywords: Karacabey, sheep breeding, farm owners, care-feeding practices, lamb fattening, grazing on pasture, marketing.

KARACABEY İLÇESINDE BESİ KOYUNCULUĞU YAPAN İŞLETMELERIN YAPISAL ÖZELLİKLERİ VE SORUNLARI

ÖZET

Bu çalışmada, Bursa ilinin Karacabey ilçesinde besi koyunculuğu yapan işletmelerdeki bazı yapısal özelliklerin ve yetiştiricilik konularındaki uygulamaların belirlenmesi ve bu konularla ilgili karşılaşılan sorunların saptanması amaçlanmıştır. Çalışmanın materyalini, 2025 yılında Karacabey ilçesinde yetiştiricilik yapan 76 adet besi koyunculuğu işletmesinin sahipleri ile yapılan anket verileri oluşturmuştur. Anket yapılan işletmelerde, işletme sahiplerinin sosyo-ekonomik özelliklerinin yanı sıra, işletmelerde yetiştirilen koyunların ırkları, anaç koyun sayıları, anaç ve kuzuların bakım ve beslenmesi, yemleme şekilleri, kuzu üretimi, kaba yem temini, kullanılan kaba yemler, silaj üretimi, mera durumu, besi süresi, pazarlama, desteklemeler ve sık karşılaşılan hastalıklar konuları incelenmiştir.

Elde edilen sonuçlara göre; işletme sahiplerinin ortalama yaşlarının 49.26 olduğu, %44.7'sinin ilkokul ve %15.8'inin üniversite mezunu olduğu ve ortalama 25.6 yıldan beri koyunculuk yaptıkları belirlenmiştir. İncelenen işletmelerin arazi büyüklüklerinin ortalama 169.36 da olduğu saptanmıştır. Anket yapılan işletmelerde, anaç koç ve koyun varlığı ortalama 141.4 adet olarak belirlenmiştir. İşletmelerde yetiştirilen koyun varlığının çok büyük bir kısmı Karacabey Merinosu olup, tüm işletmelerdeki oranı %79.9 olarak hesaplanmıştır. İşletmelerde anaç koç ve koyunları elden çıkarma yaşları ortalama olarak sırasıyla; 4.88 ve 6.93 yaş olarak bulunmuştur.

İşletme sahipleri yılda ortalama 173.75 adet kuzu elde ettiklerini açıklamışlardır. Kuzuların sütten kesime kadar ölüm oranları %9.11 olarak saptanmıştır. Kuzuların ortalama sütten kesim yaşı 3.78 ay olup, uygulanan besi süresi ortalama 4.82 ay olarak belirlenmiştir. Besi sonunda kuzuların canlı ağırlıklar 48.33 kg olarak hesaplanmıştır.

İşletmelerin %56.6'sının kesif yem kullandığı, %43.4'ünün ise kullanmadığı görülmüştür. İşletme sahiplerini %78.9'unun hayvanları günde 2 kez yemlediği belirlenmiştir. Silaj kullanımı bakımından, işletmelerin %72.4'ünün silaj kullanmadığı, %27.6'sının ise kullandığı saptanmıştır. Silaj yapan işletmelerin oranı ise %15.8 olarak bulunmuştur. İşletme sahiplerinin %93.5'inin koyunlarını meraya çıkardıkları, %57.9'unun ise hayvanlarını yıl boyu merada tutuğu belirlenmiştir. İncelenen işletmelerde yem desteği alanların oranı %15.8 olarak tespit edilmiştir. İşletme sahipleri, en önemli sorunlar olarak, yüksek yem maliyetleri, çoban sorunu, ilaç-tedavi giderlerinin yüksekliği, kaba yem sorunu, yetersiz destekler ve mera sorununu gördüklerini beyan etmişlerdir.

Sonuç olarak, incelenen besi koyunculuğu işletmelerinde, uygulanan bakım-besleme, yem desteğinden yararlanma, silaj üretimi ve kullanımı, kuzu ölümleri ve hastalıklar konusunda bazı eksikliklerin olduğu, işletmelerin karlılığının arttırılması açısından söz konusu sorunların çözülmesine yönelik çalışmaların yapılması önemlidir.

Anahtar Kelimeler: Karacabey, koyun yetiştiriciliği, işletme sahipleri, bakım- yemleme uygulamaları, kuzu besisi, mera durumu, pazarlama.

SPATIAL ANALYSIS OF THE IMPACT OF FERTILIZER USE PRACTICES ON NITRATE POLLUTION IN COTTON FARMING USING REMOTE SENSING TECHNIQUES: THE CASE OF HARRAN PLAIN

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ABSTRACT

This study was conducted to determine the impact of fertilizer use practices on nitrate pollution in the Harran Plain, one of Turkey's most important cotton production regions. Using remote sensing and Geographic Information System (GIS) techniques, the spatial distribution of fertilizer applications was analyzed, and the environmental effects of excessive fertilization were evaluated.

As part of the research, surveys were conducted with approximately 400 farmers to assess fertilizer use habits (both base and top fertilizing) in agricultural lands where cotton is grown. The surveys examined in detail farmers' fertilizer preferences, application times, the amounts of nitrogen fertilizers used, and fertilization methods. The GPS coordinates of farmers' fields were recorded, and soil samples were collected from designated points before cotton planting for nitrate analysis. Laboratory analyses determined soil nitrate levels, which were then evaluated in relation to fertilization practices.

For this study, conducted during the 2024 cotton production season, Sentinel-2 satellite data from August 2024 was utilized to determine the relationship between cropping patterns and fertilization. Cotton cultivation areas were mapped using satellite images, and the overall fertilizer use distribution was spatially assessed by integrating GPS coordinates of selected areas with farmers' fertilization practices.

Using ArcGIS software, fertilizer application rates, soil nitrate levels, and remote sensing data from farmers' fields were integrated to identify areas of excessive fertilization. The study results revealed that there was an average difference of 15 kg/da between the recommended nitrogen fertilizer amount for cotton production and the actual amount applied by farmers, significantly increasing nitrate pollution.

The findings provide scientific contributions to the development of sustainable agricultural policies, highlighting the need for regional management strategies to optimize fertilization practices and mitigate environmental impacts.

Keywords: Nitrate pollution, cotton, Harran Plain, Remote Sensing

PAMUK TARIMINDA GÜBRE KULLANIM ALIŞKANLIKLARININ NİTRAT KİRLİLİĞİNE ETKİSİNİN UZAKTAN ALGILAMA TEKNİKLERİ İLE ALANSAL ANALİZİ: HARRAN OVASI ÖRNEĞİ

ÖZET

Bu çalışma, Türkiye'nin en önemli pamuk üretim bölgelerinden biri olan Harran Ovası'nda, gübre kullanım alışkanlıklarının nitrat kirliliğine etkisini belirlemek amacıyla yürütülmüştür. Çalışmada, uzaktan algılama ve Coğrafi Bilgi Sistemleri (CBS) teknikleri kullanılarak, gübre uygulamalarının mekânsal dağılımı analiz edilmiş ve aşırı gübreleme kaynaklı çevresel etkiler değerlendirilmiştir.

Araştırma kapsamında, pamuk ekilen tarım alanlarını temsil edecek şekilde yaklaşık 400 çiftçi ile gübre kullanımı (taban ve üst gübre) alışkanlıklarını belirlemek amacıyla anketler gerçekleştirilmiştir. Anketlerde, çiftçilerin gübre tercihi, uygulama zamanları, kullanılan azotlu gübre miktarları ve gübreleme yöntemleri detaylı bir şekilde incelenmiştir. Çiftçi tarlalarının GPS koordinatları kaydedilmiş ve nitrat analizi için pamuk ekim öncesinde belirlenen noktalardan toprak örnekleri alınmıştır. Laboratuvar analizleri sonucunda toprak nitrat seviyeleri belirlenerek gübreleme uygulamaları ile ilişkileri değerlendirilmiştir.

2024 yılı pamuk üretim sezonunda gerçekleştirilen bu çalışma kapsamında, ürün deseni ile gübreleme arasındaki ilişkinin belirlenmesi ve çiftçi uygulamalarının uzaktan algılama verileri ile karşılaştırılması için 2024 yılı Ağustos ayına ait Sentinel-2 uydu verileri kullanılmıştır. Uydu görüntüleri ile pamuk ekim alanları haritalanmış, çiftçilerin gübre kullanım alışkanlıklarını analiz etmek amacıyla belirlenen alanlara ait GPS koordinatlarıyla entegre edilerek genel gübre kullanım dağılımı mekânsal olarak değerlendirilmiştir.

ArcGIS yazılımı kullanılarak çiftçi tarlalarındaki gübre kullanım miktarı, toprak nitrat seviyesi ve uzaktan algılama verileri bütünleştirilerek aşırı gübreleme alanları tespit edilmiştir. Çalışma sonuçlarına göre, pamuk üretiminde önerilen azotlu gübre miktarı ile çiftçilerin uyguladığı miktar arasında ortalama 15 kg/da fark olduğu ve bu aşırı kullanımın nitrat kirliliğini önemli ölçüde artırdığı belirlenmiştir. Elde edilen bulgular, sürdürülebilir tarım politikalarının oluşturulmasına bilimsel katkı sağlamakta olup, gübreleme stratejilerinin optimize edilmesi ve çevresel etkilerin azaltılması için bölgesel yönetim stratejilerinin geliştirilmesi gerektiğini ortaya koymaktadır.

Anahtar Kelimeler: Nitrat Kirliliği, Pamuk, Harran Ovası, Uzaktan Algılama

AGRICULTURAL LAND AND PAKISTAN

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ABSTRACT

It is commonly known that land is a basic natural resource, which supports lives through agriculture, where superposition of agricultural lands for other uses, especially for urbanization is great concern. Therefore, this study aim is to investigate causes and consequences of agricultural land conversion Pakistan. The country is select as a study, because agricultural land parcels are being greatly converting to residential areas in Pakistan as compared to the other countries. it is also intent to draw the attention of policy makers towards this issue, while sharing a recent experience. Both primary and secondary data sources will be use in this research. The primary data will be collecting through questionnaires, first from the local respondents (accused residents/farmer) in the study area, and second from professional/experts (real estate agents/valuers and physical planner). The data will also be collect through Arial-views and treated through geographic informative system (GIS). While, secondary data will be collect from economic survey of Pakistan, Pakistan bureau of statistics, government offices and websites, UN population division, magazines, daily press and from NGOs and offices. From the Arial-views show that agricultural lands are being considerably decreasing in last four decades. Similarly, on average every respondent has sold about more than four acres of agricultural land in last 10 years. Additionally, the study describes that three types of conflicts (proprietorship, distribution/fragmentation, and encroachment) have influenced the respondent's personal lives, such as; threat to life, lower property values, loss of income, abundance of land. Therefore, Institutional framework with good governance is a need to create or strengthen coherence between land regulatory institutions with powers and capacity to regulate land conversions system. On the other hand, local population needed to be educated regarding agricultural land conversion, through public participation, management and development policy seminars, to ensure sustainable agricultural developed.

Keywords: Agriculture, Land, Conversion and Pakistan.

EXPLORING MICROBIAL DYNAMICS AND METABOLOMIC PROFILING OF ISOFLAVONE TRANSFORMATION IN BLACK AND YELLOW SOYBEAN TEMPE FOR SUSTAINABLE FUNCTIONAL FOODS

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ABSTRACT

Tempe, a traditional Indonesian fermented soybean product, is celebrated for its rich bioactive profile, including peptides and isoflavones, which impart significant health benefits. In this

study, we investigated the microbial dynamics and metabolomic changes that drive isoflavone transformation in tempe produced from black and yellow soybeans. Two fermentation strategies were compared: a commercial Raprima™ starter culture and a co-culture of *Rhizopus oligosporus* and *R. stolonifer*. Metabolomic analysis using LC-HRMS revealed that co-culture fermentation notably increased the levels of bioactive aglycones such as genistein, daidzein, and glycitein, thereby enhancing isoflavone bioavailability and antioxidant capacity. Metagenomic profiling indicated that *Proteobacteria* (78%) and *Firmicutes* (18%) dominated the bacterial communities, with distinct microbial shifts observed between fermentation methods. Specifically, co-culture fermentation enriched genera such as Stenotrophomonas, while Raprima™ favored Acinetobacter. The fungal community was predominantly composed of Mucoromycota (92%), with *Rhizopus arrhizus* strongly associated with enzymatic hydrolysis of isoflavone glycosides. Statistical correlations demonstrated significant relationships between microbial taxa and metabolite intensities, confirming the role of microbial synergy in isoflavone conversion. Although yellow soybeans yielded higher total isoflavone content, black soybeans exhibited superior genistein levels and greater adaptability to tropical conditions. These findings underscore the impact of fermentation method and substrate selection on tempe's nutritional quality, supporting its development as a sustainable, functional food that leverages local resources and microbial interactions for improved health benefits. Advanced metabolomic and metagenomic analyses reveal the intricate interplay among soybean composition, fermentation conditions, and microbial communities, providing a basis for optimizing tempe production with superior nutritional and functional attributes.

Keyword: tempe, metabolomics, metagenomics, soybean, fermentation.

THE IMPACT OF RENEWABLE ENERGY IMPLEMENTATION ON RURAL ECONOMIC GROWTH

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ABSTRACT

The use of renewable energy has become an important strategy to promote sustainable development, especially in rural areas which rural areas usually have more natural resources, but limited human resources. This research explores the impact of renewable energy implementation on economic growth in rural areas, focusing on how access to clean energy solutions-such as solar, wind, and biogas-can stimulate economic activity, increase productivity, and improve people's lives. By analyzing various case studies and reviewing existing literature, the research highlights the direct and indirect economic benefits of renewable energy, including job creation, increased agricultural productivity, and reduced energy costs as considering safety factors. The research findings show that the adoption of renewable energy not only helps address the issue of energy poverty, but also stimulates the local economy by empowering small industries, improving health and education services, and encouraging entrepreneurship. However, challenges such as high initial investment costs, lack of technical expertise, and inadequate policies remain significant barriers and need to be addressed as soon as possible. This study concludes that targeted interventions, including public-private partnerships, capacity-building programs, and supportive policies, are critical to maximizing the economic potential of renewable energy in rural areas. The results provide valuable insights for policymakers, development practitioners, and stakeholders seeking to achieve sustainable rural development through renewable energy integration.

Keywords: Reneweble energy, rural economic growth, sustainable development, energy poverty, policy frameworks

REACTIONS TO WHEAT LEAF RUST (*Puccinia triticina*) AND ITS EFFECT ON GRAIN QUALITY

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ABSTRACT

Kazakhstan is one of the world's leading producers of high-quality wheat. Therefore, controlling biotic and abiotic stresses affecting wheat yield and quality is critical to Kazakhstan's wheat production. Leaf rust (*Puccinia triticina*) is widespread in wheat-growing areas of Kazakhstan and limits yield and quality to varying degrees. This research aimed to determine the yield response of 75 wheat lines to leaf rust under natural epidemic conditions at the Almaty site in the 2022-2023 growing season. Phenological control and analysis of biomass index indicators were also carried out. The test materials were sown by hand in 6 rows at 2.5-3.0 g of seed per row. The research was carried out using a randomized block design with three replications. Susceptible control varieties were scored 90S-100S, and the results were reliable. The evaluations were carried out between 5 and 16 June 2023. As a result of the study, it was observed that five materials were in the resistant group (CI; 0.1-5). The plant height of 8 test materials was measured to be 1.40 cm longer. Six materials matured early compared to the control. Twenty-nine test materials had the highest plant biomass index compared to the control. It was found that materials resistant to leaf rust reactions with 1.40 cm shorter plant height and high biomass can be registered or used as genitors in leaf rust resistance breeding programs.

Keywords: Bread wheat, Leaf rust (*Puccinia triticina*), Yield, Quality

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THE EFFECT OF EXPERIMENTAL YIELD TRIAL MATERIALS ON BUNT REACTIONS AND WHEAT YIELD

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ABSTRACT

Wheat is a critical economic and strategic crop for Kazakhstan, with an annual production of 17–18 million tonnes, of which 8 million are exported to Europe, the Middle East, and Arab countries. However, wheat production is significantly hindered by common bunt, a disease caused by *Tilletia* species, poses a global challenge. Although seed treatment with fungicides is a common practice to control this disease, it carries environmental and human health risks and increases production costs.

This study aimed to investigate the bunt reactions and yield potential of 75 bread wheat lines under artificial epidemic conditions caused by *Tilletia caries* (D.C.) Tul. during the Almaty research site's 2022–2023 growing season. The experimental material consisted of seeds prepared in paper envelopes, each containing 4–5 grams of seed inoculated with bunt spores at a concentration of 0.5%. Bunt reactions were assessed by counting the number of diseased and total spikes for each genotype and calculating the bunt infection rate (%). The susceptible control genotypes exhibited bunt infection rates of 90–100%, confirming the reliability of the experimental results.

The study was conducted using a randomized block design with three replications. Yield-related traits evaluated included plant height, main spike length, number of spikes per central spike, number of grains per spike, grain weight per spike, and 1000-grain weight. Among the 75 wheat lines tested, 16 lines demonstrated resistance to common bunt. These resistant lines also exhibited superior yield characteristics compared to the other genotypes.

The findings suggest that the resistant and high-yielding lines identified in this study have the potential to be registered and utilized as parental lines in breeding programs aimed at developing tillage-resistant wheat varieties.

Keywords: Bread wheat, Common bunt (*Tilletia caries*), Yield, Resistance

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STATISTICAL MODELING OF WIND DATA USING TYPE I HALF-LOGISTIC EXPONENTIATED INVERSE LOMAX DISTRIBUTION

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ABSTRACT

In this paper, we explore the properties and importance of a lifetime distribution so called type I half-logistic Exponentiated Inverse Lomax. We investigate some of its mathematical and statistical properties such as the explicit form of the ordinary moments, moment generating function, conditional moments, Bonferroni and Lorenz curves, mean deviations, residual life and reversed residual functions, Shannon entropy and Renyi entropy. The maximum likelihood method is used to estimate the model parameters. Finally, we illustrate the importance and applicability of the model by the study by application to wind data.

Keywords: Type I half logistic exponentiated inverse Lomax distribution, moment generating function, moments, maximum likelihood estimate.

HEALTH AND DISEASE IMPLICATIONS OF SORGHUM IRRIGATED WITH TRICKLING FILTER-TREATED WASTEWATER IN NORTH AFRICA'S SEMI-ARID REGIONS

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ABSTRACT

The goal of this work was to investigate the effect of treated wastewater irrigation on the physiological and agronomic properties of *sorgham area major source human food and are an excellent source of all essential nutrients like protein ,carbohydrates, fat, minerals,and bioactive compounds*. An experimental reuse study was performed using raw (RWW) and treated urban wastewater (TWW) by Trickling Filter (TF) process to irrigate Millet in comparison to well water (WW) as a control over a period of 5 months. The water quality was determined for irrigation based on sodium adsorption ratio (SAR), sodium percentage (Na %) and residual sodium carbonate (RSC) indicating that all treatments were suitable for irrigation purposes. In this study, we also assessed the agro-physiological and biochemical proprieties of the crops. Hence, the highest productivity of sorgham and leaf area were obtained in response to irrigation with RWW and TWW compared to WW; while macro-elements (TP, TKN, and K) were also affected in millet irrigated with RWW compared to TWW and WW. However, the plants irrigated with well water accumulate more Ca, Na, and Mg than those irrigated with RWW and TWW. All the crops irrigated with three water treatments showed a relatively similar concentration of micro-nutriments. The prevalence of total chlorophyll content in the plants increased with well water irrigation. Nevertheless, the biochemical parameters (protein and sugar content) were adversely affected in millet irrigated with RWW as compared to TWW and WW. Moreover, the use of treated urban wastewater improves the physicochemical properties and fertility of the soil compared to well water and enhances crop productivity.

Keywords: *Millet;* irrigation; treated wastewater reuse; physiological proprieties; Trickling Filter.

Pearl millet also known as Bachna or IRNY, is one of the four most important cereals (rice, maize, sorghum and millets) grown in tropical semi-arid regions of the world primarily in Africa and Asia. Our aim is to review the potential health benefits of pearl millet., libraries,

PubMed and other web sources. Pearl millet is rich in several nutrients as well as non-nutrients such as phenols. It has high energy, has less starch, high fiber (1.2g/100g, most of which is insoluble), 8-15 times greater α-amylase activity as compared to wheat, has low glycemic index (55) and is gluten free. The protein content ranges from 8 to 19% and it is low in lysine, tryptophan, threonine and the sulfur-containing amino acids. The energy of millet is greater than sorghum and nearly equal to that of brown rice because the lipid content is generally higher (3 to 6%). Pearl millet can be recommended in the treatment of celiac diseases, constipation and several non-communicable diseases. Nutritional studies on the population living in the pearl millet belts of the world and clinical trials on the impact of pearl millet in specific disease conditions are needed

Le millet perlé, également connu sous le nom de Bachna ou IRNY, est l'une des quatre céréales les plus importantes (riz, maïs, sorgho et millets) cultivées dans les régions tropicales semi-arides du monde, principalement en Afrique et en Asie. Notre objectif est de passer en revue les avantages potentiels du millet perlé pour la santé, en consultant des bibliothèques, PubMed et d'autres sources Internet. Le millet perlé est riche en plusieurs nutriments ainsi qu'en non-nutriments tels que les phénols. Il est très énergétique, contient moins d'amidon, beaucoup de fibres (1,2 g/100 g, dont la plupart sont insolubles), une activité α-amylase 8 à 15 fois supérieure à celle du blé, un faible indice glycémique (55) et ne contient pas de gluten. La teneur en protéines varie de 8 à 19 % et le millet est pauvre en lysine, tryptophane, thréonine et acides aminés soufrés. L'énergie du millet est supérieure à celle du sorgho et presque égale à celle du riz brun car la teneur en lipides est généralement plus élevée (3 à 6 %). Le millet perlé peut être recommandé dans le traitement des maladies cœliaques, de la constipation et de plusieurs maladies non transmissibles. Des études nutritionnelles sur la population vivant dans les ceintures de millet perlé du monde et des essais cliniques sur l'impact du millet perlé dans des conditions pathologiques spécifiques sont nécessaires.

EFFECT OF ENVIRONMENTAL FACTORS ON HEAVY METAL IN SEAWEED: A BIBLIOMETRIC ANALYSIS OF 20 YEARS OF RESEARCH PUBLICATIONS

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ABSTRACT

Heavy metal accumulation in seaweed is significantly influenced by environmental factors such as salinity, temperature, pH, and anthropogenic activities. Understanding how these factors interact with seaweed physiology is crucial for evaluating the ecological risks and potential applications of seaweed in environmental monitoring and bioremediation. Despite increasing scientific interest in this topic, no bibliometric study has systematically mapped the evolution of research in this area. This study presents a bibliometric analysis of literature published between 2005 and 2024, retrieved from the Web of Science Core Collection. Using VOSviewer and Biblioshiny, the analysis explores co-occurrence of keywords, collaboration networks, and thematic development over time. The study focuses on research involving key terms such as salinity, temperature, pH, anthropogenic, seaweed, macroalgae, and heavy metals. Preliminary findings indicate growing interest in the role of environmental stressors on metal uptake mechanisms in macroalgae, with emerging themes related to climate change, pollution, and sustainable bioremediation. This work provides insight into current research hotspots and future directions, offering a foundation for deeper ecological studies and applied research in marine environmental management.

Keywords: Seaweed, macroalgae, heavy metals, environmental factors, climate changes.

CROP FARMERS' KNOWLEDGE OF E-BANKING IN ENUGU EAST SENATORIAL ZONE OF ENUGU STATE, NIGERIA

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ABSTRACT

The study assessed crop farmers' knowledge of e-banking in Enugu East Senatorial Zone of Enugu state, Nigeria. Data was collected from sixty crop farmers through the use of a structured interview schedule. Analysis of the data was done using frequency, percentage, mean and standard deviation. Results show that the majority (73%) of the respondents had a high knowledge of e-banking. Also, data show that the most frequently used ICT for transactions amongst the respondents was the debit card (75.0%). The study further revealed that the crop farmers' show more positive satisfaction with the cashless policy including: security and protection of funds ($\overline{x}$=3.20), ease of usage ($\overline{x}$=3.00), quick access to finances ($\overline{x}$=2.95), mobile banking reliability ($\overline{x}$=2.90), mobile network availability ($\overline{x}$=2.87), support and assistance by financial institution ($\overline{x}$=2.63), reduction in the cost of access to funds ($\overline{x}$=2.62), convenient environment for farmers ($\overline{x}$=2.53). There is need for more sensitization of farmers on the gains of using e-banking technologies for seamless daily farm transaction by actors including government. Such sensitization and possible subsidization of cost of the technologies by government would help them to access and use more of such technologies.

Keywords: E-banking, Farmers, knowledge, Agriculture

IDENTIFYING CONSTRAINTS IN THE ADOPTION OF PULSES CULTIVATION: CHALLENGES AND POLICY INTERVENTIONS

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ABSTRACT

Pulses are an essential source of vegetable protein, contributing significantly to food security and sustainable agriculture. Despite their increasing demand and high market value, pulses cultivation in Pakistan remains limited, leading to a growing reliance on imports. This study aims to identify the constraints faced by farmers in pulses production in Faisalabad (Sadar), Pakistan. A structured survey was conducted with 124 farmers, selected through proportionate random sampling. Data were collected through interviews and analyzed using the Statistical Package for Social Sciences (SPSS). The findings reveal multiple barriers to pulses cultivation. High fertilizer costs (mean=4.38) ranked as the most significant constraint, followed by middleman monopoly (mean=4.32), lack of farmer interest (mean=4.23), high pesticide costs (mean=4.02) and expensive irrigation (mean=3.98). Other challenges included limited technical knowledge of pulses production (mean=3.75), poor extension services, lack of government policies and inadequate access to certified seeds (mean=2.08). Farmers mainly relied on fellow farmers (mean=4.03) and pesticide agents (mean=3.80) for agricultural information, reflecting gaps in the role of extension workers. Due to small landholdings, many farmers preferred cultivating staple crops such as wheat, rice and maize to maximize profits, further limiting pulse production. To address these challenges, the study suggests the need for government intervention in the form of targeted extension programs, awareness campaigns, subsidized input provision and enhanced access to improved pulse varieties. Additionally, fair pricing mechanisms, training programs for both farmers and extension staff and better market linkages

should be implemented to incentivize pulses cultivation. Strengthening extension services and ensuring equal access to resources can help reduce import dependency and promote sustainable agricultural practices in Pakistan.

Keywords: Pulses, Farmer Constraints, Extension Services, Agricultural Policy, Production Challenges

FORMULATION OF VEGETARIAN ICE CREAM FROM MAJA FRUIT (*Aegle marmelos*) AS A COW'S MILK SUBSTITUTE AND ANTIOXIDANT SOURCE

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ABSTRACT

Maja fruit (*Aegle marmelos*) is rich in nutrients and bioactive compounds. However, its hard outer shell and bitter taste when unripe make it underutilized in the food industry. Additionally, its seeds, which are often discarded as waste, contain essential vitamins and fatty acids. This study aims to develop an innovative vegetarian ice cream formulation using maja fruit pulp and seed extract as a cow's milk substitute while evaluating its sensory, physicochemical, and bioactive properties. The ice cream was made using five different formulations, varying the amounts of maja seed extract, maja fruit pulp, soy milk, coconut milk, and palm sugar. Cow's milk was used as the control. The results show that the formulated vegetarian ice cream was well-accepted by consumers and exhibited significant functional properties, with antioxidant activity exceeding 50% and antihyperglycemic activity over 90%. The total phenolic content exceeded 100 mg GAE/100 g, highlighting its potential as a functional food. Furthermore, the product meets the Indonesian National Standard (SNI 01-3717-1995) for total soluble solids, fat content, and protein content in ice cream.

Keywords: Antioxidant, *Aegle marmelos*, vegetarian ice cream

ADAPTATION STRATEGIES TO FUEL SUBSIDY REMOVAL AMONG FARMERS IN NSUKKA AGRICULTURAL ZONE, ENUGU STATE, NIGERIA

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ABSTRACT

The study assessed the adaptation strategies to fuel subsidy removal among farmers in Nsukka agricultural zone, Enugu State, Nigeria. A multistage sampling procedure was used to select 60 farmers used for the study. Data collected were analyzed using frequencies, percentages, mean scores and factor analysis. The findings show that all (100%) of the respondents reported an increase in operational costs due to the removal of fuel subsidies, highlighting significant impacts of this policy on farmers. The effects of fuel subsidy removal on farmers' livelihood were majorly on farmers inability to purchase farm inputs, reduction in labour force, reduction in crop and livestock productivity and increased crop diversification due to fuel subsidy removal. Also, the major adaptation strategies to the effects of fuel subsidy removal by the farmers were resorting to the use of organic farming methods, reduction of farm size to manage production costs and increased focus on high value crops. However, the major factors that constrain farmers from adapting to the effects of fuel subsidy removal were lack of community support for adaptation strategies and lack of processing activities for value addition. The study concluded that there is a need for policymakers to develop strategies that support farmers in adapting to the effects of fuel subsidy removal and therefore recommend that policies should be developed and implemented to support farmers in adapting to the effects of fuel subsidy removal, such as providing subsidies for farm inputs and equipment, provide training and extension services to farmers on sustainable agricultural practices, farm resilience strategies, and farm development diversification strategies.

Keywords: adaptation strategies, fuel subsidy removal, farmers in Nsukka

EFFECTS OF FUEL SUBSIDY REMOVAL ON HOUSEHOLD FOOD CONSUMPTION AND DIETARY PATTERNS OF FARMERS IN ENUGU EZIKE AGRICULTURAL ZONE, ENUGU STATE, NIGERIA

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ABSTRACT

The study assessed the effects of fuel subsidy removal on household food consumptions and dietary pattern of farmers in Enugu ezike Agricultural Zone, Enugu state, Nigeria. Specifically, the study sought to: ascertain the effects of fuel subsidy removal on the farmers' food consumption and dietary patterns, ascertain the effects of fuel subsidy removal in farming practices and ascertain copying strategies employed by the respondents in cushioning the effects of fuel subsidy removal. A multistage sampling procedure was used to select 60 farmers used for the study. Data collected were analyzed using frequency, percentage, mean, standard deviation and factor analysis. The major effects of fuel subsidy removal on the farmers were: preparing meals at home than buying outside ($\bar{x}$=3.65), forming of a community buying group to purchase food in bulk ($\bar{x}$=3.52). The effects of fuel subsidy removal on farmers farming practices were majorly on environmental sustainability, behavioral adjustment and adaptive effects. The effects of fuel subsidy removal on household food consumption and dietary pattern were majorly on economic, nutritional and socio-economic effects. The coping strategies used in cushioning the effects of fuel subsidy removal were distress-based coping strategies, financial coping strategies and resilience-based coping strategies. The study concluded that the fuel subsidy removal has led to reduced food availability, increased food prices and reduced dietary diversity, ultimately exacerbating food insecurities among farmers. The study recommended that government should monitor and evaluate the impacts of fuel subsidy removal on farmers and adjust it policies and should implement policies that support farmers' food security and livelihood.

Keywords: Fuel subsidy removal, Household food consumption. Dietary partern

THE EFFECT OF CO_2 AND H_2O REMOVAL FROM TOP GAS FUEL STREAM UPON ITS HEATING VALUE AT GOHARZAMIN COMPANY

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ABSTRACT

In the Midrex unit of the Goharzamin Mining and Industrial Company, located in Kerman Province, the top gas fuel stream, which is produced by the increased gas volume from the cracking of natural gas in the reformer tubes, plays a significant role in the operation of the reformer unit. This gas is enriched with natural gas every hour to meet the required thermal value for the reformer unit to reach optimal temperatures. However, due to the high carbon dioxide and water content in the top gas fuel stream, using it in the reformer burners causes several operational issues, including reduced heating value and process efficiency, corrosion of pipeline, increased natural gas consumption, and an increased carbon footprint. This research focuses on evaluating the impact of removing carbon dioxide and water from the top gas fuel stream on the reformer unit's energy efficiency and overall process optimization. By eliminating carbon dioxide and water content, the combustion energy of the top gas fuel stream significantly increases, reducing the amount of natural gas required for the reformer's operation and improving process efficiency. Additionally, in this paper Aspen HYSYS software was utilized to evaluate and simulate the heat duty transferred to the reformer across six scenarios with varying conditions for the top gas fuel stream. These scenarios include the removal of water and carbon dioxide from the top gas fuel stream, as well as changes in the amount of natural gas added to the top gas fuel stream. In this study, the amount of natural gas saved, the reduction in carbon dioxide emissions, the amount of water removed from the top gas fuel stream, and the revenue generated from the sale of carbon dioxide and water removed from the top gas fuel stream have been evaluated and documented. This study also investigates the environmental benefits of removing carbon dioxide, which can be captured and sold for various applications.

Additionally, this process helps reduce the carbon footprint, a critical factor in addressing global warming and complying with future environmental regulations.

Keywords: Top Gas Fuel, Carbon Dioxide, Water, Natural Gas, Aspen HYSYS.

SUBSTITUTION OF BEACH WELL INTAKE TECHNOLOGY FOR OPEN INTAKE TECHNOLOGY AS SEAWATER INTAKE FOR REVERSE OSMOSIS DESALINATION PLANT

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ABSTRACT

In the city of Bandar Abbas, within the Hormozgan Steel Company, reverse osmosis (RO) desalination plant plays a crucial role in supporting industrial water needs. This study focused on improving the energy efficiency and performance of the RO desalination plant through equipment upgrades and system modifications. One key innovation introduced in this study was the use of beach well intake technology, which provide an alternative to conventional open intake technology. Beach well technology draw seawater from beneath the seabed, filtering it naturally through sand and subsurface layers. This modification significantly enhances the quality of the intake water, reducing the risk of membrane fouling caused by pollutants, marine organisms, and sediments commonly encountered in open intakes technology. This research involves assessing the operational performance of the RO plant both before and after the modification. Results indicated significant improvements in energy efficiency, with reductions in operational costs and maintenance requirements. Additionally, the natural filtration provided by the beach well intake technology lowered the need for extensive pre-treatment, resulting in reduced chemical usage and energy consumption. Furthermore, this study highlighted the environmental benefits of this system, including less impact on marine life, improved water quality, and lower visual and acoustic disruptions at the coastline. These findings also support

the feasibility of adopting beach well intake technology as a sustainable and cost-effective alternative to traditional open intake technology. This research also aligns with international environmental standards and agreements, such as the Convention on Biological Diversity (CBD) and the European Union's Water Framework Directive (WFD), emphasizing on the reduction of environmental impacts in desalination plants. Overall, this study demonstrates the potential for beach well technology to optimize desalination plant operations while promoting sustainability and reducing ecological footprints. In this paper, the key indices for the substitution of beach well technology with open water intake technology for the RO desalination plant in Bandar Abbas are provided and documented, including investment volume required, cost reduction, operation duration, internal rate of return (IRR), net present value (NPV), and both normal and adjusted payback periods.

Keywords: Beach Well Technology, Open Intake, Reverse Osmosis Desalination Plant, Seawater Intake Technology, Hormozgan Steel Company.

EXPLORING THE ANTICANCER POTENTIAL OF AGRICULTURALLY RELEVANT *Mimosa pudica* (Linn.): A NETWORK PHARMACOLOGY PERSPECTIVE

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ABSTRACT

The increasing need for diverse and sustainable resources, coupled with growing interest in the bioactive potential of traditionally used plants, necessitates the exploration of novel applications for agricultural species. This study employs a network pharmacology approach to elucidate a potential new dimension for *Mimosa pudica*, an agriculturally relevant plant, by investigating its anticancer properties against luminal-type breast cancer. Bioactive compounds identified from *M. pudica* were subjected to in silico analysis using SwissADME and SwissTargetPrediction to assess their drug-likeness and predict potential protein targets. Gene expression analysis utilizing UALCAN was conducted to identify differentially expressed genes in luminal-type breast cancer. Protein-protein interaction (PPI) network construction and visualization were performed using Cytoscape to delineate interactions between target proteins and identify key hub nodes. Molecular docking simulations evaluated the binding affinity of selected ligands, including apigenin, galangin, kaempferol, diosmetin, and chrysin, to proteins implicated in cell cycle regulation. The analysis revealed that *M. pudica* harbors diverse bioactive compounds with putative anticancer properties. Identified target proteins, encompassing AURKA, AURKB, CA12, CDK1, ERBB2, ESR1, KIF11, KMO, MIF, MMP1, MMP9, NEK2, PLK1, PTK6, SQLE, TOP2A, TYMP, and TYMS, are involved in critical cellular processes associated with cancer progression, including cell cycle regulation, DNA metabolism, growth factor signaling, angiogenesis, metastasis, and invasion. Notably, the ligands exhibited strong binding affinities to AURKA and CDK1, pivotal cell cycle regulators, with binding energies ranging from -7.6 to -8.9 kcal/mol. These findings offer valuable mechanistic insights into the potential of *M. pudica* beyond its traditional uses, underscoring its

potential as a promising source of therapeutic agents for the treatment of luminal-type breast cancer and highlighting the broader value that agricultural resources can offer to human health.

Keywords: Cell cycle, Co-chemotherapy, Folk medicine, Invasive plant, Breast cancer, *Mimosa pudica*

A DIAGNOSTIC ANALYSIS OF ROLE OF MIDDLEMEN IN FINANCING AND MARKETING OF AGRICULTURE BUSINESS, ITS IMPACT ON THE EARNINGS OF FARMERS AND CONSUMER PRICE: A CASE STUDY OF POTATO FARMERS

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ABSTRACT

Growing consumer demand and rising government attention to the development of horticultural crops has significantly contributed to the expansion of potato area and production in Pakistan. Expansion in the processing industry have also contributed to increasing consumption of potato products. Furthermore, potato is the cheapest source of carbohydrates, vitamins, minerals, and proteins. This study uses field survey data collected from Sahiwal, Okara and Depalpur (major potato producing areas in Punjab province, Pakistan) to quantify the roles of various stakeholders (Farmers, Commission Agents, Wholesalers, Retailers and Consumers) in potato value chain. Study findings shows that majority of the farmers use their own savings to meet cost of production of potato crop and some also borrowed from Aarthi. Benefit-Cost Ratio for all the three varieties of potato crop is greater than one which indicates that farmers are making profit from investment on potato crop. Price fluctuation and exploitation by middleman are the major issues farmers facing while marketing their produce. Majority of commission agents had their personal investment in business, some also borrowed from informal (friends, relatives etc.) and formal sources such as banks. Most of the surveyed commission agents also provide finances to farmers. On ana average commission agent charges 4 percent commission from both sellers and buyers. Majority of wholesalers uses their personal capital in business, and some also borrowed formal banks as well. They earn reasonable profit from their business. Retailers use both personal capital and borrow money from banks for their business. Retailers earn Rs.5-10/kg from sale of potato crop to consumers. At farm level, there is need to ensure good quality seed and other inputs. Subsidies are not reaching to farmers. Farmers are being exploited by market intermediaries. To save losses at sowing and harvesting time proper farm machinery is a major constraint. Market committee collects the fee but does not provide proper facilities at marketplace. There is need of electronic auction and mandi.

Keywords: Agricultural Marketing and Financing, Farmer Earnings and Consumer Prices, Middlemen Role

IMPACT OF RAPS BASED ADAPTATION PACKAGE ON AGRICULTURE IN PUNJAB-PAKISTAN

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ABSTRACT

The paper provides an impact analysis of interventions undertaken in one of the case studies in Punjab where Representative Agricultural Pathways (RAPs) based analysis were carried out. The Punjab- based analysis benefited from more elaborate data that were gathered in the field.

For the case study community in Punjab, the main interventions were:

- Promoting cultivation of water-saving 'low delta' crops, notably mung bean.
- Use of bed and furrow water saving technologies.
- Improving soil health by applying organic matter.

A total of 154 farmers were interviewed. The number of mung bean adopters were 76 while non-adopters were 78 from the same area. Data gathered were analyzed using statistical and econometric techniques. The Data Envelopment Analysis (DEA) technique was used to calculate technical efficiency of inputs, while the Tobit model was used to identify the major factors affecting efficiency of mung bean growers. The results show that adopters of low delta crops had a relatively higher average year of schooling compared with non-adopters. Among efficient growers of mung bean, the returns per month were higher as compared with cotton and maize. The Tobit model results showed that education and experience had a positive impact on technical efficiency, while non-availability of high yielding seed, non-availability of machinery, and volatility in selling prices had a negative impact. It is recommended that awareness among farmers should be enhanced for the adoption of new technologies and innovations.

Keywords: Representative Agricultural Pathways (RAPs), Impact assessment, Interventions

GENETIC DIVERSITY AND POPULATION STRUCTURE of LETTUCE MOSAIC VIRUS BASED ON COAT PROTEIN GENE REGION

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ABSTRACT

Lettuce mosaic virus (LMV) belongs to the genus *Potyvirus* within the family *Potyviridae*. It is transmitted by seed and aphids in a non-persistent manner by *Myzus persicae* and *Macrosiphum euphorbiae*. To date, several studies conducted in different regions have declared that LMV is a widespread pathogen across the country and negatively affects lettuce production. In this study, newly obtained LMV isolates from the Eastern Mediterranean region of Turkey were analyzed with global LMV isolates to provide detailed insights into their genetic diversity and population structure. To investigate the prevalence of LMV, 105 leaf samples were collected from lettuce plants displaying virus-like symptoms. The surveys were conducted in Adana, Osmaniye, Hatay, and Kahramanmaraş in 2024-2025. As a result of the RT-PCR analysis, 26 out of 105 lettuce samples were found to be infected with LMV. The LMV infection rates were determined as 33.3%, 15%, 28%, and 20% in the provinces of Adana, Osmaniye, Hatay, and Kahramanmaraş, respectively. Ten LMV isolates selected based on their geographical origin, and their coat protein gene were amplified using specific primers by RT-PCR, then cloned, and sequenced. As a result of in pairwise comparisons, it was determined that the isolates show identities more than 96% at the nucleotide levels. A BLASTn and BLASTx analysis revealed that isolates share more than 89% nucleotide identity and over 92% amino acid identity with other LMV isolates in GenBank. The genetic diversity and population structure of LMV were examined by analysis of the coat protein gene of 45 isolates. As a result of the analyses, thirty-seven haplotypes were identified, and the haplotype diversity and nucleotide diversity (π) were 0.98 and 0.038 respectively. Furthermore, DataMonkey-based analysis indicated that the genome of the LMV population is being driven by negative selection as the average dN/dS ratio of the LMV genome remained <1 i.e., dN/dS= 0.13.

Keywords: LMV, RT-PCR, genetic diversity

KILIF PROTEİN GEN BÖLGESİNE GÖRE MARUL MOZAİK VİRÜSÜNÜN GENETİK ÇEŞİTLİLİĞİ VE POPÜLASYON YAPISI

ÖZET

Marul mozaik virüsü *Potyviridae* familyasında olup, *Potyvirus* cinsine aittir. Virüs tohumla ve yaprakbitleriyle (*Myzus persicae* ve *Macrosiphum euphorbiae*) non-persistent olarak taşınmaktadır. Bugüne kadar farklı bölgelerde yapılan çeşitli çalışmalar, marul mozaik virüsünün ülke genelinde yaygın bir patojen olduğunu ve marul üretimini olumsuz etkilediğini bildirilmiştir. Bu çalışmada, Türkiye'nin Doğu Akdeniz bölgesinden yeni elde edilen LMV izolatları, küresel LMV izolatlarıyla birlikte analiz edilerek genetik çeşitlilikleri ve popülasyon yapıları hakkında ayrıntılı bilgiler sağlanmıştır. Saha çalışmaları Adana, Osmaniye, Hatay ve Kahramanmaraş illerinde 2024–2025 yıllarında gerçekleştirilmiştir. LMV'nin yaygınlığını araştırmak için, virüs benzeri simptom gösteren marul bitkilerinden 105 yaprak örneği toplanmıştır. RT-PCR analizi sonucunda, 105 marul örneğinin 26'sının LMV ile enfekteli olduğu tespit edilmiştir. LMV enfeksiyon oranı Adana, Osmaniye, Hatay ve Kahramanmaraş illerinde sırasıyla %33.3, 15, 28, 20 olarak belirlenmiştir. Coğrafi orijinlerine göre seçilen 10 LMV izolatın kılıf protein genleri, spesifik primerler kullanılarak RT-PCR ile çoğaltılmış, ardından klonlanmış ve sekanslanmıştır. İkili dizi karşılaştırmaları sonucunda, izolatların kendi aralarındaki nükleotid benzerliğinin %96'dan fazla olduğu belirlenmiştir. BLASTn ve BLASTx analizleri ise, izolatların gen bankasındaki LMV izolatlarıyla %89'un üzerinde nükleotid benzerliği ve %92'nin üzerinde amino asit benzerliği gösterdiğini ortaya koymuştur. LMV'nin genetik çeşitliliği ve popülasyon yapısı, toplam 45 izolatın (bu çalışmadan elde edilen 10 izolat ve gen bankasındaki 35 izolat) kılıf proteini geninin analizi ile incelenmiştir. Analizler sonucunda, 37 haplotip tespit edilmiş olup, haplotip çeşitliliği ve nükleotid çeşitliliği (π) sırasıyla 0.98 ve 0.038 olarak bulunmuştur. Ayrıca, DataMonkey tabanlı analiz, LMV popülasyonunun dN/dS oranı 0.13 olarak belirlenmiş olup, popülasyonun negatif seçilim etkisinde olduğunu göstermiştir.

Anahtar Kelimeler: LMV, RT-PCR, genetik çeşitlilik

EFFECT OF PLANT DENSITY AND SHADING TREATMENTS ON BROAD BEAN (*Vicia faba* L.) YIELD

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ABSTRACT

In this study, the effects of different plant densities and different shading intensities on the yield and yield-related parameters of broad bean (Vicia faba L.) were investigated. The research was carried out in the Field Crops Research and Application area of Dicle University, Faculty of Agriculture, during the 2022 crop growing season. Three broad bean varieties, namely Emiralem, Kuşadası and Sorgun, were used as material in the study. For plant density applications, planting densities of 10 plant/m2 and 20 plant/m2 were used, while shading applications at 0% (control group), 40%, 75% and 95% intensities were used for shading applications. The experiment was carried out according to the split-plot experimental design in randomized blocks with three replications. In the study, plant height, number of pods per plant, pod weight per plant, number of grains per pod, number of grains per plant and grain yield parameters were examined. According to the analysis results, the effects of variety, plant density and shading on all parameters except number of grains per pod were found to be statistically significant. When plant density and shading applications were evaluated in the study, the highest grain yield was determined in Emiralem (181.5 kg/da) variety at a density of 20 plants/m2 and in Sorgun (183.5 kg/da) variety under 40% shading, respectively. While plant densities did not affect grain number per pod and grain number per plant, shade treatments had a significant effect. The highest grain number per pod was obtained from 75% shade treatment in the Sorgun variety, and the highest grain number per plant was obtained from 40% application in the Emiralem variety. Intensive shading conditions increased plant height but caused weak development of plant stems. As a result, it was determined that moderately shaded and unshaded plants had higher performance compared to intensely shaded plants in terms of pod number, grain per plant and grain yield. It is thought that considering shade intensities in future studies will be effective in achieving the desired performance in broad bean cultivation.

Keywords: *Vicia faba*, faba bean, shading, density, yield.

BİTKİ SIKLIĞI VE GÖLGELEME UYGULAMALARININ BAKLA (*Vicia faba L.*) VERİMİNE ETKİSİ

ÖZET

Bu araştırmada, farklı bitki sıklıkları ve farklı yoğunluktaki gölgeleme uygulamalarının bakla (*Vicia faba* L.) bitkisinin verim ve verimle ilişkili parametreleri üzerine etkisi araştırılmıştır. Araştırma 2022 yılı ürün yetiştirme sezonunda Dicle Üniversitesi Ziraat Fakültesi Tarla Bitkileri Araştırma ve Uygulama alanında yürütülmüştür. Çalışmada Emiralem, Kuşadası ve Sorgun olmak üzere üç bakla çeşidi materyal olarak kullanılmıştır. Bitki sıklığı uygulamaları için 10 bitki/m^2 ve 20 bitki/m^2 ekim sıklıkları, gölgeleme uygulamaları için ise %0 (kontrol grubu), %40, %75 ve %95 yoğunluktaki gölgeleme uygulamaları kullanılmıştır. Deneme, tesadüf bloklarında bölünen bölünmüş parseller deneme desenine göre üç tekrarlamalı olarak yürütülmüştür. Araştırmada bitki boyu, bitkide bakla sayısı, bitkide bakla ağırlığı, baklada tane sayısı, bitkide tane sayısı ve tane verimi parametreleri incelenmiştir. Analiz sonuçlarına göre çeşit, bitki sıklığı ve gölgelemenin baklada tane sayısı hariç diğer tüm parametrelere etkisi istatistiki olarak önemli bulunmuştur. Araştırmada bitki sıklığı ve gölgeleme uygulamaları değerlendirildiğinde; en yüksek tane verimi sırasıyla 20 bitki/m^2 sıklığında Emiralem (181,5 kg/da) çeşidinde ve %40 gölgeleme altındaki Sorgun (183,5 kg/da) çeşidinde saptanmıştır. Baklada tane sayısı ve bitkide tane sayısı üzerine bitki sıklıklarının etkisi olmazken, gölge uygulamalarının önemli etkisi olmuştur. En yüksek baklada tane sayısı Sorgun çeşidinde %75 gölge uygulamasından, en yüksek bitkide tane sayısı ise Emiralem çeşidinde %40 uygulamasından elde edilmiştir. Yoğun gölgeleme koşulları bitki boyunu artırmış ancak bitki saplarının zayıf gelişmesine neden olmuştur. Sonuç olarak orta derecede gölgelenen ve gölgelenmeyen bitkilerin, yoğun gölgelenen bitkilere göre bakla sayısı, bitki başına tane ve tane verimi bakımından yüksek performansa sahip olduğu tespit edilmiştir. Gelecekte yapılacak çalışmalarda gölge yoğunluklarının dikkate alınmasının bakla yetiştiriciliğinde istenen performansın yakalanmasında etkili olacağı düşünülmektedir.

Anahtar Kelimeler: *Vicia faba*, faba bean, gölgeleme, sıklık, verim.

INVESTIGATION OF GROWTH AND DEVELOPMENT OF BEAN (*Vicia faba* L.) IN DIFFERENT PLANT DENSITIES AND SHADE TREATMENTS

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ABSTRACT

In this study, the effects of different plant densities and different intensities of shading applications on the growth of broad bean (*Vicia faba* L.) were investigated. The research was carried out in the 2022 crop growing season at the Field Crops Research and Application area of Dicle University Faculty of Agriculture. Three broad bean varieties, Emiralem, Kuşadası and Sorgun, were used as material in the study. For plant density applications, planting densities of 10 plants/m^2 and 20 plants/m^2 were used, and for shading applications, shading applications at 0% (control group), 40%, 75% and 95% intensities were used. The experiment was carried out according to the split-plot design divided in randomized blocks with three replications. In the study, leaf area, leaf area index, leaf assimilation rate, relative leaf area and specific leaf area parameters were examined. The effects of varieties and applications on the parameters examined in the study were found to be significant. The highest values in the Sorgun variety were obtained at 10 plants/m^2 plant density in leaf area during full flowering and pod binding periods. Leaf area index showed the highest value in 10 plant/m^2 (1.53 m^2) and 20 plant/m^2 (1.25 m^2) plant densities and 75% shade treatments (2.98 m2) in samples taken on the 60th day. Leaf assimilation rate showed a stable course from the 32nd day to the 60th day for 10 plant/m^2 and 20 plant/m^2 plant densities, but showed a negative decreasing course after the 60th day with 10 plant/m^2 plant density. Leaf area ratio gave a higher value in the 75% shade treatment (37.05 cm/d) compared to the open field and other shade treatments in samples taken on the 67th day. Relative leaf area showed a regular decreasing course in the two plant densities and shade treatments and decreased as plant age progressed. Specific leaf area varied between 180.0 cm^2 g^{-1} and 155.0 cm^2 g^{-1}, and specific leaf area decreased as the number of days progressed regardless of plant densities. In addition, all shade treatments showed a decrease in specific leaf area. As a result, considering that open field conditions will reveal some stress factors in the plant, it is inevitable that shade treatments will be effective in plant growth.

Keywords: Faba bean, leaf area, specific leaf area, relative leaf area, leaf area ratio.

FARKLI BİTKİ SIKLIKLARI VE GÖLGE UYGULAMALARINDA BAKLANIN (*Vicia faba* L.) BÜYÜME VE GELİŞİMİNİN İNCELENMESİ

ÖZET

Bu araştırmada, farklı bitki sıklıkları ve farklı yoğunluktaki gölgeleme uygulamalarının bakla (*Vicia faba* L.) bitkisinin büyümesine etkisi araştırılmıştır. Araştırma 2022 yılı ürün yetiştirme sezonunda Dicle Üniversitesi Ziraat Fakültesi Tarla Bitkileri Araştırma ve Uygulama alanında yürütülmüştür. Çalışmada Emiralem, Kuşadası ve Sorgun olmak üzere üç bakla çeşidi materyal olarak kullanılmıştır. Bitki sıklığı uygulamaları için 10 bitki/m^2 ve 20 bitki/m^2 ekim sıklıkları, gölgeleme uygulamaları için ise %0 (kontrol grubu), %40, %75 ve %95 yoğunluktaki gölgeleme uygulamaları kullanılmıştır. Deneme, tesadüf bloklarında bölünen bölünmüş parseller deneme desenine göre üç tekrarlamalı olarak yürütülmüştür. Araştırmada yaprak alanı, yaprak alan indeksi, yaprak asimilasyon oranı, nispi yaprak alanı ve spesifik yaprak alanı parametreleri incelenmiştir. Araştırmada incelenen parametreler üzerine çeşit ve uygulamaların etkisi önemli bulunmuştur. Yaprak alanı 10 bitki/m^2 bitki sıkılığında tam çiçeklenme ve bakla bağlama dönemlerinde en yüksek değerleri Sorgun çeşidinde vermiştir. Yaprak alan indeksi 60. Günde alınan örneklerde 10 bitki/m^2 (1.53 m^2) ve 20 bitki/m^2 (1.25 m^2) bitki sıklıkları ve %75 gölge uygulamalarında (2,98 m^2) en yüksek değeri göstermiştir. Yaprak asimilasyon oranı 10 bitki/m^2 ve 20 bitki/m^2 bitki sıklıkları için 32. günden 60. güne kadar stabil bir seyir göstermiş, ancak 10 bitki/m^2 bitki sıklığı 60. günden sonra negatif yönde azalan bir seyir göstermiştir. Yaprak alanı oranı 67. günde alınan örneklerde %75 gölge uygulaması (37,05 cm/g) açık alan ve diğer gölge uygulamalarına oranla yüksek değer vermiştir. Nispi yaprak alanı iki bitki sıklığında ve gölge uygulamalarında düzenli bir azalma seyri göstermiş ve bitki yaşı ilerledikçe azalmıştır. Spesifik yaprak alanı 180,0 cm^2 g^{-1} ile 155,0 cm^2 g^{-1} arasında değişmiş, bitki sıklıklarına bağlı olmaksızın gün sayısı ilerledikçe spesifik yaprak alanı azalmıştır. Ayrıca tüm gölge uygulamalarında da spesifik yaprak alanı azalış göstermiştir. Sonuç olarak, açık saha koşullarının bitkide bazı stres faktörlerini ortaya çıkaracağı göz önünde bulundurulduğunda gölge uygulamalarının bitki büyümesinde etkili olması kaçınılmazdır.

Anahtar Kelimeler: Faba bean, yaprak alanı, spesifik yaprak alanı, nispi yaprak alanı, yaprak alan oranı.

STUDY OF TURKISH SUGAR INDUSTRY AND SUGAR POLICIES BETWEEN 1923-1956

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ABSTRACT

Sugar beet is a versatile product with possibilities and uses that go far beyond sweetening products. When harvested under the right conditions and at the right time, sugar beets consist of 18-20% sugar, 75% water and the rest proteins, polysaccharides, minerals and fibers. Uses of sugar beet: as part of a balanced diet in many varieties, in the production of animal feed, in the use of its water for production purposes, in the use of beet leaves left in the field after harvesting as green manure, in the use of molasses for the yeast industry and alcohol, in the production of bioethanol as an alternative to fossil fuels, in the production of biomethane for injection into the general gas grid, in the production of bioplastics for sustainability, in the use of carbonated lime in production as fertilizer. Among the resolutions of the Economic Congress, which was held in Izmir between February 17 and March 4, 1923 and attended by people from various sectors, to promote the establishment of sugar factories in our country was the need to "grow beets in our country, establish sugar factories and expand the method of rotation in agriculture and thus improve and increase our livestock and grain." In 1951, the government aimed to expand the Turkish sugar industry. With the sugar industry expansion program prepared in this direction, 11 new sugar factories were opened between 1953 and 1956, making 1956 a historic year for the Turkish sugar industry.

Keywords: Sugar Policies, Sugar Factories, Food Safety.

1923-1956 YILLARI ARASI TÜRKIYE ŞEKER SANAYII VE ŞEKER POLİTİKALARI İNCELEMESİ

ÖZET

Şeker pancarı, ürünlerin tatlandırılmasının çok ötesine geçen yeteneklere ve kullanım alanlarına sahip çok yönlü bir üründür. Şeker pancarı, uygun koşullarda ve doğru zamanda hasat edildiğinde, %18-20 oranında şeker, %75 oranında su ve kalan kısmında da proteinler, polisakkaritler, mineraller ve liflerden oluşmaktadır. Şeker pancarının kullanım alanları; dengeli beslenmenin bir parçası olarak birçok çeşitte, hayvan yemi üretiminde, içeriğindeki suyun üretim amaçlı kullanımında, hasattan sonra tarlada kalan pancar yapraklarının yeşil gübre olarak kullanımı, melasın maya endüstrisi ve alkol için kullanımı, fosil yakıtlara alternatif olarak biyoetanol üretimi, genel gaz şebekesine tedarik için biyometan üretimi, sürdürülebilirlik için biyoplastik üretimi, üretimde kullanılan karbonatlı kirecin gübre olarak kullanılmasıdır. Ülkemizde şeker fabrikalarının kuruluşunun teşvik edilmesi ile ilgili olarak 17 Şubat – 4 Mart 1923 tarihleri arasında İzmir'de düzenlenen ve farklı sektörlerden kişilerin katılımıyla gerçekleştirilen İktisat Kongresi'nin kararları arasında yer alan "Memleketimizde pancar yetiştirilerek, şeker fabrikaları tesis ve ziraatta münavebe usulünün tevsii ve bu suretle hayvanatımızın ve hububatımızın ıslah ve çoğaltılması" zaruriyeti ortaya konmuştur. 1951 yılında hükümet tarafından Türkiye şeker sanayinin genişletilmesi amaçlanmış ve bu doğrultuda hazırlanan Şeker Sanayi Tevsi Programı ile 1953 ve 1956 yılları arasında açılan 11 yeni şeker fabrikası ile 1956 yılı Türkiye şeker sanayisi için tarihi bir yıl olmuştur.

Anahtar Kelimeler: Şeker Politikaları, Şeker Fabrikaları, Gıda Güvenliği.

COMPARAITIVE USABILITY OF DIFFRETENT IMAGE PROCESSING TECHNIQUES AND YIELD COMPONENTS IN WHEAT (*T. AVESTIUM L.*) BREEDING

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ABSTRACT

The aim of this study is to analyse different image processing techniques and yield components comparatively to reveal their usability in bread wheat (*T. avestium.* L) breeding and to determine how different image processing techniques and agronomic elements affect grain yield.

In the study, yield elements such as plant height, number of grains per spike, 1000 grain weight, grain yield were discussed by using image processing techniques such as NDVI (provides information about plant biomass and chlorophyll), CM1000 (chlorophyll meter) and thermal camera (measures plant canopy temperature), and their effects on varieties and the superiority of varieties over each other in terms of these measurements and the effect of these measurements on grain yield were investigated.

As a result of the research, the highest grain yields of bread wheat genotypes were found in lines 11 and 4, 694.75 kg/da and 583 kg/da, respectively, and these lines were determined to be the lines that gave the best results in terms of both yield and image processing elements. These prominent lines also showed good performance in terms of protein, hectolitre and sedimentation. According to the results obtained in the study, a negative and significant relationship was found between image processing elements and yield and grain yield and quality elements such as protein and sedimentation. A significant and positive relationship was found between hectoliter and yield with NDVI, CM1000, thermal camera measurements.

The results obtained in this study will contribute to the wheat breeding program carried out by transferring them to practice.

As a result of this study, lines numbered 11 and 4 stood out as the lines with the highest performance and were determined as lines with high hopes for registration. In addition, the use of image processing techniques such as NDVI, CM1000, thermal camera and quality elements

such as 1000 grain weight, hectoliter weight, protein BM will increase the success of breeding studies.

Keywords: Bread wheat, image processing techniques, yield and quality elements, breeding, grain yield

FARKLI GÖRÜNTÜ İŞLEME TEKNİKLERİ VE VERİM UNSURLARININ BUĞDAY (*T. AVESTIUM L.*) ISLAHINDA KARŞILAŞTIRMALI OLARAK KULLANILABİLİRLİĞİ

ÖZET

Bu çalışmanın amacı farklı görüntü işleme tekniklerini ve verim unsurlarını analiz ederek karşılaştırmalı olarak ekmeklik buğday (*T. avestium.* L) ıslahında kullanılabilirliğini ortaya koymak ve farklı görüntü işleme teknikleriyle agronomik unsurların tane verimi üzerine nasıl etki ettiğini belirlemektir.

Çalışmada NDVI (bitki biomass'i ve klorofil hakkında bilgi sağlar), CM1000 (klorofil ölçer) ve termal kamera (bitki örtü sıcaklığını ölçer) gibi görüntü işleme teknikleri kullanılarak bitki boyu, başakta tane sayısı, 1000 tane ağırlığı, tane verimi gibi verim unsurları ele alınmış olup, bunların çeşitler üzerindeki etkileri ve bu ölçümler açısından çeşitlerin birbirine olan üstünlüğü ve bu ölçümlerin tane verimine etkisi araştırılmıştır.

Araştırma sonucunda ekmeklik buğday genotiplerinin tane verimleri bakımından en yüksek tane verimi sırasıyla 11 ve 4 numaralı hatlar olup 694,75kg/da ve 583kg/da bulunmuş ve bu hatlar gerek verim gerekse görüntü işleme unsurları açısından en iyi sonuçları veren hatlar olarak belirlenmiştir. Öne çıkan bu hatlar protein, hektolitre ve sedimentasyon yönünden de iyi bir performans göstermiştir.

Çalışmada elde edilen sonuçlara göre görüntü işleme unsurlarıyla verim ve tane verimi ile protein, sedimentasyon gibi kalite unsurları arasında negatif ve önemli ilişki bulunmuştur. NDVI, CM1000, termal kamera ölçümleriyle hektolitre ile verim arasında önemli ve pozitif ilişki tespit edilmiştir.

Bu çalışmada elde edilen sonuçların uygulama aktarılması ile yürütülen buğday ıslah programına katkı sağlayacaktır.

Bu çalışmanın sonucunda 11 ve 4 numaralı hatlar en fazla performansa sahip hatlar olarak öne çıkmış ve tescil konusunda ümit var hatlar olarak belirlenmiştir. Ayrıca NDVI, CM1000, termal kamera gibi görüntü işleme teknikleri 1000 tane ağırlığı, hektolitre ağırlığı, protein BM gibi unsurların kullanımı gibi kalite unsurlarının kullanımı ıslah çalışmalarının başarısını arttıracaktır.

Anahtar Kelimeler: Ekmeklik buğday, görüntü işleme teknikleri, verim ve kalite unsurları, ıslah, tane verimi

MOLECULAR DOCKING ANALYSIS OF BIOACTIVE COMPOUNDS FROM ASPARAGUS OFFICINALIS REVEALS POTENTIAL ANTIDIABETIC INTERACTIONS WITH HUMAN PROTEINS

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ABSTRACT

The The present study investigates the antidiabetic potential of phytochemicals derived from Asparagus officinalis through molecular docking analyses using AutoDock Vina. The objective was to evaluate the binding affinity and interaction dynamics of major bioactive compounds—saponins, quercetin, and kaempferol with key human proteins implicated in diabetes pathophysiology, including β-glucosidase, NR4A1 nuclear receptor, and GLUT4. Compounds were selected based on their prevalence in A. officinalis and known or suspected antidiabetic mechanisms. Protein structures were retrieved from the Protein Data Bank (PDB codes: 1OGS for β-glucosidase, 2QW4 for NR4A1, 7WSM for GLUT4), and ligand structures were sourced from PubChem[1]. Docking simulations were conducted with a focus on binding energy, root-mean-square deviation (RMSD), and ligand-protein conformational stability. Among the compounds tested, saponins demonstrated the strongest binding affinity to β-glucosidase with a ΔG of −13.2 kcal/mol, suggesting potent inhibitory activity that may delay carbohydrate digestion and absorption . Quercetin and kaempferol exhibited moderate to strong affinities with their respective targets, reflecting mechanisms such as GLUT4 activation, inhibition of intestinal glucose absorption, and enhanced insulin sensitivity[2].

inhibits α-glucosidase and DPP-IV; kaempferol activates AMPK and enhances GLUT4-mediated uptake. The observed binding affinities and predicted interactions reinforce the therapeutic relevance of A. officinalis phytochemicals in diabetes management. This study lays the groundwork for future in vivo studies and clinical trials. The findings underscore the promise of Asparagus officinalis as a source of natural compounds for the development of plant-based antidiabetic therapeutics.

Compound	Target Protein	PDB Code	Best Affinity (kcal/mol)	Key Effect
Saponins	β-glucosidase	1OGS	−13.2	Enhanced β-cell function
Quercetin	NR4A1 ligand domain	2QW4	−9.7	Insulin secretion & glucose uptake
Kaempferol	GLUT4 transporter	7WSM	−8.9	Promotes GLUT4 translocation & uptake

Table 1: Binding Affinities and Targets

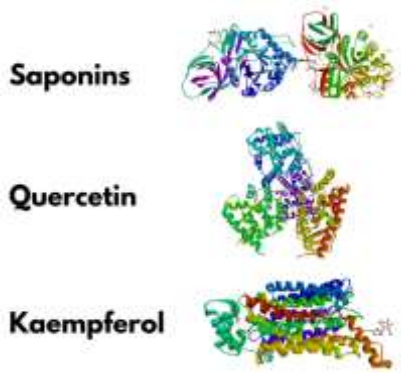

Figure 1 : Docked Complexes of Key Antidiabetic Compounds

Keywords: Asparagus officinalis, Molecular Docking, Antidiabetic Activity, Phytochemicals, Protein–Ligand Interactions

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ASSESSMENT OF TRACE ELEMENT POLLUTION AND POTENTIAL HEALTH HAZARDS IN AGRICULTURAL SOILS OF THE BENI MOUSSA SUB-PERIMETER, MOROCCO

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ABSTRACT

The accumulation of trace metals in agricultural soils represents a serious environmental and public health concern, particularly in intensively cultivated areas. This study examines the extent of soil contamination, its spatial distribution, and the associated ecological and human health risks in the irrigated agricultural area of Beni Moussa, Morocco. A total of 67 surface soil samples were collected and analyzed for key physicochemical parameters, as well as for concentrations of cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), chromium (Cr), nickel (Ni), and arsenic (As), using ICP-AES and ICP-MS techniques.

To assess the severity of contamination, several indices were applied, including the geo-accumulation index (Igeo), enrichment factor (EF), contamination factor (CF), and pollution load index (PLI). The results show that 94.02% of the samples exhibit PLI values greater than 1, indicating substantial metal accumulation—particularly for Ni and As, which displayed the highest enrichment levels.

Ecological risk assessment (RI) suggests low to moderate potential risks, with contamination hotspots identified near Afourer, Sidi Jaber, and Ouled Ayyad. Human health risk analysis indicates that ingestion is the primary exposure pathway, with children being particularly vulnerable. While most elements present low non-carcinogenic risks (HI < 1), nickel may pose a concern for adults. Moreover, Cr, As, and Ni have potential carcinogenic effects, particularly in children.

These findings underscore the urgent need to implement sustainable soil management practices, regulate agrochemical inputs and wastewater reuse, and establish long-term monitoring programs. Further research is recommended to develop effective mitigation strategies aimed at preserving soil quality and minimizing exposure risks.

Keywords : Trace metals, Soil pollution, Ecological risk, Human health impact, Irrigated land, Morocco

EVALUATION ON THE THERAPEUTIC EFFICACY OF GREEN SYNTHESISED COPPER OXIDE NANOPARTICLES FROM *GRACILARIA Sp*

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ABSTRACT

The increasing interest in nanotechnology for cancer therapy has led to the exploration of green synthesis methods for producing biocompatible copper oxide nanoparticles. This study evaluates the therapeutic efficacy of copper oxide nanoparticles synthesized using an eco-friendly approach from *Gracilaria Sp*, a marine red algae. The synthesis of copper oxide nanoparticles is characterize by UV-Vis spectroscopy, Dynamic light scattering (DLS) Zeta potential, X-ray diffraction (XRD), scanning electron microscopy (SEM), and Fourier-transform infrared (FTIR) analysis. Further, proceeded towards anti-oxidant & anti- cancer activities. This study suggests that copper oxide nanoparticles synthesized from *Gracilaria Sp* exhibit strong potential as an effective therapeutic agent for cancer treatment, offering a sustainable and green alternative to conventional nanoparticle synthesis methods.

Keywords: Green synthesis, copper oxide nanoparticles, *Gracilaria Sp* cancer therapy

PRECISION AGRICULTURE: A POSSIBLE BEDROCK ON WHICH NIGERIA PAST GLORY IN CASHEW PRODUCTION CAN BE REBUILT/RESTORED

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ABSTRACT

Cashew (*Anarcardium occidentales*) is currently one of agricultural commodity of interest in the country due to its contribution to the nation's gross domestic product (GDP) and its high foreign exchange gain. Within the Nigeria states, cashew trees are cultivated in almost all of the six geo-political zones. Currently, its cultivation has spread to about 27 states of the country accounting for more than 60% local production. In the past, Nigeria's annual raw cashew nut yield was reported to surpass that of Cote d'Ivoire (the current best producer) that happens to be her close competitor as at the dawn of the millennium especially during the first decade of the millennia (within the years 2000-2010) due to a lot of factors. However, After the year 2010, especially during the following decade i.e within the years (2011-2020), due to fewer land area, lack of governmental organizations' involvement in cashew value chain, gap in government policies, lack of support and aid from government at all levels, difficulty in land acquisition and as well as pests and diseases, Cote D'Ivoire soon surpassed Nigeria in nut production in due course as a result of their ability to act on the weakness leading to the downfall of Nigeria in cashew production. For Nigeria to restore her past glory precision agriculture could be the possible bedrock of restoration. Precision agriculture is a system of agriculture that involves the adoption of advanced technology such as drones, GPS, blockchain, AI, satellite imaging, sensors, IoTs, e.t.c to collect data on weather patterns, soil conditions and crop health, while such data can be used by various stakeholders to make informed decision that will increase the yield of cashew nut in the country. Precision agriculture could help in early detection of pests and diseases outbreaks, reduce waste, help farmers and other stakeholders make informed decisions on crop management e.t.c. However, its adoption will require careful plannings, trainings, and huge investments (by government and NGOs) in order to make it accessible, acceptable and avoidable for smallholding farmers.

Keywords: Cashew nuts, Competitor, Pests and diseases, Yield, Production

OCCURRENCE AND CHARACTERIZATION OF ANTIBIOTIC-RESISTANT *Salmonella* ISOLATES FROM FRESH PRODUCE IN AGRICULTURAL ENVIRONMENTS

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ABSTRACT

Introduction and Purpose: *Salmonella* contamination of fresh produce, including watermelon, poses a significant public health concern. This study aimed to investigate the presence and characteristics of *Salmonella* isolates in watermelon, soil and water samples obtained from agricultural sources.

Materials and Methods: A total of 1450 watermelon samples were collected from different farms in Bejaia and subjected to microbiological analysis. *Salmonella* spp. were isolated using standard culture methods and confirmed by molecular techniques. The isolates were further characterized for antimicrobial susceptibility, serotype determination, and genetic relatedness using whole genome sequencing.

Results: The results revealed the presence of *Salmonella* in 19% of the total samples, indicating a potential risk of foodborne illness associated with watermelon consumption. Antimicrobial susceptibility testing demonstrated varying resistance patterns among the isolates. Serotyping revealed diverse *Salmonella* serotypes, suggesting multiple contamination sources. Molecular analysis indicated genetic diversity among the isolates, with some strains showing close relatedness to clinical isolates.

Discussion and Conclusion: These findings underscore the importance of implementing stringent food safety measures throughout the vegetables production and distribution chain to mitigate the risk of *Salmonella* contamination and subsequent foodborne outbreaks.

Keywords: *Salmonella*, antimicrobial resistance, watermelon, agricultural environments, genotypic characterization, food safety

DIFFERENT PROTEIN HYDROLYSATES DERIVED FROM ANIMAL AND PLANT SOURCES: AN OVERVIEW ON THEIR NUTRACEUTICAL PROPERTIES

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ABSTRACT

Protein, classified as a macronutrient and the only source of amino acids, can have a wide range of benefits by breaking down into its components, i.e., peptides and amino-acids, which are called hydrolysates. These bioactive compounds are inactive within the protein structure but can be released by enzymatic hydrolysis, fermentation, and gastrointestinal digestion.

Different protease enzymes are used to break down the intramolecular bonds of proteins . After the interaction of proteins and enzymes, the outcome contains a complex mixture of peptides consist of different amino acid sequences, composition, length with different chemical and biological properties that can pose various types of bioactivities in the body and food systems. The hydrolysis of proteins leads to increased bioactivities because the functional peptide sequences are released, and large, low-bioavailable molecules (proteins) change into smaller compounds (peptides) with lower weight, improved functionality, and greater bioavailability, with added value to the initial compound.

Various protein sources, including wheat, quinoa, fish and fish by-products, insects, soybean, milk, egg, etc., are explored for their ability to produce bioactive peptides through enzymatic hydrolysis. These peptides exhibit numerous biological activities, such as anti-hypertensive, anticancer, antioxidant, anti-obesity, cholesterol-lowering, hypoglycemic, anti-inflammatory, and immunomodulatory effects. Furthermore, these peptides contribute in functional properties such as improved solubility, foaming capacity, and emulsification which are valuable in food technology and development of functional foods.

This review will discusses the potential of diverse protein sources, from traditional animal proteins to innovative plant-based proteins, in showing nutraceutical benefits and promoting

health and food applications, with a focus on enzymatic hydrolysis as a key process for enhancing bioavailability and functionality.

Keywords: Biopeptides, Hydrolysates, Nutraceutical, Protein

BIOLOGICAL ACTIVITY & BIOACTIVE MOLECULES OF ESSENTIAL OIL:*Origanum vulgare, Rosmarinus officinalis* FROM ALGERIAN REGION

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ABSTRACT

Plants were always a part of the everyday life of the man, because he uses it to look after itself for a long time. Medicinal plants were used during centuries as remedies for the human diseases because they contain components of therapeutic value. Oil is located in various parts of plants (flowers, sheets, barks, wood, fruits, seeds … etc.), for the obtaining of these gasolines there are several variable techniques.

Essential Oil content bioactive molecules, exhibiting a multiple biological activities. Within the framework of the valuation of the Algerian botanical species, and considering the therapeutic virtues which represents Lamiacees, we were interested in the extraction of *Origanum vulgare*L essential oil, coming from the region of Blida, Medea, Khemis Miliana, M'sila in Algeria.

A study Physico-chemical, biological : the test of antibacterial activity, so antioxydant activity and the molecular identification of the compositions by the technique of GC-MS on essential oil *Rosmarinus officinalis*. The yield obtained from leaves. This yield is in accordance with the standards recommended international. The composition of the essential oil was analyzed by chromatography in gas phase GC-MS. The obtained results show that the essential oil of Rosemary has a big antioxidizing activity. The study of the antibacterial power by the method of distribution of records (disks), essential oil showed an activity moderated against *E coli* , Staphylococcus and Pseudomonas, Klebsiella. In food systems, antioxidants are useful in retarding lipid oxidation and protect during storage.

Keywords: Bioactive Molecules, *Rosmarinus officinalis*, GC-MS, Antioxidant activity, Antibacterial activity

ECONIMIC ANALYSIS OF OIL PALM FRUITS MARKETING AMONG WOMEN IN EDO STATE, NIGERIA

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ABSTRACT

Oil palm and its products is a multi-adaptable tree crop with almost all parts having economic value and useful for everyday livelihood. The fruit leads vegetable oils produced globally, accounting for one-quarter of global consumption and approximately 60% of international trade in vegetable oils. The participation of women in oil palm production cannot be underemphasized couple with the profitability for economic value. The information were elicited carefully from 155 respondents using structural interview schedule and analysed with descriptive statistics. The Gross margin profits is ₦257,400, therefore the gross ratio is 0.50 which signifies that for every 1 naira invested, a profit of 50 k is profited. The regression revealed that there was significant difference between Age (t= 0.158), farm size (0.16) at 5%, also Experience (0.199) at 10 % and their profits from oil palm fruits production in the study area. Therefore, Government and private organizations are encouraged to invest in capacity building of oil palm fruits production for optimum productivity.

Keywords ; Economic, fruits, women

COMPARATIVE INVESTIGATION OF VOLATILE OILS EXTRACTED FROM TWO CUPRESSUS SPECIES

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ABSTRACT

The present wok is a comparative study between two volatil oils extracted from two cupressus species which consisted on Arizona cypress and common cypress that grown in the north of Algeria. The oils were respectively obtained by submitting each plant material to hydrodistillation method. The volatile oils were characterized through their aspects, colours, odours, and some of their physico-chemical properties (pH, miscibility in ethanol, density, refractive index, Fourier-transform infrared spectroscopic analysis). The results show that both Arizona and common cypress volatile oils are limpid and mobile liquids which have characteristic odours. Arizona cypress extract is pale yellow however common cypress oil is pale yellow to transparent. Arizona cypress oil is less acidic and more miscible in ethanol than common cypress extract. Also, Arizona cypress oil has slightly higher density and refractive index in comparison to common cypress oil. Attenuated total reflectance-Fourier transform infrared spectroscopy identified the presence of alcohols, aldehydes, ketones, alkanes, esters and aromatics in the chemical composition of Arizona cypress oil. It is also showed the presence alkanes, alkenes, alcohols, esters, ethers, esters, ketones and aromatics in common cypress extract. These findings indicate that the two local cupressus volatil oils have good qualities and similarities in their properties. They constitute interesting natural products that may use in food, pharmaceuticals and cosmetics.

Keywords: volatile oil, cupressus species, comparative study, organoleptic properties, physico-chemical characteristics.

ASSESSMENT OF CLIMATE CHANGE EFFECTS AND ADAPTATION PRACTICES AMONG CEREALS CROP FARMERS IN BWARI AREA COUNCIL FCT, ABUJA, NIGERIA

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ABSTRACT

The study assessed farmers' awareness of climate change and adaptation practices among cereals crop farmers in Bwari Area Council F.C.T. Abuja. Five (5) wards were purposively selected using multistage sampling procedures. Eighty (80) cereals crop farmers were selected for the study and the data obtained was analyzed using descriptive statistics. The result revealed that farmers in the study area were young and active with mean age of 33 years. 91.25% of the farmers were male and married. The cereals crop farmers in the study area were educated. The mean household size was 9 persons; the mean farm size was 1ha and 48.75% of the land acquired by inheritance. The mean annual income was ₦10,500: 00k. The study revealed further that the farmers were aware of climate change with 62.5% awareness. The adaptation practices adopted by the farmers were early planting 28%, early maturing crop 27% and using resistance varieties 11%. The causes of climate change according to this study were: deforestation (35.00%), human activities (33.75%) and overgrazing (23.75%). The constraints to adaptation practices includes: lack of capital (36.25%), lack of adequate information (12.50%), lack of extension agents (15.0%) and lack of access to adaptation practices (31.25%). Farmers should endeavor to form cooperative societies to access credit facilities, Government should organize training and workshops on climate change adaptation practices and Government should control the removal of trees and provide rangeland for livestock were offered as recommendations.

Keywords: Assessment, Climate Change, Effects, Adaptation, Cereals

ANALYSIS OF ORGANIC MOLECULES AND PHYSICOCHEMICAL PARAMETERS AS INDICATORS OF AUTHENTICITY AND QUALITY OF ACACIA HONEY SAMPLES

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ABSTRACT

Acacia honey is a unifloral honey produced by bees fed on acacia flowers. It is transparent to light yellow with a mild taste and floral fragrance.

The high-quality acacia honey is assessed based on both physical-chemical parameters.

Measuring honey quality standards is important to confirm its authenticity, ensure safety, and maintain its nutritional value, which helps protect consumer health and support the reputation of producers.

The aim of this paper is to compare changes in the quality analysis based on properties such as the determination of proline, the determination of flavonoids and specific rotation through a polarimeter, in three samples of acacia honey, from the region of Kosovo, North Macedonia and Croatia.

Proline is an indicator of honey quality and adulteration when it falls below a certain value. For its determination, we have prepared honey solutions, and nynhidrin solution. The other necessary reagents are HCOOH 98% and 2-propanol. To perform the measurements, we used the UV-Vis spectrophotometer, and the spectrophotometric measurements were taken at a wavelength of 510nm.

For the determination of flavonoids, we have prepared honey solutions, and 2% solution of $AlCl_3$. Measurements were performed using a UV-Vis spectrophotometer at 430nm.

For the dermination of specific rotation throught polarimeter, we have prepared honey solutions, then we added solutions Carrez I and Carrez II. We filtered it and used the filtrate.

Our results align with standard norms, demonstrating good quality and reliability of the honey.

Keywords: acacia honey, proline, flavonoids, specific rotation, spectrophotometer, polarimeter honey quality.

EVALUATION OF FRUIT JUICE QUALITY THROUGH CHEMICAL AND PHYSICAL ANALYSIS

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ABSTRACT

Fruit juices are rich in vitamins, minerals, and antioxidants, and they play an important role in maintaining health. They are known for their high content of healthy substances that help strengthen the immune system and improve metabolism. The preparation of fruit juices starts with selecting pre-washed fruits, which are then squeezed to extract the juice.

This study aims to evaluate the quality and chemical composition of juices. The study focuses on analyzing four fruit juices, specifically multivitamin juice and apple juice, purchased from different regions of Kosovo. Various laboratory methods were used in the conducted analyses to identify the chemical composition of the juices. The use of UV-VIS spectrophotometry enabled the measurement of vitamin A content, while thin-layer chromatography (TLC) was used to identify preservatives. Additionally, specific analyses were conducted to detect the presence of saponins using appropriate laboratory methods. Moreover, conductivity measurements were performed to assess the presence of electrolytes and ash content, as well as the analysis of mineral salts. These analyses allow us to identify the nutritional quality of juices and assess their safety. The results showed that the juices contained important health components, but some also contained preservatives that could affect the quality and safety of the product. This study has contributed to expanding knowledge about the fruit juice industry in Kosovo.

Keywords: fruit juices, vitamin A, preservatives, UV-VIS spectrophotometry, thin-layer Chromatography (TLC), health, laboratory analysis.

STUDY OF THE CHEMICAL COMPOSITION OF *Fumaria parviflora* FROM THREE REGIONS OF MOROCCO

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ABSTRACT

Fumaria parviflora, known vernacularly in Morocco as "nar lbarda", is a green, herbaceous, annual plant that grows in wheat fields, plains and low hills. An ubiquitous species, it can be found in Europe, Africa, America, Australia and, most importantly, India, Pakistan and Iran. In traditional medicine, it has been used to cure numerous illnesses and infections such as diabetes, digestive disorders, eczema, burns, fever, flu, headaches and toothaches, intoxication, hepatobiliary dysfunction, blood disorders, urinary diseases and male infertility. Our aim is to carry out a comparative study of the chemical composition of *F. parviflora* harvested in three different Moroccan regions (Casablanca, El Jadida and Khouribga).

Moisture, lipids, carbohydrates, proteins, minerals and pigments were determined by standard methods. Secondary metabolites were assessed by screening.

Our results show that the macronutrients and secondary metabolites of the plant vary according to the harvesting region. The F. parviflora sample from Casablanca had the highest fat content compared with those from El Jadida and Khouribga (6.49 ± 0.135% VS 4.1 ± 0.133% and 4.65 ± 0.144% respectively), while all three samples had equivalent protein and carbohydrate values. Polyphenols, saponins and tannins were detected qualitatively in F. parviflora samples from all three regions, while flavonoids were only detected in those from El Jadida and Khouribga. We can therefore conclude that environmental conditions in each region probably influence the chemical composition of *F. parviflora*.

Key words: *Fumaria parviflora, comparative study, chemical composition, screening.*

AWARENESS AND UNDERSTANDING OF ORGANIC FOOD AMONG THE MOROCCAN POPULATION

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ABSTRACT

In recent decades, shifts in food production and consumption patterns have emerged, impacting significantly the food system and having repercussions on both the environment and health. These changes are largely driven by an increased food production to meet the needs for food security and global population growth. This surge in production has, in turn, influenced people's eating habits, enhancing food availability and improving food security. All these changes are also causing negative environmental consequences such as the depletion of natural resources, deforestation, biodiversity loss, pollution, climate change, water scarcity, and air quality degradation, among others. At the same time, unsustainable food consumption exacerbates these imbalances in terms of both quantity and quality, intensifying the effects during and after the COVID-19 health crisis on human health and environmental sustainability. In this context, organic agriculture emerges as a promising alternative to promote sustainable food consumption. This paper aims to assess Moroccans' perception of organic agriculture through an online questionnaire, to which 423 participants responded.The results reports that 81.7% of survey respondents consumed organic foods for reasons mainly related to their benefits on health environment, 85.5% claimed the high cost as reason for not eating them. The study revealed also a confusion of organic products with local products in a large part of the participants (66.3%). In conclusion, Moroccan population perceives organic food superior to conventionally grown products in terms of quality or taste. However, the consumption of organic products is still modest or even low among the population. The data from this study indicate that although the development of organic agriculture is still insufficient in Morocco, it appears to be a promising approach for sustainable food consumption.

Keywords: Organic food; local food; consumption; perception.

SIMULATION AND EVALUATION OF THE IMPACT OF REMOVING CARBON DIOXIDE AND WATER FROM THE TOP GAS FUEL STREAM EXITING THE TOP GAS SCRUBBER IN MIDREX UNIT OF THE GOHAR ZAMIN MINING AND INDUSTRIAL COMPANY

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ABSTRACT

In the Midrex unit of the Gohar Zamin Mining and Industrial Company, located in Kerman Province, the top gas fuel stream, which is produced by the increased gas volume from the cracking of natural gas in the reformer tubes, plays a significant role in the operation of the reformer unit. This gas is enriched with natural gas every hour to meet the required thermal value for the reformer unit to reach optimal temperatures. However, due to the high carbon dioxide and water content in the top gas fuel stream, using it in the reformer burners causes several operational issues, including reduced heating value and process efficiency, corrosion of pipeline, increased natural gas consumption, and an increased carbon footprint.

This research focuses on evaluating the impact of removing carbon dioxide and water from the top gas fuel stream on the reformer unit's energy efficiency and overall process optimization. By eliminating carbon dioxide and water content, the combustion energy of the top gas fuel stream significantly increases, reducing the amount of natural gas required for the reformer's operation and improving process efficiency. Additionally, in this paper Aspen HYSYS software was utilized to evaluate and simulate the heat duty transferred to the reformer across six scenarios with varying conditions for the top gas fuel stream. These scenarios include the removal of water and carbon dioxide from the top gas fuel stream, as well as changes in the amount of natural gas added to the top gas fuel stream.

In this study, the amount of natural gas saved, the reduction in carbon dioxide emissions, the amount of water removed from the top gas fuel stream, and the revenue generated from the sale of carbon dioxide and water removed from the top gas fuel stream have been evaluated and documented. This study also investigates the environmental benefits of removing carbon dioxide, which can be captured and sold for various applications. Additionally, this process

helps reduce the carbon footprint, a critical factor in addressing global warming and complying with future environmental regulations.

Keywords: Top Gas Fuel, Carbon Dioxide, Water, Natural Gas, Midrex Process, Heating Value, Aspen HYSYS, Carbon Footprint

SUBSTITUTION OF BEACH WELL INTAKE TECHNOLOGY FOR OPEN INTAKE TECHNOLOGY AS SEAWATER INTAKE FOR REVERSE OSMOSIS DESALINATION PLANT

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ABSTRACT

In the city of Bandar Abbas, within the Hormozgan Steel Company, reverse osmosis (RO) desalination plant plays a crucial role in supporting industrial water needs. This study focused on improving the energy efficiency and performance of the RO desalination plant through equipment upgrades and system modifications. One key innovation introduced in this study was the use of beach well intake technology, which provide an alternative to conventional open intake technology. Beach well technology draw seawater from beneath the seabed, filtering it naturally through sand and subsurface layers. This modification significantly enhances the quality of the intake water, reducing the risk of membrane fouling caused by pollutants, marine organisms, and sediments commonly encountered in open intakes technology. This research involves assessing the operational performance of the RO plant both before and after the modification. Results indicated significant improvements in energy efficiency, with reductions in operational costs and maintenance requirements. Additionally, the natural filtration provided by the beach well intake technology lowered the need for extensive pre-treatment, resulting in reduced chemical usage and energy consumption. Furthermore, this study highlighted the environmental benefits of this system, including less impact on marine life, improved water quality, and lower visual and acoustic disruptions at the coastline. These findings also support the feasibility of adopting beach well intake technology as a sustainable and cost-effective alternative to traditional open intake technology. This research also aligns with international

environmental standards and agreements, such as the Convention on Biological Diversity (CBD) and the European Union's Water Framework Directive (WFD), emphasizing on the reduction of environmental impacts in desalination plants. Overall, this study demonstrates the potential for beach well technology to optimize desalination plant operations while promoting sustainability and reducing ecological footprints. In this paper, the key indices for the substitution of beach well technology with open water intake technology for the RO desalination plant in Bandar Abbas are provided and documented, including investment volume required, cost reduction, operation duration, internal rate of return (IRR), net present value (NPV), and both normal and adjusted payback periods.

Keywords: Beach Well Technology, Open Intake, Reverse Osmosis Desalination Plant, Seawater Intake Technology, Hormozgan Steel Company.

DIFFERENT PROTEIN HYDROLYSATES DERIVED FROM ANIMAL AND PLANT SOURCES: AN OVERVIEW ON THEIR NUTRACEUTICAL PROPERTIES

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ABSTRACT

Protein, classified as a macronutrient and the only source of amino acids, can have a wide range of benefits by breaking down into its components, i.e., peptides and amino-acids, which are called hydrolysates. These bioactive compounds are inactive within the protein structure but can be released by enzymatic hydrolysis, fermentation, and gastrointestinal digestion.

Different protease enzymes are used to break down the intramolecular bonds of proteins . After the interaction of proteins and enzymes, the outcome contains a complex mixture of peptides consist of different amino acid sequences, composition, length with different chemical and biological properties that can pose various types of bioactivities in the body and food systems. The hydrolysis of proteins leads to increased bioactivities because the functional peptide sequences are released, and large, low-bioavailable molecules (proteins) change into smaller compounds (peptides) with lower weight, improved functionality, and greater bioavailability, with added value to the initial compound.

Various protein sources, including wheat, quinoa, fish and fish by-products, insects, soybean, milk, egg, etc., are explored for their ability to produce bioactive peptides through enzymatic hydrolysis. These peptides exhibit numerous biological activities, such as anti-hypertensive, anticancer, antioxidant, anti-obesity, cholesterol-lowering, hypoglycemic, anti-inflammatory, and immunomodulatory effects. Furthermore, these peptides contribute in functional properties such as improved solubility, foaming capacity, and emulsification which are valuable in food technology and development of functional foods.

This review will discusses the potential of diverse protein sources, from traditional animal proteins to innovative plant-based proteins, in showing nutraceutical benefits and promoting health and food applications, with a focus on enzymatic hydrolysis as a key process for enhancing bioavailability and functionality.

Keywords: Biopeptides, Hydrolysates, Nutraceutical, Protein

PRICE VOLATILITY OF RICE PRODUCTION IN NIGERIA (AN APPRAISAL OF RICE PRODUCTION IN KEBBI STATE)

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ABSTRACT

This study examines rice price volatility in Kebbi State, Nigeria, focusing on WACOT, LABANA, and RAYHAN using data from January 2010 to February 2024. Statistical and econometric methods, including descriptive analysis, unit root tests, and GARCH-type models, are employed to assess volatility dynamics. Descriptive statistics show WACOT has the highest mean price (19,961.8) and standard deviation (12,653.8), indicating the greatest volatility. LABANA follows with a mean of 19,229.9 and standard deviation of 12,199.0, while RAYHAN exhibits the lowest mean (3,733.3) and standard deviation (12,002.7). Skewness and kurtosis suggest WACOT and LABANA have a higher likelihood of extreme price fluctuations. Graphical analysis highlights volatility spikes from late 2023 to early 2024. Correlograms and unit root tests confirm non-stationarity, necessitating first differencing. Post-differencing analysis establishes stationarity with stable mean and variance. GARCH-type models identify FIGARCH (1,d,1) as optimal for WACOT and LABANA, while ARFIMA (1,1,1) is best for RAYHAN. The FIGARCH model for WACOT shows the highest volatility persistence ($\alpha + \beta = 0.996$) and moderate negative asymmetry ($\Upsilon = -0.252$). LABANA's FIGARCH model exhibits strong asymmetry ($\Upsilon = -0.607$) and persistent volatility ($\alpha + \beta = 0.951$). RAYHAN's ARFIMA model reveals long memory effects ($\alpha + \beta = 0.917$) and moderate asymmetry ($\Upsilon = -0.324$). WACOT has the highest volatility, while LABANA shows the strongest asymmetry. The findings emphasize the need for effective risk management strategies in Kebbi State's rice market. This study provides critical insights for policymakers and stakeholders seeking to mitigate price volatility risks.

Keywords: Volatility dynamics, Stationarity, Rice prices, Unit root tests, FIGARCH and ARFIMA models

CROP FARMERS' KNOWLEDGE OF E-BANKING IN ENUGU EAST SENATORIAL ZONE OF ENUGU STATE, NIGERIA

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ABSTRACT

The study assessed crop farmers' knowledge of e-banking in Enugu East Senatorial Zone of Enugu state, Nigeria. Data was collected from sixty crop farmers through the use of a structured interview schedule. Analysis of the data was done using frequency, percentage, mean and standard deviation. Results show that the majority (73%) of the respondents had a high knowledge of e-banking. Also, data show that the most frequently used ICT for transactions amongst the respondents was the debit card (75.0%). The study further revealed that the crop farmers' show more positive satisfaction with the cashless policy including: security and protection of funds ($\overline{x}$=3.20), ease of usage ($\overline{x}$=3.00), quick access to finances ($\overline{x}$=2.95), mobile banking reliability ($\overline{x}$=2.90), mobile network availability ($\overline{x}$=2.87), support and assistance by financial institution ($\overline{x}$=2.63), reduction in the cost of access to funds ($\overline{x}$=2.62), convenient environment for farmers ($\overline{x}$=2.53). There is need for more sensitization of farmers on the gains of using e-banking technologies for seamless daily farm transaction by actors including government. Such sensitization and possible subsidization of cost of the technologies by government would help them to access and use more of such technologies.

Keywords: E-banking, Farmers, knowledge, Agriculture

ENHANCE THE PROPERTIES OF RICE PAPER BY INCORPORATING CITRONELLA ESSENTIAL OIL (*Cymbopogon nardus* (L.) RENDLE)

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ABSTRACT

Rice paper is a thin sheet made from rice commonly used for wrapping other foodstuffs. Rice paper manufacturing technology can help increase product diversification from rice. However, rice paper still lacks elasticity after rehydration and has a short shelf life. Citronella essential oil contains monoterpene as the hydrophobic component that can be used to improve the characteristics of rice paper. The use of citronella essential oil can increase the utility and functional value of food products. This study aimed to determine the effect of citronella essential oil addition at various concentrations on rice paper's physicochemical and mechanical characteristics. The research method used was an experimental method using One Way Analysis of Variance (ANOVA) and Duncan's further test. The results showed that the best treatment was found in the sample by adding 1.5% (v/w) citronella essential oil. The addition of citronella essential oil concentration had a significant effect on the characteristics of rice paper on moisture content, water activity, rehydration power, color a*, color b*, tensile strength, elongation, and hedonic quality (color, texture, aroma, taste). This study provides important insights into optimizing rice paper formulations for various food product applications. Rice paper could be an alternative plastic for more sustainable food packaging.

Keywords: Rice paper, citronella essential oil, mechanical, physicochemical, sustainable packaging

A SPATIAL ATTENTION-ENHANCED CNN FOR EARLY DETECTION OF NPK DEFICIENCIES IN RICE CROPS

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ABSTRACT

Nutrient deficiencies, particularly nitrogen (N), phosphorus (P), and potassium (K), significantly impact rice growth and yield. Early and accurate identification of these deficiencies is essential for precision agriculture and effective crop management. This study presents a **deep learning-based automated classification model** that leverages a **spatial attention mechanism** to enhance feature extraction and improve deficiency detection in rice leaves. The model is built on a convolutional neural network (CNN) framework, integrating spatial attention to focus on critical regions of the leaf images, improving classification accuracy.

A carefully curated dataset of rice leaf images categorized into N, P, and K deficiency classes was used for training and evaluation. The dataset was preprocessed using **normalization, data augmentation, and the Synthetic Minority Over-sampling Technique (SMOTE)** to improve model generalization and address class imbalance. Experimental results demonstrate that the **spatial attention-enhanced CNN achieved an accuracy of 96.3%, a precision of 95.7%, recall of 94.8%, and an F1-score of 95.2%**, significantly outperforming conventional CNN models and traditional machine learning classifiers. The **AUC-ROC scores for deficiency classification were 0.98**, confirming the model's high discriminating power.

This study highlights the potential of deep learning with spatial attention as a **robust tool for real-time crop health monitoring**, enabling **early intervention and optimized fertilizer application**. Future work will explore multi-modal approaches by incorporating hyper-spectral imaging and environmental data for further improvements.

Keywords: *Deep Learning, Nutrient Deficiency, Rice, Spatial Attention, CNN, Precision Agriculture.*

INVESTIGATING YOUNG CONSUMERS ATTITUDES TOWARDS FOOD WASTE REDUCTION: KEY INSIGHTS AND LESSONS LEARNED

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ABSTRACT

Food is always being a necessity of life as it's not a matter of greed or taste. Food waste is defined as the portion of digestible food that is not consumed and contains material for human consumption that is subsequently lost, polluted, degraded, or discarded. It has been noticed there is an enormous amount of food available, which has led to an increase in food waste behavior by all individuals but in recent years technological advancement has been incurred. This research aims to understand young consumer perception about the food waste and to analyze dynamics which affects the young consumer attitude towards food waste. We will propose an integrated theoretical framework that considers social, behavioral, psychological, and economic factors. As a basis for this framework, could be used structural equation modelling (SEM) and logistic regression approaches for estimating how socio-psychological drivers influence young consumers' attitude towards minimizing food losses. The primary data will be collected from three districts of South Punjab as Multan, Bahawalpur and Khanewal using stratified random sampling technique with equal allocation. The targeted people are students of universities of given districts. This study aims to identify local priorities and knowledge bases, facilitating the development of appropriate and viable solutions that enhance the subjective well-being of consumers. By understanding the specific context and needs of the community, the research seeks to ensure that pragmatic interventions are both relevant and effective.

Keywords: Young consumers, food waste reduction, subjective well-being, pragmatic interventions

GENÇ TÜKETİCİLERİN GIDA ATIKLARININ AZALTILMASINA YÖNELİK TUTUMLARININ ARAŞTIRILMASI: ÖNEMLİ GÖRÜŞLER VE ÖĞRENİLEN DERSLER

ÖZET

Yiyecek, açgözlülük veya tat meselesi olmadığı için her zaman hayatın bir gerekliliği olmuştur. Yiyecek israfı, tüketilmeyen ve daha sonra kaybolan, kirlenen, bozulan veya atılan insan tüketimi için malzeme içeren sindirilebilir yiyecek kısmı olarak tanımlanır. Tüm bireylerde yiyecek israfı davranışında artışa yol açan muazzam miktarda yiyecek olduğu fark edildi, ancak son yıllarda teknolojik ilerleme kaydedildi. Bu araştırma, genç tüketicilerin yiyecek israfı hakkındaki algısını anlamak ve genç tüketicilerin yiyecek israfına karşı tutumunu etkileyen dinamikleri analiz etmeyi amaçlamaktadır. Sosyal, davranışsal, psikolojik ve ekonomik faktörleri dikkate alan entegre bir teorik çerçeve önereceğiz. Bu çerçevenin temeli olarak, sosyo-psikolojik faktörlerin genç tüketicilerin yiyecek kayıplarını en aza indirme tutumunu nasıl etkilediğini tahmin etmek için yapısal denklem modellemesi (SEM) ve lojistik regresyon yaklaşımları kullanılabilir. Birincil veriler, eşit tahsisle tabakalı rastgele örnekleme tekniği kullanılarak Güney Pencap'ın Multan, Bahawalpur ve Khanewal olmak üzere üç bölgesinden toplanacaktır. Hedeflenen kişiler, belirli ilçelerdeki üniversitelerin öğrencileridir. Bu çalışma, yerel öncelikleri ve bilgi tabanlarını belirleyerek tüketicilerin öznel refahını artıran uygun ve uygulanabilir çözümlerin geliştirilmesini kolaylaştırmayı amaçlamaktadır. Araştırma, toplumun özel bağlamını ve ihtiyaçlarını anlayarak, pragmatik müdahalelerin hem alakalı hem de etkili olmasını sağlamayı amaçlamaktadır.

Anahtar Kelimeler: Genç tüketiciler, gıda israfının azaltılması, öznel refah, pragmatik müdahaleler

PATHOLOGICAL FINDINGS OF LAMB MORTALITY DUE TO HIGH DOSE DRUG USAGE

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ABSTRACT

This study aims to present the macroscopic and histopathological findings obtained from the tissues of three lambs subjected to necropsy following deaths caused by high-dose drug usage. It was noted that sudden death cases were observed in the lambs of the herd after the administration of certain drugs. A detailed examination revealed that the recommended safe dose limit per kilogram, as specified in the drug's prospectus, had been significantly exceeded. As a result, a comprehensive systemic necropsy examination was performed on the three lambs.

Macroscopic examination showed that the abomasum (stomach) was among the most affected organs. When the abdominal cavity was opened, severe and widespread congestion in the serosa of the abomasum was noted. The macroscopic examination also revealed severe congestion and hemorrhages in the abomasal mucosa. The liver was macroscopically highly affected and appeared pale yellow. Kidneys, which were pale and soft in consistency, were also recorded as another significantly affected organ.

Histopathological examination of the liver revealed severe and widespread coagulative necrosis of hepatocytes, indicating acute liver toxicity. Other findings included congestion in blood vessels, cholestasis, and destruction of bile duct epithelium. In the kidneys, hydropic degeneration of tubular epithelial cells, and atrophy and destruction of glomeruli were detected.

In conclusion, severe damage and toxic effects were observed in vital organs such as the stomach, liver, and kidneys due to high-dose drug usage. The findings of this study provide important information regarding the potential toxic effects of high-dose drugs on lambs, highlighting points that veterinarians should consider in clinical practice. Additionally, it was concluded that safer dosage protocols should be developed to prevent such toxic incidents.

Keywords: High dose drug, necropsy, histopathology

YÜKSEK DOZ İLAÇ KULLANIMINA BAĞLI KUZU ÖLÜMÜNDE PATOLOJİK BULGULAR

ÖZET

Bu çalışma, kliniğimizde yüksek doz ilaç kullanımına bağlı ölümler sonrasında nekropsileri yapılan üç kuzunun dokularından elde edilen makroskobik ve histopatolojik bulguları sunmayı amaçlamaktadır. Sürüdeki kuzularda, belirli ilaç uygulamasının ardından ani ölüm vakaları gözlemlendiği belirtildi. Ayrıntılı inceleme, ilaç prospektüsünde belirtilen kilogram başına önerilen güvenli doz sınırının önemli miktarda aşıldığı ortaya koydu. Bunun üzerine üç kuzuda kapsamlı sistemik nekropsi incelemesi gerçekleştirildi.

Makroskobik inceleme, abomazumun (mide) etkilenen organların başında geldiğini gösterdi. Karın boşluğu açıldığında abomazumun serozasında şiddetli ve yaygın konjesyon kaydedildi. Makroskobik inceleme ayrıca abomazum mukozasında şiddetli konjesyon ve kanamalar olduğunu ortaya koydu. Karaciğer makroksobik olarak oldukça etkilenmiş durumdaydı ve açık sarı renkteydi. Solgun ve kıvamları yumuşak olan böbreklerin de önemli derecede etkilenen bir diğer organ olduğu kaydedildi.

Karaciğerin histopatolojik incelemesi, akut karaciğer toksisitesinin göstergesi olan hepatositlerin şiddetli ve yaygın koagulasyon nekrozu bulgularını ortaya koydu. Damarlarda konjesyon, kolestazis ve safra kanalı epitelinde destrüksiyon kaydedilen diğer bulgulardı. Böbreklerde ise tubul epitel hücrelerinde hidropik dejenerasyon ve glomeruluslarda atrofi ve yıkım tespit edildi.

Sonuç olarak, yüksek doz ilaç kullanımına bağlı olarak mide, karaciğer ve böbrek gibi vital organlarda ciddi hasar ve toksik etkiler gözlemlendi. Bu çalışmanın bulguları, yüksek doz ilaçların kuzular üzerinde potansiyel toksik etkileri hakkında önemli bilgiler sunmakta olup, veteriner hekimler için klinik uygulamalarda dikkat edilmesi gereken noktaları vurgulamaktadır. Ayrıca, bu tür toksik olayların önlenmesi amacıyla daha güvenli dozaj protokollerinin geliştirilmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimeler: Yüksek doz ilaç, nekropsi, histopatoloji

FACTORS AFFECTING CONSUMERS' GREEN PRODUCT PREFERENCES: THE CASE OF KIRŞEHİR PROVINCE

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ABSTRACT

This study aims to identify the factors influencing green product consumption preferences among consumers residing in the central district of Kırşehir Province, in terms of various demographic characteristics. Data were collected from 581 participants through questionnaire and analyzed using descriptive statistics, frequency tables, and Chi-square tests. Findings revealed that 87.8% of the respondents reported consuming green products (female = 267; male = 314). Results from the Chi-square analysis indicated that marital status, level of education, presence of chronic illness, and awareness of environmentally friendly products were statistically significantly associated with green product consumption ($p < 0.05$). Participants commonly defined green products as those with restricted use of chemicals and hormones and cited this attribute as a primary reason for their preference. The majority of respondents stated that green products differ from organic products and reported the internet as their main source of information. Most participants stated that they typically accessed green products at local bazaars, with fruits and vegetables, as well as grains and legumes, being the most frequently consumed product groups. The results indicate that, according to consumer opinions, the most significant barriers to purchasing green products are price, difficulties in access, and consumption habits. In response to a question regarding factors that could potentially increase green product consumption, the majority of participants selected “raising consumer awareness” and “reasonable pricing” as the most influential options. The results contribute to businesses and policy makers in developing strategies to raise consumer awareness and facilitate access to green products, with the aim of disseminating sustainable consumption behaviors and increasing environmental awareness.

Keywords: Green Product, Consumer Behaviours, Kırşehir.

TÜKETİCİLERİN YEŞİL ÜRÜN TERCİHLERİNİ ETKİLYEN FAKTÖRLER: KIRŞEHİR İLİ ÖRNEĞİ

ÖZET

Bu çalışmada, Kırşehir İli Merkez İlçe'de ikamet eden tüketicilerin yeşil ürün tüketim tercihlerine etki eden faktörlerin çeşitli demografik özellikler bakımından belirlenmesi amaçlanmıştır. Araştırma kapsamında, 581 katılımcıdan anket yoluyla elde edilen veriler tanımlayıcı istatistikler, frekans tabloları ve Ki-Kare analizi kullanılarak değerlendirilmiştir. Katılımcıların %87.8'inin yeşil ürün kullandığı belirlenmiştir (Kadın=267, erkek= 314). Ki-Kare analizi bulguları; medeni durum, eğitim düzeyi, kronik hastalık varlığı ve çevre dostu ürün farkındalığı değişkenlerinin yeşil ürün tüketimiyle istatistiksel olarak anlamlı bir ilişkiye sahip olduğunu ortaya koymaktadır ($p<0.05$). Tüketiciler yeşil ürünleri, ilaç ve hormon kullanımının sınırlandığı ürünler olarak tanımlamış ve tercih sebebi olarak belirtmişlerdir. Tüketicilerin büyük çoğunluğu yeşil ürünler ile organik ürünler arasında fark olduğunu düşünmekte olup, bu ürünler hakkında bilgiye en çok internet aracılığıyla ulaştıklarını ifade etmişlerdir. Yeşil ürünlere sıklıkla semt pazarlarında ulaştıklarını belirten katılımcıların en çok tükettikleri ürün gruplarının meyve-sebze ile tahıl ve baklagiller olduğu saptanmıştır. Bulgular; tüketici görüşlerinde yeşil ürünlerin satın alınmamasında rol oynayan en önemli faktörün fiyat, ürün teminine ilişkin zorluklar ve alışkanlıklar olduğunu göstermektedir. Bunun yanı sıra, yeşil ürün tüketiminin artırılmasında etkili olabilecek faktörlere ilişkin yöneltilen soruda, katılımcıların büyük çoğunluğu 'tüketicilerin bilinçlendirilmesi' ve 'fiyatların makul seviyelerde olması' yönünde görüş bildirmişlerdir. Araştırma sonuçları, sürdürülebilir tüketim davranışlarının yaygınlaştırılması ve çevresel farkındalığın artırılması amacıyla, tüketicilerin bilinçlendirilmesi ve yeşil ürünlere erişimin kolaylaştırılmasına yönelik stratejiler geliştirilmesinde işletmelere ve politika yapıcılara katkı sunmaktadır.

Anahtar Kelimeler: Yeşil Ürün, Tüketici Davranışları, Kırşehir

MICROSATELLITE ANALYSIS OF THE CLPP GENE IN CANNABIS SATIVA PLANT

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ABSTRACT

Hemp plant (*Cannabis sativa*) is an annual herb with significant potential across various industries, including medicine, food, and manufacturing. For many years, the plant's psychoactive properties, particularly due to tetrahydrocannabinol (THC), led to widespread bans on cultivation, limiting research and applications. However, recent changes in regulations have opened the door for broader cultivation and research, particularly in industrial and medicinal uses. This shift has sparked growing interest in improving the plant's agronomic traits using molecular breeding techniques. Molecular breeding heavily relies on genetic markers to enhance desirable traits, which are crucial for efficient breeding programs and for distinguishing between different *C. sativa* genotypes. One such marker is the *clpP* gene, which encodes a key subunit of the *clpP* protease complex, an ATP-dependent protease involved in protein regulation within plant cells. The *clpP* gene has been identified as a hotspot in many plant genomes, although its specific content may vary between species. This study analyzed the *clpP* gene in *C. sativa* to identify microsatellites, which are highly variable DNA regions useful as molecular markers. Microsatellites are ideal for genetic studies due to their high polymorphism and ease of detection. These markers can be employed for marker-assisted breeding, genetic diversity assessments, and precise genotype identification. The findings from this research provide valuable insights into the genetic structure of *C. sativa*, offering promising avenues for future research aimed at enhancing hemp cultivation. The identification of microsatellite markers linked to the *clpP* gene presents an opportunity to improve breeding strategies and optimize the agronomic and medicinal traits of hemp, contributing to the continued expansion of the hemp industry. The study also highlights the potential for applying these findings to other plant species with similar genetic characteristics, broadening the scope of molecular breeding applications.

Keywords: Bioinformatics Analysis, Hemp, Molecular Markers, Plant Genetics

CANNABIS SATIVA BİTKİSİNDE CLPP GENİNİN MİKROSATELİT ANALİZİ

ÖZET

Kenevir bitkisi (*Cannabis sativa*), tıp, gıda ve üretim gibi çeşitli endüstrilerde önemli bir potansiyele sahip yıllık otsu bir bitkidir. Uzun yıllar boyunca, bitkinin psikoaktif özellikleri, özellikle tetrahidrokannabinol (THC) nedeniyle, yetiştiriciliği yasaklanmış ve araştırmalar ile uygulamalar sınırlanmıştır. Ancak, son yıllarda düzenlemelerdeki değişiklikler, özellikle sanayi ve tıbbi kullanımlar alanında daha geniş bir yetiştiriciliğe ve araştırmaya kapı açmıştır. Bu değişim, bitkinin tarımsal özelliklerini moleküler ıslah teknikleriyle geliştirme konusunda artan bir ilgiye yol açmıştır. Moleküler ıslah, istenilen özelliklerin geliştirilmesinde genetik markörlere büyük ölçüde dayanır; bu markörler, verimli ıslah programları için ve farklı *C. sativa* genotiplerini ayırt etmek için hayati önem taşır. Bu markörlerden biri, bitki hücrelerinde protein düzenlemesinde rol oynayan, ATP-bağımlı bir proteaz olan *clpP* proteaz kompleksinin ana alt birimini kodlayan *clpP* genidir. *ClpP* geni, birçok bitki genomunda önemli bir bölge olarak tanımlanmış olup, türler arasında bu bölgenin içeriği farklılık gösterebilir. Bu çalışma, *C. sativa*'nın *clpP* genini analiz ederek, moleküler markör olarak kullanılabilecek yüksek varyasyona sahip DNA bölgeleri olan mikrosatellitleri belirlemiştir. Mikrosatellitler, yüksek polimorfizmleri ve kolay tespit edilmeleri nedeniyle genetik çalışmalar için ideal işaretçiler olarak kabul edilir. Bu işaretçiler, markör yardımlı ıslah, genetik çeşitlilik değerlendirmeleri ve kesin genotip tanımlamaları için kullanılabilir. Bu araştırmanın bulguları, *C. sativa*'nın genetik yapısına dair değerli bilgiler sunmakta ve kenevir yetiştiriciliğini geliştirmeyi hedefleyen gelecekteki araştırmalar için umut verici yollar açmaktadır. *ClpP* geni ile ilişkilendirilen mikrosatellit markörlerin tanımlanması, ıslah stratejilerini geliştirme ve kenevirin tarımsal ve tıbbi özelliklerini optimize etme fırsatı sunarak kenevir endüstrisinin sürekli genişlemesine katkıda bulunacaktır. Çalışma ayrıca, bu bulguların benzer genetik özelliklere sahip diğer bitki türlerine uygulanma potansiyelini vurgulamakta ve moleküler ıslah uygulamalarının kapsamını genişletmektedir.

Anahtar Kelimeler: Biyoinformatik Analiz, Kenevir, Moleküler Markör, Bitki Genetiği

A STUDY ON THE EFFECTIVENESS OF MODIFICATIONS IN REDUCING ANTI-NUTRITIONAL FACTORS IN BARLEY

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ABSTRACT

Barley is a widely utilized cereal grain in poultry farming due to its low cost and easy availability. However, the performance decline observed in poultry fed with barley-based diets remained unexplained for many years. It was later determined that this negative performance was caused by β-glucans present in barley. Consequently, under certain farming conditions where intensive barley usage is necessary, enzyme supplementation becomes essential to mitigate the adverse effects of β-glucans. Compared to other cereal grains, barley contains lower levels of phytate, which reduces phosphorus bioavailability. However, the presence of anti-nutritional factors such as β-glucans and phytic acid requires careful consideration, particularly in poultry feeding, as they limit the digestibility and efficiency of barley in the diet. Various modifications can enhance barley's usability, especially in the feeding of large poultry species such as turkeys and geese, by facilitating its utilization as both a concentrated feed and a forage source. Additionally, the potential of barley as a high-quality roughage source when grown in a hydroponic environment requires further evaluation. The effects of different modifications—such as the use of dry barley grains in rations, soaking, germination, and cultivation for grazing—on β-glucan and phytic acid content have been a subject of interest. This study investigates the impact of specific modifications on the β-glucan and phytic acid composition of barley. The modifications were compared to a control group consisting of untreated barley grains. The experimental treatments included (1) Control (no treatment applied), (2) Soaking, (3) Hydroponic germination, and (4) Pasture cultivation. Significant changes in β-glucan and phytic acid levels were observed in barley subjected to different treatments. Structural modifications were particularly evident in barley grown in soil and hydroponically germinated barley, with notable reductions in β-glucan (0.69–0.82 g/100g) and phytic acid levels (0.03–1.37 mg/g).

Keywords: barley pasture, soaked barley grain, hydroponic barley, β-glucan, phytic acid

ARPADAKİ ANTİ-BESİNSEL FAKTÖRLERİN AZALTILMASINA YÖNELİK MODİFİKASYONLARIN ETKİNLİĞİ ÜZERİNE BİR ARAŞTIRMA

ÖZET

Arpa, kanatlı besisinde, ucuz olması ve kolay bulunması gibi nedenlerden dolayı yoğun bir şekilde kullanılan bir tahıldır. Arpanın kanatlı rasyonlarında yoğun bir şekilde kullanıldığında sebep olduğu performans düşüklüğünün yıllarca sebebi bilinememişti. Bu olumsuz performansın arpadaki ***β-glukan***'lar dan kaynaklandığı ortaya çıkarılmıştır. Bu nedenle yoğun arpa kullanımını zorunlu kılan bazı yetiştirme şartlarında enzim kullanımı ***β-glukan'***ların olumsuz etkisini elimine etmek için zorunludur. Diğer tahıl danelerine kıyasla arpadaki fosfordan yararlanmayı azaltan bağlı form olan fitat düzeyinin daha düşük olması arpayı bu açıdan diğer tahıllar kadar sorunlu yapmamaktadır. Ancak özellikle kanatlı besisinde arpanın kullanımını kısıtlayan ve sindirimde olumsuzluklara sebep olan bu gibi anti nutrisyonel faktörlerin (***β-glukan*** ve fitik asit gibi) üzerinde dikkatle durmak gerekmektedir. Bazı modifikasyonlar ile arpanın kullanılabilirliğinin artırılması özellikle hindi ve kaz gibi büyük kanatlı besisinde, arpanın hem kesif yem hem de bir mera otu kaynağı olarak değerlendirilmesini geliştirebilir. Ayrıca topraksız ortamda tek yıllık olan arpanın çimlendirilmek suretiyle iyi bir kaba yem kaynağı olup olmadığı değerlendirilmesi mümkündür. Çeşitli modifikasyonların, örneğin kuru arpa tanesinin rasyonda kullanımı, ıslatma, çimlendirme ve otlatma amacıyla ekiminin, arpanın ***β-glukan*** ve fitik asit içeriği üzerindeki etkileri ilgi konusu olmuştur. Bu çalışma, arpaya uygulanan belirli modifikasyonların ***β-glukan*** ve fitik asit içeriği üzerindeki etkilerini araştırmaktadır. Bu modifikasyonlar, kontrol grubu olan işlenmemiş arpa tanelerinden elde edilen sonuçlarla karşılaştırılmıştır. Çalışmada arpa tanelerine uygulanan işlemler şunlardır: (1) Kontrol (taneye herhangi bir işlem uygulanmamıştır), (2) Islatma, (3) Çimlendirme (hidroponik) ve (4) Arpa merası oluşturma. Farklı modifikasyonlara maruz kalan arpanın ***β-glukan*** ve fitik asit seviyelerinde önemli değişiklikler gözlemlenmiştir. Toprakta yetiştirilen ve hidroponik olarak çimlendirilen arpada önemli yapısal değişiklikler meydana gelmiştir. Bu arpa türlerinde sırasıyla ***β-glukan*** (0.69–0.82 g/100g) ve fitik asit seviyeleri (0.03–1.37 mg/g) önemli ölçüde azalmıştır.

Anahtar kelimeler: arpa merası, ıslak arpa danesi, hidroponik arpa, β-glukan, fitik asit

THE EFFECT OF SEED COATING APPLICATION ON YIELD AND QUALITY IN FIELD CROPS

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ABSTRACT

Seed is the basic building block of crop production and the most important input that directly affects agricultural productivity and product quality. It constitutes the most basic and vital input for the continuity of agriculture and the vital cycle. Approximately 90% of agricultural production for food production is carried out using seeds. For this reason, the role of seed in the agricultural sector is of primary importance. Achieving high yield and quality product targets in field crops depends not only on the use of genetically superior seeds, but also on the ability of these seeds to germinate and develop healthily under appropriate environmental conditions. However, seeds may suffer losses during germination and emergence stages due to heterogeneity in genetic structure, environmental stress factors and soil-borne diseases. One of the most effective methods developed to reduce these losses and improve seed performance is seed coating technology.

Seed coating is the process of applying protective and supportive substances on the seed with adhesives. This application offers many advantages such as increasing germination and emergence rates, facilitating the sowing process, protecting the seed against pests and diseases and ensuring more regular plant growth. This technology, which has two basic methods, film coating and pellet coating, gives effective results especially in the treatment of small and irregularly shaped seeds.

In this study, the effects of seed coating on germination performance, seedling quality, seed saving potential and final crop yield in field crops were evaluated. The findings of the study show that seed coating applications both increase agricultural production efficiency and significantly reduce losses during the seedling stage.

As a result, seed coating technology stands out as an innovative application that improves seed quality and optimizes the production process in line with sustainable agriculture goals.

Keywords: Seed, Pellet Coating, Film Coating, Agriculture

TARLA BİTKİLERİNDE TOHUM KAPLAMA UYGULAMASININ VERİM VE KALİTEYE ETKİSİ

ÖZET

Tohum, bitkisel üretimin temel yapı taşı olup, tarımsal verimliliği ve ürün kalitesini doğrudan etkileyen en önemli girdidir. Tarımın ve yaşamsal döngünün devamlılığı için en temel ve hayati girdiyi teşkil etmektedir. Gıda üretimi amaçlı yapılan tarımsal üretimin yaklaşık olarak %90'ı tohum kullanılarak gerçekleştirilmektedir. Bu nedenledir ki tarım sektöründe tohumun rolü birincil öneme sahiptir. Tarla bitkilerinde yüksek verim ve kaliteli ürün hedeflerine ulaşmak, yalnızca genetik olarak üstün tohumların kullanımına değil; aynı zamanda bu tohumların uygun çevre koşullarında sağlıklı bir biçimde çimlenip gelişebilmesine bağlıdır. Ancak tohumlar; genetik yapıdaki heterojenlik, çevresel stres faktörleri ve toprak kaynaklı hastalıklar gibi nedenlerle çimlenme ve çıkış aşamalarında kayıplara uğrayabilmektedir. Bu kayıpları azaltmak ve tohum performansını artırmak amacıyla geliştirilen en etkili yöntemlerden biri tohum kaplama teknolojisidir.

Tohum kaplama, tohumun üzerine koruyucu ve destekleyici maddelerin yapıştırıcılarla uygulanması sürecidir. Bu uygulama; çimlenme ve çıkış oranlarını artırmak, ekim işlemini kolaylaştırmak, tohumu zararlılara ve hastalıklara karşı korumak ve daha düzenli bitki gelişimi sağlamak gibi birçok avantaj sunmaktadır. Film kaplama ve pellet kaplama olmak üzere iki temel yöntemi bulunan bu teknoloji, özellikle küçük ve düzensiz şekilli tohumların işlenmesinde etkin sonuçlar vermektedir.

Bu çalışmada, tarla bitkilerinde tohum kaplama uygulamasının çimlenme performansı, fide kalitesi, tohumdan tasarruf sağlama potansiyeli ve nihai ürün verimi üzerindeki etkileri değerlendirilmiştir. Araştırma bulguları, tohum kaplama uygulamalarının hem tarımsal üretim verimliliğini artırdığını hem de fide dönemindeki kayıpları önemli ölçüde azalttığını göstermektedir.

Sonuç olarak, tohum kaplama teknolojisi; sürdürülebilir tarım hedefleri doğrultusunda, tohum kalitesini artıran ve üretim sürecini optimize eden yenilikçi bir uygulama olarak öne çıkmaktadır.

Anahtar Kelimeler: Tohum, Pellet Kaplama, Film Kaplama, Tarım

MICROPLASTIC CONTAMINATION IN FOOD AND ITS EFFECTS ON HUMAN HEALTH

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ABSTRACT

Plastics have become an integral part of daily life thanks to their easy processability, durability, lightness and low cost. In the food industry, they are widely used especially in packaging and transportation processes due to their advantages. However, when these plastics are exposed to environmental impacts, they decompose into small particles called microplastics and mix into nature.

Microplastics (MP) are synthetic polymer particles with a diameter of less than 5 mm and have attracted attention as one of the important components of environmental pollution in the world in recent years. The transfer of microplastics into the food chain poses a great risk, especially for human health. The presence of these pollutants has been detected in many foodstuffs such as seafood, drinking water, table salt, sugar, dairy products, fruits and vegetables. In addition, plastic packaging, food processing, packaging methods and agricultural activities also cause contamination of food with microplastics. The possible effects of microplastics on human health are currently being intensively researched. It has been determined that these particles can be taken into the body through the digestive system, overcome the intestinal barrier, mix with the circulatory system and cause toxic effects at the cellular level. It is thought that the heavy metals and toxic chemicals carried by microplastics may cause endocrine system disorders, immune system weakening, neurotoxicity, hormonal disorders and even health problems such as cancer.

As a result of recent studies, it has been determined that microplastics have become a global threat to both the environment and human health. It is of great importance to develop methods to contaminate the food chain, examine the factors affecting contamination, and determine their amounts in foods. In this study, the ways in which microplastics contaminate food, the presence of microplastics in food, the methods used to detect them in food, and the potential effects of these contaminants on human health will be discussed.

Keywords: Microplastics, food safety, human health, toxicity, environmental contaminants, analysis methods.

GIDALARDA MİKROPLASTİK KİRLİLİĞİ VE BU KİRLİLİĞİN İNSAN SAĞLIĞI ÜZERİNE ETKİLERİ

ÖZET

Plastikler, kolay işlenebilirliği, dayanıklılığı, hafifliği ve düşük maliyeti gibi özellikleri sayesinde günlük yaşamın ayrılmaz bir parçası haline gelmiştir. Gıda sektöründe ise özellikle ambalajlama ve taşıma süreçlerinde sağladığı avantajlar nedeniyle yaygın olarak kullanılmaktadır. Ancak, bu plastikler çevresel etkilere maruz kaldıklarında, mikroplastik adı verilen küçük parçacıklara ayrışarak doğaya karışmaktadır.

Mikroplastikler (MP), çapı 5 mm'den küçük olan sentetik polimer parçacıklarıdır ve son yıllarda dünyada çevre kirliliğinin önemli bileşenlerinden biri olarak dikkat çekmektedir. Mikroplastiklerin besin zincirine geçişi, özellikle insan sağlığı açısından büyük bir risk oluşturmaktadır. Deniz ürünleri, içme suyu, sofralık tuz, şeker, süt ürünleri, meyve ve sebzeler gibi birçok gıda maddesinde bu kirleticilerin varlığı tespit edilmiştir. Ayrıca, plastik ambalajlar, gıda işleme süreçleri, ambalajlama yöntemleri ve tarımsal faaliyetler de gıdaların mikroplastik ile kontaminasyonuna neden olmaktadır. Mikroplastiklerin insan sağlığı üzerindeki olası etkileri, günümüzde yoğun bir şekilde araştırılmaktadır. Bu partiküllerin sindirim sistemi yoluyla vücuda alınarak bağırsak bariyerini aşabileceği, dolaşım sistemine karışarak hücresel düzeyde toksik etkilere yol açabileceği tespit edilmiştir. Mikroplastiklerin taşıdığı ağır metallerin ve toksik kimyasalların endokrin sistem bozukluklarına, bağışıklık sistemi zayıflamasına, nörotoksisiteye, hormonal bozukluklara ve hatta kanser gibi sağlık sorunlarına neden olabileceği düşünülmektedir.

Son yapılan çalışmalar neticesinde hem çevre hem de insan sağlığı için küresel bir tehdit haline geldiği tespit edilen Mikroplastiklerin besin zincirine kontamine olması, kontaminasyonu etkileyen faktörlerin incelenmesi ve gıdalardaki miktarlarının belirlenmesi için yöntemlerin geliştirilmesi büyük önem arz etmektedir. Bu çalışmada, mikroplastiklerin gıdalara bulaşma yolları, gıdalarda mikroplastik varlığı, gıdalarda tespitinde kullanılan yöntemler ve bu kirleticilerin insan sağlığı üzerindeki potansiyel etkileri ele alınacaktır.

Anahtar Kelimeler: Mikroplastik, gıda güvenliği, insan sağlığı, toksisite, çevresel kirleticiler, analiz yöntemleri.

THE EFFECT OF USE OF PHOSPHORUS FERTILIZERS WITH ORGANIC MATERIALS ON THE PHOSPHORUS CONTENT OF CORN PLANT GROWING IN DIFFERENT SOILS pH

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ABSTRACT

This study aimed to determine the effects of phosphorus fertilizers (Triple Super Phosphate (TSP) and Ground Phosphate Rock) and various organic materials (Biochar, Vermicompost and Farmyard Manure) applied to soils with different pH on phosphorus (P) uptake by maize plants. The experiment was conducted as a pot experiment under greenhouse conditions in three different soil conditions: acidic (pH = 5.2), neutral (pH = 6.9) and basic (pH = 8.0). The results of the experiment showed that both fertilizer type and soil reaction had significant effects on the phosphorus content of maize plants. In acidic soil, the highest phosphorus content was observed in the combination of Ground Phosphate Rock + Biochar with 0.426%. The highest phosphorus content was observed in TSP + Vermicompost (0.340%) in neutral soil and Ground Phosphate Rock + Vermicompost (0.313%) in basic soil. The control group gave the lowest P contents in all soils with different pH (0.197-0.210%), indicating that phosphorus uptake increased with organic material application. Solubility properties of fertilizers, the effect of organic materials on soil properties and pH-dependent phosphorus uptake are thought to be the main reasons for the differences between treatments. TSP increased uptake especially under neutral soil conditions due to its high solubility, whereas ground Phosphate Rock increased phosphorus uptake under acidic and basic conditions when used with organic materials despite its low solubility. The fact that vermicompost increases phosphorus solubility through microbial life and organic acid release supports this conclusion. The use of phosphorus fertilizers in combination with suitable organic materials offers an effective strategy to increase plant phosphorus uptake, especially under very high and low pH conditions. The use of organic materials, especially the potential to increase the usefulness of phosphate rocks, is very important in making fertilization more efficient and increasing sustainability.

Keywords: Phosphorus, pH, Corn, Phosphorus Fertilizer, Organic Material

FOSFORLU GÜBRELERIN ORGANIK MATERYALLERLE BIRLIKTE KULLANIMININ FARKLI pH'YA SAHIP TOPRAKLARDA MISIR BİTKİSİNİN FOSFOR İÇERİKLERİNE ETKİSİ

ÖZET

Bu çalışma, farklı pH'ya sahip topraklara uygulanan fosforlu gübrelerin (Triple Süper Fosfat (TSP) ve Öğütülmüş Fosfat Kayası) ve çeşitli organik materyallerin (Biochar, Vermikompost ve Çiftlik Gübresi) birlikte kullanımının mısır bitkisinin fosfor (P) alımı üzerindeki etkilerini belirlemeyi amaçlamıştır. Deneme, asidik (pH = 5.2), nötr (pH = 6.9) ve bazik (pH = 8.0) olmak üzere üç farklı toprak koşulunda sera koşullarında saksı denemesin şeklinde yürütülmüştür. Deneme sonunda elde edilen bulgular, hem gübre tipi hem de toprak reaksiyonunun mısır bitkisinin fosfor içeriği üzerinde belirgin etkiler yarattığını göstermiştir. Asidik toprakta en yüksek fosfor içeriği %0,426 ile Öğütülmüş Fosfat Kayası + Biochar kombinasyonunda gözlenmiştir. Nötr toprakta TSP + Solucan Gübresi (%0,340) ve bazik toprakta Öğütülmüş Fosfat Kayası + Solucan Gübresi (%0,313) uygulamalarında fosfor içeriğinin en yüksek çıktığı görülmüştür. Farklı pH'ya sahip toprakların hepsinde kontrol grubu en düşük P içeriklerini vermiştir (%0,197–0,210), bu da fosfor alımının organik materyal uygulamasıyla artığını ortaya koymaktadır. Uygulamalar arasındaki farklılıkların temel nedenleri olarak gübrelerin çözünürlük özellikleri, organik materyallerin toprak özelliklerine etkisi ve pH'ya bağlı fosforun alınabilirliği düşünülmektedir. TSP'nin yüksek çözünürlüğü sayesinde özellikle nötr toprak koşullarında alımı artmış, buna karşın öğütülmüş fosfat kayası düşük çözünürlüğüne rağmen organik materyallerle birlikte kullanıldığında asidik ve bazik koşullarda fosfor alımını artırmıştır. Vermikompostun mikrobiyal yaşam ve organik asit salınımı ile fosfor çözünürlüğünü artırması bu sonucu desteklemektedir. Fosforlu gübrelerin uygun organik materyallerle birlikte kullanılması, özellikle çok yüksek ve düşük pH koşullarında bitkinin fosfor alımını arttırmak için etkili bir strateji sunmaktadır. Organik materyallerin kullanımı özellikle fosfat kayalarının yarayışlılığını artırma potansiyeli, gübrelemenin daha etkin yapılması ve sürdürülebilirliğin arttırılması konusunda oldukça önemlidir.

Anahtar Kelimeler: Fosfor, pH, Mısır, Fosforlu Gübre, Organik Materyal

A GENERAL OVERVIEW OF THE STINGER STRUCTURE AND POISON SECRETION IN HONEYBEES

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ABSTRACT

Throughout human history, bees and humans have continued to be together. Honey bees produce various products important for human nutrition and play an important role in the pollination of plants. This report provides information about bee stings and their venom. Queen bees and worker bees, which are female members of the bee family except for male bees, have a sting on the last tergite of their abdomens. The structure of the sting found in the queen bee is flat and is used only to kill rival queen candidates, and since the sting does not remain in the skin, the queen bee continues her normal life. In contrast, the stings of worker bees are surrounded by irregular backward notches, and when they sting living beings in danger, the acid and alkaline poison secretion glands attached to the sting remain there, and since their intestines come out together, the worker bee dies. After death, the poison secretion glands remaining in the skin continue to contract and inject the poison into the skin. For this reason, the bee's sting should be removed immediately after the sting. Local swelling, edema and redness that we call local occur in bee stings. When it stings in respiratory areas such as the nostrils, tongue, pharynx, and larynx, the swelling that will occur will prevent breathing and cause the creature to die. The general symptoms that occur when bee venom spreads throughout the body are difficulty breathing, redness in the eyes, increased pulse, and fever up to 40 degrees. The mixing of bee venom with the blood causes allergic and even anaphylactic symptoms that can lead to death.

In order to protect yourself from bee stings, you should not disturb the bees. A mask should be worn when entering the apiary. Strong, irritating odors should be avoided, and dark and woolen clothes should not be worn. The entrance and exit of bees to the hive should not be prevented.

In the treatment of bee stings, ice should be applied to the area stung by the bee. Adrenaline should be used against systemic reactions. In the case of anaphylactic shock, adrenaline should be administered intravenously. Coramin, Cardiazol and Caffeine should be given to support the heart. Antihistamines should be used against allergic reactions.

Bee venom treatment, known as apitherapy, is also performed. It is used especially in inflammatory rheumatism and Multiple Sclerosis (MS) patients. It is used in medicine as an alternative treatment for nervous system diseases, cardiovascular disorders, menstrual pain, joint pain, strengthening the immune system, hormonal disorders, varicose veins and hypertension diseases.

Keywords: Honey Bee, Needle Structure, Venom Secretory Glands, Protection, Treatment, Apitherapy

BAL ARILARINDA İĞNE YAPISI VE ZEHİR SALGISINA GENEL BİR BAKIŞ

ÖZET

İnsanlık tarihi boyunca arılarla insanların birlikteliği devam etmiştir. Bal arıları insan beslenmesinde önemli çeşitli ürünleri üretmekte ve bitkilerin polinasyonunda önemli rol almaktadır. Bu bildiride, arı sokması ve zehirleri hakkında bilgi verilmiştir. Arı ailesi bireylerinden erkek arı hariç dişi olan kraliçe arı ve işçi arıların abdomenlerinin son tergitinde iğne mevcuttur. Kraliçe arıda bulunan iğnenin yapısı düz olup sadece rakip ana arı adaylarını öldürmek için kullanılmakta, iğne deride kalmadan geri çektiği için ana arı normal yaşamına devam etmektedir. Buna karşın işçi arıların iğnelerinin üzeri düzensiz geriye dönük çentiklerle çevrili olup, tehlike durumunda canlıları soktuğunda, iğneye bağlı asit ve alkalen zehir salgı bezleri ile birlikte orada kalmakta, beraberinde bağırsakları da dışarı çıktığından işçi arı ölmektedir. Öldükten sonra deride kalan zehir salgı bezleri kontraksiyonuna devam ederek zehri deriye zerk etmektedir. Bu nedenledir ki arının iğnesi sokmadan hemen sonra çıkarılmalıdır.

Arı sokmalarında lokal dediğimiz şişlik, ödem ve kızarıklıklar şekillenmektedir. Burun delikleri, dil, farenks, larenks gibi solunumla ilgili yerlerden soktuğunda oluşacak şişlik solunumu engelleyeceğinden canlının ölmesine sebep olmaktadır. Arı zehrinin tüm vücuda dağılmasıyla oluşan genel semptomlar olarak nefes almada zorluk, gözlerde kızarıklık, nabız artışı, 40 dereceye varan ateş şekillenmektedir. Arı zehrinin kana karışması alerjik hatta ölüme varan anafilaktik semptomlara sebep olmaktadır.

Arı sokmalarından korunmak için arıları rahatsız etmemek gerekir. Arılığa girerken maske takılmalıdır. Ağır irkiltici kokulardan kaçınılmalı, koyu renk ve yünlü kıyafetler giyilmemelidir. Arıların kovana giriş ve çıkışları engellenmemelidir.

Arı sokmalarında tedavide, arının soktuğu bölgeye buz uygulaması yapılmalıdır. Sistemik reaksiyonlara karşı adrenalin kullanılmalıdır. Anafilaktik şok durumunda adrenalin damar içi uygulanmalıdır. Kalbi desteklemek için de Coramin, Kardiazol ve Kafein verilmelidir. Alerjik reaksiyonlara karşı antihistaminikler kullanılmalıdır.

Apiterapi olarak bilinen arı zehri tedavisi de yapılmaktadır. Özellikle iltihaplı romatizmada ve Multipl Skleroz (MS) hastalarında kullanılmaktadır. Sinir sistemi hastalıkları, kalp damar rahatsızlıkları, menstrual ağrılar, eklem ağrıları, bağışıklık sisteminin güçlendirilmesi, hormonal rahatsızlıklar, varis ve hipertansiyon hastalıklarında alternatif tedavi olarak tıpta yer almaktadır.

Anahtar Kelimeler: Bal Arısı, İğne Yapısı, Zehir Salgı Bezleri, Korunma, Tedavi, Apiterapi

DETERMINANTS OF COMPLIANCE BEHAVIOR OF FARMERS TOWARDS AGRICULTURAL TAXATION IN PUNJAB

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ABSTRACT

Taxes are the primary means of generating revenue in the world. Pakistan lags well behind other countries when it comes to taxation of individual income, especially income from agriculture. Agricultural taxes have been implemented; however, compliance with tax laws and collection is poor. Since farmers' compliance behavior affects agricultural income tax, the agriculture tax's generated revenues have been insufficient, and the tax's base of collection is limited. Tax compliance is a major concern, especially in developing nations where governments seek ways to increase tax-collecting efficiency to finance their budgets. Agriculture tax is collected from an inadequate base, and its revenues have been insufficient because the compliance behavior of farmers affects agricultural income tax. This study aims to identify factors of tax compliance that affect agriculture taxation in Punjab, Pakistan, by using binary logistic regression. The cluster sampling was used to collect data from 557 farmers. The study's findings show that education, tax knowledge, satisfied tax authorities, and low levels of crime and conflict positively affect tax compliance. On the other hand, government waste taxes and poor agriculture services have statistically negative effects on tax compliance. Moreover, tax authorities should take steps to improve tax compliance rates.

Keywords: Compliance behavior, agriculture taxation, logit model, tax authorities

EVALUATION OF THE ANTI-INFLAMMATORY AND ANTI-HEMOLYTIC POTENTIAL OF POLYPHENOLIC COMPONENTS OF COMMON MALLOW (*Malva sylvestris*)

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ABSTRACT

This work aims at the assessement of anti-inflammatory and anti-hemolytic effect of *Malva sylvestris*. The anti-inflammatory potential was evaluated by the inhibition of protein denaturation method. It was followed by the study of anti-hemolytic potential, based on two methods (haemolysis by hydrogen peroxide (H2O2) and by hypotonic haemolysis). The macerated aqueous extract of *M. sylvestris* (250 µg/ml) exhibited the highest inhibition percentage of BSA denaturation compared to other extracts but it appeared to be slightly lower than the drug diclofenac sodium (80.97±1.23%). On the other hand, the macerated aqueous extract showed more protective power against haemolysis (93.42±3.45%). While it was almost similar to the percentage recorded for ascorbic acid (93.68±3.21%). For the second method, it was observed that the decocted acetone extract of *M. sylvestris* showed a rate of haemolysis inhibition which was the highest (98.09±1.26%) but that it remained slightly lower than aspirin (98.77±0.44%). All of these results showed that *M. sylvestris* extracts have interesting anti-inflammatory and anti-haemolytic potential and therefore have considerable interest as an alternative treatment against inflammatory mechanisms.

Keywords: Anti-hemolytic, Anti-inflammatory, *Malva sylvestris*, Polyphenols.

ANALYSIS AND DESIGN OF G + 5 FLOORS APARTMENT BUILDING

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ABSTRACT

Our main aim to complete a G+5 Floor Apartment building is to ensure that the structure is safe against all possible loading conditions and to full fill the function for which they have built. Safety requirements must be met so that the structure is able to serve its purpose with the maintain cost. Detailed planning of the structure usually comes from several studies made by town planners, investors, users, architects, and other engineers. On that, a structural engineer has the main influence on the overall structural design and an architect is involved in aesthetic details. For the design of the structure, the dead load, live load seismic and wind load are considered. The analysis and design for the structure done by using software package STAAD PRO. In this Apartment construction, we are going to adopted limit state method of analysis and design the structure. The design is confirmation with IS456-2000.the analysis of one frame is worked out manually and simultaneously it has been checked using STAAD PRO. Therefore, an attempt has been made to present the G+5 Apartment for residential purpose in the upcoming busy city of Vijayawada. The Apartment consisting of five storey's the structure is design based on the theory of Limit State Method which provides adequate strength, serviceability, and durability besides economy

Keywords: *Concrete, G+5 Floor, STAAD PRO Safety requirements, IS456-2000, Limit State Method and Global environmental*

In vitro ANTIOXIDANT AND ANTIBACTERIAL EFFECT OF *Thymus hirtus subsp. algeriensis* (Boiss. & Reut.) LEAVES EXTRACTS

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ABSTRACT

This study was designed to investigate the antioxidant and antibacterial effect of the aqueous and ethanolic extracts from *Thymus hirtus subsp. algeriensis*. leaves. The preparation of the aqueous and ethanolic extracts and evaluating the antioxidant effect by the means of two methods: DPPH radical-scavenging assay and the ß-carotene–linoleic acid assay as well as testing the antibacterial effect by the disk diffusion method.

The results of this study showed that the aqueous and ethanolic extracts showed antioxidant activity with a percent of antioxidant activity up to 88.13 % in the ß-carotene-linoleic acid assay while in the DPPH radical-scavenging assay the ethanolic extract of *Thymus hirtus subsp. algeriensis* displayed highest anti-radicalar power (0.170). But on the antibacterial effect, all the extracts of leaves plants exerted an inhibiting effect on the pathogenic bacteria with diameters of the zones of inhibition going up to 16.00 ± 00.00 mm.

The overall results suggested that the *Thymus hirtus subsp. algeriensis* leaves showed an antioxidant and antibacterial effect due to the presence of active biomolecules such as phenolic compounds and flavonoids.

Keywords: Antioxidant effect, Antibacterial effect, Plants extracts, *Thymus hirtus subsp. algeriensis*.

ASSESSMENTS OF PHYTOPHARMACEUTICALS WITH THERAPEUTIC POTENTIALS IN HEALTH MANAGEMENT

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Oral presentation

ABSTRACT

Global health emphasizes a broad, multidisciplinary approach to understanding emerging health challenges, considering social, cultural, economic and environmental factors that underlie health inequities. Health encompasses medical conditions such as hypertension, diabetes, and infectious diseases or congenital anomalies. The continents around the world are endowed with several biodiversity. For instance, Africa is known to have the richest biodiversity in the world, with an avalanche of many food plants used as herbs, health foods and for pharmaco-therapeutic purposes in the forest and associated flora and fauna. Phytopharmaceuticals are plant-derived (phytochemicals) compounds with pharmacological activities. They make up a good part of drugs made from plant-based molecules as opposed to synthetics. Thus, the need to access some phytopharmaceuticals with therapeutic potentials in health management. These phytopharmaceuticals span from laboratory investigations involving several methods such as solvents extraction, thin layer or paper chromatography for fractionation of bioactive molecules, and characterization using high performance liquid chromatography (HPLC) analysis of some plants. *In vitro* phytopharmaceuticals investigation of some plants in albino Wistar rats investigated include flavonoids from *Bryophyllum pinnatum*, lime juice, honey and *Jatropha Tanjorensis* leaf possessing anti-conjunctivitis, hypoglycemic, hypolipidemic, and anti-obesity activities, alkaloids from *Jatropha Tanjorensis* leaf possessing anti-inflammatory and hematinic activities, tannin from *Vernonia amygdalina* (bitter leaf) and bee bread with antidiabetic and hypoglycemic activities, dihydrophenantherene from *Khaya Senegalensis* stem bark with hypoglycemic and anti-diabetic activities, 3-nitrophthalic acid, and coumarine from *Alstonia boonei* stem bark with antimalarial activity, f*lacourtia indica* leaf, stem bark and fruit with hypoglycemic, hepatoprotective, hematinic and gluco-stabilizing activities, *Phaseolus Vulgaris* (Kidney Bean Seeds), and *Vigna unguiculata* (Black-eyed Bean Seeds) possessing renal protection and practically non-toxic at LD_{50} greater than 5000mg/kg in albino Wistar rats. In conclusion, phytopharmaceuticals in plant largely work by targeting specific receptors, interrupting disease pathways, and disrupting pathogenic life cycles.

NOVEL INTELLIGENT NAKED-EYE FOOD PACKAGING PH-SENSITIVE AND FLUORESCENT SULFUR, NITROGEN-CARBON DOTS BIOSENSORS FOR TOMATO SPOILAGE DETECTION INCLUDING DFT AND MOLECULAR DOCKING CHARACTERIZATION

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ABSTRACT

Tomatoes are susceptible to microbial spoilage, leading to significant economic losses. This study investigates the microbial quality of different tomato grades and introduces a novel approach to monitor tomato spoilage. Carboxymethyl cellulose (CMC) films incorporated with sulfur and nitrogen-doped carbon dots (SN–CDs) were developed as pH-sensitive colorimetric sensors for tomatoes. The SN–CDs, derived from red onion peel waste (OPW), exhibited excellent fluorescence properties and antimicrobial activity XPS analysis confirmed the successful synthesis of SN–CDs with incorporated N and S. The incorporation of OPW significantly reduced the Young's modulus of the CMC hydrogel film, likely due to structural disruptions and increased free volume within the film. The color of the prepared colorimetric sensors was changed after tomato spoilage which means the effectiveness of these films in the tomato spoilage detection by naked eye. It exhibited pH-sensitivity because of the presence of flavonoids,.The color of flavonoids is influenced by pH, shifting from yellow in acidic conditions to orange in neutral and red in alkaline environments due to structural changes, including protonation and deprotonation. This pH sensitivity allows for visual indication of pH changes, as demonstrated by the CMC-SN-CDs3 film, which turns yellow in acidic conditions and red in alkaline conditions. The CMC-SN–CDs films displayed a distinct color change in response to pH variations, enabling visual detection of tomato spoilage. The films also demonstrated antimicrobial properties, inhibiting the growth of foodborne pathogens. This innovative approach provides a rapid, non-invasive, and cost-effective method for monitoring tomato freshness and quality, reducing food waste and ensuring food safety. DFT calculations and molecular docking studies further support the findings of this research.

Keywords: Flavonoids, Visual naked-eye biosensor, Bacterial detection, pH-sensing, Sulfur, nitrogen doped carbon dots, Food packaging.

WASTE TO WEALTH: INSIGHTS FROM THE CASSAVA PEEL VALUE CHAIN MANAGEMENT IN SOUTHWESTERN NIGERIA

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ABSTRACT

The Cassava peel value chain can contribute significantly to the bio-economy of Nigeria. However, the cassava peel value chain is weak and there is a paucity of information about the value chain actors. We thus analyzed the profitability of participating in the cassava peel value chain and examined the constraints faced by these actors using descriptive statistics, Semantic differential scale, gross margin analysis, and Ordinary Least Square regression analysis. The study relied on primary data obtained from 438 cassava peel value chain actors randomly selected from three States in Southwestern Nigeria. Our result reveals that the majority of the cassava peel actors are peelers, 183 (41.78%), and local processors, 190 (43.37) who rely mainly on traditional processing methods. The actors realize an average monthly gross margin of ₦54, 641 ($ 54.83). The monthly expenditure. monthly income, education, and household size of actors are the drivers of profitability (P value, 0.05). The instability of cassava prices, inadequate access to credit facilities, and the high cost of hiring labour are the pressing constraints faced by the actors. Efforts should be geared towards the stabilization of cassava prices as well as the offering credit facilities to enhance overall productivity of the cassava value chain.

Keywords: cassava peel, value chain, waste, profitability

FUSARIUM WILT OF A TOMATO: A REVIEW

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ABSTRACT

Tomato is one of the most significant commercial crops. All across the world, tomatoes are grown commercially. This crop has higher chances of disease attack. One of the most significant diseases of tomato crops is *Fusarium* wilt, which is caused by *Fusarium oxysporum* f sp. *lycopersici*. Tomato yield is greatly reduced by this disease. The pathogen *Fusarium oxysporum* f sp. *lycopersici* is a soil borne pathogen and can transmit disease through soil in tomato plants. This fungus firstly enters the vascular plant tissues of the roots through the soil, where it causes wilting of the plant and eventually causes the plant death. The major symptoms of Fusarium wilt include plant wilting, discolouration of the lower leaves, and drying of the leaves. The use of suitable management approaches is essential in field and greenhouse settings to prevent Fusarium wilt. This review paper provides a comprehensive overview of the main diseases of tomato crop that is *Fusarium* wilt, its symptoms, cause of infection, disease development, life cycle of the pathogen, disease epidemiology, disease ecology and novel methods in the control of the pathogen.

The study of *Fusarium* wilt is very important mainly in the tomato crop because it causes great loss in the commercial production of tomato crop.

Keywords: Crop, disease, Fusarium, infection, tomato, wilting and pathogen.

NUTRITIONAL VALUE OF SOME RARE VARIETIES OF DATES FROM SOUTHERN ALGERIA

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ABSTRACT

This study was conducted to determine the morphological and physicochemical parameters necessary to characterize the different stages of maturation (Tamr) of seven varieties of dates with varying consistencies: Amrane, Tamdjouhert, Tezerza, Takrbouchet, Tantbouchet, Tenisin, and Tanselit.

The research found that soft and semi-soft dates are dark in color, tender in texture, and fragrant in taste. These two classes of dates differ in several physicochemical factors, some of which significantly affect the characterization of the fruit.

The study highlighted an interesting variability among the seven varieties of dates: Amrane, Tamdjouhert, Tezerza, Takrbouchet, Tantbouchet, Tenisin, and Tanselit. Our work identified various morphological, physicochemical, and biochemical characteristics of the dates, including weight, dimensions, water content, pH, electrical conductivity, ash content, titratable acidity, reducing sugars, mineral elements, and total sugar levels.

The weight of the dates studied ranged from 5.68 to 15.01 grams, while the weight of the pulp varied from 4.79 to 9.25 grams. The length of the dates was between 18.84 and 50.30 mm, and the diameter ranged from 11.72 to 25.32 mm. The water content was between 17.66% and 22.74%, and the pH values, which were slightly acidic, ranged from 5.01 to 6.21. Electrical conductivity ranged from 0.00 to 9.00, titratable acidity was low (0.02%–0.89%), total sugar levels ranged from 29.16% to 57.03%, reducing sugar content varied from 51.86% to 77.62%, and potassium (K+) content ranged from 770.97 to 1070.36.

Overall, the determination of the nutritional value of the studied date varieties, which have different characteristics, was based on biometric analysis. This analysis showed that the length and weight of the dates and stones varied considerably among the varieties. Similarly, the physicochemical and biochemical analyses confirmed this variability.

According to the analyses conducted, the varieties Tanselit, Amrane, and Takrbouchet stand out from the others due to their favorable characteristics across all studied parameters, followed by Tamdjouhert and Tantbouchet in the second position. In contrast, Tezerza and Tenisin exhibited less favorable characteristics in three of the studied parameters.

The importance of these analyses lies in their ability to enable quality control of dates based on their degree of maturity, using not only classical morphological criteria but also biochemical criteria. This evaluation provides a comprehensive understanding of the morphological (weight and size), nutritional (sugar content, mineral elements), and functional values of the dates.

Keywords: date palm, rare varieties, arid region, nutritional value, valorization.

CONTEMPORARY APPROACHES IN ANIMAL BREEDING AND THEIR IMPACT ON SUSTAINABLE AGRICULTURE

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ABSTRACT

Agriculture and animal breeding are vital sectors that contribute significantly to the global food supply chain and rural economies. The development of sustainable agricultural practices integrated with advanced veterinary science has become increasingly important to ensure livestock health, productivity, and welfare. This study aims to analyze contemporary approaches in animal breeding techniques and their impact on agricultural sustainability. Emphasis is placed on genetic selection, nutritional management, and disease prevention strategies to enhance animal performance and resilience. The research employs a multidisciplinary methodology combining field surveys, laboratory analyses, and statistical modeling to provide a comprehensive overview of the current trends and challenges in the sector. The findings indicate that integrated management practices significantly improve productivity and animal welfare, while also contributing to environmental conservation. Furthermore, the role of veterinary interventions in mitigating disease outbreaks and enhancing reproductive efficiency is highlighted as a critical factor for successful breeding programs. This paper underscores the necessity for continuous innovation, capacity building, and policy support to promote the adoption of best practices among farmers and breeders. In conclusion, the synergistic relationship between agriculture, animal breeding, and veterinary science holds the key to achieving sustainable food systems and rural development. Future research should focus on emerging technologies such as genomic selection and precision farming to further optimize production systems. This study provides valuable insights for policymakers, researchers, and practitioners aiming to advance sustainable agricultural and animal breeding practices.

Keywords: Agriculture, Animal Breeding, Veterinary Science, Sustainable Development

LAND, WATER AND BORDERS: THE GEOPOLITICAL CONTEST OVER AGRİCULTURAL RESOURCES IN SOUTH ASIA

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ABSTRACT

South Asia, home to nearly a quarter of the world's population, faces an intensifying struggle over agricultural resources driven by the intertwined dynamics of land scarcity, water insecurity, and contested borders. This research explores the geopolitical contest surrounding agricultural resources in the region, focusing on how land and water have become tools of both cooperation and conflict among South Asian states. Employing a mixed-method approach, the study combines qualitative case studies with quantitative data analysis to provide a holistic understanding of the issue. Qualitatively, the research examines key bilateral and multilateral tensions involving India, Pakistan, Bangladesh, Nepal, and China such as disputes over the Indus Waters Treaty, the Teesta River, and borderlands in Ladakh and the Siliguri Corridor. Through document analysis, elite interviews, and media discourse, the study uncovers how political narratives, historical grievances, and regional ambitions shape the geopolitics of agriculture. Quantitatively, the study utilizes satellite imagery, hydrological data, and agricultural productivity statistics from 2000 to 2024 to map changes in land use, irrigation patterns, and crop yields. Correlation and regression analyses assess the impact of transboundary water flows, land acquisition, and climate variability on food security and rural livelihoods. Findings indicate a growing interdependence among South Asian countries on shared natural resources, yet increasing politicization of resource access exacerbates mistrust and strategic competition. The paper concludes by advocating for regional frameworks that prioritize sustainable agricultural practices, equitable resource sharing, and conflict-sensitive policies. By integrating geopolitical analysis with empirical data, this study contributes to the broader discourse on resource governance, climate resilience, and regional stability in South Asia offering timely policy insights in an era of environmental and political uncertainty.

RECOMBINANT DNA TECHNOLOGY AS TOOL FOR THE PRODUCTION OF POULTRY FEED ENZYMES

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ABSTRACT

Poultry sector is one of the major established industries of Pakistan that is committed to provide valuable meat to our community. Phytases, cellulases, xylanases and proteases are the main enzymes being added in the poultry feed. The addition of these enzymes is important because their addition in feed put a positive impact on the growth of poultry bird. Phytases are responsible for the availability of free phosphorus while the xylanases and cellulases are responsible for the availability of monomeric absorbable sugars for the growth of bird whereas proteases also involve for the improvement of digestion of proteins. In the absence of these enzymes the phytate, cellulose and xylan are not being digested by the poultry bird and these components of feed simply pass through the digestive track and are removed from the body with manure and contribute in environmental pollution.

In the current study the phytase, cellulase and xylanase genes from hyper-thermophilic bacterium were amplified by using the PCR and ligated into the cloning vector pTZ57R/T. These vectors were transferred in the *E.coli* DH5α cells. The expression of phytase, cellulase and xylanase genes were analyzed in *E.coli* BL21CodonPlus cells with the help of pET expression system. Recombinant proteins were purified through different chromatographic techniques and their molecular masses were determined through SDS-PAGE. Recombinant proteins were characterized. The locally produced recombinant enzymes were utilized for supplementation of poultry feed to examine their effect on the growth of poultry birds. The supplementation of poultry feed with locally produced enzymes showed significant growth enhancing effect on poultry birds and improved the feed uptake and feed conversion ratio.

Keywords: Poultry enzymes, Recombinant proteins, hyper-thermophilic bacterium

INVESTIGATING THE ROLE OF BACILLUS SUBTILIS BIOPRIMING TO ENHANCES SALT-STRESS TOLERANCE IN SOYBEAN VARIETIES

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ABSTRACT

Crop growth and productivity are highly important in the agricultural sector, and salt stress is a major challenge for the germination and survival of salt-sensitive crops. Biopriming is a promising solution for mitigating the negative effects of salt stress. To evaluate the effects of *B. subtilis* biopriming, a bacterial suspension was prepared, and seeds of the different varieties were soaked in the suspension for 4 hours in darkness. Compared with wild type, the germination percentage of the seeds bioprimed by *B. subtilis* but not stressed improved by 7% in both varieties. In contrast, the T4 and T5 treatments (*B. subtilis* primed and challenged with salt stress) resulted in 11% and 19% (in the salt-tolerant variety) and 35% and 34% (in the salt-sensitive variety) improvement in the percentage of germination compared with that of nonbioprimed salt-stressed seeds (T1 and T2). Similarly, *B. subtilis* bioprimed salt-stressed plants (T4 and T5) presented increases (4% and 10%) in terms of root length and number of nodes (18% and 20%) in the salt-tolerant variety, whereas 26% and 9% increases in root length and 34% and 35% increases in the number of nodes were recorded in the salt-sensitive variety compared with those in the salt-stressed nonbioprimed plants (T1 and T2). Additionally, the salt-tolerant variety treated with *B. subtilis* and salt-stressed plants presented 50% and 35% increases, whereas the sensitive variety presented 29% and 63% increases in SOD activity. POD activity was shown to be increased by 22% and 15% in the salt-tolerant variety, and 21% and 13% increases were observed in the salt-sensitive variety compared with the nonbiotrimed salt-stressed (T1 and T2) plants. In contrast, *B. subtilis* bioprimed salt-stressed plants (T4 and T5) presented 15% and 33% decreases in the Na^+/K^+ ratio, respectively, in the salt-tolerant variety but 12% to 48% in the salt-sensitive variety in comparison with nonbioprimed salt-stressed (T1 and T2) plants. The relative gene expression of *GmSOS1* was shown to be upregulated by up to 33% in the salt-tolerant variety and 32% in the salt-sensitive variety in the *B. subtilis* bioprimed salt-stressed plants compared with the nonbioprimed salt-stressed plants. Taken together, our results show that seed biopriming with *Bacillus subtilis* could be an effective solution for improving plant stress tolerance by activating plant defense mechanisms and salt stress tolerance pathways at the molecular level and may be adopted by farmers in the future.

Keywords: *Bacillus subtilis*, NaCl stress, biopriming, soybean

SILICON-MEDIATED MITIGATION OF CLIMATE CHANGE IMPACTS ON WHEAT PRODUCTION IN MENA: PHYSIOLOGICAL AND AGRONOMIC INSIGHTS

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ABSTRACT

Wheat (Triticum aestivum L.) is a cornerstone of human nutrition and health, particularly in the Middle East and North Africa (MENA) region, where it plays a crucial role in sustaining livelihoods and ensuring food security. However, climate change poses significant threats to wheat production through escalating heat, drought, and salinity stresses. These abiotic stressors reduce wheat yields by impairing physiological processes and triggering defense mechanisms that compromise plant growth and productivity. This study explores the role of silicon (Si) as a mitigating agent against these climate-induced challenges. By applying Si at optimal rates, timing (aligned with wheat phenology), sources (e.g., potassium silicate vs. nano-Si), and methods (fertigation or foliar spray), we observed notable improvements in wheat resilience. Silicon supplementation enhanced water use efficiency, enabling plants to better cope with drought, while also bolstering physiological responses such as photosynthesis, antioxidant activity, and nutrient uptake under heat and salinity stress. These adaptations collectively minimized yield losses and strengthened the plant's defense mechanisms. Our findings highlight the agronomic and physiological insights into Si-mediated stress alleviation, offering a promising strategy for sustaining wheat production in MENA amid worsening climate conditions. This approach could serve as a scalable, practical solution to safeguard food security in vulnerable regions facing similar environmental pressures.

YOUTH AS CATALYSTS FOR AGRICULTURAL TRANSFORMATION IN THE DIGITAL ERA

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ABSTRACT

The digital era presents unprecedented opportunities to revolutionize agriculture and attract a new generation of young farmers. With access to emerging technologies such as precision farming, artificial intelligence, drones, remote sensing, mobile-based advisory platforms, and digital marketplaces, today's youth have the potential to lead a transformation in agricultural practices. This paper explores the dynamic role of youth as key drivers of digital innovation in agriculture, examining how their digital literacy, entrepreneurial mindset, and adaptability can reshape the sector for improved productivity, sustainability, and profitability. Using a mixed-method approach that includes surveys and case studies from various regions, the study highlights successful youth-led Agri-initiatives that leverage technology to address challenges such as low yields, labor shortages, and market inefficiencies. The findings reveal that while digital tools are increasingly accessible, gaps in training, awareness, infrastructure, and policy support continue to hinder full-scale adoption. However, youth who are digitally empowered are more likely to engage in agri-business ventures, adopt climate-resilient technologies, and promote sustainable farming methods. The paper concludes by emphasizing the need for youth-centered agricultural policies, digital skill development programs, and inclusive innovation platforms to harness the full potential of young change makers. Encouraging youth participation not only ensures the modernization of agriculture but also contributes to rural development, food security, and job creation in the agricultural value chain. As digital natives, youth are uniquely positioned to act as catalysts for agricultural transformation.

Keywords: Youth Empowerment, Digital Agriculture and Agri-Tech Innovation

AGRICULTURAL BIOTECHNOLOGY FOR SUSTAINABLE DEVELOPMENT GOALS: A HOLISTIC APPROACH FOR ECOSYSTEM RESTORATION, ENVIRONMENTAL CONSERVATION, AND SUSTAINABLE RESOURCE MANAGEMENT

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ABSTRACT

The United Nations' 2030 Agenda for Sustainable Development addresses the importance of food security and nutrition, while acknowledging the role of sustainable agriculture in ending hunger, achieving food security, and promoting healthy nutrition for all people worldwide. On the one hand, the Organization for Economic Co-operation and Development focuses on analyzing the linkages between the sustainable agriculture practices and the specific Global Goals, and, on the other hand, the Food and Agriculture Organization of the United Nations emphasis that biotechnology represents an impressive promising tool in creating sustainable agriculture for improving soil health, enhancing nutrient cycling, and ensuring environmental sustainability. These days, navigating the agricultural biotechnology sector tackles innovation for inclusive and resilient food production by revolutionizing production for sustainable growth, while offering science-driven solutions for building sustainable food systems. The research draws on the advantages of biotechnology in supporting biodiversity and sustainable agriculture. Likewise, it stresses some concerns and risks raised by the development and applications of biotechnology. The literature review section presents the outcomes highlighted by important international organizations in their recently published reports centered on biotechnology for Sustainable Development Goals, while examining the potential of eco-friendly farming techniques and the interdisciplinary efforts to integrate biological sciences with environmental and technological solutions targeting sustainable long-term solutions. Several case studies are displayed in order to promote various innovative approaches for agricultural biotechnology based on developing strategies for pollution mitigation, resource recovery, and ecosystem restoration. Results show the necessity of the holistic systems approach and the synergies between harnessing biological systems and processes in agriculture, while addressing economic profitability, social equity, and environmental conservation and preservation.

Keywords: Agricultural Biotechnology; Nature-Positive Agriculture; Agro-Ecology; Regenerative Agriculture; Environmental Quality; Risk Management; Food Management; Wealth Creation; Ecological Restoration; Economic Growth; Collective Knowledge; Competitiveness; Fair Value.

A CRITICAL ANALYSIS OF THE ROLE OF WOMEN IN AGRICULTURE AND ANIMAL WELFARE IN RELATION TO THE SUSTAINABILITY OF RURAL FOOD SYSTEMS

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ABSTRACT

Women represent a substantial segment of the global agricultural workforce, yet they consistently face systemic barriers that hinder their full participation and recognition in the agriculture and animal welfare sectors. These challenges include limited access to land ownership, financial services, education, and technology-critical components for enhancing productivity and sustainability in rural food systems. In many regions, entrenched cultural norms and discriminatory policies further exacerbate these disparities, restricting women's agency and decision-making capacities within their communities. Despite these obstacles, women's contributions are indispensable to the advancement of sustainable agricultural practices and the assurance of food security. Their active involvement in agroecology, biodiversity preservation, and the implementation of climate-resilient farming techniques has been pivotal in fostering environmental sustainability. Furthermore, women's participation in animal husbandry is crucial for maintaining animal welfare standards and augmenting livestock productivity. By integrating traditional knowledge with innovative practices, women have effectively managed livestock health and contributed to the diversification of rural economies. Nevertheless, their contributions frequently remain undervalued and underreported, leading to a lack of targeted support and resources. Addressing these gender disparities necessitates the implementation of policies that promote equitable access to resources, education, and decision-making platforms for women. Empowering women in agriculture and animal welfare not only enhances the resilience and sustainability of rural food systems but also drives broader socio-economic development. Recognizing and supporting women's roles in these sectors is imperative for achieving global food security and sustainable development goals.

Keywords: *Women in Agriculture, Animal Welfare, Sustainable Agricultural Practices, Rural Food Systems, Gender Disparities in Agriculture.*

EFFECT OF GREEN AND HAY ALFALFA ON MILK QUALITY AND QUANTITY

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ABSTRACT

Algeria has a chronic shortage of milk and dairy products, mainly due to poor livestock feed in terms of quantity and quality. The aim of this study was therefore to investigate the influence of feeding green alfalfa and hay on the production and physical and chemical composition of milk. Twelve Pie noire dairy cows were allocated for the experiment. The experiment consisted of two periods of four weeks each, during which green alfalfa was compared with two control diets based on green barley and green sorghum, while a diet based on alfalfa hay was compared with a diet based on alfalfa hay. The results show that the introduction of alfalfa green at the budding stage and as hay in the ration of dairy cows resulted in a significant increase in milk production, protein content, non-fat dry matter and milk density compared with the other control diets, while no significant increase was recorded for the other physico-chemical parameters of the milk (fat content, lactose content, acidity and freezing point). At the flowering stage, milk production and physico-chemical parameters did not increase significantly.

Keywords: *Alfalfa, milk production, cows, Algeria.*

SOCIAL CAPITAL AND ENTREPRENEURIAL INTENTIONS AMONG WOMEN FARMERS IN PUNJAB, PAKİSTAN

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ABSTRACT

Entrepreneurship is an important driver of economic development, innovation, economic competition, and social mobility in societies, particularly in rural areas. Women business owners are regarded as successful due to their intense drive and capacity for efficient economic growth. However, women are tied up with strong social and cultural norms, which may hinder them from achieving their aim to be entrepreneurs. This study investigated women's intention to engage in entrepreneurial activities by analyzing their intention in the light of social capital theory. For this purpose, data was collected from 120 rural women of Punjab province through a purposive sampling technique. Quantitative techniques guided the key factors affecting rural women in generating new businesses, which were further explored using the order probit model to assess the direct impact of social capital on women's entrepreneurial intentions at the community's wider level. The results showed that Participation in the local community (PLC) and feeling of trust and safety (FTS) have significantly increased the intention of rural women. The findings suggested that entrepreneurship programs in rural communities can be successful and more effective if the development agencies focus on neighborhood connection along with friend and family support.

Keywords: Entrepreneurial Intention, Rural women, Social Capital, Local economic development

POTATOES, PEPPER, LAMB, TOMATO: TURKISH COMPONENTS OF HUNGARIAN GASTRONOMY AS PARTS OF THE MULTICULTURAL HERITAGE

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ABSTRACT

The great Turkish sultan Süleyman the Magnificent captured Buda, the capital city in 1541, and Hungary since that time was partitioned into three parts: the Turkish occupation in the central part, growing more and more, and the tiny Hungarian Kingdom in the West and North, being a province of the Habsburg Empire, and Transylvania in the East, being a vassal state of the Ottoman Turkish Empire, ruled by the Princes of Transylvania. Ottoman Turks contributed much to the cultural heritage: we Hungarians eat potatoes, cultivate wonderful roses, and visit wellness baths in five-hundred-year-old Turkish buildings (such as in Budapest and Eger), that have remained for us as the valuable Turkish cultural heritage. (Papp, 2018) The Hungarian archaeologist Győző Gerő excavated more than a hundred Turkish buildings in Hungary and restored some of them, which are still working as baths or a small mosque as a türbe of Gül Baba in Buda. (Gerő, 1980) The Turkish State awarded him in the last part of the 20th century for his great, lifelong work on the Turkish cultural heritage in Hungary. (Dávid, 2016)

The background principle of this paper is, that the Turkish cultural heritage became an organic part of the Hungarian culture, such as the baths at medical waters, the rose motifs in the folk-tales rose gardens around the houses, as well as potatoes in the Hungarian foods, and still other elements of the built and intellectual heritage. We aim to pay attention to the multiculturality of the Hungarians and any nation and emphasize the Turkish contribution.

Tomato, poppy, and eggplant are also of Turkish origin. But what is especially important in Hungarian culture: Hungarian wine grapes are called Hungarian characteristics, and today's nationalist Hungarians are proud that American California grapes were brought to California by Hungarian immigrants. However, grape culture was developed by the Turks in the Hungarian Plain, which is the Turkish occupation zone. They did not make wine from it, they brought sweet white grape varieties to Hungary.

Keywords: Hungary, Ottoman, food, cultural_heritage, Early_Modern_Age.

AGRO-PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF THE 'ANGELINO' CULTIVAR (*Prunus salicina* L) UNDER CONDITIONS OF DROUGHT AND HEAT STRESS

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ABSTRACT

This study examines the impact of deficient irrigation and high temperatures on the levels of growth, production and physico-chemical quality of the plum cultivar 'Angelino' (*Prunus salicina* L). The study was conducted in the field of the National Agricultural Research Institute (INRA) experimental estate at 'Ain Taoujdate'. Two stress treatments were applied, namely a drought stress (DS) level of 50% of crop evapotranspiration (ETc), and exposure to a heat stress (HS) of 2.5°C, were compared with on-demand irrigation (100% of ETc) not under thermal stress, during the fruit development period from the fruit set stage until harvest time. Observations were made on various traits that could be stress descriptors, including fruit yield, certain vegetative growth characteristics including shoot length, number of leaves and leaf area, as well as physiological characteristics such as stomatal characteristics, leaf proline, cuticular wax and chlorophyll a and b pigment content, with some chemical and biochemical components of plum quality. The results obtained showed that the effect of drought and heat stress reduced plum productivity by a general average of 61%, vegetative growth also declined by 49% and physiological characteristics decreased by 48% except proline and cuticular wax, although the taste quality of plums has been improved thanks to increases in the content of sugars, amino acids and polyphenols. This illustrates the need for agriculture in the study area to adapt to the conditions imposed and predicted by climate change in terms of water resources and high temperatures.

Keywords: *Prunus salicina* L, Drought stress, Temperature, Production, Growth, Quality.

ACCESS AND USE OF INFORMATION AND COMMUNICATION TECHNOLOGY AMONG RICE FARMERS IN ISHIELU, EBONYI STATE, NIGERIA

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ABSTRACT

The study assessed the use of information and communication technology among rice farmers in Ishielu, Ebonyi State, Nigeria. Multistage sampling procedure was used to select a hundred and twenty respondents for the study. Data were analysed with frequencies, mean scores and regression analysis. Results show that 63.3% of the respondents were above 30 years with 22.2% not having formal education. The main sources of agricultural information were mass media (67%), extension services (34%), and fellow farmers (32%). Majority of the respondents (66.72%) had access to information and communication technology. Factors that influenced rice farmers access to information communication technology include education, income, membership of cooperative society and extension contact. Some of the challenges of accessing information and communication technology include high cost (73.4%), low level of digital literacy (67.3%), inadequate access to power supply (54.8%), and high cost of maintenance of ICT tools (48.7%). The study concludes that rice farmers have adopted ICTs and recommends that government should subsidize the cost of ICT and improving power supply in the rural areas.

Keywords: Mass media, extension contact, power supply.

DYEING OF COTTON WITH REACTIVE DYES USING MICROWAVE TREATMENTS

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ABSTRACT

Sustainable textile is the demand of global community. The study has been concerned with the utilization of radiation as sustainable tool for dyeing of cotton with reactive dye. Dyeing parameters were assessed and shades made were evaluated as per ISO standards. The study findings show that if cotton treated for 6 min is used to dye with reactive dye of 7pH at 80 ℃ for 50 min, than good shade are found. Colourfastness ratings have been improved if shades are made at selected condition. It is informed that these MW-rays have potential to improve the dyeing of fabrics with dyes.

Keywords: Cotton, Colorfastness, Green products, ISO Standards, MW Radiations, Sustainability

THE LEGAL DIMENSIONS OF FOOD SECURITY IN THE CONTEXT OF AGRICULTURAL DEVELOPMENT POLICY: A CRITICAL ANALYSIS OF REGULATORY APPROACHES AND GOVERNANCE MECHANISMS

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ABSTRACT

Food security constitutes a fundamental objective within global development agendas, particularly in regions where agricultural sustainability, economic resilience, and legal governance are intricately connected. As agricultural development policies adapt to the challenges posed by population growth, climate change, and resource scarcity, the legal framework underpinning these policies plays a crucial role in fostering equitable and resilient food systems. This study undertakes a critical analysis of the legal dimensions of food security within the context of agricultural development policy, with a particular focus on how regulatory structures and governance mechanisms facilitate or impede the realization of the right to adequate food. Employing an interdisciplinary legal methodology, the study examines international, national and regional legal instruments, including soft law mechanisms, constitutional provisions, statutory regulations, and institutional mandates. Particular emphasis is placed on the extent to which food security objectives are embedded in agricultural legislation, land tenure regimes, investment laws, and environmental governance. The study further evaluates the coherence, effectiveness, and accountability of institutional frameworks responsible for implementing food security measures. Comparative case studies from both developed and developing economies are utilized to illuminate diverse regulatory approaches, identify normative and institutional gaps, and highlight best practices. The findings reveal an urgent need for comprehensive legal frameworks that integrate food security within broader development strategies, while simultaneously advancing social equity, environmental sustainability, and human rights compliance. Ultimately, the research advocates for a rights-based and participatory legal paradigm, reframing food security not merely as a policy aspiration but as a legally enforceable entitlement grounded in both international and domestic legal obligations.

Keywords: *Food Security, Agricultural Development Policy, Legal Frameworks, Governance Mechanisms.*

ENVIRONMENTALLY SUSTAINABLE PEST MANAGEMENT STRATEGIES AGAINST *Frankliniella occidentalis* (WESTERN FLOWER THRIPS)

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ABSTRACT

In protected cultivation systems, a wide range of pest species adversely affect crop quality and yield, either directly or indirectly. Globally, insect-related crop losses in greenhouse production are estimated to reach approximately 40%, while in Turkey, this figure is around 35%. To date, seven major thrips species have been identified as key contributors to yield losses in greenhouse environments. Among these, *Frankliniella occidentalis* (Western flower thrips) is recognized as one of the most economically significant species, infesting over 600 plant species, including both ornamental and horticultural crops, in greenhouse and open-field conditions. *F. occidentalis* causes both direct and indirect damage to host plants. Direct damage is associated with the pest feeding on young leaves, flowers, and fruits, resulting in leaf curling, discoloration, and fruit deformation. Indirect damage arises from its capacity to act as a vector

for plant viruses, leading to substantial economic losses. In some instances, the presence of this pest necessitates the destruction of entire crops to prevent further viral transmission. Owing to its adaptability to a wide host range, rapid life cycle, high reproductive capacity, and ability to develop resistance to synthetic chemical insecticides, *F. occidentalis* has become a pervasive and resilient pest in modern agriculture. Chemical insecticides remain the predominant method employed for the management of *F. occidentalis*. However, their indiscriminate and excessive use has contributed to resistance development and the suppression of natural enemies. While chemical agents can effectively suppress pest populations, the implementation of rotation strategies is recommended to mitigate resistance development. The excessive and unconscious use of chemical methods in the control of harmful organisms in cultivated plants has caused serious adverse effects on human, animal, and environmental health. This situation has led producers to seek alternative and environmentally friendly methods. In this context, biological control methods have come to the forefront, and the use of biological agents such as predatory insects, entomopathogenic fungi (EPF), entomopathogenic nematodes (EPN), and plant growth-promoting rhizobacteria (PGPR) has become increasingly widespread. The combined use of these agents within the framework of integrated pest management strategies plays a significant role in the effective and sustainable control of pests. This review investigates the potential use of entomopathogenic agents as environmentally sustainable alternatives to chemical control methods for the management of the Western Flower Thrips (*Frankliniella occidentalis*), and evaluates current strategies based on recent findings in the scientific literature.

Keywords: Biological Control, *Frankliniella occidentalis*, Protected Cultivation, Sustainable Agriculture

BATI ÇİÇEK TRİPSİ (*Frankliniella occidentalis*) ZARARLISINA KARŞI SÜRDÜRÜLEBİLİR VE ÇEVRE DOSTU MÜCADELE YÖNTEMLERİ

ÖZET

Örtü altı tarımda, ürün kalitesini ve verimini doğrudan veya dolaylı olarak olumsuz yönde etkileyen pek çok zararlı bulunmaktadır. Örtü altı tarım alanlarında böcekler nedeniyle meydana gelen ürün kaybı, dünya genelinde %40 seviyelerindeyken, Türkiye'de bu oran %35 civarındadır. Bugüne kadar, örtü altı tarım alanlarında ürün kaybına neden olan yedi önemli trips zararlısı tespit edilmiştir. Bu zararlılardan biri, hem seralarda hem de açık alanlarda, süs bitkileri ve bahçe bitkileri dahil olmak üzere 600'den fazla bitki türüne zarar veren *Frankliniella occidentalis* (Batı çiçek tripsi) türüdür. *F. occidentalis*, bitkiler üzerinde doğrudan ve dolaylı zararlar yaratmaktadır. Doğrudan zarar, bitkilerin genç yapraklarını, çiçeklerini ve meyvelerini emerek beslenmesiyle başlar. Bu beslenme sonucu bitkilerde yaprak bükülmeleri, renk değişiklikleri ve meyve deformasyonları gözlemlenir. Dolaylı zarar ise, bu zararlının bitki virüslerini taşıması nedeniyle önemli ekonomik kayıplara yol açmasıdır. *F. occidentalis*'in varlığı, tarımda büyük ekonomik kayıplara yol açmakta olup, virüsün yayılmasını önlemek amacıyla bazen tüm mahsullerin imha edilmesi gerekmektedir. Bu zararlı, geniş bir bitki yelpazesinde uyum sağlayabilen ve dünya çapında birçok üründe zarar veren bir türdür. Kısa yaşam döngüsü, yüksek üreme potansiyeli, geniş konak bitki yelpazesi ve sentetik kimyasal insektisitlere karşı direnç geliştirme yeteneği gibi faktörler, *F. occidentalis*'i tarım alanlarında önemli bir zararlı hâline getirmiştir. Bu zararlıyla mücadelede en yaygın yöntem kimyasal insektisitlerin kullanımıdır. Ancak, bu insektisitlerin yanlış ve aşırı kullanımı, zararlının direnç kazanmasına ve doğal düşmanlarının zarar görmesine neden olabilmektedir. Kimyasal insektisitler, zararlı popülasyonlarını kontrol altına almada etkili olabilse de, direnç gelişimini önlemek amacıyla bu ürünlerin dönüşümlü kullanımının tercih edilmesi önerilmektedir. Kültür bitkilerinde zararlı organizmalarla mücadelede kimyasal yöntemlerin aşırı ve bilinçsiz kullanımı, insan, hayvan ve çevre sağlığı üzerinde ciddi olumsuz etkilere neden olmaktadır. Bu durum, üreticileri alternatif ve çevre dostu yöntemlere yönlendirmiştir. Bu sebeple özellikle biyolojik mücadele yöntemleri ön plana çıkmakta; predatör böcekler, entomopatojenik mantarlar (EPF), entomopatojen nematodlar (EPN) ve bitki büyümesini teşvik eden rizobakteriler (PGPR) gibi biyolojik ajanların kullanımı giderek yaygınlaşmaktadır. Bu ajanların entegre mücadele stratejileri kapsamında birlikte kullanımı ise, zararlıların etkin ve sürdürülebilir bir şekilde kontrol altına alınmasında önemli bir rol oynamaktadır. Bu derlemede, Batı Çiçek Tripsi (*Frankliniella occidentalis*) ile mücadelede çevre sağlığı ve doğal dengenin korunması amacıyla kimyasal mücadeleye alternatif olabilecek entomopatojenlerin kullanım yöntemleri incelenmiş ve güncel literatür bulguları ışığında değerlendirilmiştir.

Anahtar Kelimeler: Biyolojik Mücadele, *Frankliniella occidentalis*, Örtü Altı Tarım, Sürdürülebilir Tarım

SENSOR TECHNOLOGIES AND CONTROL STRUCTURES IN HYDROPONIC SYSTEMS

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ABSTRACT

Hydroponics is a modern agricultural method where plants are cultivated without soil, using nutrient-rich solutions. In such systems, precise control of environmental conditions is essential for optimal plant growth and productivity. Sensor technologies have become a fundamental component in enhancing automation and efficiency in hydroponic applications.

By integrating sensors, key parameters such as pH, EC (Electrical Conductivity), temperature, humidity, light intensity, and water level can be continuously monitored, allowing for real-time feedback and adjustments. For instance, pH sensors measure the acidity or alkalinity of the nutrient solution, which affects nutrient uptake, while EC sensors evaluate ion concentration to maintain appropriate nutrient levels. Temperature and humidity sensors help manage plant stress, and light sensors optimize the amount of light required for effective photosynthesis. Water level sensors assist in managing the reservoir system efficiently.

These data are processed via microcontroller platforms such as ESP32, Arduino, and Raspberry Pi, which enable the automatic control of components like pumps, lights, fans, and valves. Programming environments such as Arduino IDE, Python, and Node-RED are commonly used for developing control logic. With the integration of Internet of Things (IoT) technologies, remote monitoring is made possible via Wi-Fi and MQTT protocols, while cloud-based data logging and real-time alert systems (e.g., SMS, email, mobile notifications) enhance system responsiveness.

Advanced implementations now include artificial intelligence and machine learning for decision support and irrigation optimization, aiming to improve energy and resource efficiency. Nevertheless, reliable operation depends on regular maintenance and calibration of sensors—especially pH and EC sensors—which must be cleaned and calibrated periodically. Redundant sensor setups are also recommended to ensure data integrity.

In conclusion, sensor-based hydroponic systems not only boost productivity but also contribute to sustainable agricultural practices. These systems are scalable and can be applied across a wide range of production levels, from small-scale setups to large commercial farms. Integrating data-driven technologies into agriculture paves the way for the future of "smart and sustainable farming."

Keywords: Hydroponics, Sensor Technology, IoT-based Agriculture

HİDROPONİK SİSTEMLERDE SENSÖR TEKNOLOJİLERİ VE KONTROL YAPILARI

ÖZET

Hidroponik, bitkilerin toprak kullanılmadan, doğrudan besin çözeltisi ile beslendiği modern bir tarım yöntemidir. Bu yöntemde çevresel koşulların hassas biçimde kontrol edilmesi, bitki gelişimi ve verimliliği açısından kritik öneme sahiptir. Sensör teknolojileri, hidroponik sistemlerin otomasyonunu ve verimliliğini artırmak amacıyla temel bir yapı taşı haline gelmiştir.

Sensör kullanımı sayesinde pH, EC (Elektriksel İletkenlik), sıcaklık, nem, ışık ve su seviyesi gibi parametreler sürekli olarak izlenebilmekte; bu da çevresel değişkenlere anında tepki verilmesini mümkün kılmaktadır. Örneğin, pH sensörleri bitki besinlerinin emilimini etkileyen asit-baz dengesini ölçerken, EC sensörleri çözeltideki iyon yoğunluğunu belirleyerek doğru besin seviyesinin korunmasına yardımcı olur. Sıcaklık ve nem sensörleri, bitkilerin stres düzeylerini kontrol altında tutarken; ışık sensörleri, fotosentez için gerekli olan ışık miktarını optimize etmekte kullanılır. Su seviyesi sensörleri ise rezervuar yönetimini destekler.

Bu veriler, mikrodenetleyici platformlar (ESP32, Arduino, Raspberry Pi) aracılığıyla işlenmekte ve pompa, ışık, fan ya da valf gibi sistem bileşenlerinin otomatik olarak kontrol edilmesini sağlamaktadır. Programlama dilleri ve platformları olarak Arduino IDE, Python ve Node-RED gibi araçlar yaygın şekilde kullanılmaktadır. IoT (Nesnelerin İnterneti) teknolojileri sayesinde bu sistemler Wi-Fi ve Bluetooth gibi protokollerle uzaktan izlenebilir, bulut tabanlı veri kaydı yapılabilir ve anlık bildirim sistemleri oluşturulabilir.

İleri düzey uygulamalarda yapay zeka ve makine öğrenmesi, karar destek sistemleri ve sulama optimizasyon algoritmalarıyla entegre edilerek enerji ve kaynak verimliliği artırılmaktadır. Ancak bu teknolojilerin etkin çalışabilmesi için sensörlerin düzenli bakım ve kalibrasyonu büyük önem taşır. Özellikle pH ve EC sensörlerinin doğru veri üretebilmesi için periyodik kalibrasyon, temizlik ve gerektiğinde yedekli sistem önerilmektedir.

Sonuç olarak, sensör destekli hidroponik sistemler yalnızca üretim verimliliğini değil, aynı zamanda sürdürülebilirliği de artırmaktadır. Bu yapı küçük ölçekli bireysel uygulamalardan büyük endüstriyel seralara kadar geniş bir yelpazede uygulanabilir. Veriye dayalı karar mekanizmalarının tarıma entegrasyonu, geleceğin "bilinçli ve teknoloji destekli" üretim modellerinin temelini oluşturmaktadır.

Anahtar Kelimeler: Hidroponik Tarım, Sensör Teknolojileri, Nesnelerin İnterneti (IoT) Tabanlı Tarım.

A STUDY ON THE USE OF CANNED AND FROZEN AGRICULTURAL PRODUCTS

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ABSTRACT

The ever-renewing and developing technology has changed the habits of societies over time and shaped their cultures. After the industrial revolution, it has been observed that the nutritional habits of individuals and families have changed rapidly with the acceleration of women's participation in economic activities. Variables such as individual habits, attitudes, beliefs and values, age, education, income, marital status are factors that affect individuals' nutritional habits. In addition to these social demographic factors, factors such as easy to cook, delicious, easy to find, quality products, and low price are among the reasons why consumers prefer various food products when purchasing food. Canned and frozen foods have become a visible part of our lives in the age we live in, as they can be prepared both at home and purchased from markets. The aim of this study is to understand the principles of a number of food preservation methods, the superior and deficient aspects of frozen food products, the importance of packaging and environmentally friendly packaging techniques, the details of the production processes of frozen and canned products produced with developing technology, and the perspective of women working in our country on these foods. This study was found to be worth examining in terms of the fact that there are very few studies in our country that reveal the consumption demands, awareness levels, tendencies and consumption patterns of working women for these foods. In this study, which was conducted using the survey method on 211 working women in the city center of Kırşehir, the important finding determined within the scope of the study was that the participants found frozen foods superior to canned products in terms of nutritional content and first-day freshness (67.8%). As a result, ease of use, nutritional value and freshness stand out among the basic factors affecting the frozen food preferences of working women in our study. It was also found that working women preferred frozen foods more in their cooked and frozen forms.

Keywords: Frozen food, canned food, working woman.

KONSERVE VE DONDURULMUŞ TARIM ÜRÜNLERİNİN KULLANIMINA YÖNELİK BİR İNCELEME[1]

ÖZET

Her geçen gün yenilenen ve gelişen teknoloji toplumların alışkanlıklarını zamanla değiştirerek kültürlerine yön vermiştir. Sanayi devriminden sonran kadınların ekonomik faaliyetlere katılımının hızlanması birlikte bireylerin ve ailelerin de beslenme alışkanlıklarının hızla değiştiği gözlemlenmiştir. Bireysel alışkanlıklar, tutumlar, inançlar ve değerler, yaş, eğitim, gelir, medeni durum gibi değişkenler bireylerin beslenme şekline etki eden faktörlerdir. Gıda satın alırken bu sosyal demografik faktörlerin yanı sıra, pişirmesi kolay, lezzetli, bulunması kolay, kaliteli ürün, düşük fiyat gibi etkenler de tüketicilerin çeşitli gıda ürünlerini tercih nedenleri arasındadır. Konserve ve dondurulmuş gıdalar, hem evde hazırlanabilmesi hem de marketlerden satın alınabilmesi nedeniyle içinde bulunduğumuz çağda gözle görülür şekilde hayatımızın bir parçası haline gelmiştir. Bu çalışmanın amacı bir dizi gıda muhafaza yöntemlerinin prensiplerini, dondurulmuş gıda ürünlerinin üstün ve eksik yönlerini, ambalajlamanın önemini ve çevre dostu ambalajlama tekniklerini anlamak, gelişen teknoloji ile üretilen dondurulmuş ve konserve ürünlerin üretim süreçlerinin detaylarını ve ülkemizde çalışan kadınların bu gıdalara bakış açısını ortaya koymaktır. Bu çalışma, ülkemizde çalışan kadınların bu gıdalara olan tüketim talepleri, bilinç düzeyleri, eğilimleri ve tüketim desenlerini ortaya koyan pek az çalışma bulunması bakımından incelenmeye değer bulunmuştur. Kırşehir İli Merkezinde 211 çalışan kadın üzerinde anket yöntemi kullanılarak gerçekleştirilen bu çalışmada, katılımcıların dondurulmuş gıdaları besin içeriği ve ilk günkü tazelik açısından konserve ürünlere göre daha üstün bulmaları (%67,8) çalışma kapsamında belirlenen önemli bulgu olmuştur. Sonuç olarak, çalışmamızda çalışan kadınların dondurulmuş gıda tercihlerini etkileyen temel etmenler arasında kullanım kolaylığı, besin değeri ve tazelik öne çıkmaktadır. Ayrıca çalışan kadınların dondurulmuş gıdaları pişirilmiş ve dondurulmuş haliyle daha çok tercih ettiği bulunmuştur.

Anahtar Kelimeler: Dondurulmuş gıda, konserve, çalışan kadın.

[1] Bu çalışma Filiz HAYKIR tarafından hazırlanan yayınlanmamış Yüksek Lisans Tez çalışmasından türetilmiştir.

A STRUCTURALLY REINFORCED VINEYARD POST DESIGN SUITABLE FOR MASS PRODUCTION BY ROLL FORMING LINE

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ABSTRACT

This study aims to develop a new vineyard post design that can solve structural problems such as tilting and bending of vineyard posts, which are frequently encountered in vineyards. The wooden, concrete and conventional steel poles used in existing systems deform over time due to tensile forces applied to the wires and wind loads, negatively affecting the vineyard yield and the life of the system. As a solution to this problem, a special pole design made of high strength HX340LAD+Z galvanised steel material with U profile and multiple bends was developed.

In the design, a 52x55 mm profile with a total of 10 bends and 12 mm long ear structures inclined inwards by 60° at the edge ends was preferred. This structure both increases the cross-sectional strength and increases the resistance against wind and wire loads. The pole is 2200 mm long and designed to be used as the main supporting element in the vineyard rows.

On three sides of the pole, there are 8 mm diameter holes placed every 100 mm intervals. Thanks to this arrangement, the vine wires can be positioned flexibly according to the desired height and can be adapted to different vineyard layouts. Adjustability makes it possible to easily adapt the system to the development needs of different grape varieties and offers functional advantages to the user.

In the part that is buried in the soil, thanks to the flag-shaped sheet metal attachments welded to the middle of the two sides, it can be stuck into the ground to a depth of 300 mm without the need for excavation and concrete pouring. This structure provides significant convenience in the assembly process in terms of both labour and time.

The proposed vineyard post design has been developed in such a way that it can be produced by pulling it through the roll forming line, which is widely used in the industry. This production method offers a great advantage in terms of both cost and production efficiency with its high precision, reproducible and suitable for mass production. In addition, thanks to roll forming technology, complex bending geometries in the profile can be obtained with high quality.

As a result of the engineering analyses and structural evaluations, it has been determined that the proposed new pole model shows higher performance in terms of leaning and bending resistance compared to conventional tie poles. Developed to be compatible with T and Y type trellis systems, this pole contributes to the long-lasting and durable survival of the vineyard

system in open areas, harsh climatic conditions and sloping terrains. The galvanised steel structure used increases corrosion resistance, allowing the system to offer long-term protection against outdoor conditions.

As a result, this new vineyard post design aims to eliminate the structural weaknesses seen in existing applications, can be produced on the roll forming line, easy to assemble, height adjustable, long-lasting and suitable for field conditions.

Keywords: Vineyard Post Design, Roll Forming, Structural Reinforcement, Corrosion Resistance

ROLLFORM PROSESİYLE SERİ ÜRETİME UYGUN, YAPISAL OLARAK GÜÇLENDİRİLMİŞ BİR BAĞ DİREĞİ TASARIMI

ÖZET

Bu çalışma, üzüm bağlarında sıklıkla karşılaşılan bağ direklerinin yatması ve eğilmesi gibi yapısal sorunlara çözüm getirebilecek yeni bir bağ direği tasarımının geliştirilmesini amaçlamaktadır. Mevcut sistemlerde kullanılan ahşap, beton ve klasik çelik direkler zamanla tellere uygulanan çekme kuvvetleri ve rüzgar yükleri nedeniyle deformasyona uğrayarak bağ verimini ve sistemin ömrünü olumsuz etkilemektedir. Bu probleme çözüm olarak, yüksek mukavemetli HX340LAD+Z galvanizli çelik malzemeden üretilmiş, U profilli ve çok bükümlü özel bir direk tasarımı geliştirilmiştir.

Tasarımda, 52x55 mm ebatlarında, toplamda 10 adet büküm içeren ve kenar uçlarında içe doğru 60° eğimli, 12 mm uzunluğunda kulak yapıları bulunan bir profil tercih edilmiştir. Bu yapı, hem enkesit dayanımını artırmakta hem de rüzgar ve tel yüklerine karşı direnci yükseltmektedir. Direk, 2200 mm uzunluğunda olup, bağ sıralarında ana taşıyıcı eleman olarak kullanılmak üzere tasarlanmıştır.

Direğin üç kenarında, her 100 mm aralıklarla yerleştirilmiş 8 mm çaplı delikler bulunmaktadır. Bu düzenleme sayesinde, bağ telleri istenilen yüksekliğe göre esnek bir şekilde konumlandırılabilmekte ve farklı bağ düzenlerine uyum sağlanabilmektedir. Ayarlanabilirlik özelliği, özellikle farklı üzüm türlerinin gelişim ihtiyaçlarına göre sistemin kolaylıkla adapte edilebilmesini mümkün kılmakta, kullanıcıya işlevsel avantajlar sunmaktadır.

Toprağa gömülen kısmında, iki kenarın ortasına kaynakla birleştirilen bayrak formlu sac eklentiler sayesinde, kazı ve beton dökme işlemlerine gerek kalmaksızın 300 mm derinliğe kadar zemine saplanarak stabil bir duruş sağlanmaktadır. Bu yapı, hem işçilik hem de zaman açısından montaj sürecinde ciddi kolaylık sağlamaktadır.

Önerilen bağ direği tasarımı, sanayide yaygın olarak kullanılan rollform hattı üzerinden çekilerek üretilebilecek şekilde geliştirilmiştir. Bu üretim yöntemi, yüksek hassasiyetli, tekrarlanabilir ve seri üretime uygun yapısıyla hem maliyet hem de üretim verimliliği açısından büyük avantaj sunmaktadır. Ayrıca, rollform teknolojisi sayesinde profildeki karmaşık büküm geometrileri yüksek kalite ile elde edilebilmektedir.

Yapılan mühendislik analizleri ve yapısal değerlendirmeler sonucunda, önerilen yeni direk modelinin yatma ve eğilme direnci açısından geleneksel bağ direklerine göre daha yüksek performans gösterdiği tespit edilmiştir. T ve Y tipi kafes sistemleri ile uyumlu olacak şekilde geliştirilen bu direk, açık alanlarda, sert iklim koşullarında ve eğimli arazilerde bağ sisteminin uzun ömürlü ve dayanıklı şekilde ayakta kalmasına katkı sağlamaktadır. Kullanılan galvanizli çelik yapı, korozyona karşı dayanımı artırarak sistemin dış ortam koşullarına karşı uzun süreli koruma sunmasına olanak tanımaktadır.

Sonuç olarak, bu yeni bağ direği tasarımı, mevcut uygulamalarda görülen yapısal zayıflıkları ortadan kaldırmayı hedefleyen, rollform hattında üretilebilen, montajı kolay, yükseklik ayarlanabilir, uzun ömürlü ve saha koşullarına uygun bir çözüm olarak modern bağcılık sistemlerine katkı sağlayacak niteliktedir.

Anahtar Kelimeler: Bağ Direği Tasarımı, Roll Form Üretim, Yapısal Güçlendirme, Korozyon Direnci

EFFECT OF GROWTH REGULATORS ON THE LEAF MORPHOLOGY OF SPINACH (SPINACIA OLERACEA L.) GROWN UNDER SALT STRESS

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ABSTRACT

The problems posed by global climate change mean that the problems caused by regional climate change are becoming even more prominent. While agricultural land and water resources are directly affected, both pollution and salinization problems are reaching the highest levels. Salinity, to which plants in agriculture are most exposed, is one of the most important abiotic stress problems. This problem significantly reduces yield in agricultural production and deteriorates quality.

In this study, salicylic acid (SA) and proline (P) doses (K= pure water, SA=1.5 mM, P= 0.5 mM) were applied to spinach (Spinacia oleracea L.) plants grown under stress conditions caused by different salinity of irrigation water (0.58 dS/m, 1dS/m, 3dS/m, 7dS/m and 10 dS/m) together with the control (K). For this purpose, the changes in some leaf morphological characteristics of spinach plants were investigated. In the study, the number of leaves increased with increasing salinity. However, the application of proline from growth regulators increased the number of leaves, while the application of salicylic acid decreased it. Apart from this, morphological characteristics decreased with increasing salinity, except at a salinity of 1dS/m. While the highest plant height was observed at a salinity of 1dS/m when salicylic acid was applied, the lowest plant height was observed at a salinity of 10dS/m in the control.

As a result, salinity stress is quite effective in altering leaf morphology. When this change exceeds the threshold of the plants, the plants are negatively affected, while up to the threshold the plants are positively affected by this mild stress. Although growth regulators generally have a positive effect on plant growth and development, salicylic acid (1.5 mM) gave the best results, especially at low salinity. Therefore, growth regulators at appropriate doses in agricultural areas where stress conditions prevail and in plants exposed to stress are an important proposed solution for sustainable agricultural activities.

Keywords: abiotic stress, salinity, growth regulators, morphology, spinach

TUZ STRESİ ALTINDA YETİŞTİRİLEN ISPANAK BİTKİSİNDE *(SPİNACİA OLERACEA L.)* BÜYÜME DÜZENLEYİCİLERİN YAPRAK MORFOLOJİSİNE ETKİSİ

ÖZET

Küresel iklim değişiminin getirdiği sorunlar, bölgesel iklim değişikliğinden kaynaklanan sorunların daha şiddetli görülmesine sebep olmaktadır. Tarımsal alanlar ve su kaynakları doğrudan etkilenirken, hem kirlilik hem de tuzluluk sorunları en üst düzeye çıkmaktadır. Tarımda bitkilerin en çok maruz kaldığı tuzluluk en önemli abiyotik stres sorunları arasında yer almaktadır. Bu sorun tarımsal üretimde verimi önemli derecede düşürüken kaliteyi bozmaktadır.

Bu çalışmada, farklı sulama suyu tuzluluğu (0,58 dS/m, 1dS/m, 3dS/m, 7dS/m ve 10 dS/m) ile oluşturulan stres koşullarında yetiştirilen ıspanak *(Spinacia oleracea L.)* bitkisine, kontrol (K) ile birlikte salisilik asit (SA) ve prolin (P) dozları (K= saf su, SA=1,5 mM, P= 0,5 mM) uygulanmıştır. Bu amaçla; ıspanak bitkisine ait bazı yaprak morfolojik özelliklerindeki değişimler incelenmiştir. Çalışmada, yaprak sayısı artan tuzluluk düzeyi ile artış göstermiştir. Bununla beraber, büyüme düzenleyicilerden prolin uygulaması yaprak sayısını artırırken salisilik asit uygulaması azaltmıştır. Bunun dışında, morfolojik özellikler 1dS/m tuzluluk düzeyi hariç, tuzluluk seviyesi arttıkça azalmıştır. En yüksek bitki boyu 1dS/m tuzluluk düzeyindeki salisilik asit uygulamasında görülürken, en düşük bitki boyu 10dS/m tuzluluk düzeyindeki kontrol konusunda tespit edilmiştir.

Sonuç olarak, tuzluluk stresi yaprak morfolojisinin değişiminde oldukça etkilidir. Bu değişim bitkilerin eşik değerini aştığında, bitkiler olumsuz etkilenirken eşik değerine kadar bitkiler bu hafif stresten olumlu etkilenmektedir. Ayrıca büyüme düzenleyiciler, genel olarak bitkinin büyüme ve gelişiminde pozitif etki göstersede salisilik asit (1.5 mM) özellikle düşük tuzluluk koşullarında en iyi sonucu vermiştir. Bunun için, stress koşullarının yaşandığı tarımsal alanlarda ve strese maruz kalan bitkilerde uygun dozlarda kullanılacak büyüme düzenleyiciler, sürdürülebilir tarımsal faaliyetler açısından önemli bir çözüm önerisi olmaktadır.

Anahtar Kelimeler: Abiyotik Stres, Tuzluluk, Büyüme Düzenleyiciler, Morfoloji, Ispanak

NEGATIVE EFFECTS OF INCORRECT STORAGE AND APPLICATION OF BARN MANURE

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ABSTRACT

This study investigated how improper storage and improper application of barn manure, which is very important for agriculture, affects agriculture and human health.

Traditional agricultural techniques, which began with mankind's transition from hunting and gathering to production, are still valid today. The most important of these is the use of the feces of the animals they feed as "barn manure".

Soil is constantly active because it contains microorganisms and is a source of nutrients for the plants growing on it. Microorganism activities are important for the organic matter content of the soil. Plant nutrients are constantly changing as long as agriculture is carried out or with the effect of rainfall and sunlight. For this reason, soil analysis results are very important for agricultural lands. In this context, barn manure is of great importance both in terms of the organic matter content of the soil and in completing the missing plant nutrients.

In land reclamation works, barn manure is the most effective and correct application method for small farmers to large farmers, from traditional agricultural techniques to organic agricultural practices. However, there are some points to be considered when storing and applying barn manure. If these conditions are not taken into account, barn manure becomes more harmful than beneficial.

This study evaluated how barn manure, instead of being left to rot properly until ready for use, is harmful to villagers and children when it is stored in piles in village squares; how leaving it to burn uncovered and applying it to the field while it is wet threatens the health of the people living in the village; and how wet applied barn manure damages the field from a sociological, health, economic and agricultural perspective.

Key words: Barn manure, Van region, Organic matter

AHIR GÜBRESİNİN YANLIŞ DEPOLANMASININ VE UYGULANMASININ OLUMSUZ ETKİLERİ

ÖZET

Bu çalışmada, tarım için çok önemli olan ahır gübresinin yanlış depolanmasının ve yanlış uygulanmasının tarımı ve insan sağlığını nasıl etkilediği araştırılmıştır.

İnsanoğlunun avcılık ve toplayıcılıktan üretime geçmesiyle başlayan geleneksel tarım teknikleri günümüzde hala geçerliliğini korumaktadır. Bunların en önemlisi de besledikleri hayvanların dışkılarının "ahır gübresi" olarak kullanılmasıdır.

Toprak, içerisinde barındırdığı mikroorganizmalar ve üzerinde yetişen bitkilere besin kaynağı olması sebebiyle sürekli aktiftir. Mikroorganizma faaliyetleri toprağın organik madde içeriği için önemlidir. Bitki besin maddeleri ise tarım yapıldığı sürece veya yağışlarla ve güneş ışınlarının etkisiyle sürekli değişkenlik gösterir. Bu sebeple toprak analiz sonuçları tarım arazileri için çok önemlidir. Bu bağlamda, hem toprağın organik madde içeriği açısından hem de eksik bitki besin maddelerinin tamamlanması açısından ahır gübresinin önemi büyüktür.

Arazi ıslah çalışmalarında, küçük çiftçiden büyük çiftçiye, geleneksel tarım tekniklerinden organik tarım uygulamalarına kadar ahır gübresi en etkili ve doğru uygulama şeklidir. Ancak ahır gübresinin depolanmasından uygulanmasında dikkat edilmesi gereken hususlar vardır. Eğer bu şartlar dikkate alınmazsa ahır gübresi faydadan ziyade zarara dönüşmektedir.

Bu çalışma ile ahır gübreleri kullanıma hazır hale gelene kadar doğru bir şekilde çürümeye bırakılmayıp, köy meydanlarında yığılmalar şeklinde depolanmasının hem köylüye, çocuklara nasıl zarar verdiği; üstü açık yanmaya bırakılmalarının, yaş iken tarlaya uygulamalarının hem köyde yaşayan insanların sağlığını nasıl tehdit ettiği, hemde yaş uygulanan ahır gübrelerinin tarlaya nasıl zarar verdiği sosyolojik, sağlık, ekonomik ve tarımsal açıdan değerlendirilmiştir.

Anahtar Kelimeler: Ahır gübresi, Van bölgesi, Organik madde

DETERMINATION OF HERBAGE YIELD AND QUALITY CHARACTERISTICS OF SOME SOYBEAN VARIETIES IN MAIN CROP CONDITIONS UNDER TOKAT CONDITIONS

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ABSTRACT

This research was carried out to determine the herbage yield and quality characteristics of some soybean cultivars under main crop conditions in Tokat-Kazova conditions in the field of Tokat Gaziosmanpaşa University Agricultural Research and Application Centre between 2021-2022. The study was carried out according to the randomized complete block experimental design with three replications. Adasoy, Cinsoy Mersoy, Nazlıcan, Türksoy, Umut 2002, Yemsoy and Yeşilsoy soya varieties were used as plant material in the study. Soybean plants were harvested at the R6 stage (in one of the last four nodes on the main stem, the seed is filled in the pod and is green in colour). In the study, plant height, stem diameter, branch number, leaf ratio, forage yield, dry matter yield, crude protein content, crude protein yield, ADF and NDF contents were determined.

According to the results of the two-year research, it was determined that Adasoy and Yesilsoy varieties can be grown if high herbage yield is desired to be obtained from soya bean as a main crop in Tokat-Kazova conditions, and Umut 2002 and Mersoy varieties can be grown if quality herbage is desired to be obtained.

Keywords: Soybean, Variety, Hay Yield, Crude Protein Yield, ADF content, NDF content

TOKAT KOŞULLARINDA ANA ÜRÜN ŞARTLARINDA BAZI SOYA FASULYESİ ÇEŞİTLERİNİN OT VERİM VE KALİTE ÖZELLİKLERİNİN BELİRLENMESİ

ÖZET

Bu araştırma, Tokat-Kazova koşullarında ana ürün olarak bazı soya fasulyesi çeşitlerinin ot verimi ve kalite özelliklerini belirlemek amacıyla, Tokat Gaziosmanpaşa Üniversitesi Tarımsal Araştırma ve Uygulama Merkezi'nin arazisinde 2021-2022 yılları arasında yürütülmüştür. Çalışma Tesadüf Blokları Deneme Desenine göre üç tekerrürlü olarak yapılmıştır. Çalışmada bitki materyali olarak; Adasoy, Cinsoy Mersoy, Nazlıcan, Türksoy, Umut 2002, Yemsoy ve Yeşilsoy soya çeşitleri kullanılmıştır. Denemede biçimler soya fasulyesi çeşitleri R6 (ana sap üzerindeki son dört boğumdan birinde, tohumun bakla içinde dolgunlaştığı ve yeşil renkli olduğu evre) dönemine ulaştığında yapılmıştır. Araştırmada bitki boyu, sap kalınlığı, yan dal sayısı, yaprak oranı, yeşil ot verimi, kuru madde verimi, ham protein oranı, ham protein verimi, ADF ve NDF oranları tespit edilmiştir.

İki yıllık araştırma sonuçlarına göre, Tokat-Kazova koşullarında ana ürün olarak soya fasulyesinde yüksek ot verimi elde edilmek isteniyorsa Adasoy ve Yeşilsoy çeşitlerinin; kaliteli ot elde edilmek isteniyorsa da Umut 2002 ve Mersoy çeşitlerinin yetiştirilebileceği belirlenmiştir.

Anahtar Kelimeler: Soya Fasulyesi, Çeşit, Ot Verimi, Ham Protein Verimi, ADF Oranı, NDF Oranı

ASSESSMENT OF SOIL QUALITY IN VINEYARD AREAS USING A FUZZY LOGIC-BASED DECISION SUPPORT SYSTEM: A CASE STUDY FROM KIRŞEHİR

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ABSTRACT

This study aims to evaluate the quality of soil samples collected from vineyard areas in the Kırşehir province through a fuzzy logic-based decision support system. The research utilized a dataset comprising 40 observations obtained from 20 distinct vineyards. Both physical (texture, lime content, organic matter, salinity, soil reaction) and chemical parameters (available phosphorus [P], extractable iron [Fe], manganese [Mn], copper [Cu], zinc [Zn], potassium [K], calcium [Ca], and magnesium [Mg]) were considered in the assessment of soil quality. The soils in the study area were found to be mildly alkaline (mean pH 8.12), with low organic matter content (mean 1.09%) and a high lime concentration (mean 16%). Additionally, the levels of available P, Ca, Mn and Zn were identified as insufficient. In the modelling phase, the input variables were fuzzified using triangular membership functions. The inference process was carried out using the Mamdani method, while the defuzzification stage employed the centroid method. The fuzzy rule base was constructed based on expert knowledge. The model produced a soil quality index for each observation, obtaining for the classification of vineyard areas according to their nutritional status. To assess the agreement between the model outputs and expert evaluations, the Kappa statistic was employed. All analyses were conducted in the MATLAB R2024b environment using the Fuzzy Logic Toolbox. The findings demonstrate that fuzzy logic offers a robust and effective decision support framework for monitoring and managing sustainable soil fertility in viticultural practices.

Keywords: Fuzzy Logic, Kırşehir, Soil Quality, Vineyard.

BULANIK MANTIK TABANLI KARAR DESTEK SİSTEMİ İLE BAĞ ALANLARINDA TOPRAK KALİTESİNİN DEĞERLENDİRMESİ: KIRŞEHİR ÖRNEĞİ

ÖZET

Bu çalışmada, bulanık mantık tabanlı karar destek sistemi ile Kırşehir ilindeki bağ alanlarından alınan toprak örneklerine ilişkin kalite değerlendirilmesi amaçlanmıştır. Araştırma kapsamında, 20 farklı üzüm bağına ait toplam 40 gözlemden oluşan veri seti kullanılmıştır. Toprak kalitesinin değerlendirilmesine yönelik fiziksel (tekstür, kireç, organik madde, tuzluluk, toprak reaksiyonu) ve kimyasal (yarayışlı fosfor (P), alınabilir demir (Fe), mangan (Mn), bakır (Cu), çinko (Zn), potasyum (K), kalsiyum (Ca), magnezyum (Mg)) parametreler ele alınmıştır. Hafif alkalin (ortalama pH 8.12) olan alan topraklarının organik madde içeriğinin düşük (ortalama %1.09) ve fazla kireçli (ortalama %16) olduğu, yarayışlı P, alınabilir Ca, Mn ve Zn düzeylerinin düşük seviyede olduğu bulunmuştur. Modelleme sürecinde; bulanıklaştırma aşamasında sistem girdileri üçgen üyelik fonksiyonları ile bulanıklaştırılmış, çıkarım aşamasında Mamdani yöntemi uygulanmış ve durulaştırma centroid yöntemiyle gerçekleştirilmiştir. Bulanık kural tabanı uzman bilgisine dayalı oluşturulmuştur. Model çıktısında her gözlem için toprak kalite indeksleri elde edilerek, bağ alanlarının beslenme durumlarına ilişkin kalite sınıfları elde edilmiştir. Model çıktılarının uzman görüşleri ile tutarlılığını test etmek amacıyla Kappa istatistiği kullanılmıştır. Analizler MATLAB R 2024b (Matrix Laboratory) ortamında bulanık mantık araç kutusu (Fuzzy Logic Tool Box) kullanılarak analiz edilmiştir. Sonuçlar, bulanık mantığın, bağcılıkta sürdürülebilir toprak verimliliğinin izlenmesi ve yönetiminde etkili bir karar destek aracı olarak kullanılabileceğini göstermektedir.

Anahtar Kelimeler: Bulanık Mantık, Kırşehir, Toprak Kalitesi, Üzüm Bağı.

ANALYSIS OF MILK MARKETING PREFERENCES OF DAIRY CATTLE PRODUCERS IN VAN PROVINCE BY ANALYTICAL HIERARCHY PROCESS*

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ABSTRACT

This study aims at determining the marketing preferences of dairy cattle producers of the raw milk in Van Province. The main material of the study is the original data collected from the Tuşba, Muradiye and Gevaş districts of Van by the questionnaire for the production period of 2019 from 178 dairy cattle producers. The sampling volume was determined using proportional sampling method. The Analytical Hierarchy Process (AHP) was used in determining the priorities for producers' milk marketing preferences. AHP model was developed by Saaty in 1977, which is generally used for solving decision-making problems. Descriptive statistics were also used for some variables.

Descriptive statistics revealed that the average age, average dairy cattle experience period, average number of cows, and average share of dairy cattle in total income were 47.33 years, 25.92 years, 8.33 heads and 59.63%, respectively. The average annual milk production per farm was 8910 kg. The Analytical Hierarchy Process analyses showed that in terms of the raw milk marketing preferences of the producers, the quality production was the most preferred criterion by the majority of the producers (0.51) followed by the reasonable price (0.25) and high quantity production (0.23) criteria. On the other hand, as regards of all criteria, it was determined that national firms were preferred the most (0.36), followed by local dairy firms (0.28), union or cooperative firms (0.25) and street dairy sellers (0.11), respectively. Our impression during the survey was that the producers sold the milk mainly to national firms because they received the sale price in cash or in a very short term. Therefore, we suggest that

the confidence to the local firms boosted among the producers so that the milk sales could be increased to local firms and thus contribute to the economic development of the region.

Keywords: AHP, Marketing, Dairy cattle farms, Milk, Van.

***:** This paper is derived from the BAP project of Van YYÜ FBA-2018-6414.

VAN İLİNDEKİ SÜT SIĞIRCILIĞI İŞLETMELERİNİN SÜT PAZARLAMA TERCİHLERİNİN ANALİTİK HİYERARŞİ SÜRECİ İLE ANALİZİ*

ÖZET

Bu çalışmanın amacı, Van ilinde bulunan süt sığırcılığı işletmelerinin ürettikleri çiğ sütü pazarlama tercihlerinin belirlenmesidir. Araştırmanın ana materyalini, Van ilinde süt sığırcılığı işletmelerinin yoğun olarak bulunduğu Tuşba, Muradiye ve Gevaş ilçelerinden oransal örnekleme yöntemiyle belirlenmiş 2019 yılı üretim dönemine ilişkin olarak 178 süt sığırcılığı işletmesinden anket yöntemiyle toplanan orijinal veriler oluşturmaktadır. Çiftçilerin süt pazarlama tercihlerine yönelik önceliklerin belirlenmesinde, 1977'de Saaty tarafından bir model olarak geliştirilerek karar verme problemlerinin çözümünde kullanılan Analitik Hiyerarşi Süreci'nden (AHP) yararlanılmıştır. Yanı sıra, çiftçi ve işletmelere ait bazı tanımlayıcı istatistiklerin belirlenmesinde oran ve ortalamalardan yararlanılmıştır.

Araştırmada üreticilerin ortalama yaşının 47.33, ortalama süt sığırcılığı deneyim süresinin 25.92 yıl, ortalama inek sayısının 8.33 baş, toplam gelirleri içinde süt sığırcılığının payının ortalama %59.63 olduğu belirlenmiştir. İşletme başına yıllık süt üretimi ortalama 8910 kg olarak hesaplanmıştır. AHP analiz sonuçlarına göre; çiftçilerin çiğ süt pazarlama tercihleri bakımından kriterler incelendiğinde, kaliteli üretimin çiftçilerin büyük bir çoğunluğu tarafından en çok tercih edilen kriter olduğu (0.51), bunu uygun fiyat (0.25) ve yüksek miktarda üretim (0.23) kriterlerinin izlediği belirlenmiştir. Tüm kriterler açısından çiftçilerin süt pazarlama tercihleri analiz edildiğinde, en çok ulusal firmaların tercih edildiği (0.36) bunu sırasıyla yerel mandıra (0.28), birlik veya kooperatif (0.25) ve sokak sütçüsünün (0.11) takip ettiği tespit edilmiştir. Saha çalışması sırasında edinilen izlenime göre yöre çiftçilerinin süt satışı için ulusal firmaları tercih etmelerinin sebebi süt satış bedellerini peşin veya çok kısa vadede alabiliyor olmalarıdır. Eğer, çiftçilerin yöredeki yerel firmalara olan güveni arttırılabilirse yörede üretilen sütün yine yörede değerlendirilmesi ve böylelikle araştırma yöresinin ekonomik açıdan gelişmesine katkı sağlanabilir.

Anahtar Kelimeler: AHP, Pazarlama, Süt sığırcılığı, Süt, Van.

***:** Bu bildiri Van Yüzüncü Yıl Üniversitesi BAP birimi tarafından desteklenen FBA-2018-6414 nolu projeden türetilmiştir.

FALL ARMYWORM (*SPODOPTERA FRUGIPERDA*) IN CENTRAL ASIA: AN EMERGING THREAT

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ABSTRACT

The fall armyworm (*Spodoptera frugiperda*) is an invasive and highly destructive pest insect, native to the tropical and subtropical regions of the Americas. It has a wide host range, feeding on over 80 plant species including economically important crops such as maize, rice, sorghum, millet, sugarcane, cotton, and a variety of vegetables. Due to its high mobility and rapid reproductive cycle, *S. frugiperda* has demonstrated a remarkable capacity for global spread, with recent expansion into South and Central Asian countries.

In Central Asia, the fall armyworm was observed for the first time in 2021 from maize fields in Northern Kyrgyzstan. This detection marked not only its initial occurrence in the Kyrgyz Republic but also in the entire Central Asian region. Field surveys were conducted to assess the pest's distribution and infestation intensity. In each field, 100 maize plants were inspected, and high infestation rates were observed, indicating the pest's strong establishment potential under local agro-climatic conditions.

To further monitor the population dynamics of *S. frugiperda*, pheromone traps were installed during the 2024 summer season at three separate maize-growing localities in Chuy Province. The monitoring revealed two distinct population peaks, which suggest multiple generations per growing season. These findings highlight the urgent need for integrated pest management strategies in the region.

Given the pest's capacity for rapid spread and its significant economic impact, *S. frugiperda* poses a major threat to agriculture in Central Asia. Immediate attention is required to mitigate crop losses and develop region-specific monitoring and control programs.

Keywords: *Spodoptera frugiperda*, Maize, Kyrgyzstan

MISIR ÇİZGİLİ YAPRAK KURDU (*SPODOPTERA FRUGİPERDA*) ORTA ASYA'DA YENİ BİR TEHDİT

ÖZET

Mısır çizgili yaprak kurdu (*Spodoptera frugiperda*), Amerika kıtasının tropikal ve subtropikal bölgelerine özgü, istilacı ve son derece yıkıcı bir zararlıdır. Mısır, pirinç, sorgum, darı, şeker kamışı, pamuk ve çeşitli sebzeler gibi ekonomik açıdan önemli bitkiler de dahil olmak üzere 80'den fazla bitki türüyle beslenebilmektedir. Yüksek hareket kabiliyeti ve hızlı üreme döngüsü sayesinde *S. frugiperda*, son yıllarda Güney ve Orta Asya ülkelerine kadar yayılarak küresel ölçekte dikkat çekici bir yayılma yeteneği sergilemiştir.

Orta Asya'da mısır çizgili yaprak kurdu ilk kez 2021 yılında Kırgızistan'ın kuzeyindeki mısır tarlalarında gözlemlenmiştir. Bu durum yalnızca Kırgızistan'da değil, tüm Orta Asya bölgesinde bu zararlının ilk tespiti olmuştur. Zararlının yayılışı ve bulaşma yoğunluğunu belirlemek amacıyla yapılan arazi taramalarında her bir tarlada 100 mısır bitkisi incelenmiş ve yüksek bulaşma oranları kaydedilmiştir. Bu durum, zararlının yerel iklim koşullarında güçlü bir şekilde yerleşme potansiyeline sahip olduğunu göstermektedir.

S. frugiperda'nın popülasyon dalgalanmasını izlemek amacıyla 2024 yaz döneminde Çüy Bölgesi'nde üç farklı mısır tarlasına feromon tuzakları yerleştirilmiştir. Popülasyon takibi çalışmaları, zararlının sezon boyunca iki belirgin popülasyon zirvesine sahip olduğunu ortaya koymuştur. Bu durum, bölgede birden fazla neslin geliştiğini göstermekte ve entegre zararlı yönetimi stratejilerinin acilen uygulanması gerektiğine işaret etmektedir.

Hızlı yayılma kapasitesi ve ciddi ekonomik etkisi göz önüne alındığında, *S. frugiperda* Orta Asya tarımı için büyük bir tehdit oluşturmaktadır. Ürün kayıplarını en aza indirmek ve bölgeye özgü mücadele programları geliştirmek için acil önlemler alınması gerekmektedir.

Anahtar Kelimeler: *Spodoptera frugiperda*, Mısır, Kırgızistan

SPATIAL ANALYSIS OF KONYA – CİHANBEYLİ LIVESTOCK ENTERPRISES AND DETERMINATION OF ENVIRONMENTAL POLLUTION POTENTIAL

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ABSTRACT

In recent years, the rapid growth of the global population has necessitated an increase in agricultural production efficiency to ensure adequate and balanced nutrition. However, intensive agricultural practices aimed at boosting yield have led to significant environmental pollution. The increasing impacts of climate change have further intensified pressure on natural resources. In particular, the uncontrolled storage of wastes generated by livestock farms poses a serious pollution threat to the natural environment, especially to water resources.This study aims to evaluate the spatial distribution and characteristics of livestock enterprises in the Cihanbeyli district of Konya Province and to assess their potential contributions to environmental pollution, with a specific focus on nitrate contamination. A structured questionnaire was administered to 144 livestock enterprises identified within the study area. To determine the extent of environmental pollution associated with livestock farming, annual average nitrate concentrations measured in groundwater wells were obtained from the Department of Agricultural Environment and Natural Resources Protection under the General Directorate of Agricultural Reform, Ministry of Agriculture and Forestry of the Republic of Türkiye. Based on the collected data, the relationship between livestock activities and pollution was analyzed with respect to soil structure, topography, climate, and water resources. For the purpose of consistent field analysis and accurate interpretation of data, the study area was divided into three regions—Gölyazı, Karabağ, and Taşpınar—based on selected distinguishing features.Findings revealed that none of the livestock enterprises in the study area employed any formal waste management systems. Although the annual average nitrate concentration in groundwater generally remained below the threshold value of 50 mg/L, seasonal fluctuations—especially those influenced by rainfall and irrigation practices—may lead to increased levels. This highlights the urgent need for the implementation of effective waste management practices, particularly for livestock-origin waste, in order to protect environmental quality.As an outcome of this study, a waste management system model was proposed as an alternative solution to mitigate environmental damage caused by livestock enterprises in the region. Furthermore, it is recommended that producers in the area be introduced to the *Nitrate Pollution Control Regulation* (Resmi Gazete, No. 29779, dated 23.07.2016) and the *Code of Good*

Agricultural Practices (Resmi Gazete, No. 29976, dated 11.02.2017) through targeted training programs, where correct implementation methods can be demonstrated. These efforts will contribute significantly to the sustainability of both livestock production and environmental health in the region.

Keywords: Spatial analysis, Nitrate, Environmental pollution, Livestock, Waste management

KONYA – CİHANBEYLİ HAYVANCILIK İŞLETMELERİNİN MEKÂNSAL ANALİZİ VE ÇEVRE KİRLİLİĞİ POTANSİYELİNİN DEĞERLENDİRİLMESİ

ÖZET

Günümüzde, dünya nüfusunun hızla artmasına bağlı olarak nüfusun dengeli ve yeterli beslenebilmesi için tarım sektöründe de üretimde verim artışı zorunlu hale gelmiştir. Verim artışı için yapılan yoğun uygulamalar sonucunda çevre kirliliği oluşmaktadır. İklim değişikliğinin günümüzde iyice hissedilir bir hal alan olumsuz etkileri ile birlikte doğal kaynaklar üzerindeki baskı iyice artmıştır. Özellikle hayvancılık işletmelerindeki ortaya çıkan atıkların kontrolsüz koşullarda depolanması, başta su kaynakları olmak üzere doğal çevre için ciddi bir kirletici yük oluşturmaktadır. Bu çalışmada, Konya İli Cihanbeyli ilçesindeki hayvancılık işletmelerinin, araştırma alanı üzerindeki konum özelliklerinin değerlendirilmesi ve bu işletmelerin özellikle nitrat kaynaklı çevre kirliliğine olan etkilerinin belirlenmesi amaçlanmıştır. Araştırma alanında belirlenen 144 adet hayvancılık işletmesinde öncelikle anket çalışması yürütülmüştür. Araştırma alanında hayvancılıktan kaynaklanan çevre kirliliği potansiyelinin belirlenebilmesi için, T.C. Tarım ve Orman Bakanlığı Tarım Reformu Genel Müdürlüğü Tarımsal Çevre ve Doğal Kaynakları Koruma Daire Başkanlığı'ndan alanda bulunan kuyulardan ölçülen nitrat seviyelerine ilişkin yıllık ortalama değerler temin edilmiştir. Elde edilen veriler yardımıyla hayvancılık işletmelerinin toprak, topoğrafya, iklimsel ve su kaynakları bakımlarından kirlenmeye etkileri belirlenmeye çalışılmıştır. Elde edilen verilerin doğru yorumlanabilmesi ve arazi çalışmalarının homojen yürütülebilmesi için araştırma alanındaki işletmeler, belirlenen bazı özellikleri bakımından Gölyazı, Karabağ ve Taşpınar olmak üzere üç gruba ayrılmıştır. Araştırma alanındaki işletmelerin tamamında herhangi bir atık yönetim sistemi mevcut değildir. Araştırma alanı çevresindeki kuyulardan alınan nitrat seviyelerine ilişkin verilerin yıllık ortalama değer olarak 50 mg/L'nin altında kaldığı ancak bu seviyelerin yılın farklı dönemlerinde, yağışa ve suların sulamada kullanılmasına bağlı olarak daha yüksek seviyelere erişebileceği düşünülmektedir. Bu durum, bölgede özellikle de hayvansal kaynaklı atık yönetiminin büyük bir hassasiyetle uygulanması gerektiğini göstermektedir. Araştırma sonucunda, bölgedeki hayvancılık işletmeleri için çevreye verilen zararı en aza indirgeyecek biçimde atık yönetim sistemi modeli bir alternatif uygulama olarak sunulmuştur. Nitrat Yönetmeliği (23.07.2016 tarihli ve 29779 sayılı T.C. Resmî Gazete) ve İyi Tarım Uygulamaları Kodu (11.02.2017 tarihli ve 29976 sayılı T.C. Resmî Gazete), bölgedeki hayvancılık işletmelerine verilecek eğitimlerle tanıtılmalı, doğru uygulamalar üreticilere gösterilmelidir. Bu çalışmalarla, araştırma alanında gerek hayvancılık işletmelerinin gerekse sağlıklı bir çevrenin sürdürülebilirliği için önemli bir adım atılmış olacaktır.

Anahtar Kelimeler: Mekânsal analiz, Nitrat, Çevre kirliliği, Hayvancılık, Atık yönetimi

NOUVEAUX CATALYSEURS STABLES ET RÉGÉNÉRABLES À BASE DE SCHİSTES BİTUMİNEUX MAROCAİNS POUR LA RÉACTİON DE PROTECTİON DES ALDÉHYDES

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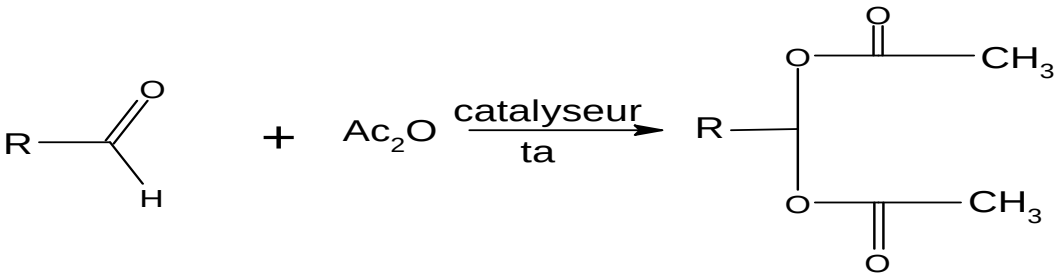
ABSTRACT

La protection des groupes carbonyles joue un rôle important dans la synthèse organique multi-étapes des produits naturels complexes. La protection des aldéhydes sous forme d'acylals, d'acétals ou de dithioacétals est l'une des transformations plus importantes au cours de la synthèse multi-étapes. De nombreuses méthodes sont disponibles pour la synthèse de 1,1-diacétates à partir d'aldéhydes et d'anhydride acétique. Bien que certaines de ces méthodes offrent un rendement plus élevé de diacétates correspondants, la majorité souffre d'un ou plusieurs inconvénients tels que des conditions acides dures, de longs temps de réaction, le besoin d'un catalyseur coûteux et une quantité stœchiométrique ou excessive de réactifs [1].

Dans ce travail, nous avons élaboré un nouveau catalyseur hétérogène, stable et régénérable à base de schiste bitumineux (**SB**) et nous l'avons utilisé dans la protection des aldéhydes aromatiques par l'anhydride acétique (schéma).



Mots clés : Schiste bitumineux, aldéhydes, amines , matériau stable, catalyse hétérogène.

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EARTHWORMS BIODIVERSITY IN AGRICULTURAL FIELDS IN TEMOUCHENT (WESTERN ALGERIA).

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ABSTRACT

Earthworms play an essential role in terrestrial ecosystems, enhancing soil structure and fertility while serving as indicators of environmental health. In 2024, a study was conducted to assess their diversity and distribution in the western Algerian region, focusing on two locations: Beni saf (S1), an agricultural area, and Keroum (S2), an orchard zone. Sampling in May used 40x40 cm squares with a depth of 30 cm for manual collection, alongside soil physico-chemical analysis. Results showed a pH of 7.2 and conductivity of 1500 µS/cm in S1, while S2 had a pH of 8.6 and conductivity of 830 µS/cm. Both stations exhibited low moisture, below 17%, indicating arid conditions. At S1, 18 juveniles, 12 sub-adults, and 9 adults were recorded, with average sizes of 2.9 ± 0.8 cm, 4.7 ± 0.5 cm, and 6.3 ± 1.7 cm. At S2, 6 juveniles, 4 sub-adults, and 3 adults were identified, with average sizes of 2.1 ± 0.7 cm, 3.9 ± 0.4 cm, and 5.9 ± 1.4 cm. Juvenile density was 40.5 ± 29.5 ind/m² in S1 and 16.2 ± 3.7 ind/m² in S2, with sub-adult density at 30.1 ± 18.2 ind/m² in S1 and 7.5 ± 1.2 ind/m² in S2, while adult density was 34.5 ± 16.2 ind/m² in S1 and 6.0 ± 0.6 ind/m² in S2. Biomass measurements showed juvenile values of 5.6 ± 4.1 g/m² for S1 and 1.5 ± 0.4 g/m² for S2, sub-adults at 24.8 ± 8.5 g/m² in S1 and 1.4 ± 0.3 g/m² in S2, and adults at 24.8 ± 8.5 g/m² in S1 and 3.1 ± 1.1 g/m² in S2. These findings revealed notable differences in soil properties and earthworm populations between the stations. Species identified included Apporectodea trapezoides (anecic), Apporectodea rosea (epigeic), and an unidentified Amynthas species, emphasizing the need for further taxonomic research on their ecological roles and contributions to soil fertility.

Keywords: Temouchent, earthworms, distribution, *Apporectodea rosea*, *Apporectodea trapezoids.*

RELATIONSHIP BETWEEN ORGANIC FOOD CONSUMPTION AND ATTENTION PERFORMANCE IN A SAMPLE OF MOROCCAN PRIMARY SCHOOL STUDENTS FROM KHEMISSET

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ABSTRACT

In last decades, as in other countries, Moroccan diet have known great changes involving foods artificial foods and fast food. This study aims to systematically assess associations between organic food consumption and cognition in sample of school children.

The study sample included data of 210 school students aging 10–13 years-old, from three elementary school cohorts. We measured all consumed foods including main meals, biscuits, chemicals and life styles. The measured cognitive domains were attention memory (d2R test) and working (N-Back task). We used two statistical approaches to assess associations between organic foods and child cognition: the exposome-wide association study (ExWAS) considering each consumed food independently, and the deletion-substitution-addition algorithm (DSA) considering all exposures simultaneously to build a general model. The results show that child organic food intake was associated with higher fluid intelligence (attention) scores (beta = 1.18; 95% CI = 0.50, 1.87) and higher working memory (N-Back) scores (0.23; 0.05, 0.41), and child fast food intake (−1.25; −2.10, −0.40) was associated with lower attention and memory scores. However, the rural origin that reflect high physical activity.

This first comprehensive study of childhood nutrition risk factors suggests that unfavourable child diet, including low organic food consumption adversely and cross-sectionally associate with cognitive function. Unexpected associations were also observed and maybe due to confounding and reverse causality.

Key words: organic food, cognitive function, d2R test, adolescents, Morocco.

PRODUCTIVE AND EFFECTIVELY SUSTAINABLE AGRICULTURE THROUGH AI

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ABSTRACT

Artificial Intelligence (AI) is revolutionizing agriculture by offering innovative solutions to enhance productivity, sustainability, and efficiency. AI-driven technologies such as machine learning, computer vision, and robotics are being increasingly integrated into agricultural practices to tackle challenges such as climate change, resource scarcity, and labor shortages. Key applications include precision farming, where AI analyzes soil conditions, weather patterns, and crop health to optimize irrigation, fertilization, and pest control. AI-powered drones and sensors enable real-time monitoring of crops, ensuring timely interventions to improve yields and reduce environmental impact. Autonomous machinery, such as harvesters and tractors, is improving labor efficiency while reducing operational costs. Additionally, AI-based decision support systems are empowering farmers with predictive analytics to make data-driven decisions, improving crop management and reducing waste. Overall, AI is driving the transformation of agriculture into a more data-centric, efficient, and sustainable industry, with the potential to meet the growing global food demand while minimizing environmental footprints.

Artificial Intelligence (AI) is revolutionizing agriculture by introducing advanced technologies that enhance productivity, sustainability, and efficiency across various farming practices. Recent developments have demonstrated AI's potential in transforming traditional agricultural methods. This paper will highlight the methods to achieve the AI based precision farming and crop management, automated irrigation systems, agricultural robotics, disease and pest

detection, livestock monitoring, supply chain optimization, climate change mitigation and decision support systems.

Keywords: Agriculture, Artificial Intelligence, Productivity, Sustainability, Farmer, Waste.

THE CONDUIT OF THE CHIA (SALVIA HISPANICA) GROWTH CYCLE DURATION BY VARYING SOWING DATE IN NORTH MOROCCO

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ABSTRACT

Chia (Salvia hispanica) is annual herbaceous plant belongs to the Lamiacae family, it is a biannually plant; it is considered a pseudo-cereal that has purple and white flowers ending in ting oval seeds ranging in size varying from 1 to 2 mm, it contains a significant amount of vitamins, minerals, protein, fiber and antioxidants . This type of seed is also a good source of omega-3 (α-linolenic acid), which makes it beneficial in a healthy human diet. Its benefits also include lowering blood cholesterol, triglycerides and prevention from diabetes and anti-cancer properties

this plant is gaining attention as a vital component of the world's food and nutrition security.

The introduction of new crops with high nutritional value into Morocco agriculture sustainable could help to combat food and nutritional insecurity, in order to maximize productivity, it is

crucial to determine the best dates for sowing by adjusting ontogenesis (the chronology of phenological stages) to the ideal environmental conditions.

Present study was carried out in rural commune Mnasra, Kenitra, Morocco. for examines chia's adaptability and tested for different sowing dates (from Mars to Mai): (12thMars, 02nd April ,23rd April,14th Mai and 28th Mai), and their effect on plant growth is evaluated. The results show a significant effect of sowing dates on plant phenology and yield. Photoperiod, temperature and wind speed are the main environmental factors explaining the variation in terms of crop growth and development between sowing dates. can be highly productive (above 1300-1500 kg ha-1) when sown between 14 and 28 May.

Keywords: Chia (Salvia hispanica)**,** sowing dates, plant phenology, harvests, Morocco agriculture sustainable.

FACTORS INFLUENCING STRAWBERRY FLAVOR: THE ROLE OF VARIETY AND RIPENESS

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ABSTRACT

Strawberries are widely celebrated for their flavor, yet consumers often report noticeable differences in taste quality. This study examines the key factors contributing to these variations, focusing on strawberry variety and ripeness. Initial findings highlight that sugar content, a critical determinant of sweetness, varies significantly between varieties. For instance, the Sabrina variety demonstrates higher sweetness levels, reaching up to 10.10% sugar content toward the end of the season, compared to the Fortuna variety, which typically does not exceed 9.14%. Harvest timing emerges as a significant factor influencing these differences. Additionally, ripeness affects other important quality traits such as acidity, texture, and aroma. As strawberries ripen, acidity and firmness progressively decline, while their aroma becomes most pronounced during the final stages of maturation. These insights enhance our understanding of the sensory characteristics of strawberries and underscore the importance of variety selection and ripeness in optimizing flavor quality.

Keywords:. Strawberries, variety, quality, sugar, acidity, sensory

Methodology

This study dives into the interplay between strawberry variety and ripeness in determining taste quality, with a particular focus on two widely cultivated varieties: Sabrina [1] and Fortuna [2]. The research aims to provide a detailed understanding of how these factors shape sensory characteristics and physicochemical properties, contributing to the overall flavor profile of strawberries. A total of five representative samples will be collected from farm-sourced strawberries and analyzed in the controlled environment of the Frulact company laboratory. To ensure data accuracy, only strawberries meeting specific criteria will be selected—fruits must be uniform in size, exhibit proper coloration indicative of maturity, and be free from deformities, bruises, or signs of disease.

The methodology integrates both sensory and physicochemical analyses to provide a holistic evaluation of taste quality. Sensory assessments will involve trained panelists evaluating visual appearance, aroma, and taste differences between the two varieties at varying stages of ripeness (ripe and partially ripe). These analyses will offer insights into how subjective perceptions of quality change with ripeness.

Physicochemical tests, on the other hand, will objectively quantify key quality indicators such as pH, sugar content (measured in degrees Brix), and firmness. In the laboratory, juice samples from the selected strawberries will be analyzed using advanced instruments. A pH meter will measure acidity levels, while a refractometer will determine sugar content, reflecting sweetness. Firmness, an indicator of texture and structural integrity, will be measured using a penetrometer, allowing the study to track how texture evolves during the ripening process.

To further enhance reliability, the study will control external factors such as storage conditions, temperature, and humidity. These controls aim to eliminate external variability, ensuring that the observed differences in taste quality are attributable solely to the variety and ripeness of the strawberries.

This approach offers a detailed analysis of strawberry flavor, emphasizing the importance of variety selection and harvesting practices. The findings aim to guide growers and producers in improving strawberry quality, with Figure 1 summarizing key factors linking sensory attributes to measurable properties.

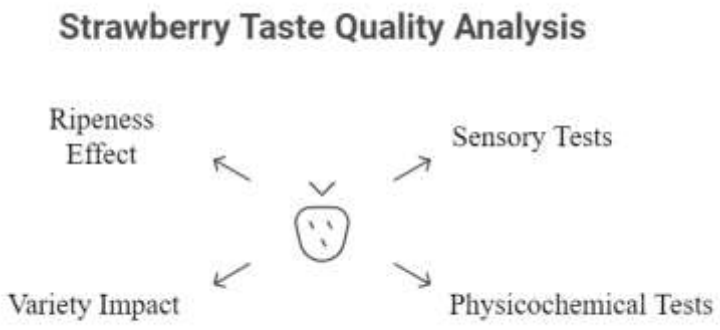

Figure 1. Factors Influencing Strawberry Taste Quality

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ASSESSMENT OF TRACE ELEMENT POLLUTION AND POTENTIAL HEALTH HAZARDS IN AGRICULTURAL SOILS OF THE BENI MOUSSA SUB-PERIMETER, MOROCCO

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ABSTRACT

The accumulation of trace metals in agricultural soils represents a serious environmental and public health concern, particularly in intensively cultivated areas. This study examines the extent of soil contamination, its spatial distribution, and the associated ecological and human health risks in the irrigated agricultural area of Beni Moussa, Morocco. A total of 67 surface soil samples were collected and analyzed for key physicochemical parameters, as well as for concentrations of cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), chromium (Cr), nickel (Ni), and arsenic (As), using ICP-AES and ICP-MS techniques.

To assess the severity of contamination, several indices were applied, including the geo-accumulation index (Igeo), enrichment factor (EF), contamination factor (CF), and pollution load index (PLI). The results show that 94.02% of the samples exhibit PLI values greater than 1, indicating substantial metal accumulation—particularly for Ni and As, which displayed the highest enrichment levels.

Ecological risk assessment (RI) suggests low to moderate potential risks, with contamination hotspots identified near Afourer, Sidi Jaber, and Ouled Ayyad. Human health risk analysis indicates that ingestion is the primary exposure pathway, with children being particularly vulnerable. While most elements present low non-carcinogenic risks (HI < 1), nickel may pose a concern for adults. Moreover, Cr, As, and Ni have potential carcinogenic effects, particularly in children.

These findings underscore the urgent need to implement sustainable soil management practices, regulate agrochemical inputs and wastewater reuse, and establish long-term monitoring programs. Further research is recommended to develop effective mitigation strategies aimed at preserving soil quality and minimizing exposure risks.

Keywords : Trace metals, Soil pollution, Ecological risk, Human health impact, Irrigated land, Morocco

MICROPLASTICS IN AGRICULTURAL SOIL- A GROWING ECOLOGICAL CHALLENGE

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ABSTRACT

Microplastic (MP) pollution, primarily driven by human activities, has emerged as a growing global environmental concern. During agricultural practices, substantial amounts of plastic residues are left in the fields, which gradually break down into microplastics - plastic particles smaller than 5 mm in diameter. These MPs significantly alter the physicochemical properties of soil, affecting porosity, enzymatic and microbial activity, plant growth, and crop yield. Due to their widespread presence, large surface area, and hydrophobic nature, MPs also act as carriers for harmful substances such as plasticizers, polycyclic aromatic hydrocarbons (PAHs), antibiotics, and potentially toxic elements (PTEs). They can migrate deep into the soil, potentially contaminating groundwater. This review explores the adverse impacts of MPs on soil ecosystems, including microbial communities, enzyme functions, plant and animal health, and agricultural productivity, while offering insight into the broader environmental implications of MP contamination.

Keywords: Microplastics, Plasticizers, Polycyclic hydrocarbon, Farmland soil

ENHANCING FOOD SAFETY AND SUSTAINABILITY: AI-POWERED INNOVATIONS IN SMART PACKAGING

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ABSTRACT

Environmental concerns and food safety challenges have prompted individuals to seek improved packaging alternatives. Conventional food packaging, although providing fundamental protection, has disadvantages such as being non-biodegradable and utilizing non-renewable resources. Intelligent packaging, enhanced by artificial intelligence, is the optimal option for augmenting the quality, sustainability, and safety of food products. The study seeks to explore ways AI can transform food packaging through real-time tracking, freshness detection, and supply chain tracing. The utilization of AI technologies such as deep learning and computer vision to evaluate food quality enables the quantification of food freshness through the assessment of color, texture, and microbial proliferation. The integration of IoT enhances the real-time surveillance of food goods within packaging materials. Blockchain technology guarantees customer responsibility via traceability and transparency. Moreover, features like QR codes on items and RFID chips enable shoppers to examine the products in depth, hence enhancing interaction. Nonetheless, substantial implementation costs, inadequate sensitivity of current sensors, and compliance-related concerns impede widespread use. In summary, integrating AI and smart packaging into the food sector may ensure food safety, extend food shelf life, and reduce food waste, all of which pave the way for the creation of a sustainable future. Research and development must be done to overcome current constraints in order to guarantee widespread use.

Keywords: Food safety, Food quality, Freshness detection, Deep learning, Blockchain technology, Smart packaging, Real-time monitoring, Internet of Things (IoT).

ECONOMIC ANALYSIS OF POTATO PRODUCTION THROUGH CONTRACT FARMING INMULTAN

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ABSTRACT

Potato *(Solanum tuberosum)* is the cash crop of Pakistan. After wheat, rice, and maize as high-yielding cash crops, potatoes have become popular in Pakistan. Potato production reached 7.94 million tons in 2022–2023 over an area of around 0.330 million hectares. The nation, which produces the ninth-most potatoes worldwide, has experienced a more than 35 percent increase in production over the previous three years, going from 5.87 million tons in 2020–21 to an expected 8.01 million tons in 2022–2023. This production level represents a 31.8 percent target exceeding a 1.9 percent growth over the previous year. Agriculture is produced under contract when a buyer and farm producer have a written agreement to that effect Credit facilities and marketing resources are the two factors that influence non-contract potato producers the most. 120 farmers will provide the information and data, which will be gathered on a primary basis. Using a straightforward random sampling procedure, 60 farmers will be chosen as contractors and 60 will be non-contractors and small land holders. The data will be analyzed using descriptive statistics of a Cobb Douglas production function. This study can aid in the formulation of decisions and policy initiatives in Multan City to benefit the city's contract farmers who grow potatoes.

Keywords: Contract Farming, Potato Growers, Descriptive statistics, Cobb Douglas production function, Credit facilities

APPRAISING FOOD WASTE REDUCTION BEHAVIOR IN UNIVERSITY STUDENTS: AN APPLICATION OF EXTENDED NORM ACTIVATION MODEL

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ABSTRACT

Food waste is a growing global concern, with severe consequences on the environment, culture and economy. Efforts are required to minimize waste at source and promote food waste reduction behavior, which activate norms and values or reinforce the individual attitude for the prevention of resources loss. For this reason, empirical investigation is required to understand the psychological and psychographic factors, which may activate or reinforce norms and attitudes about food waste reduction intentions. In this study, data from 400 respondents collected from the university students of Multan city to look into how psychographic and psychological factors affect consumers' intentions and shape their behavior to use sustainable food waste management practices. Moreover, relationship between religious value, compassion, personal norms, egostic value, utilitarian value, environmental concern and moral attitude toward food waste reduction intentions are examined. To analyze the casual relationship among variables Structural equation modelling technique employed to analyze data. The finding of this study helped in the formulation of robust policy recommendations and initiatives with the goal of lowering waste of food in Pakistan.

Keywords: Food waste, Psychographic factors, Management practices, Consumer behavior, Religion, Pakistan

A SYNERGISTIC MODELING AND EXPERIMENTAL APPROACH FOR SELF-PROPELLED SEEDERS DESIGN

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ABSTRACT

In the current era by increasing emphasis on sustainable agriculture and energy-efficient field operations, accurate estimation of draft force has become essential for the design and optimization of tillage and planting machinery, particularly self-propelled seeders. This study presents an integrated methodology that combines Discrete Element Method (DEM) simulations, ASABE-based theoretical modeling, and field validation to estimate draft force under various operational conditions. DEM simulations, employing the Hysteretic Spring contact model, revealed that the maximum normal force required to pull a single seeder unit reached approximately 2100 N, corresponding to a power requirement of around 3.7 hp for a five-row planter system (excluding frame load). Theoretical estimations based on ASABE standards, using data from three different implement types (A, B, and C) across operational depths of 2 to 5 cm, indicated a maximum draft power requirement of about 4.12 hp. Field experiments conducted using a dynamometer further validated these models, with measured draft force peaking at 4.3 hp for the five-seeder configuration. The DEM results showed close alignment with both theoretical and field data, although slight deviations were observed due to real-world factors such as soil moisture, field terrain, and border effects. These variations underscore the importance of empirical validation in draft force estimation. Overall, the strong correlation among DEM, theoretical, and experimental results confirms the robustness of the integrated approach, supporting the design of energy-efficient agricultural implements and advancing the precision and sustainability of modern farming systems.

Keywords: Draft force estimation, Discrete Element Method (DEM), ASABE standards, self-propelled seeder, precision agriculture.

THE FEASIBILITY STUDY OF REPLACING HALOXYLON WITH NITREBUSH IN DESERTIFICATION OPERATIONS

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ABSTRACT

Haloxylon is a genus of small trees or shrubs with a thick trunk and many branches. This plant is one of the valuable plants resistant to drought stress, which grows mainly in sandy habitats to stop the wind picking up the sands and spreading them through the atmosphere. Although Haloxylon has a great value in desert areas to control soil erosion, the yellowing of the hills has been observed and the problem has been spread to a large extent. Therefore, it is necessary to investigate the possibility of replacing other suitable species that exist in Iran's natural resources, especially in desert areas, while maintaining and managing the restored areas in the future policies. One of these plants is Nitrebush (*Nitraria schoberi*), which is a halophyte shrub with a wide spread canopy. This may be important in the prevention of soil erosion. Nitrebush is mainly spread in the desert areas on the edge of the existing playas with high underground water table. Nitrebush is considered as a key species for salty desert areas, which create green cover in salty areas and provides the ground for stabilization the sands adjacent to salt marsh. Collecting the sands next to the branches of Nitrebush leads to the creation of roots from the stem that are in contact with the soil, and finally provides the basis for plant multiplication at the base of the bush. Due to its high tolerance to salt stress and high ability to produce new roots from the stems, they have the ability to spread on the soil surface and produce enough forage for livestock's. it also creates a suitable green space. In this research, the high salt tolerance of Nitrebush in the natural habitat was investigated and it was found that the lush and green plants of Nitrebush continued to grow at a salinity limit of 97 dS/m at a depth of 0-30 cm and a salinity limit of 35 dS/m at a depth of 60-90 cm. One of the limitations of Nitrebush is the low germination and establishment of seeds under salinity stress. To overcome this limitation, different methods of accelerating germination including cold, acid, wet and drying treatments were studied, among which the five times wet treatment and drying of the seeds before planting showed more germinated seeds and vigor seedlings.

Keywords: Aridity, Desertification, Erosion, Forage, Halophyte, Salinity

EXPLORING THE RELATION BETWEEN FARM SIZE AND TECHNICAL EFFICIENCY IN PAKISTAN: A DIRECTIONAL DISTANCE FUNCTION APPROACH

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ABSTRACT

Agriculture, being the mainstay of the economy, ensures the livelihood of millions of people in Pakistan. Punjab and Sindh are the major crop-producing provinces of Pakistan. Replacing cotton with other crops like sugarcane, maize and rice has increased over the last two decades in cotton-producing areas of these provinces. Many studies have explored the technical efficiency of the cotton growers. However, no one has explored the technical efficiency of the farms in multi-output systems. This research will evaluate the production efficiency of multi-output agricultural farms in cotton-growing areas of Pakistan by keeping in view the farm size. This study will use the Directional distance function (DDF) by employing the data collected under the RASTA project, namely: Impact of Major Agricultural Policies on Cotton Production in Pakistan. The possible outcome may find in which direction the small, medium, & large farms should lead them to enhance their efficiency. Furthermore, this research will help to enhance resource use efficiency (SGD 12: Responsible Production) and suggest policies to enhance farmers' livelihood (SDG 1: Zero Poverty).

Keywords: efficiency of the cotton growers, Directional distance function (DDF), (SGD 12: Responsible Production), (SDG 1: Zero Poverty)..

RESEARCH ON THE INFLUENCE OF FOLIAR CLEAN FERTILIZERS APPLIED TO MAIZE AND SUNFLOWERS UNDER CURRENT CLIMATE CHANGE CONDITIONS

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ABSTRACT

Under current climate change conditions, with increasingly longer periods of soil drought and atmospheric heat, agricultural technologies must be adapted by using slow-absorbing liquid fertilizers. ADVAGREEN is a company based in Belgium, currently one of the major distributors of slow-release liquid nitrogen fertilizers, called Clean Fertilizer, certified in accordance with environmental protection regulations. In 2024, at the Agricultural Development Research Station of Braila, Romania, several clean fertilizers were tested, in different doses, on maize and sunflower, which proved an increase in production from 19.9% to 38.5% in maize, and from 5.9% to 17.7% in sunflower, compared to the standard fertilized control.

Keywords: drought; maize; sunflower; clean fertilizers; yield

IMPACT OF FARM SERVICES AND AGRONOMIC PRACTICES ON COTTON YIELD

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ABSTRACT

Cotton, often referred to as 'white gold,' is a cornerstone of Pakistan's economy, contributing significantly to livelihoods and exports. Recently, cotton yields have dropped by factors such as climate change, pest infestations, outdated farming practices, poor seed quality, soil degradation, and competition from more profitable crops like sugarcane. This study will investigate the impact of farm services and modern agronomic practices on improving cotton yield and sustainability in Pakistan. Using a quantitative approach, data collected from farmers across Punjab, Sindh, and Baluchistan through a structured digital questionnaire. Propensity Score Matching (PSM) will be employed to compare farmers with and without access to farm services and advanced practices. Key variables include cotton yield, access to farm services (extension services, subsidies on fertilizers ,seed and on machinery, irrigation ,weather information) and adoption of agronomic practices (seed quality, fertilizers, pest control). The study aims to identify critical factors influencing productivity and sustainability, addressing gaps in existing research by focusing on the role of farm services and modern techniques. Findings are expected to inform policies and practices that enhance cotton yield, promote climate-resilient farming, and support rural development, ultimately contributing to Pakistan's sustainable agricultural growth.

Keywords: Agriculture advisory service, Cotton Production, Cotton Farmers, Cotton Yield,PSM.

SAFE SCIENCE IN THE AGE OF BIOTECH ADVANCEMENTS AND AI: IMPERATIVES FOR EFFECTIVE BIORISK MANAGEMENT

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ABSTRACT

The swift convergence of biotechnology and artificial intelligence (AI) yields transformative breakthroughs, but also introduces substantial risks to human health, environmental sustainability, and global security. The integration of AI in cutting-edge biotechnologies, such as gene editing and synthetic biology, poses distinct challenges, including unforeseen outcomes, biosecurity vulnerabilities, and complex ethical considerations. To navigate these intricacies, a comprehensive framework merging scientific expertise, policy guidance, and ethical principles is essential. By emphasizing proactive biorisk management, stakeholders can optimize the benefits of biotechnology and AI while minimizing adverse consequences, ultimately promoting sustainable development, public well-being, and responsible innovation. The article attempts to raise the conversation around biorisk leadership, highlighting its essential significance in ensuring breakthroughs in science, averting accidents, and reducing adverse environmental impacts. By taking a preventive strategy, scientists, politicians, policy makers, and stakeholders can reduce the potential biosecurity and biosafety risks, safeguard human well-being, advance animal welfare and environmental sustainability, ensure regulatory compliance, foster a culture of responsibility and ethical innovation, and increase public trust. We provide actionable recommendations for effective biorisk management using expert analysis, real-world examples, and evidence-based case studies, fostering open conversation and interdisciplinary collaboration among scientists, policymakers, industry leaders, and ethics experts. The audience will gain a better understanding of proactive biorisk management imperatives, as well as increased knowledge of emerging biorisks, practical insights for incorporating biorisk considerations into research design, and strategies for effective interdisciplinary collaboration to address complex challenges, and eventually encourage environmentally conscious innovation that is ethically sound and meets safety standards.

Keywords: Biotechnology, Artificial Intelligence, Biorisk Management, Biosecurity, Ethical Considerations, Public Engagement, Sustainable Development.

VALORIZATION OF A WHEY BY-PRODUCT AND RESEARCH INTO LACTIC ACID BACTERIA ISOLATED FROM WHEY

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ABSTRACT

The rejection of whey, considered as a dairy by-product rich in nutrients, in the effluents constitutes an enormous economic loss. Summary this work aims at the valorization of whey in different fields. We carried out physic-chemical, microbiological and sensory analyzes to determine the quality of the finished product.

Lactic acid bacteria have acquired a great importance by their presence in the food industry and this for a long time.

The isolation of lactic acid strains from five whey samples from the ARIBBE dairy in the country of Ain-Defla, allowed us to obtain 05 Gram positive and catalase negative strains.

Lactic bacteria have been an effective means of bio-preservation of many food products for thousands of years, thanks to their metabolism. However, their role has extended to other sectors, such as the clinical environment thanks to their antimicrobial power.

Among the metabolites of lactic acid bacteria, antimicrobial substances called bacteriocins are effective and highly sought after antimicrobial bimolecular for various applications, thus making it possible to overcome resistance problems.

Keywords: whey, lactic acid bacteria, antimicrobial power.

EFFECTS OF DIFFERENT NITROGEN DOSES ON FORAGE YIELD AND YIELD COMPONENTS IN SWEET SORGHUM [*SORGHUM BICOLOR* VAR. *SACCHARATUM* (L.) MOENCH] GENOTYPES

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ABSTRACT

The study aimed to determine the forage production potentials of different sweet sorghum genotypes under Bursa conditions as a second crop. The field experiments were conducted in Bursa Uludag University, Faculty of Agriculture, Agricultural Application and Research Center in 2020-2021. The experimental design was a randomized complete block with three replications. Three different sweet sorghum genotypes (Erdurmuş, Uzun varieties, and M81-E line) and four nitrogen doses (0, 75 125, 175 kg ha^{-1}) were used in this research. Some parameters such as plant height, stem diameter, leaf number, leaf and stem ratio, forage yield, and dry matter yield of sweet sorghum were investigated in the experiment. The three sweet sorghum genotypes studied showed varied range values between; plant height 262-288 cm, stem diameter 19.2-24.8 mm, leaf ratio 11.5%-14.4%, stem ratio 85.6%-88.5%, forage yield 28.6-56.2 t ha^{-1}, and dry matter yield 7.8-15.7 t ha^{-1} respectively. According to the research results obtained in the second crop conditions; it can be recommended to grow the M81-E genotype using a nitrogen dose of 175 kg ha^{-1} in terms of high forage and dry matter yields.

Keywords: Sweet Sorghum, Forage Yield, Nitrogen Doses

FARKLI AZOT DOZLARININ ŞEKER SORGUM [*SORGHUM BICOLOR* VAR. *SACCHARATUM* (L.) MOENCH] GENOTİPLERİNDE YEM VERİMİ VE VERİM KOMPONENTLERİ ÜZERİNDEKİ ETKİLERİ

ÖZET

Bu çalışma, Bursa ekolojik koşullarında ikinci ürün olarak yetiştirilen farklı şeker sorgum genotiplerinde yem bitkisi üretim potansiyellerinin belirlenmesi amacıyla yürütülmüştür. Tarla denemeleri Bursa Uludağ Üniversitesi Ziraat Fakültesi Tarımsal Uygulama ve Araştırma Merkezi'nde 2020-2021 yıllarında, tesadüf blokları deneme desenine göre üç tekerrürlü olarak yürütülmüştür. Çalışmada üç farklı şeker sorgum genotipi (Erdurmuş, Uzun ve M81-E) ve dört farklı azot dozu (0, 75 125, 175 kg ha^{-1}) kullanılmıştır. Araştırmada bitki boyu, sap çapı, yaprak oranı, sap oranı, yeşil ot ve kuru ot verim parametreleri incelenmiştir. İncelenen üç farklı şeker sorgum genotipinde; bitki boyu 262-288 cm, gövde çapı 19.2-24.8 mm, yaprak oranı %11.5-14.4, sap oranı 85.6-88.5 mm, yeşil ot verimi 28.6-56.2 t ha^{-1} ve kuru ot verimi 7.8-15.7 t ha^{-1} arasında değişmiştir. İkinci ürün koşullarında elde edilen araştırma sonuçlarına göre; yeşil ot ve kuru ot verimlerinin yüksek olması açısından M81-E genotipinin 175 kg ha^{-1} azot dozu kullanılarak yetiştirilmesi önerilebilir.

Anahtar Kelimeler: Şeker Sorgum, Yem Verimi, Azot Dozları

PROMOTING SUSTAINABLE AGRICULTURE PRACTICES THROUGH WHEAT-PEA INTERCROPPING: DETERMINING IDEAL RATIOS AND HARVEST STAGES FOR ENHANCED YIELD

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ABSTRACT

The present study investigated the agronomic performance of wheat (Triticum aestivum L.) and pea (Pisum sativum L.) under different seed mixture ratios and harvesting stages, aiming to determine optimal conditions for maximizing yield and supporting sustainable intercropping. The experiment involved five seed combinations (100% wheat, 75% wheat–25% pea, 50% wheat–50% pea, 25% wheat–75% pea, and 100% pea) and three harvesting stages (start of pea flowering, 50% pea flowering, and 100% pea flowering). Key parameters measured included plant height, green yield, and dry yield for both crops.

Results revealed significant effects ($p < 0.01$) of both seed ratio and harvest stage on most traits. The highest wheat green yield was recorded in 100% wheat at the second harvest (2992.7 kg/da), while maximum pea green yield was achieved in 100% pea plots at the first harvest (2565.6 kg/da). Dry matter accumulation increased with delayed harvesting, with peak wheat dry yield at 1129.2 kg/da (100% wheat, 3rd harvest) and maximum pea dry yield at 551.7 kg/da (100% pea, 1st harvest). The 50–50 mixture notably enhanced plant height in both species (wheat: 82.6 cm; pea: 143.5 cm), suggesting beneficial early vegetative interaction, though yield was generally reduced due to interspecific competition.

These findings suggest that wheat thrives with lower pea ratios, especially when harvested later, while pea benefits from higher mixture dominance and earlier harvest. Strategic management of crop ratio and timing can significantly improve biomass yields and intercropping efficiency.

Keywords: Wheat, pea, intercropping, harvest timing, forage yield

BUĞDAY-BEZELYE KARIŞIK EKİMİ İLE SÜRDÜRÜLEBİLİR TARIM UYGULAMALARI: YÜKSEK VERİM İÇİN İDEAL ORANLARIN VE HASAT ZAMANLARININ BELİRLENMESİ

ÖZET

Bu çalışma, buğday (*Triticum aestivum* L.) ve bezelye (*Pisum sativum* L.) bitkilerinin farklı karışım oranları ve hasat dönemlerine göre agronomik performansını inceleyerek, verimi maksimize eden ve sürdürülebilir tarımı destekleyen en uygun koşulları belirlemeyi amaçlamıştır. Denemede beş farklı karışım oranı (100% buğday, 75% buğday–25% bezelye, 50% buğday–50% bezelye, 25% buğday–75% bezelye, 100% bezelye) ve üç farklı hasat dönemi (bezelye çiçeklenmesinin başlangıcı, %50 çiçeklenme ve %100 çiçeklenme dönemleri) değerlendirilmiştir. Ölçülen özellikler bitki boyu, yeşil ve kuru ot verimidir.

Sonuçlar, hem karışım oranı hem de hasat döneminin çoğu parametre üzerinde anlamlı etkiye sahip olduğunu göstermiştir ($p < 0.01$). En yüksek buğday yeşil ot verimi, ikinci hasatta 100% buğday parsellerinde elde edilmiştir (2992.7 kg/da). En yüksek bezelye yeşil ot verimi ise ilk hasatta 100% bezelye parsellerinde kaydedilmiştir (2565.6 kg/da). Kuru ot verimi geç hasatlarda artmış, maksimum buğday kuru ot verimi 3. hasatta (1129.2 kg/da), en yüksek bezelye kuru ot verimi ise 1. hasatta (551.7 kg/da) gözlenmiştir. 50–50 karışım oranı, her iki türde de bitki boyunu artırmış (buğday: 82.6 cm; bezelye: 143.5 cm), ancak verimde genel bir düşüş yaşanmıştır; bu da türler arası rekabetin etkisini ortaya koymaktadır.

Sonuç olarak, buğday düşük bezelye oranlarında ve geç hasatla daha verimli olurken, bezelye yüksek karışım oranlarında ve erken hasatta daha yüksek verim göstermektedir. Buğday-bezelye karışım oranı ve hasat zamanının doğru yönetimi, verim ve sistemin sürdürülebilirliği açısından büyük önem taşımaktadır.

Anahtar Kelimeler: Buğday, bezelye, karışık ekim, hasat zamanı, ot verimi

DETERMINATION OF THE EFFECT OF AMINO ACID APPLICATION ON SOME MORPHOLOGICAL CHARACTERISTICS IN BEANS (*Phaseolus vulgaris* L.) APPLIED WITH DIFFERENT DOSES OF HERBICIDE

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ABSTRACT

Herbicide application is a method that can be easily applied and gives immediate results, and therefore is highly preferred by farmers. Amino acids provide resistance to stress conditions such as high temperature, low humidity, frost, insect damage, hail damage, and flooding. Herbicides are sometimes mistakenly applied in high doses by farmers. Reducing high-dose herbicide damage by applying amino acids is a method tried by farmers in recent years. The aim of this study was to investigate the effects of amino acid application on some morphological characteristics in beans due to treated with different doses of herbicide.

The experiment was designed as factorial arrangement in the randomized plots design with three replications in controlled conditions. The effect of three amino acid application [control (none amino acid) amino acid after 3 days and amino acid after 6 days] and 5 herbicide doses [control (recommended dosage), half the recommended dose, twice the recommended dose, three times the recommended dose and four times the recommended dose] were investigated.

Main branch diameter, seedling height, root length, leaf number and leaf area characteristics were examined in the study. The differences between amino acid treatments were statistically significant in all of the investigated charecters. Herbiside treatments and amino acid x herbicide treatments interactions were statistically significant only in root length charecter.

When the herbicide dose increases, decreases in values were observed in all of the characters. The lowest values were determined when four times the recommended dose was applied.

Plants were stressed with herbicide applications. No increase was detected in the main branch diameter and seedling length of the plants with the amino acid applied afterwards. However,

[2] Bu çalışma Fahreddin Ataman'ın Yüksek Lisans tez çalışmasının bir parçasıdır.

amino acid after 3 days application increased root length, leaf number and leaf area. Amino acid application has given positive results in these characters. Amino acid after 6 days application, no positive effect was observed in all of the investigated characteristics.

In the study, it was concluded that if an overdose occurs in herbicide use, the damage to the plants can be prevented to some extent by applying amino acids within 3 days without delay.

Key Words: Bean, herbicide, amino acid, morphological characters

FARKLI DOZLARDA HERBİSİT UYGULANMIŞ FASULYE (*Phaseolus vulgaris* L.) BİTKİSİNDE AMİNOASİT UYGULAMASININ BAZI MORFOLOJİK ÖZELLİKLER ÜZERİNE ETKİSİNİN BELİRLENMESİ

ÖZET

Tarımsal savaş yöntemleri içerisinde yer alan kimyasal savaş kolay uygulanabilirliği ve sonucunun hemen alınabilmesi gibi çeşitli avantajları sebebiyle üreticiler tarafından en çok tercih edilen yöntemlerden biridir. Amino asitler yüksek sıcaklık, düşük nem, don, böcek zararı, dolu zararı, sel gibi, ürün kalitesini ve miktarını azaltan, bitki metabolizmasını üzerinde olumsuz bir etkiye sahip stres koşullarına direnç sağlar. Yabancı otlarla mücadelede kullanılan herbisitler çiftçiler tarafından zaman zaman yanlışlıkla yüksek dozda uygulanmaktadır. Yüksek dozda herbisitten zarar gören bitkilere aminoasit uygulayarak stresi ortadan kaldırmaya çalışma son yıllarda çiftçiler tarafından denenen bir yöntemdir. Bu çalışmada; farklı dozlarda herbisit uygulanan fasulyede farklı zamanlarda uygulanan aminoasidin bazı morfolojik özellikler üzerine etkilerini incelenmek amaçlanmıştır.

Deneme kontrollü koşullarda ve tesadüf parsellerinde faktöriyel deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Araştırmada 3 aminoasit uygulaması [kontrol (aminoasit uygulaması yok), 3 gün sonra aminoasit uygulaması ve 6 gün sonra aminoasit uygulaması] ile 5 herbisit dozu [kontrol (tavsiye edilen doz), tavsiye edilen dozun yarısı, tavsiye edilen dozun iki katı, tavsiye edilen dozun üç kat ve tavsiye edilen dozun dört katı] denenmiştir.

Araştırmada ana dal çapı, fide boyu, kök uzunluğu, yaprak sayısı ve yaprak alanı özellikleri incelenmiştir. İncelenen tüm özelliklerde aminoasit uygulamaları arasındaki farklar istatistiki anlamda önemliyken, herbisit uygulamaları ve aminoasit x herbisit uygulamaları interaksiyonu sadece kök uzunluğu özelliğinde istatistiki anlamda önemli bulunmuştur.

İncelenen tüm özelliklerde uygulanan herbisitin dozu arttıkça değerlerde düşüşler görülmüştür. En düşük değerler tavsiye edilen dozun dört katı uygulandığında belirlenmiştir.

Herbisit uygulamaları ile bitkiler strese girmiş ve sonrasında uygulanan aminoasit ile bitkilerin ana dal çapı ve fide boylarında bir artış saptanmamıştır. Bu özelliklerde herbisitler daha etkili olmuştur. Ancak 3 gün sonra aminoasit uygulaması ile kök uzunluğu, yaprak sayısı ve yaprak alanı artmıştır. Bu özelliklerde aminoasit uygulaması olumlu sonuçlar vermiştir. 6 gün sonra aminoasit uygulamanın incelenen tüm özelliklerde olumlu bir etkisi görülmemiştir.

Yapılan bu araştırmada; herhangi bir nedenden ötürü herbisit kullanımında doz aşımı meydana gelirse çok geç kalmadan 3 gün içerisinde aminoasit uygulaması ile bitkilerde meydana gelen zararın bir noktaya kadar engellenebileceği sonucuna ulaşılmıştır.

Anahtar Kelimeler: fasulye, herbisit, amino asit, morfolojik özellikler

BUCKWHEAT: ITS ORIGIN, COMPOSITION AND HEALTH IMPORTANCE

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ABSTRACT

Buckwheat, an Asian-origin plant belonging to the Polygonaceae family, is an annual species known as a pseudo-cereal. Common buckwheat (Fagopyrum esculentum Moench) and Tatar buckwheat (Fagopyrum tataricum Gaerth) are the most widely cultivated buckwheat species as a food source.

Buckwheat is used in bread, pasta, bakery products and various traditional dishes. Especially foods such as "soba" in Japan, "kasha" in Russia, "naengmyeon" in Korea and "pizzoccheri" in the northern regions of Italy are widely consumed. Starch is a main component of buckwheat grain and constitutes 55-75% of the grain. Due to its resistant starch content, buckwheat has a low glycemic index and plays an important role in the diet of diabetics by helping regulate blood sugar levels. The protein content of buckwheat grain varies between 8.5 and 19%, depending on the variety. It contains essential amino acids such as lysine, threonine, and tryptophan. Buckwheat protein has high nutritional quality due to its balanced amino acid profile. Buckwheat is classified as a gluten-free product. Therefore, it is an excellent alternative for celiac disease. Buckwheat grain contains 7.0-10.7% total fat, the majority of which consists of unsaturated fatty acids. It is richer in B and E vitamins compared to cereals such as rice, corn, and wheat. Buckwheat exhibits antioxidant, antitumor, antidiabetic, and antibacterial properties due to its rich composition. In addition to its health benefits, buckwheat is considered as an allergen food and several researches are conducted to eliminate its allergenic properties.

Interest in buckwheat is increasing in our country due to its high nutritional properties. It is recommended that this plant, which is newly cultivated in Turkey, should be promoted more and its production should be increased due to the beneficial properties for human health. In this study, the origin, composition, and health effects of buckwheat are reviewed.

Keywords: Buckwheat, Celiac, Chemical Composition, Health Effects

KARABUĞDAY: KÖKENİ, BİLEŞİMİ VE SAĞLIK AÇISINDAN ÖNEMİ

ÖZET

Asya kökenli bir bitki olan karabuğday, Polygonaceae familyasına ait, pseudo tahıl olarak bilinen tek yıllık bir bitkidir. Yaygın karabuğday (Fagopyrum esculentum Moench) ve Tatar karabuğdayı (Fagopyrum tataricum Gaerth) gıda kaynağı olarak en çok yetiştirilen karabuğday türleridir.

Karabuğday, ekmek, makarna, unlu mamuller ve çeşitli geleneksel yemeklerde kullanılmaktadır. Özellikle Japonya'da "soba", Rusya'da "kasha", Kore'de "naengmyeon", İtalya'nın kuzey bölgelerinde "pizzoccheri" gibi yiyecekler oldukça yaygın olarak tüketilmektedir. Karabuğday tanesinin esas bileşeni olan nişastanın tanedeki oranı %55-75 arasında değişmektedir. İçerdiği yüksek miktardaki dirençli nişasta sayesinde karabuğday glisemik indeksi düşük gıdadır ve kan şekerini düzenlediği için şeker hastalarının diyetinde önemli bir yere sahiptir. Karabuğday tanesinin protein içeriği çeşide bağlı olarak %8.5-19 arasında değişmektedir. Lisin, treonin, triptofan gibi elzem aminoasitleri içermesi ve dengeli bir aminoasit dağılımına sahip olması nedeniyle karabuğday proteini yüksek besin kalitesine sahiptir. Karabuğday gluten bulundurmayan bir ürün olarak tanımlanmaktadır ve özellikle çölyak hastaları için iyi bir alternatiftir. Karabuğday tanesi toplam %7.0-10.7 oranında yağ içermekte olup bu yağın büyük çoğunluğu doymamış yağ asitlerinden oluşmaktadır. Karabuğday tanesi B grubu ve E vitaminleri açısından pirinç, mısır ve buğday gibi tahıllardan daha zengindir. Sahip olduğu zengin içeriği sayesinde karabuğdayın antioksidan, antitümör, antidiyabetik ve antibakteriyel etkileri bulunduğu bildirilmiştir. Sağlık açısından yararlarının yanında karabuğday alerjen gıdalardan biri olarak kabul edilmekte ve bu özelliğinin giderilmesi için çeşitli çalışmalar yapılmaktadır.

Yüksek besleyici özelliği nedeniyle karabuğdaya olan ilgi ülkemizde de giderek artmaktadır. Türkiye'de tarımı yeni yapılmaya başlanan bu bitkinin, besleyici ve sağlığa faydalı özellikleri nedeni ile daha fazla tanıtılması ve üretiminin arttırılması önerilmektedir. Bu çalışmada karabuğdayın kökeni, bileşimi ve sağlık üzerine olan etkileri derlenmiştir.

Anahtar Kelimeler: Bileşim, Çölyak, Karabuğday, Kimyasal, Sağlık Etkileri

VEGETABLE SEED DISEASES IN KYRGYZSTAN AND THEIR CONTROL

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ABSTRACT

Vegetable growing is one of the key sectors of agriculture in Kyrgyzstan. Vegetable crops not only possess high nutritional value, but also serve as a primary source of vitamins, minerals, carbohydrates, pectins, organic acids, essential oils, and phytoncides.

Over 80% of infectious plant diseases are caused by fungal organisms, with seeds acting as a major vector for their spread. It is estimated that more than 30% of crop pathogens are seed-borne, with some studies suggesting that this number exceeds 60%.

In this study, the pathogenic and saprophytic microflora of vegetable seeds officially registered in Kyrgyzstan were identified. To achieve this, the mycological and bacterial composition of the seeds was analyzed using several methods: visual inspection, the roll method, and cultivation on nutrient media. Biological control methods were then applied to manage bacterial and fungal infections.

The results of the phytopathological survey revealed the presence of 15 fungal species, including representatives of the genera *Mucor*, *Cladosporium*, and *Penicillium*. Additionally, three bacterial species were identified: *Xanthomonas* spp., *Erwinia carotovora*, and *Xanthomonas campestris* pv. *vesicatoria*. The study demonstrated that both internal and external phytopathogens were present in nearly all examined seed samples. Notably, fungi from the genus *Aspergillus* were detected in all types of vegetable seeds. These included *Aspergillus niger*, *Aspergillus terreus*, *Aspergillus flavus*, and *Aspergillus fumigatus*.

The *Streptomyces alfalfae* strain CI-4 was found to be effective in protecting the seed coat from infection, particularly at a concentration of 1×10^6 spores per milliliter.

Keywords: seed infection, *Streptomyces* bioagents, plant protection

WATER CONSUMPTION PATTERN OF KONKAN KANYAL GOATS FED FINGER MILLET STRAW SUPPLEMENTED WITH VARYING LEVELS OF DRIED POULTRY DROPPING BASED DIETS

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ABSTRACT

This study was conducted to estimate the water intake of Konkan Kanyal goats fed finger millet straw supplemented with varying levels of dried poultry droppings-based diet. Thirty Konkan Kanyal goats aged above 12 months weighing 14.00-14.67 kg were used in a randomized block design (RBD) experiment. The experimental goats were randomly assigned to five treatments (TI-T5). T1 were goats fed with 0% dried poultry droppings-based diets (DPDBD), T2 were fed with 20% dried poultry droppings-based diets (DPDBD), T3 were fed with 40% dried poultry droppings-based diets (DPDBD), T4 were fed with 60% dried poultry droppings-based diets (DPDBD), T5 were fed with 80% dried poultry droppings-based diets (DPDBD. Water was offered at 5L goats-1 daily. Water and feed refusal were recorded on a daily basis before feeding in the morning. Feed and faeces samples were analyzed for proximate constituents. Live weight changes were also measured. The results revealed that treatment groups supplemented with dried poultry droppings-based diets had superior water intake compared to the control group. Daily water intake of the experimental goats was 1.4, 2.2, 3.5, 2.7, and 1.7 L head-1, respectively. Konkan Kanyal goats fed finger millet straw supplemented with varying levels of dried poultry dropping based diets requires up to 3.5L of water head-1 day-1 for optimum utilization of the feed.

Keywords: Crop residue, Goats, Poultry litters, Water intake.

ECONOMIC RETURNS OF RABI CROPS IN PUNJAB: STRATEGIES FOR ENHANCING FARM INCOME

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ABSTRACT

Agriculture plays a pivotal role in the socio-economic fabric of Pakistan, and the province of Punjab stands as the agricultural heartland of the country. The rabi season, encompassing the winter months, is of paramount importance in the agricultural calendar, contributing significantly to the overall agricultural output. Understanding the economic dynamics of Rabi crops in Punjab is crucial for policy formulation, resource allocation, and sustainable agricultural development. The methodology involves a systematic collection of primary data through surveys and interviews with farmers of Sahiwal division, that includes three districts Sahiwal, Okara and Pakpattan. Various economic indicators such as cost of production, yield per acre, market prices, and income generated are meticulously examined to gauge the financial viability and sustainability of Rabi crops cultivation in the region. Benefit cost ratio of respective crops was calculated in order to find strategic efficiency, comparative advantage, and the level of government interventions in production. The BCR calculated for wheat was 0.85, 0.84 for maize, 1.28 for potato, 0.80 for canola and for 1.62 Tobacco. Tobacco is identified as most profitable crop following potato in place. Wheat, maize and canola are having positive gross margins but negative net returns indicating high fixed costs. High land rent is a factor responsible for negative net returns as wheat, maize and canola are having BCR 1.69, 1.20 and 1.48 respectively without land rent, but the main cause responsible for negative net returns are low output prices of these crops this year. Logistic regression model was used to analyze the factors that affects crop diversification in the region, i.e. to identify the factors that affect the crop diversification decisions of the farmer. Land holding is the only factor that affects diversification decision of farmers. Moreover, a constraint analysis was done on Likert scale to find out the constraints that farmers were facing in production i.e. agronomic, environmental and market constraints. Most critical issues identified are the lack of support price or procurement guarantees, the high input costs, poor seed quality and yield variability. Policy recommendations were derived from these findings, emphasizing the ways to increase crop diversification, improving input access, enhancing irrigation infrastructure, strengthening pest and disease management, ensuring price stability, promoting financial inclusion, and investing in climate-resilient agriculture and research. The study underscores the need for targeted policy

interventions to address the multifaceted challenges facing Punjab's agricultural sector while capitalizing on the promising opportunities for sustainable development. By implementing these recommendations, policymakers can foster an enabling environment for inclusive growth, improved livelihoods, and enhanced food security in the region.

Keywords: Farm Income Stability, Cost-Benefit Analysis, Economic Efficiency, Crop Diversification, Sustainable Crop Production.

INFLUENCE OF ON-TREE NUTRIENT SPRAYS AND BAGGING ON THE QUALITY AND POSTHARVEST PHYSIOLOGY OF MANGO CV. AMRAPALI UNDER AMBIENT CONDITIONS

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ABSTRACT

Extending the shelf life of mango fruits is crucial to ensure year-round market availability and support long-distance transportation without compromising fruit quality. Mango (*Mangifera indica* L. cv. Amrapali), being a climacteric fruit, undergoes rapid ripening and senescence, which significantly limits its storability. This study aimed to evaluate the influence of selected preharvest interventions, including nutrient sprays and fruit bagging, on the postharvest quality and physiological behavior of mango fruits stored under ambient conditions (25 ± 3 ºC and 80–85% RH). The treatments comprised bagging alone, 2% calcium chloride ($CaCl_2$), 1.5% potassium sulfate (K_2SO_4), and a combined treatment of 2% $CaCl_2$ + 1.5% K_2SO_4 with bagging. Fruits were analyzed at 0, 4, 8, 12, and 16 days of storage for key quality parameters such as weight loss, fruit firmness, pH, total soluble solids (TSS), ascorbic acid, total sugar, carotenoid content, total phenolics, DPPH radical scavenging activity, ethylene production, respiration rate, and enzymatic activities including polyphenol oxidase (PPO), catalase (CAT), and peroxidase (POD). The combined application of 2% $CaCl_2$ + 1.5% K_2SO_4 with bagging was found to be the most effective, resulting in reduced physiological deterioration, delayed ripening, better peel and pulp color, enhanced antioxidant content, and significantly lower decay incidence compared to untreated fruits. These findings highlight the potential of integrating nutrient sprays with physical protection techniques like bagging to improve the postharvest quality and extend the shelf life of mango fruits in ambient storage conditions.

Keywords: Pre-harvest treatment, Shelf life, Postharvest physiology

ENGINEERING THE FUTURE OF FARMING: CHEMICAL INNOVATIONS FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

The intersection of agriculture and chemical engineering holds transformative potential for addressing global challenges such as food security, resource efficiency, and environmental sustainability. This abstract explores innovative applications of chemical engineering principles to revolutionize agricultural practices, focusing on precision farming, agrochemical optimization, waste valorization, and renewable energy integration.

Key Focus Areas:

Smart Agrochemicals:

Development of nanocarriers and controlled-release fertilizers/pesticides to enhance nutrient uptake and reduce environmental runoff.

Green synthesis of biodegradable agrochemicals using plant-based or microbial feedstocks.

Agricultural Waste Valorization:

Conversion of crop residues, manure, and food waste into biofuels (e.g., biogas, bioethanol), biochar, or platform chemicals via pyrolysis, anaerobic digestion, and enzymatic hydrolysis.

Integration of biorefineries to create circular economies in rural areas.

Precision Agriculture Technologies:

IoT-enabled sensors and AI-driven analytics for real-time monitoring of soil health, moisture, and crop stress.

Chemical engineering solutions for water-efficient irrigation (e.g., hydrogels, membrane filtration).

Sustainable Food Processing:

Energy-efficient drying, extraction, and preservation techniques (e.g., supercritical CO_2 extraction, membrane separation) to minimize post-harvest losses.

Novel food packaging materials (e.g., edible films, antimicrobial coatings) to extend shelf life.

Renewable Energy in Farming:

Solar/wind-powered on-farm biofuel production and ammonia synthesis for fertilizers.

Electrochemical reduction of nitrogen to reduce reliance on Haber-Bosch process.

Challenges and Innovations:

Scalability: Bridging lab-scale innovations to field applications.

Policy Support: Aligning with SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption).

Farmer Adoption: Cost-effective and user-friendly technologies for smallholder farms.

Conclusion:

The synergy of chemical engineering and agriculture can drive a paradigm shift toward resource-efficient, low-carbon food and energy systems. Future research must prioritize collaborative frameworks involving engineers, agronomists, and policymakers to scale solutions globally.

Keywords: Precision agriculture, no-till, multi-crop seeding, seed distribution, sustainable agriculture

IMPACTS OF CLIMATE CHANGE ON CITRUS PRODUCTION IN DISTRICT SARGODHA

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ABSTRACT

Climate change is the global environmental problem which effects agricultural productivity, natural ecosystem and human health. Pakistan is among the countries which are facing unpredictable weather patterns like high temperature and low precipitation. Climate change has adversely affected on the yield of citrus fruit in Sargodha, Pakistan. Increase in temperature lead to drop in citrus production. similarly, low and high rain fall reduce the juice content and fruit quality respectively. Additionally, severe drought conditions can lower tree productivity and necessitate irrigation for the production of citrus and other crops. The objective of the study was to investigate the climatic impacts on growth and yield of citrus fruit in addition to socio economic characteristics of citrus growers in Sargodha district. The present research utilized the primary data and stratified random sampling technique was used to collect the data from district Sargodha. A sample of 100 citrus growers were selected for the study. A well-structured questionnaire was employed to collect the relevant data. collected data was analyzed using Statistical Package for Social Sciences (SPSS). The main findings of the study showed that citrus orchards were more sensitive towards temperature. Extremely high temperature altered the fruit growth pattern and yield. while the rain fall showed positive effect on citrus yield and production. Similarly, socio-economics factors like age, education, family size and farming experience fluctuate the yield of citrus. This study can help policymakers to design better policies which can improve farmers perceptions, and motivate them to enhance the yield of citrus in Sargodha.

Keywords: climate change, Citrus, Yield, Pakistan

STUDY OF *in vitro* PROPAGATION AND SELECTION FOR SALT TOLERANCE OF LOCAL OPUNTIA CACTUS

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ABSTRACT

Opuntia cactus is a horticultural crop, which is extensively used as food for humans and feed for animals in many countries of the world. This crop has widely adapted to different parts of Tunisia and is an integral part of the culture and economy of arid and semi-arid zones of the country. Recently, to fulfil the demand for large-scale cultivation in a short period by rapid mass multiplication, organogenesis and embryogenesis experiments were conducted with the aim of developing a protocol for *in vitro* propagation of local cactus from areole explants and *in vitro* selection of cactus for salinity tolerance and resistance. For the first experiment, a reliable strategy was followed for micropropagation of *Opuntia ficus-indica* (L.) and *Opuntia robusta* L. cactus pear in the presence of the growth regulators, 6-benzylaminopurin (BAP) and metatopolin (mT), at four different concentrations (0.5, 1, 2 and 3 mg/l) and via callogenesis with 2,4-D and picloram at 2, 4, 6 and 8 mg/l. Results of the first experiment revealed that best values of shoot evolution for the 2 cactus species was recorded on media supplemented with BAP, mainly. Media with mT lead to vitroplants with less quality. *Opuntia robusta* vitroplantlets show better evolution results than *Opuntia ficus-indica* vitroplantlets. In the second experiment, large and compact calli were initiated on MS medium enriched with 2 and 4 mg/l picloram. For salinity stress tolerance, a decreasing pattern in number and quality of cactus shoots and calli were observed with increasing salinity levels and widely affected at 8 and 10 g/l NaCl. On media with 2, 4 and 6 g/l of NaCl, plantlets show a normal morphologic evolution indicating that cactus can tolerate relatively high salinity levels.

Keywords: Opuntia cactus, mT, *in vitro* propagation, NaCl, salinity stress.

ROLE OF SOCIAL SUPPORT FOR SUSTAINABLE RURAL FOOD SECURITY IN COVID-19 PANDEMIC

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ABSTRACT

Food security is the most debatable topic for the last few decades. It plays a very effective role in the economic condition of a country. Food insecurity is the cause of many problems in the health and medical field. Social support plays a very important role in decreasing malnutrition if it is provided according to the needs of people especially during the pandemic of Covid-19. The initiative was taken by the Pakistani government in the form of the 'Ehsaas Emergency program' plays a vital role in decreasing food insecurity and provides brief information about the relationship between food security and social support. To find the relationship between food security and social support and support given by the government we collected data from 246 rural households from district Jhang and Multan. We collected data using the Dietary Intake Assessment questionnaire, USDA questionnaire, and MSPS scale. We also use a self-generated questionnaire to investigate the role of the 'Ehsaas emergency program' on food security and the financial needs of people. We used Propensity Score Matching (PSM) to find the role of social support in the sustainability of food security. The results of propensity score matching show that there is a strong relationship between social support and food security. Education, family size, age of household head, income, gender, and distance from cities has negative impacts on food security. It is concluded that social support programs are necessary for sustainable food security.

Keywords social support, food security, Covid-19, Propensity Score Matching, income

THE LINKAGE BETWEEN LIVING STANDARD OF SMALL FARMER AND AGRICULTURAL POVERTY IN RURAL PUNJAB, PAKISTAN

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ABSTRACT

Living standards refer to the quality of life and material comfort of individuals and society. Punjab being most densely populated province of Pakistan has a highly differentiated society in terms of living standards. Clear differences can be observed among the urban Punjab and rural Punjab. Agriculture remains the only source of income for the bulk of the rural population although. Majority of the rural population in Punjab are small land holders. These small farmers are mostly poor and have lower levels of living standard. The lower levels of living standard among small farmers obstructs the growth of agriculture in Punjab. Therefore, agricultural production remains insufficient in quantity or inferior in quality which leads to poor agricultural production in Punjab. This poverty of agricultural production leads to lesser earnings. This study investigates the relationship between the living standards of small farmers and poverty of agriculture in rural Punjab, Pakistan. Primary data was collected from 250 small farmers in 5 districts of Punjab. Binary Logistic Regression analysis was used to analyze the relationship between the various indicators of living standard and agricultural poverty. The study found an inverse relationship between agricultural poverty and living standard of the small farmers. The results revealed that the per capita income of the family, participation of the female, infrastructure, agriculture mechanization and utilization of agricultural credit may reduce the occurrence of agricultural poverty. Therefore, measures should be taken to improve off-farm employment, infrastructure and credit system.

Keywords: Small farmers, Living standard, Agricultural poverty.

PERFORMANCE OF SOME ANISE GENOTYPES UNDER TOKAT ECOLOGICAL CONDITIONS

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ABSTRACT

The study aimed to determine the performance of some anise genotypes under Tokat's ecological conditions. The research was conducted during the 2023 growing season in Tokat-Kazova ecological conditions according to the Randomized Complete Block Design with three replications. Materials consisted of 10 different populations collected from various regions of Turkey and three registered varieties. The study evaluated findings regarding emergence time, flowering time, maturation time, plant height, number of branches per plant, number of fruiting branches per plant, number of umbels per plant, number of fruits per umbel, seed yield per plant, thousand-seed weight, seed yield, essential oil ratio, and essential oil yield. Among the examined traits, thousand-seed weight was found to be statistically insignificant, whereas all other parameters were determined to be highly significant ($p<0.01$). Emergence time ranged from 30-33 days, flowering time from 65-71 days, and maturation time from 97-102 days. Plant height varied from 57.60 to 69.53 cm, branch number per plant from 4.50 to 6.70, fruiting branch number per plant from 3.90 to 5.90, number of umbels per plant from 4.20 to 7.90, fruits per umbel from 367.97 to 698.87, seed yield per plant from 0.89 to 2.59 g, thousand-seed weight from 2.07 to 2.66 g, seed yield per decare from 28.00 to 67.00 kg/da, essential oil ratio from 1.62% to 2.59%, and essential oil yield from 0.46 to 1.51 l/da. The population from Syria exhibited the highest seed yield (67.00 kg/da) and essential oil yield (1.51 l/da). According to the study results, the Syrian population and Altın 8 variety stood out in terms of seed and oil yield.

Keywords: Adaptation, *Pimpinella anisum* L., Essential oil, Yield

BAZI ANASON GENOTİPLERİNİN TOKAT EKOLOJİK ŞARTLARINDAKİ PERFORMANSLARI

ÖZET

Araştırmada, Tokat ekolojik koşullarında bazı anason genotiplerinin performanslarının belirlenmesi amaçlanmıştır. Çalışma 2023 yılı yetiştirme döneminde Tokat- Kazova ekolojik şartlarında Tesadüf Blokları Deneme Desenine göre 3 tekerrürlü olarak yürütülmüştür. Materyal olarak Türkiye'nin çeşitli bölgelerinden toplanan 10 adet farklı popülasyon ve 3 adet tescilli çeşit kullanılmıştır. Araştırmada çıkış süresi, çiçeklenme süresi, olgunlaşma süresi, bitki boyu, bitkide dal sayısı, bitkide meyve dal sayısı, bitkide şemsiye sayısı, şemsiyedeki meyve sayısı, bitki başına tohum verimi, bin tane ağırlığı, tohum verimi, uçucu yağ oranı ve uçucu yağ verimine ait bulgular değerlendirilmiştir. İncelenen özelliklerden bin tane ağırlığı istatistiki olarak önemsiz bulunurken diğer tüm parametrelerin ise çok önemli ($p<0.01$) olduğu tespit edilmiştir. Çıkış süresi 30-33 gün, çiçeklenme süresi 65-71 gün ve olgunlaşma süresi 97-102 gün arasında değişmiştir. Bitki boyu 57.60-69.53 cm, dal sayısı 4.50-6.70 adet/bitki, meyve dal sayısı 3.90-5.90 adet/bitki, bitkide şemsiye sayısı 4.20-7.90 adet/bitki, şemsiyedeki meyve sayısı 367.97-698.87 adet, bitki başına tohum verimi 0.89-2.59 g, bin tane ağırlığı 2.07-2.66 g, dekara tohum verimi 28.00-67.00 kg/da, uçucu yağ oranı %1.62-2.59 ve uçucu yağ verimi 0.46-1.51 l/da arasında bulunmuştur. En yüksek dekara tohum verimi (67.00 kg/da) ve uçucu yağ verimine (1.51 l/da) sahip popülasyon Suriye'dir. Çalışma sonuçlarına göre; tohum ve yağ verimi bakımından Suriye popülasyonu ve Altın 8 çeşidi öne çıkmıştır.

Anahtar Kelimeler : Adaptasyon, *Pimpinella anisum* L., Uçucu yağ, Verim

EFFECTS OF ROW SPACING AND SEEDING RATE APPLICATION ON SEED YIELD AND SOME YIELD COMPONENTS IN CRESTED WHEATGRASS (*AGROPYRON CRISTATUM* L. GAERTN.) IN THE TOKAT ZONE OF THE TURKİYE

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ABSTRACT

Successful seed production depends on identifying a suitable environment for the species and proper agronomic practices.

This research was carried out for three years between 2023 and 2024 to determine seed yield and some yield characteristics of different row spacing and seeding rates in crested wheatgrass

(*Agropyron cristatum* (L.) Gaertn.) under Tokat ecological conditions. The field trials were carried out under non-irrigated conditions at a medium-high (599 m) altitude between 40° 18'latitude and 36° 34' longitude in the experimental fields of the Central Black Sea Transitional Zone Agricultural Research Institute. Crested wheatgrass (*Agropyron cristatum* L) 'Geçit 1' variety registered by the Institute was used as plant material. The field trials were established according to the 'Split Plots Experimental Design in Randomized Complete Blocks' with three replications. Different row spacings (30, 45, 60 and 75 cm) were used in the main plot and seed rates (10, 20, 30 and 40 kg ha-1) were used in the sub-plots.

In this study, for seed yield components yield traits including plant height, fertile tillers per square meter (FTD), seed yield per plant, thousand -seed weight (TSW)and seed yield(SY) were investigated.

An increase in yield was achieved by increasing the row spacing and seed sowing rate; however, a decrease in yield was observed when the optimum density was exceeded (75 cm and 40 kg ha -1). The seed production different row spacing (except thousand seed weight) and seed quantity applications had a high level of statistical significance ($p<.0001$) on the examined parameters. Seed yield was influenced significantly row spacing, seeding rate and the interactions of and row spacings and seeding rate, but was not affected by experiment year.

According to the results of the research, seeding rate of 20 or 30 kg ha -1 and a row spacing of no wider than 45 cm proffered adequate for seed production in this research location and in similar ecological regions.

Keywords: Crested wheatgrass, row spacing, seeding rate, thousand -seed weight, seed yield

TÜRKİYE TOKAT BÖLGESİNDE SIRA ARALIĞI VE TOHUM EKIM ORANI UYGULAMASININ OTLAK AYRIĞI (*AGROPYRON CRISTATUM* L. GAERTN.) TOHUM VERIMI VE BAZI VERIM BILEŞENLERI ÜZERINDEKI ETKILERI

ÖZET

Başarılı tohumu üretimi, türler için uygun bir ortamın ve uygun tarımsal uygulamaların belirlenmesine bağlıdır.

Bu araştırma, Tokat ekolojik koşullarında farklı sıra arası ve tohum miktarlarının otlak ayrığı (*Agropyron cristatum* (L.) Gaertn.) tohum verimi ve bazı verim özelliklerine etkisinin belirlenmesi amacıyla 2022-2024 yılları arasında üç yıl süre ile yürütülmüştür. Tarla denemeleri Orta Karadeniz Geçit Kuşağı Tarımsal Araştırma Enstitüsü deneme alanlarında 40° 18' enlem ve 36° 34' boylamları arasında, orta-yüksek (599 m) rakımda sulanmayan koşullar altında gerçekleştirilmiştir. Enstitü tarafından tescil ettirilen otlak ayrığı (*Agropyron cristatum* L) "Geçit 1" çeşidi bitki materyali olarak kullanılmıştır. Arazi denemeleri "Tesadüf Bloklarında Bölünmüş Parseller Deneme Desenine" göre üç tekerrürlü olarak kurulmuştur. Farklı sıra aralıkları (30, 45, 60 ve 75 cm) ana parselde, tohum miktarları (1.0, 2.0, 3.0 ve 4,0 kg/da) alt parsellerde yer almıştır. Bu çalışmada, tohum verimi bileşenleri için bitki boyu, metrekare başına verimli kardeş (FTD), bitki başına tohum verimi, bin tohum ağırlığı (TSW) ve tohum verimi (SY) parametreleri incelenmiştir.

Sıra aralığı ve tohum ekim oranının artırılması ile incelenen parametrelerde artış sağlanmış; ancak optimum yoğunluğun üzerine çıkıldığında (75 cm ve 4,0 kg/da) azalma eğiliminde olduğu görülmüştür.

Tohum üretiminde farklı sıra aralığı (bin tohum ağırlığı hariç) ve tohum miktarı uygulamalarının incelenen parametrelere etkisi yüksek düzeyde istatistiksel anlamlı (p<,0001) olmuştur.

Tohum verimi, sıra aralığı, tohum ekim oranı ve sıra aralıkları ile ekim oranının etkileşimlerinden önemli ölçüde etkilenmiştir, ancak deneme yılından etkilenmemiştir.

Araştırma sonuçlarına göre, bu araştırma lokasyonunda ve benzer ekolojik bölgelerde tohum üretimi için 2,0 veya 3,0 kg /da tohum oranı ve 45 cm'den geniş olmayan sıra aralığının yeterli olduğu görülmektedir.

Anahtar Kelimeler: Otlak ayrığı, sıra aralığı, tohum miktarı, 1000 tane ağırlığı, tohum verimi

INFLUENCE OF PLANT GROWTH REGULATORS ON *IN-VITRO* SHOOT REGENERATION IN GINGER (*Zingiber officinale* Rosc.)

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ABSTRACT

Ginger (*Zingiber officinale* Rosc.) is a valuable medicinal and spice crop that belongs to the family Zingiberaceae. Rhizomes are the commercially valuable part of the plant, and it is widely used in the food, pharmaceutical, and cosmetic industries. Due to the richness of various phenolic compounds such as gingerol, shogaol, and zingerone, ginger possesses multiple biological activities, including antioxidant, anti-inflammatory, antimicrobial, anticancer, antidiabetic, antinausea, and antiemetic effects. Typically, once the plant has blossomed, the rhizomes are mature enough for harvesting, usually in about 8 to 10 months from sprouting.Conventional propagation method which is primarily by rhizomes is insufficient to satisfy the increasing demand for high-quality planting materials due to slow growth rates, low propagation efficiency, vulnerability to diseases, and seasonal dependency. This research aimed to develop an efficient *in-vitro* protocol to enhance the mass production of a variety of ginger, namely Chinese ginger, ensuring the year round availability of disease-free planting materials. Sprouting rhizome buds were surface sterilized using fungicide (Thiram 30% (W/W)) followed by 70% ethanol and 30% Clorox (commercial bleach) for 15 minutes twice. Solid Murashige and Skoog (MS) medium was used as a basal medium, with variations in hormonal combinations, BAP (6-Benzylaminopurine)(1.0, 2.0, 3.0, 4.0, 5.0 mg/L) and NAA (1-Naphthaleneacetic acid) (0, 0.25, 0.5 mg/L) to regenerate shoots. The highest shoot multiplication was achieved on a medium supplemented with 2 mg/L BAP and 0.25 mg/L NAA, while the greatest shoot elongation was observed with 5 mg/L BAP and 0 mg/L NAA. Spontaneous rooting occurred in some treatments, with the highest root number recorded on a medium containing 5 mg/L BAP and 0.25 mg/L NAA. In conclusion, the results of this study

provide an efficient and reproducible in-vitro propagation protocol, which has the potential to address the challenges of traditional propagation and can be utilized for large-scale ginger production using rhizome buds.

Keywords: *Zingiber officinale* Rosc., *In-vitro* propagation, Sterilization, Shoot regeneration, Mass production

PEATLAND RESOURCES OF UKRAINE: PROBLEMS AND CHALLENGES

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ABSTRACT

The article highlights the problem of inefficient management of peatland land resources of Ukraine. The necessity of transition to scientifically based, ecologically safe approaches, renaturalization of degraded territories and optimization of their use is considered. The importance of differentiating the areas of use of peatland lands is emphasized, based on the assessment of their productive, ecological and social functions. Each individual peatland massif, in accordance with its genetic nature and location in the landscape, has certain useful functions that should be used to the maximum extent. Attention is drawn to the processes of depletion and loss of the powerful water, carbon and nitrogen fertility potential of drained peatlands under conditions of intensive agriculture. It is noted that there is a need to renaturalize (rehabilitate) a significant part of drained peat bogs that have undergone degradation with the introduction of marsh culture on these lands, which involves secondary watering (boiling) of drained bog massifs and growing hydrophilic vegetation. As for environmentally more stable cultivated humus-peat, ash-rich soils with high potential fertility, it is advisable to leave them in the agricultural land fund. For such soils, there is a wide range of environmental protection uses, thanks to environmentally sound methods of land reclamation and justified agro-technological techniques. Ways to solve the problem of effective management of peat bogs are proposed. The authors emphasize the importance of differentiating the directions of peatland use, legislative regulation and the implementation of projects aimed at reducing greenhouse gas emissions for the preservation and restoration of ecosystems.

Keywords: peat bog lands; drained peatlands; renaturalization

STUDIES ON MEDICINAL APPLICATIONS OF TANNINS

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ABSTRACT

Tannins are known for their astringent properties, have various medicinal applications. There are different types of tannins, including hydrolyzable and condensed tannins, each with unique properties and potential applications. The aim of this study was to investigate on medicinal applications of tannins. Medicinal applications of tannins in traditional and potential uses includes Gastrointestinal Issues such as Diarrhea and Intestinal Bleeding: Tannins' astringent nature helps constrict tissues, potentially stopping diarrhea and internal bleeding, Hemorrhoids: Tannins have been used to treat hemorrhoids due to their ability to reduce inflammation and constrict tissues and Ulcers and Gastritis: Some tannins may act as a protective coating for the gastrointestinal tract, potentially aiding in the treatment of ulcers and gastritis. Antimicrobial and Antiseptic Properties such as Skin Irritations and Wounds: Topical application of tannins can help remove skin irritants, reduce inflammation, and even aid in the treatment of burns and wounds due to their anti-hemorrhagic and antiseptic properties and Bactericidal Action: Tannins can react irreversibly with bacterial proteins, disrupting their function and potentially leading to their inactivation. Antioxidant and Anti-Inflammatory Effects such as Free Radical Scavenging: Tannins possess antioxidant properties, helping to protect against cellular damage caused by free radicals and Anti-Inflammatory: Some tannins exhibit anti-inflammatory effects, potentially beneficial in treating various conditions. Nutraceuticals and Pharmaceuticals: Tannins are being explored as potential components in nutraceuticals and pharmaceuticals, leveraging their diverse pharmacological properties. They are considered an indispensable component with external and internal effects in a variety of nutraceuticals, pharmaceuticals, and medicinal preparations. Other Potential Applications are Anticancer Properties, Neurodegenerative Diseases, Antipyretic and Anthelmintic, Cardiovascular Health and Diabetes and Obesity. The medicinal properties of tannins can vary depending on the plant source and the concentration of tannins present. More research is needed to fully understand the mechanisms of action and potential benefits of tannins in various medical applications.

Keywords: Tannins, Medicinal Application, Astringent Properties, Anti-Inflammatory.

EXPLORING ALTERNATIVE SOLUTIONS TO RICE GROWERS' CHALLENGES THROUGH MIXED-METHOD APPROACHES

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ABSTRACT

Agriculture play a vital role as a backbone in the economic sector of Pakistan. Rice crop is not only used just for eating purpose as well as used by products in the various forms. Rice growers faced various complications regarding to developing of yields. High costs of contributions of agribusiness items, increment of diesel costs, lack of electrical energy and minimum information about most recent systems of raising yield were the essential production issues looking by the producers. In Asia eighty percent of total fresh water is consume for rice production. Rice requires more water than the other field crops which are widely grown. It is estimated of 24-30% of freshwater resource in world are used by rice. The study was conducted in Tehsil Sheikhupura, five union councils Butter, Jatri Kohna, Kot Sondha, Farooqabad and Easherke were selected randomly. Focus groups and interview schedules with rice growers were used to gather data. The analysis was conducted using SPSS and content analysis techniques, study found that the majority of farmers experienced water scarcity, unaware of advanced production technology and faced challenges such pesticide adulteration, high labor costs and expensive harvesting machinery. Additionally, market access challenges due to middlemen exploitation were significant. To address these issues, recommendations include the provision of resistant seed varieties, prevention of input adulteration, fair crop pricing, improved market linkages, government-subsidized solar-powered tube wells, easy loan access,

construction of storage facilities, and digitalization of land records. Policy interventions focusing on farmer welfare are crucial for sustainable rice production.

Keywords: Rice cultivation, farmers problems, yield enhancement, mixed method approaches, agricultural policy

IMPACT OF ANIMAL NUTRITION ON MILK PRODUCTION EFFICIENCY IN ALGERIA

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ABSTRACT

Animal nutrition is a key factor in the physiology of milk biosynthesis, influencing both its quantity and quality. The composition of the diet affects the biochemical and microbiological characteristics of milk, which in turn determine its nutritional value and technological properties. This study examines the impact of different feeding practices on milk production in cows, sheep, and goats in Algeria. By analyzing the relationship between diet composition, environmental factors, and milk quality, this research aims to identify strategies for optimizing dairy production while maintaining high nutritional and hygienic standards. The results will contribute to improv feeding practices adapted to local farming conditions.

Keywords: Animal nutrition, milk biosynthesis, milk quality, biochemical composition, microbiological properties, environmental factors.

POISONOUS SPONTANEOUS PLANTS AS SOURCES OF TRADITIONAL AND MODERN MEDICINES IN BISKRA, SOUTH ALGERIA-NOTH AFRICA

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ABSTRACT

Since antiquity, humanity has used medicinal plants to treat and cure various diseases. Today, plants continue to play a crucial role in the field of healing worldwide. In objectif to examinate the significance use of poisonous spontaneous plants as sources of traditional medicinal plants in arid conditions our study was carried out in Northern Africa South Algeria at the Biskra region. The obtained results indicated a significant use of poisonous spontaneous plants in preparing bio drugs. The study also highlights the great ecological diversity of the Biskra region, with species adapted to different environments. The survey on the use of toxic plants in traditional medicine in Biskra shows that the majority of respondents (65%) are between 30 and 60 years old, with women (59%) being more involved than men (41%). Most live on the outskirts of Biskra (62%), and university graduates (36%) are the most knowledgeable about medicinal plants. The main sources of information are family (49%) and herbalists (20%). Among the most commonly used plants are Citrullus colocynthis, Ruta chalepensis, and Thapsia garganica. The used plants are primarily used to treat digestive (20%) and dermatological (20%) disorders. The leaves are the most commonly used parts (38%), with common preparations, decoctions (33%) and powders (29%). The majority of remedies are administered orally (54%). In terms of toxicity, digestive effects are the most frequent (30%), followed by dermatological, neurological, and renal toxicities (15%). Plants may contain both beneficial and toxic compounds, making preparations risky.

Keywords: toxic plants, inventory, ethnobotanical survey , traditional medicine, Biskra

THE ROLE OF AGRICULTURAL POLICIES IN DEVELOPING LIVESTOCK IN DESERT AREAS OUED SOUF (ALGERIA) AS A MODEL

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ABSTRACT

The agricultural policy adopted by the Algerian state and the programs and privileges it has allocated since independence aim to achieve food security by increasing the area of agricultural land.

The increase and diversification of agricultural production in both plant and animal sectors, using new means and methods for optimal land exploitation, has yielded significant results, especially in desert areas that have experienced considerable agricultural dynamics due to their share of reclamation and agricultural development programs. It has become an agricultural hub by recently achieving a significant production of crops and livestock.

Through this study, we aim to highlight the role of agricultural policies and land reclamation in developing livestock in desert areas, especially in Wadi Souf, which has known in recent years a continuous increase as a result of the policy adopted by the state in this field. This is by allocating large financial credits to farmers to increase their animal wealth and products, as the valley state is the main driver of the livestock market in the southeast, especially sheep and goats compared to the rest of the livestock, in addition to camel breeding.

Keywords: livestock, desert agriculture, agricultural policies, agricultural sector.

COMPARATIVE IMPACT OF MONOCOT AND DICOT INVASIVE PLANT SPECIES ON WILDLIFE: ASSESSING HABITAT DISRUPTIONS AND BIODIVERSITY LOSS

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ABSTRACT

Aggressive colonizers that outcompete native vegetation are known as invasive plant species, and they cause habitat degradation and biodiversity loss. They pose a serious ecological hazard because of their capacity to change the chemistry of soil, destabilize food webs, and alter geomorphological structures. Although invasive species have a general effect on ecosystems, little is known about how monocot and dicot invasive plants differ from one another. The contrasting effects of invasive monocot and dicot species on wildlife, habitat stability, and ecosystem functioning are examined in this paper. To obtain worldwide information on invasive plant species and their ecological effects, a thorough search of Google Scholar was undertaken. To guarantee a thorough examination, key terms including "invasive plant species", "wildlife impact", "ecosystem disruption", and "habitat restoration" were employed. Priority was given to studies that examined changes in plant communities, the availability of nutrients for herbivores, predators, and decomposers, as well as the introduction of new species as a result of invasions. The collected data was synthesized to compare the impact of monocot and dicot invasive plants and evaluate their effects on biodiversity and ecosystem stability. According to research, dicot invasive species cause more ecological disturbance than monocots because of their aggressive growth habits and capacity to supplant native plants. Lantana camara, Chromolaena odorata, and Prosopis juliflora are examples of species that drastically change habitat structures and decrease species diversity. This review highlights how invasive plants reshape ecosystems and emphasizes the need for further research on their long-term ecological consequences.

Keywords: Invasive plant species, Ecosystem disruption, Biodiversity loss, Habitat degradation

REAL-TIME HERD MONITORING WITH UNMANNED AERIAL VEHICLES: A THERMAL IMAGING APPROACH

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ABSTRACT

The object of this study is grazing livestock. The aim of the study is to conduct herd monitoring using data collected with a thermal imaging camera. For the observation of animal behavior, the drone Parrot ANAFI Thermal was used, enabling real-time monitoring. The study was conducted across ten farms.

One of the most important parameters during drone flights was the flight altitude, which had to be optimized to ensure the collection of detailed data in the shortest possible time. During the study, the behavior of the livestock herd was assessed.

Summarizing the observation results, it was found that in most cases, animals can be photographed from an altitude of 20 meters, as this does not cause significant stress. Although red deer showed some reaction to the drone flying at this height (mainly turning their heads), they did not flee, stop feeding or drinking, or become scattered.

The results of the study indicated that an altitude of 50 meters provides optimal monitoring conditions: a sufficiently large area is covered, and the resolution of the data meets the requirements for analysis. At higher altitudes, image detail decreases; however, if the aim is to detect the presence and location of a herd of ungulates, the level of detail is sufficient. For sheep monitoring, a flight altitude not exceeding 50 meters is recommended. Differences in the thermal image signatures and shapes of individual animals may be used during nighttime monitoring to locate lost animals or to identify the number of adult individuals and offspring.

Keywords: Remote sensing methods; Thermal images; Herd; Drone-based monitoring

EVALUATION OF PROXIMATE AND SENSORY PROPERTIES OF BREAKFAST CEREALS FROM BLENDS OF OAT, SWEET POTATO AND MALTED AFRICAN YAM BEAN

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ABSTRACT

The aim of this study was to determine the sensory and proximate evaluation of breakfast cereals produced from blends of oat, sweet potato and malted Africa yam bean flour..Breakfast cereal sample were produced by mixing the:se composite flours with sugar, water and salt after which they were dried in an electric oven. Four samples were generated by mixing the oat,sweet potato and malted African yam bean flours in the ratio of 100:0::0, 50:50:0, 50:38:12 and 46:40: 14 to which were coded as BC1, BC2, BC3, and BC4 respectively. The results showed proximate composition ranged from Moisture 7.11to .06%, Crude protein 11.49t o10.35%, Fat 12.49 to 10.35%, Crude fiber 0.51 to 6.50%, Ash 0.59to 0.90%, Carbohydrate 67.81-68.69%, and Energy 429.57 to392.69%.The result of sensory evaluation showed that sample BC1 (100% oat) was most accepted by the paralists in all the sensory attributes of colour (8.20) taste (7.80), mouth feel (7.70) flavour (7.80) and overall acceptability (7.90). Commercialization of these product will increase potential of nutritional and acceptable breakfast cereal from blends of oat, sweet potato and Africa yam bean in the world market.

Key Words: Breakfast cereals, Oat, Sweet Potato, Malted African Yam Beam

PHARMACOLOGICAL EVALUATION OF *FICUS BENGHALENSIS* LATEX IN RHEUMATOID ARTHRITIS MANAGEMENT

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ABSTRACT

Rheumatoid arthritis (RA) is a long-term inflammatory condition that causes joint pain, stiffness, and swelling. It can greatly impact daily life and, if untreated, may lead to joint damage. Current treatments for RA can help manage symptoms but often come with side effects. As a effect, there is growing interest in using natural remedies for safer and more effective treatment options. *Ficus benghalensis*, commonly known as the Indian banyan tree, has been used in traditional medicine for its healing properties. Its latex is believed to have anti-inflammatory and immune-supporting effects. This abstract focuses on understanding how the latex of *Ficus benghalensis* might help in managing the symptoms of rheumatoid arthritis. Findings suggest that the latex may help reduce joint swelling, improve movement, and lower inflammation. It appears to work by calming the immune system and decreasing substances in the body that cause inflammation. These effects support the traditional use of the plant and highlight its potential role in arthritis care. This plant-based approach could offer a gentler alternative for people looking to manage rheumatoid arthritis with fewer side effects. The abstract supports the traditional use of *Ficus benghalensis* latex and highlights its potential as a natural therapeutic agent for RA, likely due to its bioactive constituents possessing anti-inflammatory and immunosuppressive effects. Further research is recommended to isolate and characterize the active compounds responsible for its efficacy and to evaluate its safety profile in clinical settings.

Keywords: *Ficus Benghalensis*, Rheumatoid Arthritis, Joint Pain, Natural Remedy, Inflammation, Traditional Medicine

ROLE OF HORTICULTURE IN PROMOTING ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

Horticulture plays a pivotal role in promoting environmental sustainability by contributing to ecological balance, enhancing biodiversity, and mitigating the adverse effects of climate change. As a branch of agriculture concerned with the cultivation of fruits, vegetables, flowers, and ornamental plants, horticulture integrates sustainable practices that help conserve natural resources and reduce environmental degradation. The adoption of eco-friendly techniques such as organic farming, integrated pest management (IPM), and precision irrigation not only improves crop productivity but also minimizes the overuse of chemical fertilizers and pesticides, leading to healthier ecosystems. Urban horticulture, including rooftop gardening and vertical farming, further supports green infrastructure development, improves air quality, and reduces the urban heat island effect. Moreover, horticultural landscapes contribute to carbon sequestration, soil stabilization, and water conservation, fostering climate-resilient environments. Community gardening and horticultural education also raise awareness about sustainable living practices and encourage public participation in environmental stewardship. Furthermore, the development of climate-resilient plant varieties through biotechnology enhances adaptability to environmental stresses, ensuring food security while preserving ecological integrity. Overall, horticulture is a dynamic and multifaceted tool that aligns with the goals of sustainable development by harmonizing agricultural productivity with environmental preservation. By integrating horticultural strategies into national and global environmental policies, societies can advance toward a more sustainable and resilient future.

Keywords: Horticulture, Environmental Sustainability, Biodiversity, Urban Greening, Climate Change Mitigation, Sustainable Agriculture

NOVEL MX-106 HYDROXYQUINOLINE DERIVATIVES: 2D-QSAR MODELING, MOLECULAR DOCKING, MOLECULAR DYNAMICS SIMULATIONS, AND ADMET PREDICTIONS FOR POTENT SELECTIVE SURVIVIN INHIBITORS

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ABSTRACT

The urgent need for the development and discovery of new inhibitors targeting survivin (BIRC5), recognized as one of the most tightly regulated genes in tumor cells, underscores the current research focus. Survivin serves as a specific cancer biomarker and represents a promising target for anticancer medications. This study outlines the design methodology employed for crafting a series of novel and selective survivin inhibitors, drawing inspiration from the hydroxyquinoline framework of our previously documented lead compound, MX-106.

Our investigation identifies nine compounds projected to demonstrate heightened inhibitory potential compared to the most potent member within the studied set. In vitro assays confirmed the effectiveness of these compounds in impeding the proliferation of MDA-MB-435 breast cancer cells. Furthermore, the metabolic stability of these compounds surpassed that of the most active molecule within the test set.

Employing 2D-QSAR methods encompassing multiple linear regression (MLR), multiple nonlinear regression (MNR), and artificial neural networks (ANN), alongside molecular dynamics, molecular docking, and ADMET properties evaluation, we assessed the viability of 31 hydroxyquinoline scaffold derivatives of MX-106 as selective survivin inhibitors. Molecular docking simulations were conducted to gauge the stability of compound C24, revealing the establishment of multiple hydrogen bonds with diverse residues. A subsequent 100-ns molecular dynamics simulation affirmed its sustained stability over the entire duration, indicating their potential suitability for further drug development endeavors.

Building upon the insights garnered from molecular modeling outcomes, we devised nine innovative compounds (Pred1, Pred2, Pred3, Pred4, Pred5, Pred6, Pred7, Pred8, and Pred9), anticipated by MLR models to exhibit potent survivin inhibitory activity. We advocate for a comprehensive evaluation of the ADMET properties of these newly proposed compounds, positioning them as promising candidates for pioneering anticancer agents targeting survivin inhibition akin to MX-106.

Keywords: QSAR, tumor cells, Molecular Docking, Molecular dynamic, ADMET properties, selective survivin inhibitors, cancer, MX-106 hydroxyquinoline scaffold.

ENTREPRENEURSHIP IN FLORICULTURE: TURNING PASSION INTO PROFIT

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ABSTRACT
Floriculture, a dynamic sector of horticulture, has emerged as a lucrative avenue for entrepreneurship, particularly for individuals with a passion for flowers and ornamental plants. This paper explores the entrepreneurial potential within floriculture by analyzing how personal interest can be transformed into a profitable and sustainable business venture. The study delves into key components such as market trends, consumer preferences, value addition, and innovative marketing strategies, particularly in regions where floriculture is underdeveloped yet holds significant potential. With increasing demand for fresh flowers, potted plants, and floral arrangements across domestic and international markets, floriculture presents opportunities for both small-scale growers and commercial enterprises. The research highlights the importance of business planning, supply chain management, and quality control in building a competitive floriculture enterprise. Additionally, it investigates the role of technology, including greenhouse management, e-commerce, and digital marketing, in enhancing productivity and market reach. Case studies of successful floriculture entrepreneurs illustrate practical approaches to overcoming challenges such as climate variability, perishability of products, and fluctuating market prices. The paper also emphasizes government support programs, training initiatives, and cooperative models that can empower aspiring floriculture entrepreneurs. Ultimately, the study concludes that a blend of horticultural expertise, business acumen, and strategic innovation can enable passionate individuals to turn floriculture into a thriving entrepreneurial endeavor, contributing to economic development, rural employment, and environmental sustainability.

Keywords: Entrepreneurship, Floriculture, Horticultural Business, Value Addition, Market Strategy, Sustainable Agriculture

EXPLORING THE HORTICULTURAL SIGNIFICANCE OF TUBEROSE

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ABSTRACT
Tuberose (*Polianthes tuberosa*), a bulbous ornamental plant belonging to the family Asparagaceae, is esteemed for its aesthetically pleasing appearance, long-lasting flowers, and rich, sweet fragrance. Native to Mexico, this plant has gained global prominence, particularly in tropical and subtropical regions, where it is cultivated extensively for use in ornamental gardening, the cut flower industry, and perfumery. The horticultural importance of tuberose lies in its multifaceted applications ranging from floral arrangements and landscape architecture to extraction of essential oils used in high-value perfumes and aromatherapy products. This abstract delves into the comprehensive horticultural aspects of tuberose, including its morphological features, optimal growing conditions, propagation techniques (such as bulb division and tissue culture), and pest and disease management. It also addresses the plant's phenological behavior, varietal improvement, and post-harvest handling practices that affect flower quality and marketability. Furthermore, the economic potential of tuberose in both domestic and international markets is highlighted, along with its cultural and ceremonial relevance in several regions. Recent advances in biotechnology and breeding have opened new avenues for enhancing flower yield, disease resistance, and fragrance quality. As the demand for natural floral products increases, tuberose emerges as a vital crop in sustainable floriculture systems. This paper aims to provide a consolidated understanding of the horticultural significance of tuberose and promote its wider adoption in commercial and ornamental horticulture.

Keywords: Tuberose, Floriculture, Essential oils, Ornamental horticulture, Cultivation practices, Economic value

NITRATE ION (NO3-) LEVELS IN FRUITS AND VEGETABLES IN THE CITIES OF PRISHTINA AND GRAÇANICA WERE MEASURED USING THE "GREEN TEST ECO 5 F -ANMEZ" EQUIPMENT

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ABSTRACT

This study uses the "Green Test ECO 5 F-ANMEZ" instrument to measure the amount of nitrate ions (NO3-) in fruits and vegetables in Kosovo cities including Prishtina and Gracanica. In order to assess physical and chemical characteristics, such as pH, sugar content, and nitrate levels, in ten distinct plant products, the monitoring was conducted for approximately a month at six sampling locations at nearby marketplaces and warehouses. The purpose of our study is to assess how storage conditions affect the physico-chemical and organoleptic characteristics of fruits and vegetables. With the exception of a few instances of high nitrate levels in fruits like melons and other vegetables, our data demonstrated that nitrate concentrations in the majority of samples were within the allowed limits.

Additionally, by tracking changes in pH, sugar content, and structure over time, our study assessed how refrigeration affected the way fruits and vegetables were stored. Overall, our research indicates that the majority of products satisfy WHO-established local and worldwide quality criteria, and that handling and storage practices are critical to preserving the safety and quality of these agricultural products.

Keywords: refrigeration, pH, nitrate concentration, nitrate ions, fruits and vegetables, Prishtina, Gracanica, Green Test ECO 5 F-ANMEZ, and food quality requirements.

PROBIOTICS IN LIVESTOCK PRODUCTION: ENHANCING GROWTH, IMMUNITY, AND MEAT QUALITY

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ABSTRACT

To address the rapidly growing use of probiotics in animal agriculture, this review discusses the effect of probiotics on animal growth and development, immune response, and productivity. Several benefits have been associated with the use of probiotics in farm animals, such as improved growth and feed efficiency, reduced mortality, and enhanced product quality. While the mechanisms through which probiotics induce their beneficial effects are not well understood, their role in modifying the gastrointestinal microbiota is believed to be the main mechanism. The use of probiotics in fresh and fermented meat products has been also shown to reduce pathogenic and spoilage microorganisms and improve sensory characteristics. Although many benefits have been associated with the use of probiotics, their effectiveness in improving animal performance and product quality is highly variable. Factors that dictate such variability are dependent on the probiotic strain being utilized and its stability during storage and administration/inoculation, frequency and dosage, nutritional and health status as well as age of the host animal. The utilization of probiotics in animal husbandry has garnered significant attention as a natural and effective strategy to enhance production performance and meat quality. This review synthesizes current research on the impact of probiotics on various livestock, including poultry, swine, and cattle. Probiotics, which are live microorganisms that confer health benefits to the host, have been shown to improve growth rates, feed conversion ratios, and overall health status of animals. Furthermore, they contribute to enhanced meat quality by influencing factors such as muscle composition, fat content, and oxidative stability. Mechanistically, probiotics exert their effects through modulation of gut microbiota, enhancement of nutrient absorption, and stimulation of the immune system. Studies also indicate a reduction in the incidence of diseases and a decrease in the need for antibiotic growth promoters, addressing concerns over antibiotic resistance. Despite promising results, variability in outcomes suggests that probiotic efficacy is influenced by factors such as strain specificity, dosage, and administration methods. Future research should focus on finding more effective probiotic strains for the desired use and identifying the optimum dose, administration time, delivery method, and mechanism of action for each strain/host. This review highlights the

potential of probiotics as a sustainable approach to improve animal performance and meat quality, contributing to more efficient and health-conscious animal agriculture.

Keywords: probiotic; gut microbiota; immune response; growth; efficiency; meat quality

IDENTIFICATION ANALYSIS OF BIOACTIVE CONSTITUENTS OF A MEDICINAL PLANT "*Sedum villosum* L" by UHPLC-DAD-HRSM

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ABSTRACT

Several studies have shown that phytochemical compounds in medicinal plants protect against free-radical reactions, so their active ingredients are used as raw materials for medicinal chemistry modifications. Among these plants, we have chosen *Sedum villosum*, whose scientific research has confirmed that its phenolic compounds have antibacterial, antifungal and antioxidant activity.

In the present study, we are interested, to separate and identify two glycosyl the flavones from *Sedum villosum* L, family Crassulaceae collected in the flowering phase in Lakhdar Oued, village of Tlemcen (Algeria). The crude methanolic extract of the flowers part was fractionated on column chromatography, and eluted with dichloromethane/methanol each time with increasing polarity of methanol; 24 fractions were separated. One of these fractions named F16 showed more antioxidant activity to scavenge DPPH free radical with percentage inhibition of 94.849 %. F16 was separated by thin-layer chromatography (TLC) to give 10 compounds. We were chosen the sub-fractions F16.8, which has antioxidant activity of 77.02 %, provided two major molecules of glycosyl the flavones, analysed by ultra-high performance liquid chromatography coupled to mass spectrometry (UHPLC-DAD-HRSM).

Compound 1 was identified as 7, 3'-dihydroxyflavone-5-O-dihexosyl-4'-O-deoxyhexose and compound 2 was 7, 3'-dihydroxyflavone-5-O-hexose- 4'-O-deoxyhexose.

Keywords: *Sedum villosum*; column chromatography; preparative TLC; HPLC/SM; antioxidant activity; DPPH.

FIRST INVENTORY OF THE BIODIVERSITY OF AQUATIC MACROINVERTEBRATES OF LAKE SIDI BOUDAROUA OUAZZANE, MOROCCO

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ABSTRACT

Natural lakes are a strategic reservoir for water resources and are also a bank for species in aquatic environments. Macroinvertebrates are considered the best bioindicators and reflect the state of these lakes. The objective of the current study was to inventory the aquatic macro-invertebrates of Lake Sidi Boudaroua Ouazzane, Morocco.

The observations under the microscope and the identification of species using identification keys have provided a clear idea of the trophic state of the environment. From the results of these analyses, we were able to build a results matrix. On this, descriptive statistical analyses were applied with the SPSS analysis software. These results show that a distribution of species has made it possible to highlight a seasonal temporal variation. A number of 237 individuals collected in the 3 sampling sites distributed in 11 orders, 22 families, and 26 genera testify to a good diversity of the Lac Sidi Boudaroua. The most abundant family is the Scarabaeidae (Coleoptera).

The biodiversity of macroinvertebrates reflects a significant floristic richness in the case of macrophytes and phytoplankton. Further taxonomic studies of all the biodiversity would make this site a real zoological and botanical garden that would attract not only researchers but also tourists and investors.

Keywords: Biodiversity, survey, macroinvertebrates, Sidi Boudaroua lake, Morocco

PHYSICOCHEMICAL CHARACTERIZATION OF THE WATER OF SIDI BOUDAROUA LAKE, OUEZZANE, MOROCCO: TOWARDS EXPLANATION OF BIODIVERSITY OF LAKE

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ABSTRACT

A lake is an aquatic system in permanent exchange with the external environment on which it depends. The study aimed to determine the physicochemical characteristics of the Lake Sidi Boudaroua water for evaluating its impact on the biodiversity of this lake.

Seasonal sampling campaigns were organized during the year 2020 at the Sidi Boudaroua water body. The first was in January, the second in April, the third in July, and the fourth in September. Measurements of some physicochemical parameters were made in situ (pH, electrical conductivity, turbidity and dissolved oxygen). Anion contents (HCO_3^- and Cl^-) and cation contents (Ca^{2+}, Mg^{2+}, Na^+, and K^+) were measured. Four samples of sediments were collected for analyses of granulometry, organic matter and carbonate content.

The waters of the water body are weakly alkaline (average pH is 8.59) and moderately mineralized (average electrical conductivity is 1339 µs/cm). Cation levels reveal a high concentration of sodium (258.4 mg/L) and calcium (131.3 mg/L) and low concentrations of magnesium (20.80 mg/L) and potassium (6.82 mg/L). Anion levels show high values for chlorine (195.82 mg/L) and bicarbonates (134.55 mg/L). The Boudaroua water is well oxygenated (dissolved oxygen content is 8.12 mg/L on average) and weakly turbid (average turbidity is 7.38 NTU). The geochemical analysis generally reveals for all sites fairly low contents of organic matter and carbonates and high contents of minerals.

The Sidi Boudaroua water lake constitutes an interesting hydrological basin characterized by a facies of calcium-chloro-sodium bicarbonate. The chemical analyses show a variation related to seasonal climatic influence.

Key words : Sidi Boudaroua water, Biological quality, Physicochemistry, Ouezzane, Morocco.

BIOTECHNOLOGY AND GENOMICS STUDY OF A SARS-COV-2 PROTEIN

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ABSTRACT

ADAM-17, a protein disintegrin and metalloprotease domain-containing enzyme, also known as TACE (Tumor necrosis factor-alpha converting enzyme), plays a essential role in cleaving the Pro-Leu-Ala-Gln-Ala-/-Val-Arg-Ser-Ser-Ser sequence in the membrane-bound precursor of tumor necrosis factor alpha (TNF-alpha). In genomics and biotechnology, identifying the most harmful missense variants of ADAM-17 is critical for understanding its role in disease processes. To achieve this, we used a genomics approach with tools like Zinc Finger Nucleases, SIFT, PROVEAN, CRISPR-Cas9, MUpro, PyMol, Microarrays, and Swiss-Model. These tools analyze amino acid substitutions and predict their effects on protein structure and function. Zinc Finger Nucleases edit specific DNA sequences by targeting and modifying them using engineered proteins. SIFT and PROVEAN assess the functional impact of missense mutations, while CRISPR-Cas9 precisely edits DNA by cutting at specific sites for gene modification or correction.Microarrays analyze gene expression and detect genetic variations across many sequences simultaneously. MUpro predicts protein stability changes, and PyMol enables molecular visualization. Swiss-Model generates 3D protein models to assess structural changes. From the missense variants collected from the Ensembl database, seven non-synonymous single nucleotide polymorphisms (nsSNPs) were identified as high-risk and pathogenic by all prediction algorithms. These variants showed significant deleterious effects on the stability, structure, and function of ADAM-17, indicating their direct role in disease development. Further efforts are needed to fully explore the implications of these variants in genomics and disease mechanisms.

Keywords: Biotechnology, Genomics, Covid-19, SARS-CoV-2, Bioinformatics.

CONSUMER PREFERENCES AND WILLINGNESS TO PAY FOR VALUE-ADDED FISH PRODUCTS IN MUZAFARGARH

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ABSTRACT

Manufacturing, processing, and distribution technology advancements determine the modern food industry. The demand for high-quality food among customers has changed due to changes in lifestyle and increased income. As people's knowledge of healthy eating and nutrition has grown, it is now crucial to implement strict quality control, value addition, and consumer appeal in food items. This study looks at the variables affecting willingness to pay (WTP) and consumer preferences for value-added fish products. Hence, the study objectives are to examine consumer preferences for value-added fish products based on cultural and socioeconomic features and to estimate the willingness to pay for value-added fish products. The representative sample size will be 400. A simple random sampling technique will be employed for data collection, and the primary data will be gathered through questionnaires from one district of South Punjab, Muzaffargarh. District Muzaffargarh is the greatest fish-producing district in South Punjab, which accounts for 43% of the region's overall fish production. A binary logistic regression will investigate the determinants of consumer preferences for value-added fish products. Either the Contingent valuation model (CVM) or the Tobit regression model will be used to estimate the willingness to pay.

Keywords: Consumer preferences, Cultural and Socioeconomic features, value addition, and Willingness to pay

ASSESSING FARMERS' WILLINGNESS TO ADOPT AND FUTURE DEMAND FOR HYBRID WHEAT VARITIES IN PUNJAB, PAKISTAN

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ABSTRACT

Wheat is a vital crop in Pakistan that makes a substantial contribution to both the economy and food security. Wheat yield is still low and stagnant in Pakistan. There is a need to introduce hybrid wheat varieties that give a higher yield than conventional varieties. The global experience of the adoption of hybrid wheat reflects mixed results. Predominantly, hybrid wheat could not be adopted on a large scale for many reasons. There is a need to work on the adoption and demand of hybrid wheat in Pakistan. This study aims to estimate future demand for hybrid wheat varieties, analyze farmers' willingness to adopt hybrid wheat varieties, and also identify the factors affecting the adoption of hybrid wheat. The data of 240 farmers will be collected from three divisions; Multan, Faisalabad, and Bahawalpur using surveys and statistical models. The purposive sampling technique, the multinomial Probit model, and the Discrete Choice Experiment will be used. A factor analysis will also be used to identify the barriers in the adoption of hybrid wheat. The findings will help the government and seed producers to create effective marketing, pricing, and support plans.

Keywords Wheat, farmers' willingness to adopt, future demand, hybrid wheat varieties, Multinomial Probit model

MICROWAVE ASSISTED DYEING OF COTTON FABRIC USING REACTIVE GREEN 6 DYE

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ABSTRACT

Microwave radiation is gaining fame due to it cost effective nature in textile. In this study reactive green 6 dye has been used to dye cotton before and after MW rays. Dyeing variables selected were used to make the shades. It has been found that cotton and dye solution, if radiated for 2 min. high yield upto 25.19 K/S has been found. The radiated cotton if used to dye with dye bath of 10 *p*H having 2 g/100mL of salt at 80 °C for 30 min, excellent yield is found with good to excellent colorfastness. It is concluded that MW rays have potential to improve dyeing of cotton for various dyes.

Keywords: Cotton, Green dyeing, ISO Standards, Reactive Green 6, MW Radiations,

DIFFERENT MODES OF PLANT EXTRACTION AND THEIR USE AS CORROSION INHIBITORS

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ABSTRACT

The corrosion is one of the pathologies leading to the degradation of structures; it is at the origin of a large number of additional costs linked to the maintenance of these buildings. It is therefore important to adopt a preventive logic by trying to inhibit the effects of this disease, thus delaying the aging of these structures.

The aim of this work is to bring the different techniques for applying green corrosion inhibitors in reinforced concrete, which can help to assess or detect corrosion in order to minimize the damage caused by this pathology.

Two modes of corrosion inhibition are often used, either in the form of admixtures mixed with the mixing water or with the mass of fresh concrete, or on concrete hardened by surface impregnation techniques (migration inhibitors).

The introduction of corrosion inhibitors is based on the nature of these products, chemical or green, so that, we have cited the methods of extraction of green inhibitors through works in the literature.

Keywords: Corrosion, Green inhibitors, Extraction, Evaluation.

FUNGAL BIOSTIMULANTS IMPROVE GROWTH AND SALINITY STRESS TOLERANCE IN LICORICE: A FOCUS ON TRICHODERMA HARZIANUM AND EPICOCCUM NIGRUM

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ABSTRACT

This study investigated the effects of symbiotic fungi (Trichoderma harzianum and Epicoccum nigrum) on enhancing salinity tolerance in the medicinal plant licorice (Glycyrrhiza glabra L.). Salt-tolerant fungal strains were initially selected and formulated using vermiculite, compost, and sawdust as carriers. A pot experiment was then conducted under four salinity levels (0, 5, 10, and 15 dS/m). Results demonstrated that T. harzianum exhibited robust growth even at 2.14% sodium chloride concentration. While salinity stress significantly affected all measured parameters, fungal inoculation - particularly with E. nigrum - significantly improved plant height at 5 dS/m and increased root dry weight. These findings suggest that fungal treatments could serve as an effective biological approach to enhance salt stress tolerance in licorice cultivation.

Keywords: Growth-promoting fungi, *Medicinal plants,* Salinity stress.

LICORICE FARMING IN CHALLENGING ENVIRONMENTS: SUSTAINABLE METHODS FOR SALINE REGIONS

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ABSTRACT

This study was conducted to investigate the effects of different salinity stress levels on propagation methods of the medicinal plant licorice (Glycyrrhiza glabra L.) at the Sadough Research Farm of the National Salinity Research Center over three growing seasons (2020–2023). The experiment was arranged as a split-plot in a randomized complete block design with three replications, incorporating four irrigation water salinity levels (2, 4, 8, and 12 dS/m) and three propagation methods (seed, seedling, and root cuttings). The evaluated parameters included establishment percentage, plant height, and dry weight of aerial parts and roots. Results indicated that salinity significantly influenced all measured traits, whereas propagation method only affected plant height and establishment percentage. The highest plant height was recorded at 2 dS/m salinity, with no significant difference among propagation methods. At 4 dS/m, seed propagation yielded the tallest plants (44.66 cm). Under 8 dS/m salinity, root cuttings exhibited the lowest height, showing 31% and 36% reductions compared to seedling and seed propagation, respectively. At 12 dS/m, all propagation methods resulted in minimal plant height. The highest establishment rates were observed in seed propagation at 2 and 4 dS/m (77% and 66%, respectively) and in root cuttings at 8 and 12 dS/m (63% and 60%, respectively). In conclusion, root propagation proved more effective under high salinity, while seed propagation was optimal at lower salinity levels for licorice cultivation.

Keywords: Transplanting, vegetative propagation, rhizome propagation.

CONSTRAINTS, CAPACITIES, AND STRATEGIES FOR DEVELOPING THE CULTIVATION OF MEDICINAL PLANTS USING SALINE WATER AND SOIL RESOURCES

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ABSTRACT

The quantitative and qualitative shortage of water resources and the need to create new job opportunities in Iran have made the utilization of saline water and soil resources essential. Reported research on the cultivation of medicinal plants under saline conditions is very limited, while considerable diversity in the germplasm of medicinal plants in terms of salinity tolerance has been documented. On the other hand, some reports indicate that with increasing salinity stress up to a certain level, yield decreases, but in some cases, the essential oil quality of certain medicinal plants improves. The importance of halophytes, especially medicinal halophytes, and their role in the economic exploitation of these resources is undeniable. Therefore, in this publication, while considering the advantages and capacities for developing the cultivation of medicinal plants, the constraints and challenges, strategies, and potentials of medicinal halophytes have been examined. Promising medicinal halophytes have also been identified. Among the studied species, 10 medicinal plants—**Peganum harmala (wild rue), Seidlitzia rosmarinus (ashnan), Alhagi maurorum (camelthorn), Portulaca oleracea (purslane), Rubia tinctorum (madder), Suaeda fruticosa (shrubby seablite), Glycyrrhiza glabra (licorice), Halocnemum strobilaceum (saltwort), Nitraria schoberi (nitre bush), and Capparis spinosa (caper)**—were selected due to their high salinity tolerance and classification as highly resistant species. These plants can be utilized to exploit saline water and soil resources in the country.

Keywords: Salinity, Medicinal plants, Stress-tolerant, Arid regions

COMPUTATIONAL INVESTIGATION OF PHOTOVOLTAIC ENERGY IN AGRICULTURE: DFT/TD-DFT INVESTIGATIONS

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ABSTRACT

Here we present a theoretical study of non-fullerene electron acceptor-based thiophene (P1-P6) derivatives for organic solar cells using density functional theory (DFT) and time-dependent density functional theory (TD-DFT) [1]. In particular, we investigate the molecular electrostatic potential, boundary molecular orbitals, global reactivity descriptors and optical characteristics of the designed molecules. We conclude that all designed molecules exhibit low band gaps and excellent optical properties. Using PTB7-Th as an electron donor, we investigate the photovoltaic characteristics of the acceptors. As a result, the designed molecules exhibit high charge conduction capacity and efficient electron transport from PTB7-Th to the designed acceptors. The results obtained encourage researchers to study such compounds in the laboratory, which would improve the efficiency of non-fullerene organic solar cells [2].

This study was carried out in order to determine the power efficiency of the photovoltaic power plant by comparing the energy performance achieved during an unfavorable annual period over four consecutive years. The results obtained demonstrate the benefits of using photovoltaic panels to provide farmers with affordable electricity.

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SOIL INVERTEBRATE ROLE IN THE FOREST LITTER DECOMPOSITION

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ABSTRACT

Depending on climatic conditions and forest-forming species, the plant litter decomposition in forests occurs at different rates. The recycling process of plant residue by invertebrates is associated with the vital activity of saprophages, which are about 70-80% of the total number of soil-inhabiting invertebrates.

The importance of animals in the decomposition of plant remains can be reduced to the following points:

- Passing plant tissues through their intestines, soil inhabitants activate both the vital activity of microorganisms and their physical and chemical effects.
- Using their enzymes and enzymes secreted by symbiotic organisms, invertebrates decompose some of the carbohydrates and other cellular inclusions, releasing lignin, which is in complex compounds with cellulose;
- One of the products of protein metabolism in many invertebrates is ammonia. In the intestines of soil-dwelling animals, condensation of lignin with ammonia occurs, which is of great importance for accelerating humification processes;
- In the digestion process in the intestines of soil inhabitants, partial mineralization of plant residues and in some groups - partial humification were noted;

- By vertically migrating in the soil, animals bring plant remains into the deep soil horizons and mix organic and mineral particles. Animal movements improve soil aeration, which stimulates aerobic processes of decomposition of organic material.

The activity of soil animals is closely related to the activity of soil microflora, and the functions of these groups are often intertwined. In many cases, soil inhabitants consume plant residues that have already been processed by microorganisms. At the same time, saprophagous excrements provide a favorable environment for bacteria and fungi, and in the soil, they are centers of microbial activity.

The study was made in the framework of the Project "Healthy Soil for Food Safety" [FR-23-268] and was supported by the Shota Rustaveli National Science Foundation of Georgia.

Keywords: Environment, Forest, Invertebrates, Plant residues, Microorganisms.

INDUCED FISH PROPAGATION METHOD DEVELOPMENT IN AFRICAN CATFISH (*CLARIAS GARIEPINUS*) (PRELIMINARY RESULTS)

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ABSTRACT

African catfish (*Clarias gariepinus*) is a fish species of significant economic importance worldwide. Its propagation technology is based on artificial induced propagation using various hormonal preparations. In regions with less developed infrastructure, the appropriate storage of these preparations, as well as the collected sperm until use, is often challenging. The ovarian lavage/insemination method offers the possibility to store sperm for a short time obtained from a donor male within the ovary of a recipient female prior to ovulation, while the same pituitary gland of the donor can be used to prepare a suspension for hormonal treatment of the female. Our aims were to investigate the effects of treatment with a hormonal suspension prepared from freshly collected African catfish pituitary on the ovulation of females, and the feasibility of combining hormonal induction with fresh pituitary and the insemination propagation method. In this experimental cycle, three experiments were conducted. In the first experiment, the effects of intramuscular hormonal induction using freshly collected pituitary combined with insemination on the reproductive traits of the females were compared to those induced by intramuscular administration of Ovopel™ (mGnRHa + metoclopramide). In the second and third experiments, ovarian treatment with sperm mixed with freshly homogenized pituitary was compared to both the intramuscular administration of fresh pituitary followed by insemination and the intramuscular treatment with Ovopel™. According to our results, the intramuscular administration of fresh pituitary extract combined with the insemination method can be an effective tool of the induced propagation of African catfish. The experiments demonstrated that the reproductive physiological condition of the donor individual providing the pituitary fundamentally determines the success of propagation using this method.

Keywords: artificial propagation, ovarian lavage, insemination, fresh pituitary extract

Acknowledgement

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HEALTH BENEFITS AND NUTRITIONAL COMPOSITION OF GREEN PEAS

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ABSTRACT

Green Peas since thousands of years have been considered as a key ingredient in multiple food preparation, salad dressing and cooking products. Green Peas have various varieties and almost all are considered versatile, nutritious, and healthy. Green Peas provide good source of protein, calories, vitamins, carbohydrates, dietary fiber, minerals, sugars and fat contents. Green Peas possessed low cholesterol, saturated fat, and salt. They are a good source of vitamin A, vitamin C, vitamin B6, vitamin K, folate, magnesium, thiamin, and manganese. Peas as fresh, canned, frozen, or dried form contain many health benefits. Green Peas stabilizes blood sugar levels, improves gut health, reduces the risk of cancer and protects against heart disease. Overall, Green Peas are good alternative source of protein and iron, especially in a plant-based diets.

Keywords: Green Peas, Chemical Constituents, Cooking Applications, Health Benefits

BIOCONVERSION OF OLIVE MILL RESIDUES: COMPOSTING PERFORMANCE AND ENVIRONMENTAL BENEFITS

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ABSTRACT

Olive mill pomace (OMP), the semi-solid residue from olive oil production, presents a major environmental concern due to its high volume and phytotoxicity, including phenolic compounds and organic acids. This study evaluates a composting strategy to valorize OMP using bioreactor-based aerobic composting. Three bioreactors were tested with different mixtures: (1) straw + OMP, (2) urea + OMP, and (3) manure + OMP. The composting process was monitored over 60 days, with parameters such as temperature, moisture content, oxygen levels, and phenolic content tracked regularly. Bioreactor 3 (manure + OMP) demonstrated the most efficient composting profile, reaching thermophilic temperatures above 60°C within the first 5 days and sustaining them for over 10 days, ensuring effective pathogen reduction. Moisture content was maintained between 50–60%, while oxygen levels remained above 15%,

supporting aerobic microbial activity. A significant reduction in phenolic content (over 65%) was observed in Bioreactor 3, indicating detoxification of phytotoxic compounds. Nutrient analysis of the final compost showed increased nitrogen and organic carbon levels, confirming its potential as a soil amendment. The results affirm that co-composting OMP with suitable nitrogen-rich materials in controlled bioreactor conditions can convert a problematic agro-industrial waste into a valuable, nutrient-rich organic fertilizer. This aligns with sustainable waste management practices and supports circular bioeconomy initiatives in Mediterranean olive-producing regions.

Keywords: Olive pomace, composting process, physical and chemical properties, mixing materials, maturity

GENOTOXIC, MORPHO-PHYSIOLOGICAL, AND BIOCHEMICAL IMPACTS OF OLIVE POMACE ON BROAD BEAN PLANT

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ABSTRACT

Olive oil production generates large quantities of waste, mainly pomace and wastewater, posing serious environmental risks if not managed properly. This study examines the genotoxic, morpho-physiological and biochemical impact of olive pomace filtrate on hydroponically grown broad bean plant (Vicia faba). LC-MS/MS analysis identified over 20 phenolic compounds, with hydroxytyrosol (321.48 mg/l), verbascoside (86.49 mg/l) and vanillic acid (23.84 mg/l) being the most abundant. Exposure to increasing doses of pomace filtrate significantly reduced fresh and dry shoot and root biomass by 80% at high doses (20% v/v), as well as a reduction in photosynthetic pigments, carotenoids and relative water content. Conversely, increased application increased malondialdehyde (MDA) levels and the accumulation of sugars (sucrose, fructose and inulin) and 12 free amino acids. Microscopically, doses above 10% lowered the mitotic index, inhibited root cell division, and caused chromosomal abnormalities, including chromosome adhesion, fragmentation, delayed and damaged chromosomes, c-mitoses and micronuclei. These findings underscore the importance of treating olive production waste before environmental discharge or agricultural use.

Keywords: Olive pomace; Broad bean; Phenolic compounds; Genotoxicity; Free amino acids

SCREENING OF RHIZOSPHERIC ACTINOBACTERIA FROM PINE FOREST, CHAKRATA, UTTARAKHAND FOR PLANT GROWTH PROMOTION AND FUNGAL PATHOGEN BIOCONTROL POTENTIAL

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ABSTRACT

Actinobacteria are well known for their ability to promote plant growth and actively suppress fungal growth and infection in plants. This study aims to isolate and characterize Actinobacteria from rhizospheric soil samples collected from virgin Pine forests of Chakrata, Uttarakhand, India. Selective media, including Starch casein agar, Malt yeast agar and Actinobacteria isolation agar, amended with antibiotics and antifungal agents were used for isolation. Chemical and heat pretreatments were applied to enhance selectivity. A total of 15 morphologically distinct Actinobacteria were isolated. Preliminary screening based on colony morphology, Gram staining, and biochemical profiling confirmed the isolates as *Streptomyces* spp. *In vitro* tests such as Indole acetic acid production, Siderophore production, Ammonia production and Phosphate solubilization were performed to evaluate the plant growth promoting traits. The isolates were further evaluated for their antagonistic activity against phytopathogenic fungi of *Pinus roxburghii*. These findings highlight that the rhizospheric region of Pine species of Chakrata Pine forest is a reposing habitat for Actinobacteria having promising plant growth promoting traits with biocontrol potential. Future studies will involve greenhouse trials to evaluate their efficacy in growth promotion and suppressing fungal diseases in *Pinus roxburghii* and other economically important forestry species.

Keywords: Actinobacteria, antagonistic activity, disease management, forest soil microbiome, *Pinus roxburghii*, plant growth promotion

SCALE INSECT INFESTATION IN CITRUS ORCHARDS: A CASE STUDY FROM AÏN TÉMOUCHENT

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ABSTRACT

This study, conducted in the Aïn Témouchent region of Algeria across three citrus orchards, aimed to assess the diversity and abundance of scale insects. The results revealed the presence of two species: *Parlatoria ziziphi* and *Planococcus citri*, belonging to the families Diaspididae and Pseudococcidae, respectively. The family Diaspididae was dominant in terms of species representation.

The findings indicate that *Parlatoria ziziphi* (Diaspididae) was the most prevalent species across the three citrus plots. Factors such as parasitism, predation, and natural mortality were found to play key roles in regulating scale insect populations.

Analysis of the infestation pattern showed that these pests were primarily active on the leaves, especially the upper surfaces, rather than on the branches. In terms of location, scale insects exhibited a strong preference for the first two orchards studied.

Keywords: Citrus, leaves, infestation, orchard

PESTICIDES AND THE GLOBAL ECONOMY: AGRICULTURAL AND ENVIRONMENTAL CHALLENGES AND SUSTAINABLE PERSPECTIVES

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ABSTRACT

The global economy is profoundly influenced by the use of pesticides, which play a crucial role in agricultural productivity but also raise environmental and health challenges. On the one hand, these chemicals make it possible to increase crop yields, thereby reducing pest-related losses and supporting food security in the face of growing demand. On the other hand, their excessive use leads to soil and water pollution, loss of biodiversity and risks to human health, particularly in developing countries where regulations are less strict. The global pesticide market, dominated by a few multinationals, is worth several billion dollars, reflecting their economic importance. However, pressure for sustainable alternatives, such as organic farming and integrated pest management, is growing, forcing governments and industries to rethink their practices. Striking a balance between economic profitability and environmental sustainability remains a major challenge for the future of global agriculture.

Keywords: Pesticides, agricultural economics, pollution, food safety, sustainable agriculture.

MOLECULAR ANALYSIS OF CYST NEMATODE SPECIES IN THE MAIN POTATO PRODUCTION AREAS OF BLIDA PROVINCE, NORTHERN ALGERIA

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ABSTRACT

Potato cyst nematodes (PCNs) *Globodera pallida* and *G. rostochiensis* present the most damaging species to potato culture. These parasites become a harmful potential in several important potato production localities in Algeria. The aim of this study was to estimate the infestation degree, the density of cysts, and the molecular identification of PCNs from three localities of Blida "El affroun" Mouzaîa and "Meftah" regions in northern of Algeria. Cysts were extracted by using the Fenwick method from soil samples collected in each location. Extracted cysts were stored dry in tubes for molecular characterisation (Specific PCR., ITS-rDNA, *cytb* gene mtDNA and sequencing). Potato cyst nematodes were found in one out of three localities sampled in Blida province with a prevalence of 33.33%. The average density of PCNs was 2.4 cysts/100 cm^3 of soil, and the infestation degree was 12.19 juveniles and eggs per 100 cm^3 of soil. Whereas, both areas of El afroun and Mouzaîa localities were free from PCNs. Molecular identification revealed that *G. pallida* occurred mainly in the infested surveyed area. The phylogenetic association with the European populations indicated that Algerian populations of PCN were probably introduced from Europe by infested seed-potato.

Keywords: *cytb* gene mtDNA, *Globodera pallida, ITS* rDNA, sequencing, specific PCR.

AGRO-MORPHOLOGICAL CHARACTERIZATION OF 17 LENTIL VARIETIES (LENS CULINARIS MEDIK) GROWN IN NORTH MOROCCO.

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ABSTRACT

Although lentils (Lens culinaris Medik) are an essential legume in Morocco, appreciated for its nutritional benefits and its role in sustainable agriculture, its productivity remains low, with average yields below 1.5 tons per hectare, due to major challenges including the use of low-performance varieties, climate change (recurrent drought and high temperatures), soil degradation and fungal disease pressure. This study focuses on the agro-morphological characterization of 17 lentil varieties ABDA (L 593153-16), BEKRIA, BICHETTE (ILL 5562), ZARIA (L8635), HAMRIA (FLIP 87-48L), Chakkouf, Extra, L 24, ABOA, JAMAAT SHAIM, BELUGA, ANICIA, CLARA grown in the Mnasra region, Morocco, in order to assess their agronomic performance, morphological traits and adaptation to local

as well as the nutritional quality of the varieties for sustainable agriculture. Parameters measured in our field experiment include emergence time, vegetative phase duration, plant height, number of pods per plant, number of seeds per plant, 100-seed weight, seed yield and disease resistance.

The aim is to identify the best-performing varieties that are best adapted to local conditions, in order to provide recommendations to farmers and policy-makers for improving lentil productivity in Morocco. The results show variability between varieties, with Chakkouf ,Jamaat Shaim and Beluga lentils standing out for their by their rapid emergence, short vegetative phase and high yield, while Bekria is less suitable due to its sensitivity to drought. The study highlights the importance of selecting adapted varieties to improve the productivity and resilience of lentil crops in Morocco. lentil crops in Morocco.

Keywords: Lentils, climate change, sustainable agriculture, productivity, environmental stress, Mnasra, Morocco.

SENSITIVITY OF THE IMMUNE SYSTEM IN USERS OF TOBACCO AND PSYCHOACTIVE SUBSTANCES: A STUDY CONDUCTED AT CISA-BOUKHADRA, ALGERIA

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ABSTRACT

Psychoactive substances (PAS) are substances that affect an individual's psyche by altering their neuropsychological functioning. They can disrupt the central nervous system's operations or stimulate immune system activity. Generally, these substances can be divided into those that have a calming effect, such as cannabis or opioids like tramadol, and those that have a stimulating effect, like tobacco, which is considered a stimulant of the central nervous system (CNS). The effects of these substances can vary depending on the dose consumed.

The objective of our study was to examine the effects of smoking and other psychoactive substances (PAS) on the immune system, specifically focusing on mental and biological changes. The study aimed to analyze the relationship between the degree of dependence on psychostimulants and antidepressants and their effects on bodily functions, and to determine the high-risk group for developing addiction and an inflammatory syndrome (IS) based on the age of initiation of smoking (starting tobacco use in childhood [9-13 years], adolescence [14-18 years], or adulthood [19-41 years]).

A self-assessment questionnaire was administered to 100 smoking subjects to gather data on the patient's demographic characteristics (age, age of smoking initiation, risk factors, etc.), mental health status (depression, anxiety, stress), and an analytical blood study on several hematological inflammatory parameters (White Blood Cells (WBC), Hemoglobin (HB), C-Reactive Protein (CRP), Erythrocyte Sedimentation Rate (ESR)). All the data were extracted from patient records and medical files used by the Boukhadra Intermediate Addiction Care Center (CISA).

In this study, we found a strong relationship between the level of nicotine and psychoactive substance (PAS) dependence and changes in both mental and biological aspects. We suggest a high risk of personal vulnerability and a sociocultural environment for individuals with a strong cigarette addiction, particularly those who started smoking during adolescence. The inflammatory profile appears to be an interesting biomarker to consider during PAS withdrawal.

Keywords: Psychoactive substances, tobacco, dependence, inflammatory parameters.

DIVERSITY AND VALORIZATION OF CITRUS FRUITS IN ALGERIA: TOWARDS RESPONSIBLE GROWTH

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ABSTRACT

The cultivation of citrus fruits occupies a strategic place in the agricultural and agri-food sector in Algeria. It represents one of the main fruit production, with various varieties such as oranges, clementines, lemons and grapefruits. These varieties grown mainly in the north of the country (Blida, Chlef, Mostaganem, Mitidja, Skikda....) represent not only a valuable agricultural heritage but also a major economic growth potential. However, in the face of global environmental and economic challenges, it is necessary to improve cultivation techniques, promote sustainable practices and enhance their products (juices, essential oils, jams). This also means developing export markets and implementing policies that promote quality and innovation in the citrus sector.

Keywords: Citrus, production, varieties, challenges, innovation, Algeria.

BACTERIAL AND SEROLOGICAL SURVEY STUDY ON PATIENTS WITH TONSILITIS INTRODUCTION

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ABSTRACT

Background: Tonsillitis is a prevalent upper respiratory tract infection, often linked to *Group A Streptococcus (GAS)*. The evaluation of inflammatory markers such as Antistreptolysin O Titer (ASOT), C-Reactive Protein (CRP), and Erythrocyte Sedimentation Rate (ESR) plays a crucial role in diagnosing GAS infections and identifying potential complications, including rheumatic fever.**Objectives:** This study aimed to assess the levels of ASOT, CRP, and ESR in patients diagnosed with tonsillitis, investigate their variations across different age groups and genders, and determine their clinical significance. Additionally, the study sought to identify the most common bacterial pathogens associated with tonsillitis cases.**Methods:** A total of 80 patients with clinically confirmed tonsillitis were included in the study. Throat swabs were collected for bacterial culture and identification, while blood samples were analyzed for ASOT, CRP, and ESR levels. Statistical analysis was conducted using One-Way ANOVA followed by Tukey's post-hoc test to compare biomarker levels among different patient groups.**Results:**Children aged 1-10 years had significantly higher ASOT levels compared to adults ($p = 0.021$), suggesting frequent exposure to GAS infections in younger populations.CRP and ESR levels declined with increasing age, indicating a stronger inflammatory response in children compared to adults.No statistically significant gender-based differences were found in ASOT, CRP, or ESR levels ($p > 0.05$).*Streptococcus pyogenes* was the most frequently isolated bacterial species (55%), followed by *Staphylococcus aureus* (18%) and *Haemophilus influenzae* (12%).**Conclusion:** The findings of this study emphasize the clinical value of ASOT, CRP, and ESR in diagnosing GAS infections and assessing inflammation severity in tonsillitis patients. ASOT remains a reliable marker of past GAS exposure, while CRP and ESR serve as useful indicators for distinguishing bacterial from viral infections. Early diagnosis and timely antibiotic treatment can help prevent serious complications such as rheumatic fever. Future research should focus on investigating genetic and environmental influences on immune responses in patients with recurrent tonsillitis.

Keywords: Tonsillitis, *Streptococcus pyogenes*, ASOT, CRP, ESR, Rheumatic Fever, Inflammatory Markers, Bacterial Infections.

ROLE OF ESSENTIAL OILS IN IMPROVING THE QUALITY OF BEEHIVE PRODUCTS: TOWARDS SUSTAINABLE BEEKEEPING IN SUPPORT OF AGRICULTURE

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ABSTRACT :

In the context of a transition towards more sustainable and biodiversity-friendly agriculture, beekeeping plays a key role not only through the production of honey, propolis, and royal jelly, but also through its impact on crop pollination. However, the health of bee colonies remains seriously threatened by the intensive use of pesticides, pathogens, and environmental disturbances. In response to these challenges, essential oils (EOs) are emerging as a promising natural alternative.

Several studies have shown that certain EOs, such as those from thyme, eucalyptus, or rosemary, have beneficial effects: they act against pathogens (*Varroa destructor*, *Nosema spp.*), strengthen the bees' immune system, and improve the physicochemical quality of honey and other hive products.

Beyond colony protection, the rational use of EOs is part of an agroecological approach that enhances the positive interactions between beekeeping and agriculture. By improving the resilience of beehives and the quality of beekeeping products, these practices contribute to food security, the development of local value chains, and the promotion of more sustainable farming systems.

Keywords : Essential oils, sustainable beekeeping, hive products, agriculture, bee health, agroecology.

STIMULATING THE DEVELOPMENT OF THE SPRING WHEAT ROOT SYSTEM AS A WAY TO ELIMINATE THE NEGATIVE IMPACT OF OVERDENSITY SOIL

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ABSTRACT

In today's climate change conditions and intensive anthropogenic load on soils, ensuring increased crop productivity is extremely relevant for the agro-industrial sector not only in Ukraine but throughout the world. Due to a large number of technological operations, the soil undergoes physical degradation, which leads to poor plant development and reduced yields. One of the elements of the technology for growing crops on soils with unfavorable physical properties can be the selection of varieties that are most adapted to unfavorable parameters and the use of growth stimulants that help increase the efficiency of plant use of nutrients and the development of their root system.

The aim of our research was to study the effect of seed inoculation with growth stimulants on the development of the root system of spring wheat varieties of different intensity under the conditions of its cultivation on soils with an overdensity sub-seed layer**.** The study was conducted in a model laboratory experiment according to the following scheme: control (soil structure density > 1.3 g/cm^3, without seed inoculation); option 1 (soil structure density > 1.3 g/cm^3, seed inoculation with the biostimulant "Azotofit"); option 2 (soil density > 1.3 g/cm^3, seed inoculation with the growth stimulator "Vympel"). The studied spring wheat varieties are the intensive variety Moisa and the semi-

intensive variety Xanthiia. The experiment maintained an optimal level of moisture – 75 % of the lowest moisture capacity. The studies were conducted until the plants had 4 leaves. The soil is typical low-humus chernozem.

Research has shown that seed inoculation with a growth stimulant is an effective means of improving the development of the plant root system, which develops in an overdensity soil layer. It was found that the treatment of spring wheat seeds contributed to an increase in root length, depending on the variant by 2 – 12 %. The increase in the length of spring wheat roots when treated with Azotofit and Vympel growth stimulants for the intensive variety was 6 % and 12 %, respectively, and for the semi-intensive variety - by 2 % and 6 % compared to the control.

Pre-sowing treatment of spring wheat seeds contributed to an increase in root diameter from 3 to 32 % depending on the variety grown. Thus, for the intensive variety, when seeds were inoculated with the growth stimulator Azotophyte, the increase in diameter was observed by 22 %, and in the variant with Vympel by 32 % compared to the control. For plants of the semi-intensive variety of spring wheat, significantly lower increases in root diameter were noted, which amounted to only 3 % compared to the control.

A tendency to increase the biological yield of spring wheat was noted when seeds were inoculated with growth stimulants. When grown on overdensity soils, plants of the intensive variety of spring wheat, compared to the semi-intensive variety, were more adaptive and had a better response to cultivation. The greatest increase in yield was found in the variant with seed treatment with the growth stimulant Vympel when growing the intensive variety, which was 69 %, and with Azotophyt 20 % compared to the control. The increase in variants with the cultivation of the semi-intensive variety of spring wheat with seed inoculation with Vympel is 5 %, and for the variant with Azotophyt – 8 %.

Therefore, one of the ways to improve the development of the spring wheat root system in overdensity soil layer can be to inoculate seeds with growth stimulants, which contributed to the improvement of the root system parameters and the subsequent increase in biological yield.

Keywords: soil, density, growth stimulator, agricultural crop, variety.

PHYTOCHEMICAL COMPOSITION, NUTRITIONAL SIGNIFICANCE AND UTILIZATION OF VARIOUS LEAVES IN POULTRY NURITION; A REVIEW

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ABSTRACT

This review examines the agricultural, phytochemical, and medicinal aspects of six herbs commonly used in various culinary and medicinal practices: curry leaf (*Murraya koenigii*), basil (*Ocimum basilicum*), lemon grass (*Cymbopogon citratus*), fenugreek leaf (*Trigonella foenum-graecum*) nutmeg (*Myristica fragrans Houtt*), and bay (*Laurus nobilis L*). Each herb possesses unique characteristics and active compounds that contribute to its flavor, aroma, and potential health benefits. Curry leaf, native to India, Bangladesh, and Sri Lanka, is rich in phytochemicals such as flavonoids, alkaloids, and saponins. Basil, widely cultivated in Europe and the USA, contains various phytochemicals including estragole, eugenol, and linalool, which contribute to its aromatic flavor and potential health benefits. Lemon grass, native to Asia, is abundant in volatile compounds like citral and phenolic compounds such as caffeic acid, exhibiting antimicrobial and antioxidant properties. Fenugreek leaf, originating from the Mediterranean region, contains flavonoids, alkaloids, and saponins, offering potential benefits for digestive health and blood sugar regulation. These herbs play versatile roles in culinary practices, adding flavor and aroma to dishes such as curries, soups, and beverages. Moreover, they have been used in traditional medicine for their various health benefits, including anti-inflammatory, antimicrobial, and digestive properties. Additionally, the inclusion of these herbs in poultry diets may enhance growth performance, support immune function, and reduce stress in poultry production.

NANOPARTICLE (NANOCURCUMIN) AND CURCUMIN; A REVIEW ON THEIR EFFECT ON POULTRY, RABBIT AND SWINE PRODUCTION

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ABSTRACT

Nanotechnology a rapidly developing scientific discipline, that has extensive application in the medical sciences. Its applications in monogastric animal nutrition are, however, limited. Studies on curcumin and curcumin nanoparticles as pharmaceutics in animal nutrition have been conducted. Nevertheless, research has indicated that the use of curcumin or turmeric powder has little effect on the health of animals because of its limited bioavailability, which may be caused by its rapid metabolism, poor absorption, and rapid excretion from the body. These factors necessitate the use of refined curcumin formulations. Through the use of biodegradable and biocompatible nanoparticle forms, curcumin nanoparticles a recently developed area of nanobiotechnology may have positive impacts on monogastric animal health, growth performance, antimicrobial, anti-inflammatory, and neuroprotective effects. In order to emphasize the possible use of curcumin and curcumin nanoparticles in the field of monogastric animal production, this review was conducted. We think the review offers a clear perspective on how curcumin and curcumin nanoparticles will develop in the future and how they might be used in monogastric farm animal production.

DETERMINATION OF THE LEVEL OF SOME FAT-SOLUBLE VITAMINS AND WATER-SOLUBLE VITAMINS IN FARM CHICKEN, TURKEY, AND DUCK EGGS

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ABSTRACT

This study investigates the concentrations of fat-soluble (Vitamins A and E) and water-soluble (Vitamin B6 and C) vitamins in the egg yolks and whites of farm chicken, turkey, and duck eggs. The primary objective was to provide a comprehensive evaluation of their nutritional value, with a focus on vitamin content and associated health benefits. Egg samples were sourced from local markets in Damaturu, Yobe State, Nigeria, and analyzed using High-Performance Liquid Chromatography (HPLC) for precise quantification. The results revealed significant variations in vitamin concentrations among the different egg types. Duck eggs exhibited the highest levels of fat-soluble vitamins, with sample DWB (duck egg) recording the highest concentration of Vitamin A (254.6 µg/g) and Vitamin E (0.85 mg/g), surpassing those found in chicken and turkey eggs. Chicken eggs, particularly sample CWA, showed considerable Vitamin A content (194.8 µg/g), while turkey eggs contained lower concentrations of Vitamins A (ranging from 91.9 to 128.3 µg/g) and E (0.31 to 0.43 mg/g). Water-soluble Vitamin B6 was present in all samples but in relatively low amounts, with duck eggs again demonstrating the highest concentration (0.15 mg/g in sample DWB). Notably, Vitamin C was not detected in any of the egg samples analyzed, confirming that poultry eggs are generally poor sources of this water-soluble vitamin. The findings of this study highlight the superior nutritional profile of duck eggs, particularly as rich dietary sources of fat-soluble vitamins (A and E) and comparatively higher levels of Vitamin B6. These findings offer valuable insights for consumers seeking to enhance their vitamin intake through dietary choices and provide useful information for the poultry industry in product development and nutritional marketing. Furthermore, the absence of Vitamin C across all egg types reinforces the need to complement egg consumption with other dietary sources of this vitamin for balanced nutrition.

VALORIZATION OF LOCAL POMEGRANATE: A STRATEGIC PATH TO EFFICIENT RESILIENCE

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ABSTRACT

In the context of global change, characterized by climate disruptions, desertification, and biodiversity loss, the valorization of local varieties of pomegranate (*Punica granatum* L.) emerges as a strategic lever for sustainable rural development in Algeria's arid regions. These landraces, well-adapted to extreme edaphoclimatic conditions, constitute a valuable genetic resource, offering resilience against water scarcity and erratic rainfall patterns. Their cultivation not only enhances food and nutritional security for rural communities but also contributes to local economic empowerment through the valorization of derived products, such as juices, syrups, and medicinal extracts. Furthermore, their integration into sustainable agroecosystems supports the conservation of agrobiodiversity and helps mitigate rural exodus. Thus, promoting local pomegranate varieties aligns with agroecological and territorial development approaches, which are essential to address the multifaceted challenges posed by global environmental and socio-economic changes in Algeria's arid zones.

Keywords: *Punica granatum* L., local cultivar, resilient agroecosystems, arid region, sustainable rural development.

EFFICACY OF Iron MICRONUTRIENT ON FUSARIUM WILT (*Fusarium oxysporium* f.sp *lycopersici)* AND YIELD OF TOMATO (*Solanum lycopersicum* L)

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ABSTRACT

Fusarium oxysporum is a serious pathogen that causes Fusarium wilt in tomato. Iron (Fe) micronutrient has been reported to have fungicidal effect in the control of plant pathogens. In 2024, field experiments were conducted during the wet and dry seasons at the Teaching and Research Farm of Ajayi Crowther University in Oyo, Nigeria to determine the efficacy of iron micronutrient on *Fusarium* wilt and fruit yield of tomato. The experiment was a 2 x 5 factorial experiment fitted into Randomized Complete Block Design with three replicates. The treatments consisted of two tomato varieties (Roma and Royal VF), Fe, with three concentrations (1.0, 1.5 and 2.0 ml/L) and Carbendazim, a synthetic fungicide, was used as positive control. The treatments were applied using soil drenching. The untreated plots served as control. Results showed that Roma VF treated with 1.0 ml/L Fe micronutrient in both wet and dry seasons had the lowest (1.00 and 0.00 %, respectively) disease incidence and produced significantly higher yields (20.5 tons/ha and 19.5 tons/ha) respectively in both wet and dry seasons. The study concluded that application of Fe micronutrient at 1.0 ml/L significantly reduced *Fusarium* wilt and increased the fruit yield of tomato and hereby recommended for farmers to control plant fungal diseases

Keywords: Tomato, *Fusarium oxysporum*, fungicidal, iron micronutrient.

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KNOEVENAGEL REACTION CATALYZED BY APATITE AND SODIUM-MODIFIED APATITE: A FAST, EFFICIENT, AND SUSTAINABLE APPROACH

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ABSTRACT

Knoevenagel reaction is a key method for forming carbon-carbon bonds, widely used in the synthesis of bioactive compounds and functional materials. In this study, we explored the efficiency of apatite and sodium-modified apatite as catalysts for the Knoevenagel reaction at room temperature and under solvent-free conditions. Due to its porous structure and surface properties, apatite provides an excellent catalytic support. The introduction of sodium enhances catalytic activity by modifying the surface acidity and basicity[1]

Experimental results show a high yield, reaching optimal values in a relatively short reaction time, demonstrating the efficiency of these catalysts. Moreover, apatite and sodium-modified apatite can be easily recovered and reused without significant loss of activity, making them a sustainable and economically viable alternative for environmentally friendly organic reactions.

Keywords: Knoevenagel reaction ; Apatite Sodium ; modified ; apatite ; Heterogeneous catalyst ; Solvent ; free ; Recyclable catalyst ; Green synthesis ; Organic chemistry Green catalysis Ecological reactions Reusable catalys

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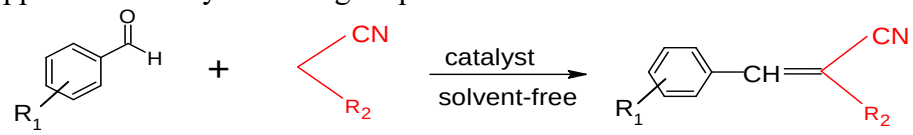

R_1 = H, CH_3, NO_2, OCH_3, Cl

AGRI-ARCHITECTURE-FOR-THE-21ST-CENTURY-INNOVATIONS-IN-RURAL-BUILT-ENVIRONMENTS.

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ABSTRACT

Rising global demands on food systems together with environmental systems and rural survival require immediate design strategies which foster countryside transformation. This article documents how agri-architecture presents itself as an innovative method for developing agricultural properties which foster multiple benefits between sustainability and agricultural growth with ecological adaptability together with traditional heritage protection. The investigation of Agrotopia in Belgium and Jianamani Visitor Center in China serves this study to explain how architectural designs boost both local food systems and maximize resources and enable local communities to gain power. Through design that combines multiple functions and renewable resources the research demonstrates how built structures develop agroecological connections. The paper establishes an academic link between architectural practice and agricultural concerns and rural planning to build a resilient community development approach built upon spatial creativity and ecological preservation. The study feeds into an increasing body of knowledge about rural design potential to tackle sustainable challenges in the twenty-first century.

Keywords: Agri-architecture; Sustainable agriculture; Rural development; Productive landscapes; Ecological design.

AGRICULTURAL HUBS: DESIGNING SPACES FOR FOOD PROCESSING, STORAGE, AND DISTRIBUTION

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ABSTRACT

Aging global concerns about food security, climate change and urbanization have led to architectural design of agricultural hubs becoming an essential answer for food system support. The research analyzes how combined spatial organization enhances the efficiency of food production and warehousing and movement operations within facilities which benefit both metropolitan and rural populations. This research examines three critical agricultural complexes Agripolis in Italy together with FoodPort in the United States and AgriNEST in India to discover operational efficient and sustainable community-centered design approaches. They establish modular approaches and renewable energy frameworks and circular economy operations together with agro-education as main components for developing sustainable food infrastructure. The study confirms how architectural design promotes flexible food networks which unite diverse users with nature-based solutions. This paper establishes a guide to creating agricultural centers that handle present-day food system operational and economic barriers while fostering sustainability principles.

Keywords: Agricultural Hubs; Food Processing Architecture; Food Storage Design; Distribution Logistics; Agri-Tech Infrastructure.

ARCHITECTURE FOR AGRICULTURAL JUSTICE: SPATIAL EQUITY IN THE DESIGN OF FOOD-PRODUCING COMMUNITIES

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ABSTRACT

The paper analyzes how architectural design creates just and equal agricultural spaces by studying their essential part in building balanced food-producing areas. Architecture serves as an influential tool to deal with systemic food access issues that result from growing urbanization together with worsening socio-economic divisions. The study analyzes several projects such as the Edible Schoolyard Project in Berkeley together with Agropolis in Paris and Mukuru Slum Upgrading Project in Nairobi by examining how various space-based interventions support food education and empower vulnerable communities while making them resilient. Through its analysis this research shows that food-system integration into cities requires planning based on rights and partnerships between communities and policy-conforming architectural approaches. Multi-functional inclusive spaces serve as a platform for architects to reach dual goals of sustainability and social equality in food production systems. Architecture demonstrates the potential for defining significant changes in food systems which requires us to adopt a complete transformation of design theory in modern urban planning approaches.

Keywords: Agricultural Justice; Spatial Equity; Urban Agriculture; Participatory Design; Food-Producing Communities.

DESIGNING THE PRODUCTIVE COUNTRYSIDE: ARCHITECTURAL APPROACHES TO SUSTAINABLE AGRICULTURE

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ABSTRACT

The combination of architecture with agriculture stands as an essential tool for promoting sustainable rural improvement because global problems continue to worsen. The paper studies how architectural design frameworks create sustainable productive environments along with ecological balance for rural territories. The research examines international projects consisting of Les Grands Voisins in France, Bujira Cultural Center in Rwanda and Songyang County in China through which the study recognizes three principal architectural techniques that comprise adaptive reuse, bioclimatic design and vernacular preservation. The strategic solutions provide evidence about how mixed-use environments create environments that support food security and maintain cultural heritage together with social cohesion. A new rural planning model is proposed by the article which transforms architecture into a dual instrument for farming productivity support while generating social empowerment and helping the environment. This research moves forward regenerative design principles through its presentation of an all-encompassing approach to design the productive rural landscape.

Keywords: Sustainable Architecture; Productive Countryside; Rural Development; Bioclimatic Design; Agro-architecture.

HYBRID LANDSCAPES: ARCHITECTURE AT THE INTERSECTION OF FARMING, ECOLOGY, AND COMMUNITY

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ABSTRACT

Cities face an urgent need for comprehensive redesign because urban dwellers grow rapidly while environmental problems become more severe between ecological systems and living spaces and urban infrastructure. The analysis studies how living landscapes enable agriculture and housing and infrastructure to unite through well-designed sustainable methods. The paper investigates spatial planning effects through an interdisciplinary approach that analyzes the Agrotopia Rooftop Greenhouse, Edible Schoolyard in New Orleans as well as Sunqiao Urban Agricultural District in Shanghai. The research implements a qualitative study design which includes spatial studies and policy assessment to identify vital design principles and implementation tools. The analysis reveals that mixed-use green areas accomplish climate cooling while improving both ecosystem diversity and community interaction and social equality. The research design introduces architectural mediation between buildings and ecology to create sustainable urban development models which can be reproduced.

Keywords: Hybrid Landscapes; Sustainable Architecture; Urban Agriculture; Ecological Design; Green Infrastructure.

LIVING LANDSCAPES: INTEGRATING AGRICULTURE, HOUSING, AND INFRASTRUCTURE THROUGH DESIGN

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ABSTRACT

The expansion of urban populations combined with worsening environmental conditions creates an essential chance to develop new urban planning methods which unite agriculture with housing and infrastructure. The article unveils the design framework Living Landscapes which unifies natural systems with built structures to create cities that are sustainable resilient and oriented toward communities. The article investigates food security alongside climate resilience and social relations in urban areas by studying three international examples namely Serenbe (USA), R-Urban (France) and Songdo (South Korea). The study confirms that inclusive design methods together with resource recycling technologies and intelligent systems help develop city areas into operational ecological systems. Optimal policy structures together with inter-sectorial institutional partnerships enable the expansion of urban food production models throughout different urban systems. The article promotes urban infrastructure transformation by advocating to treat urban agriculture as an essential element instead of a supplemental feature.

Keywords: Living Landscapes; Urban Agriculture; Sustainable Urban Design; Integrated Infrastructure; Agrihoods.

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DEVELOPMENT OF NEW HYBRID MEMBRANES APPLIED TO THE TREATMENT OF OIL EFFLUENTS FROM H'ASSI RMEL

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ABSTRACT

Our work consists of implementing manufacturing processes for composite membranes based on local materials: bentonite clay and activated carbon (CA), with a view to their use for the treatment of industrial effluents and natural waters. These discharges present quite important pollution indicators that do not meet the Algerian norm or the OMS. The membrane support was developed by mixing the activated carbon and the clay first followed by the binder then the gelling agent and lastly the organic plasticizer. It is noted that all composite parts sintered at 500°C with a CA percentage of 5wt. % and addition of solvent at 50% were retained, because their appearance is homogeneous, and does not present any cracks. MEB analysis showed that the membrane type is an ion exchange in the presence of clay and activated carbon especially in the percentage of 5 wt. % of CA. The result of the IR analysis shows us that the absorption values of the wave number before and after treatment by our membranes are different; hence the peaks which indicate the existence of effluents are shown after treatment by the effluent.

Key words: Effluents, ultrafiltartion, membrane system, composite materials.

IMPACT OF TECHNOLOGY ADOPTION ON COTTON PRODUCTION IN DISTRICT SIBBI

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ABSTRACT

Cotton as a cash crop is grown in more than 80 countries and is termed as 'white gold'. It is a widely cultivated profitable fiber crop and a major source for national economic development. However, its importance has been neglected over the past few decades due to losses in production and profitability. In the current scenario, technology adoption appears to be a viable solution to minimize production loss, enhance quality, and ensure sustainability. By examining the adoption of technological practices in cotton farming and its subsequent impact on production outcomes, this study contributes to a deeper understanding of the dynamics between technology, agriculture, and rural development in District Sibi, Balochistan. The data was collected through a comprehensive approach, employing face-to-face interviews conducted via simple random sampling to gather primary data from 120 farmers. The main analytical technique utilized in this research is propensity score matching (PSM). This technique allows for Arobust assessment of the causal relationship between technology adoption and cotton production by minimizing selection bias. Results of the analysis show that technology adopters have a significant influence on cotton production, increasing yields by up to 38% compared to conventional practice adopters. This study is at the top of the policy agenda, as it identifies the challenges faced by farmers in the study area. These challenges can only be overcome by improving farmers' access to technology and through proper policy interventions.

Keywords: Cotton, Technology Adoption, PSM, Sibi

ECONOMIC AND SUSTAINABILITY ANALYSIS OF COTTON; A COMPARISON OF CLIMATE RESILIENT PRACTICES AND CONVETIONAL PRACTICES IN MULTAN

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ABSTRACT

Cotton production is a critical component of Pakistan's agricultural economy, particularly in regions like Multan, where it serves as a major cash crop. However, conventional cotton farming practices often lead to environmental degradation, high input costs, and vulnerability to climate change. This study conducts a comprehensive economic and sustainability analysis of cotton production in Multan, comparing climate-resilient practices (such as drought-resistant varieties, precision irrigation, integrated pest management, and organic farming) with conventional practices (reliance on synthetic fertilizers, pesticides, and flood irrigation). This study used benefit-cost analysis to understand how climate-resilient practices (such as drought-resistant varieties, precision irrigation, integrated pest management, and organic farming) beneficial with conventional practices (reliance on synthetic fertilizers, pesticides, and flood irrigation). The key findings indicated that climate-resilient practices impact on water consumption, input costs, and improve soil health, though initial adoption but still barriers exist. The findings suggested that subsidies for sustainable technologies, farmer training programs, and incentives for transitioning to eco-friendly practices will play a pivotal role in upscalling the adoption and enhance economic resilience and environmental sustainability in Pakistan's cotton sector.

Keywords: Cotton farming, Climate resilience, Sustainable agriculture, Economic analysis, Multan, Pakistan.

FERMENTED FOODS AS FUNCTIONAL TOOLS IN RESILIENT AGRI-FOOD SYSTEMS

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ABSTRACT

Fermented foods, shaped by microbial activity, offer a wide spectrum of applications ranging from nutritional enhancement and therapeutic benefits to innovations in food technology. Rich in bioactive substances such as probiotics and peptides, they support immune system efficiency, metabolic balance, and gut health. Additionally, fermentation increases food quality, prolongs its shelf life, and supports both artisanal methods and industrial applications.

With a focus on their applicability in addressing modern issues like food security, sustainability, and antibiotic resistance, this presentation provides a succinct introduction to fermented foods and explore their growing potential in interdisciplinary sciences.

Keywors : Fermentation, functional food, agrifood system, microbes, resilience

PESTICIDAL EFFICACY OF *Nerium oleander* LEAF EXTRACT ON THE SURVIVAL OF *Pachnoda interrupta* (Sorghum Chafer) UNDER FIELD AND LABORATORY CONDITIONS

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ABSTRACT

Pachnoda interrupta is a damaging pest of sorghum and other cereals that leads to complete crop losses, the management of which relies heavily on chemical pesticides. This pest was exposed to *Nerium oleander* leaf extract under field and laboratory conditions to determine its pesticidal effect. Healthy mature *N. oleander* leaves were collected in a paper bag while adult Sorghum chafers were collected by handpicking and kept in plastic jars which allowed ventilation and prevented escape as they were acclimatized for three days. The leaves were rinsed with distilled water, air dried and grinded with an electric grinder. Maceration extraction was conducted, the extract was strained through a filter paper and distilled water was used to prepare four different concentrations (10, 20, 30, and 40%) to which ten insects were exposed both in the field and laboratory while a control group was treated solely with distilled water and probit analysis was conducted. The constituent compounds of the extract were identified using gas chromatography–mass spectrometry (GC–MS). Bioassay results showed no mortality in the control group, the lowest mortality was 20% in the 10% and the highest was 80% in the 40% extract treatment with the LC_{50} being 231.77 mg/l. The knock down effects in field experiment was zero in the control and 10% treatment while it was highest (11) in 40% treatment. Bioactive compounds identified were cardiac glycosides including oleandrin, neriin, folinerin, digitoxigenin etc. *Nerium oleander* extracts are strongly recommended for standardization and use as biopesticide against *Pachnoda interrupta.*

Keywords: *Pachnoda interrupta; Nerium oleander;* Maceration; Biopesticide; LC_{50}; Knock down effect

EVALUATION OF SOIL MANAGEMENT WITH VARIOUS INSECTICIDES IN CONTROLLING THE OVERWINTERING STAGES OF THE MEDITERRANEAN FRUIT FLY

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ABSTRACT

Mediterranean fruit fly, Ceratitis capitata(Wiedemann) (Diptera: Tephritidae), is the globe's most significant pest of horticulture since it has a wide host range and is economically as well as trade-destruction able. Since the harmful effects of pesticides on human beings, the ecosystem, beneficial insects, and the huge cost incurred in repeated spraying, the current study was conducted to evaluate the application of various insecticides through soil drenching to control the larval and pupal stages of this insect. With an ideal use of its biological susceptibility, the objective was to limit the population of the pest during transitional phase in next year and thereby reduce frequent spraying of the trees. Under the present study, efficacy of three insecticides abamectin benzoate, deltamethrin 10%, and fipronil with two concentrations of 1 g/L and 0.5 g/L were subjected to test using them by mode of soil drenching upon infested larvae of Mediterranean fruit fly on soil. The results indicated that all treatments significantly reduced the emergence of flies; however, the 1 g/L concentration of deltamethrin completely eliminated the emergence of flies from the soil. Therefore, it can be concluded that soil drenching after the last capture of adult insects, as part of the winter management of this pest, can effectively reduce the fly population and significantly decrease damage. Additionally, deltamethrin 10% is identified as a highly suitable option for increasing the mortality rate of this pest's pupae in the soil.

Keywords: Abamectin Benzoate, Deltamethrin 10%, Mediterranean Fruit Fly, Fipronil

COMPANION ANIMALS AND FARM ANIMALS: SPECIESISM AND WELFARE ATTITUDES AMONG EUROPEAN CITIZENS – A SOCIODEMOGRAPHIC PERSPECTIVE

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ABSTRACT

This study examines the sociodemographic factors influencing speciesist attitudes among EU citizens toward companion and farm animals. By analyzing these factors, we explore how moral inconsistencies arise in the treatment of different animal species. Using recently conducted open-access data from the Eurobarometer survey on attitudes toward animal welfare, we compared responses to questions about the perceived need for improved welfare for both farm and companion animals. Logistic regression analyses were employed to assess the impact of sociodemographic variables on speciesist attitudes. The findings reveal that approximately two-thirds of EU citizens do not differentiate between the welfare needs of companion and farm animals. Among the remaining one-third who do discriminate, further analysis identified notable disparities in attitudes. Of this group, two-thirds (representing two-ninths of the overall population) support improved conditions for farm animals, while one-third (one-ninth overall) prioritize companion animal welfare. Key sociodemographic factors shaping these attitudes include education, age, income, residence (urban vs. rural), and political orientation. Citizens with lower education and income levels, those living in rural areas, and individuals identifying politically with the right are more likely to favor companion animals over farm animals in terms of welfare. In rural communities, a more utilitarian perspective often prevails due to economic reliance on farm animals; however, stronger human-animal bonds can also lead to increased concern for animal welfare. Theories such as Social Dominance Orientation (SDO) may help explain these tendencies. These findings underscore the importance of policy measures aimed at promoting consistent animal welfare standards across species. Educational initiatives that

raise awareness about speciesism, along with advocacy efforts, can encourage more ethical consumer choices and support for policy reform. Bridging moral inconsistencies in the treatment of animals is essential for developing more humane and sustainable approaches to animal welfare

Keywords: Animal welfare, Companion animals, EU Citizens, Farm animals, sociodemographic, Speciesism

LARGE-SCALE IRRIGATION REVOLUTION: USE OF MACHINE LEARNING FOR SUSTAINABLE WATER MANAGEMENT

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ABSTRACT

One of the many issues facing modern agriculture is the effective use of water in vast agricultural areas. Although irrigation is an essential part of this management, it can be challenging to optimize due to cultural norms and weather patterns.

In this work, we suggest a unique machine learning-based method for optimizing large-scale agricultural irrigation. In order to more accurately forecast the underwater requirements of aquatic species, we employ machine learning algorithms to analyse vast amounts of meteorological, soil, and cultural data.

Our study's results show how well our machine learning-based irrigation technology works to maximize water utilization in sizable agricultural areas. Our system can minimize water wastage by dynamically modifying irrigation schedules to accommodate the distinct requirements of various cultures through the use of real-time data and prediction algorithms.

This study showed how artificial intelligence, especially machine learning, has the potential to improve water management and revolutionize agriculture. In addition to increasing their productivity and profitability, farmers that employ creative techniques like ours can help ensure that water resources are used more sustainably, which will help to solve the problems of environmental sustainability and food security.

Keywords: Agriculture, Irrigation, Machine Learning

GLOBALIZATION IMPACT ON SUSTAINABLE AGRICULTURE

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ABSTRACT

Globalization impacts sustainable agriculture both positively and negatively, offering opportunities for market access and technology transfer, but also posing challenges like increased competition, environmental degradation, and vulnerability to market fluctuations, especially for small-scale farmers. For decades, the world has produced most of its food through industrial agriculture. Industrial agriculture is characterized by large farms growing the same crop every year using quantities of chemical fertilizers and pesticides damaging to our soil, air, water, and climate. The internal working of this system guarantees that it won't last because it is built to degrade the resources it depends on. The solution to this problem is Sustainable agriculture. Sustainable agriculture aims to meet the present world's food and clothing needs without compromising the future generation's ability to meet their own needs. This type of agriculture seeks to sustain communities, farmers, and resources by encouraging farming practices that are environmentally good and simultaneously profitable. Sustainable agriculture is:

a. **Socially supportive:** It enhances the quality of life of farmers, farming families, and farming communities.

b. **Ecologically sound:** It preserves the resources needed to sustain the world.

AI IN AGRICULTURE — THE FUTURE OF FARMING

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ABSTRACT

The growth of the global population, which is projected to reach 10 billion by 2050, is placing significant pressure on the agricultural sector to increase crop production and maximize yields. To address looming food shortages, two potential approaches have emerged: expanding land use and adopting large-scale farming, or embracing innovative practices and leveraging technological advancements to enhance productivity on existing farmland. Pushed by many obstacles to achieving desired farming productivity — limited land holdings, labor shortages, climate change, environmental issues, and diminishing soil fertility, to name a few, — the modern agricultural landscape is evolving, branching out in various innovative directions. Farming has certainly come a long way since hand plows or horse-drawn machinery. Each season brings new technologies designed to improve efficiency and capitalize on the harvest. However, both individual farmers and global agribusinesses often miss out on the opportunities that artificial intelligence in agriculture can offer to their farming methods. At Intellias, we've worked with the agricultural sector for over 20 years, successfully implementing real-life technological solutions. Our focus has been on developing innovative systems for quality control, traceability, compliance practices, and more. Now, we will dive deeper into how new technologies can help your farming business move forward.

Until recently, using the words AI and agriculture in the same sentence may have seemed like a strange combination. After all, agriculture has been the backbone of human civilization for millennia, providing sustenance as well as contributing to economic development, while even the most primitive AI only emerged several decades ago. Nevertheless, innovative ideas are being introduced in every industry, and agriculture is no exception. In recent years, the world has witnessed rapid advancements in agricultural technology, revolutionizing farming practices. These innovations are becoming increasingly essential as global challenges such as climate change, population growth together with resource scarcity threaten the sustainability of our food system. Introducing AI solves many challenges and helps to diminish many disadvantages of traditional farming.

IMPACT OF GLOBALIZATION ON SUSTAINABLE LAND USE AND FARMING SYSTEM IN THE RURAL DEVELOPMENT

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ABSTRACT

Globalization can accelerate development while, at the same time, negatively impacting nations that are not ready. Globalization benefits rural communities organizing the citizens' life order systematically. Exploiting land use to fulfill human needs is a result of globalization's effects on economic activity. Agricultural and industrial sectors must increase production reasonably and suitably. There is a gray area of needs due to the dependency on the land resources use, which causes rivalry in procuring production inputs for each sector and has a significant effect on the agricultural industry. Transformation of human, environmental, financial, and institutional resources for rural agriculture by implementing effective and efficient agricultural modernization will reduce globalization's negative effects. Smart farming applies modern technology to agriculture in order to achieve more productive and sustainable agricultural production. Agricultural land intensifi¬cation initiatives must be improved through the best use of technological innovation and agricultural infrastructure. Competition for resource utilization causes changes or decreases in land resources quality, which can be anticipated by technological capacities and capabilities, and adaptive capacity to innovations. Unhealthy competition must be eliminated, even these sectors will help each other because of government policy instruments so that the goal of rural sustainable agricultural growth will be achieved. The economic activities of rural farm management have three domains namelyagricultural sector, industrial sector, and both. There is a gray area, where interac-tion between two sectors like occurred at the study site. Each sector needs inputs tothe production process. The same interest in the function and economic activitiesas inputs, production, marketing, and income cause an interaction. The interactioneffect raises land use competition and farm resource change and impacts the agricul-tural sector.Community behavior in rural areas as a form of local wisdom contributes to thepreservation of land resources. Extracting soil for raw material of roof tile industryneeds some requirements such as only taking topsoil from rice fields to a depth of0.25 m, then letting the land rest for two to three years while being treated withmanure. Hence, the production and soil quality will be returned to their initial state.

ENVIRONMENT AND NATURAL RESOURCES

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ABSTRACT

Energy and Natural Resource Management (ENRM) are central concerns in poverty reduction, since millions of people in Pakistan rely directly on agriculture and livestock management for their livelihood. Across the country, soil and water pollution and loss of natural habitats are major problems. In many areas soil salinity and water pollution have reduced yields and the amount of arable land. These and other problems lead to more people, especially the poor, being 'food insecure'. The need for information on ENRM changes rapidly because of weather-related natural disasters such as the floods of 2010 and 2011 and ongoing climate change. To address both development and emergency issues as fully as possible NRSP has one full time NRM Specialist and one full-time Doctor of Veterinary Medicine on staff in the Head Office and 8 District Livestock Officers and 32 ENRM staff in its District and Field Unit Offices.

Environment is derived from the French word Environner, which means to encircle or surround. Environment is defined as the sum total of water, air, land and the interrelationships that exist among them and with the human beings, other living organisms and materials. Natural resources are resources that exist independently of human actions, found in the environment and developed without human intervention. Natural resources are essential for human survival and development, providing food, water, energy, and materials for building and clothing. Natural resources can be defined as the resources that exist (on the planet) independent of human actions. These are the resources that are found in the environment and are developed without the intervention of humans. The world's natural resources provide food, water, fuel, fiber, and many other ecosystem services to society. Agriculture and food systems depend on healthy ecosystems and natural resources, but these resources face rising pressure from unsustainable production practices, population growth, and climate change.

WHAT IS SMART FARMING? IT'S THE FUTURE OF AGRICULTURE

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ABSTRACT

Smart farming refers to managing farms using modern Information and communication technologies to increase the quantity and quality of products while optimizing the human labor required. Many believe that IoT can add value to all areas of farming, from growing crops to forestry. While there are several ways that IoT can improve farming, two of the major ways IoT can revolutionize agriculture are precision farming and farming automation. Precision farming, or precision agriculture, is an umbrella concept for IoT-based approaches that make farming more controlled and accurate. In simple words, plants and cattle get precisely the treatment they need, determined by machines with superhuman accuracy. Precision farming enables decision-making on a per square meter or even per plant/animal basis, contrasting with the classical approach which makes decisions at the field level. By precisely measuring variations within a field, farmers can boost the effectiveness of pesticides and fertilizers, or use them selectively. As is the case of precision agriculture, smart farming techniques enable farmers better to monitor the needs of individual animals and adjust their nutrition accordingly, thereby preventing disease and enhancing herd health. Large farm owners can use wireless IoT applications to monitor the location, well-being, and health of their cattle. With this information, they can identify sick animals, so that they can be separated from the herd to prevent the spread of disease. Traditional greenhouses control the environmental parameters through manual intervention or a proportional control mechanism, which often results in production loss, energy loss, and increased labor costs. IoT-driven smart greenhouses can intelligently monitor as well as control the climate, eliminating the need for manual intervention. Various sensors are deployed to measure the environmental parameters according to the specific requirements of the crop. That data is stored in a cloud-based platform for further processing and control with minimal manual intervention. Agriculture is one of the major verticals to incorporate ground-based and aerial drones for crop health assessment, irrigation, crop monitoring, and other spheres. Importantly, IoT-based smart farming doesn't only target large-scale farming operations. It can add value to emerging trends in agriculture like organic farming, family farming, including breeding particular cattle and/or growing specific cultures, preservation of particular or high-quality varieties, and enhance highly transparent farming to consumers, society and market consciousness.

COMPOST AS A TOOL FOR ENHANCING NUTRIENT BIOAVAILABILITY ON DEGRADED LANDS

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ABSTRACT

Soil degradation is a critical environmental issue leading to reduced fertility, biodiversity loss, and overall ecosystem decline. A key aspect of restoring degraded lands is enhancing the bioavailability of nutrients, which supports plant nutrition and the recovery of soil ecosystems. Compost, derived from organic waste, emerges as an environmentally friendly and effective tool for soil restoration. It supplies macro- and micronutrients, humic substances, and beneficial microbial biota, all of which improve soil structure, increase water retention, and stimulate microbial activity. Through microbial mineralization, compost makes nutrients more accessible to plants, increasing levels of nitrogen, phosphorus, and potassium, enhancing buffering capacity, and contributing to carbon sequestration—vital for rehabilitating degraded soils. The specific effects of compost vary depending on its origin: agricultural residue compost is typically rich in potassium and phosphorus, while food waste composts offer a broader spectrum of trace elements. Selecting the appropriate compost type depends on soil needs and restoration goals. In Ukraine, composting is increasingly recognized as a sustainable method for processing organic waste and improving soil quality, supported by national policies such as the National Action Plan to Combat Land Degradation and Desertification. In the European Union, particularly in countries like Germany, composting plays a central role in the circular economy and sustainable land management, backed by strict quality standards to ensure effectiveness and environmental safety. The successful integration of composting into EU soil restoration practices serves as a valuable model for Ukraine and other countries. Overall, compost use enhances nutrient bioavailability, supports the restoration of soil physicochemical and biological functions, and promotes sustainable land management. Further research is needed to optimize compost formulations and assess their long-term impacts on different types of degraded soils.

Keywords: compost, nutrient bioavailability, degraded land, soil restoration, circular economy, sustainable development

QUESTIONING THE GENDER NARRATIVE IN AGRITECH: A CRITICAL PERSPECTIVE ON WOMEN'S ROLE IN VIKSIT BHARAT

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ABSTRACT

Despite forming a significant portion of the agricultural workforce, women in India remain structurally marginalized in agrarian systems. Their labour is often unpaid, unrecognized, and shaped by patriarchal barriers to land, credit, and technology. While the rise of agritech—drones, robotics, AI—offers potential for transformation, it risks reinforcing existing inequalities if women's access and agency are not deliberately ensured.

The Viksit Bharat@2047 vision emphasizes a shift from women's empowerment to women-led development. While aspirational, this shift requires critical interrogation. What does "women-led" signify when women remain underrepresented in agritech leadership, innovation, and ownership? Without addressing foundational disparities—land rights, digital literacy, economic autonomy—this vision may remain rhetorical.

Government schemes often cite gender inclusion, yet their impact remains uneven. For instance, programs like the Mahila Kisan Sashaktikaran Pariyojana, though well-intentioned, lack integration with emerging agritech platforms. The absence of gender-disaggregated data and targeted monitoring further dilutes impact.

A case in point is the initiative by Farmonaut, where satellite-based advisory tools were introduced to women farmers. While promising in terms of yield and efficiency, deeper analysis reveals limited control by women over inputs, outputs, and profits—highlighting that access does not equal empowerment.

Crucially, gender-responsive budgeting remains inadequate in agritech investments. Aligning fiscal priorities with the goals of women-led development and Viksit Bharat requires more than symbolic gestures—it demands systemic reform. Without a structural rethinking of agrarian gender roles, India's agritech revolution may exclude those it claims to uplift.

Keywords: *Agritech, Viksit Bharat, women led development*

USE OF MOLASSES IN ANIMAL NUTRITION

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ABSTRACT

Sugar beet is a 2-year-old agricultural plant from the spinach family, from which sugar is obtained from its fleshy root. The structure of sugar beet consists of 4.5% cell tissue, 4.5% chemically bound water and 99.95% sap. The composition of beet sap consists of 15.18% sugar (sucrose), 1.0-1.6% other non-sugar organic substances and 0.8% inorganic salts. Molasses is a syrupy substance with a high sugar and nutritional content that remains outside the main product in sugar factories and is not taken back to the factory. In Turkey, 19,253,962 tons of sugar beet was produced in 2023 and a total of 994,272.00 tons of molasses was produced from the sugar beet produced. Molasses; It is used in the production of ethyl alcohol, as animal feed, in direct distilled beverages, in industrial consumption and pharmaceutical industry, as vinegar, in dough yeast, in the production of briquette coal, in construction mortars and in the cosmetic industry. In animal nutrition, it has been determined as ruminant nutrition, liquid feed, silage additive, urea blocks and other areas of use.

With the addition of molasses to feeds, it can reduce the dustiness of the ration, be used as a binder in pellet production, stimulate microbial activities in the rumen and be used as a feed raw material. The chemical, mineral, vitamin and amino acid content of molasses also play an important role in preventing important diseases in nutrition.

As a result of the studies conducted; Adding molasses to silages has positively affected the quality of the silage and increased its quality. With the addition of molasses to plants that are difficult to ensile, it can be used as an alternative feed plant that increases the degree of ensiling. When molasses is used as a feed raw material, it increases digestion in ruminants and poultry and has a positive effect on milk and carcass weight. Molasses-added feeds can prevent metabolic and neurological diseases seen in animals. However, when molasses is given in excess, it causes neurological disorders such as coordination disorder and blindness, and when it is added insufficiently to the ration, it can cause low fiber intake and microbial proliferation. They can also cause urea toxicity, molasses toxicity and bloat in sheep and cattle. In this review, information on the use of molasses in animal nutrition is discussed.

Keywords: Molasses, Animal Feeding, Sugar Beet

MELASIN HAYVAN BESLEMEDE KULLANIMI

ÖZET

Şeker pancarı, etli kökünden şeker elde edilen, ıspanakgiller familyasından 2 yıllık tarım bitkisidir. Şeker pancarının yapısında %4,5 hücre dokusu, %4,5 kimyasal bağlı su ve %99,95 öz suyundan oluşmaktadır. Pancar öz suyunun bileşimi ise %15,18 şeker (sakkaroz), %1,0-1,6 diğer şeker dışı organik maddeler ve %0,8 inorganik tuzlardan oluşmaktadır. Melas, şeker fabrikalarında ana ürün dışında kalan ve fabrikasyona geri alınmayan, şeker oranı ve besleme içeriği yüksek olan şurup kıvamındaki maddedir. Türkiye'de 2023 yılı içerisinde 19.253,962 ton şeker pancarı üretilmiş ve üretilen şeker pancarından toplam 994.272,00 ton melas üretimi gerçekleşmiştir.

Melas; etil alkol üretiminde, hayvan yemi olarak, direk damıtılan içkilerde, endüstriyel tüketim ve ilaç sanayinde, sirke olarak, hamur mayasında, briket kömür imalinde, inşaat harçlarında ve kozmetik sanayinde kullanılmaktadır. Hayvan beslemede kullanımda ise ruminant beslemede, sıvı yem, silaj katkı maddesi, üre blokları ve diğer kullanım alanları olarak belirlenmiştir.

Yemlere melas katılması ile birlikte rasyonun tozluluğunu azaltması, pelet yapımından bağlayıcı olarak kullanılması, rumende gerçekleşen mikrobiyal aktiviteleri uyarmak ve yem hammaddesi olarak kullanılabilmektedir. Melasın kimyasal, mineral, vitamin ve aminoasit içeriği de beslemede önemli hastalıkların engellemede önemli rol üstlenmektedir.

Yapılan çalışmalara sonucunda; Silajların içine melas katılması silajı kalitesini olumlu yönde etkilemiş ve kalitesini artırmıştır. Silolaması zor bitkilere melas katılmasıyla birlikte silolama derecesi artıran ve alternatif yem bitkisi olarak kullanımı sağlanabilir. Melas yem hammaddesi olarak kullanıldığında ruminant ve kanatlı hayvanlarda sindirimi artırarak süt ve karkas ağırlığına olumlu etki yapmaktadır. Melas katkılı yemler hayvanlarda görülen metabolik ve nörolojik hastalıkları engelleyebilir. Fakat melasın fazla verildiği durumlarda koordinasyon bozukluğu ve körlük gibi nörolojik bozukluklara neden olur, rasyona eksik katıldığı zaman ise düşük lif alımına, mikropların çoğalmasına sebep olabilir. Ayrıca koyun ve sığırlarda üre toksisitesi, melas toksisitesi ve şişkinliğe sebep olabilirler. Bu derlemede, melasın hayvan beslemede kullanımına ilişkin bilgiler tartışılmıştır.

Anahtar Kelimeler: Melas, Hayvan Besleme, Şeker Pancarı

WATER FOOTPRINT IN ANIMAL FARM

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ABSTRACT

Water is a tasteless and odorless substance that is necessary for all known life forms. It is colorless when viewed with the naked eye and in small amounts. Worldwide, 97.50% of water resources consist of oceans and seas and 2.5% of fresh water resources. Worldwide water consumption is 7,600 m3 per person. With decreasing rainfall every passing year and pollution of clean water resources due to unconscious water use, approximately 600 million people worldwide will not have access to clean water by 2045. In Türkiye, the amount of usable water is 112 billion m3. In our country, the amount of fresh water per person per year is approximately 1566 m3.

Water footprint in livestock enterprises is the amount of water used directly or indirectly in the feeding, raising and production of animals. Water comes after oxygen in animals and constitutes 56-81% of the body and 90% of the blood. Animals get their water sources from drinking water (83%), from consumed feed (12% grain feed, 10-15% hay and haylage, 60-70% silage and 60-80% pastures) and from metabolic water (1/6 of the daily water requirement is water that occurs as a result of events occurring in the body). Water consumption in cattle varies according to factors such as the amount and characteristics of feed consumed, weather conditions, milk yield and lactation. The most important factor affecting water intake is ambient temperature. Ambient temperature also changes dry matter intake. While the amount of water required for 1 kg dry matter intake at ideal ambient temperature is 3-7 liters, when the temperature reaches 35 ºC and above, the amount of water that needs to be taken increases to 8-15 liters. Water is used as a building block in the animal body, as a heat regulation and lubricant. It is known that some animals consume water, cattle 25-66 l/day, dairy cattle 38-110 l/day, horses 30-45 l/day and sheep and goats 4-15 l/day. In this review, information on determining the water footprint in livestock enterprises is discussed.

Keywords: Animal, Water footprint

HAYVANCILIK İŞLETMELERİNDE SU AYAK İZİ

ÖZET

Su bilinen tüm yaşam formları içim gerekli olan, saf halde iken tatsız ve kokusuz bir maddedir. Küçük miktarlarda ve çıplak göz ile bakıldığında renksizdir. Dünya genelinde su kaynakları %97,50 ile okyanus ve denizlerden %2,5 ise tatlı su kaynaklarından oluşmaktadır. Dünya genelinde su tüketimi kişi başı 7.600 m^3 dür. Her geçen yıl azalan yağışlar, bilinçsiz su kullanılması sonucu temiz su kaynaklarının kirletilmesi ile beraber 2045 yılına kadar dünya genelinden yaklaşık 600 milyon insan temiz suya ulaşamayacaktır. Türkiye'de ise kullanılabilir su miktarı 112 milyar m^3 tür. Ülkemizde bir yılda kişi başına düşün tatlı su miktarı yaklaşık 1566 m^3'tür.

Hayvancılık işletmelerinde su ayak izi, hayvanların beslenmesi, yetiştirilmesi ve ürünlerinin elde edilmesi sürecinde doğrudan ya da dolaylı olarak kullanılan su miktarıdır. Su hayvanlarda oksijenden sonra gelen ve vücudun %56-81'i, kanın ise %90'nı oluşturmaktadır. Hayvanlar su kaynağı olarak birincisi içme suyundan (%83), ikincisi tüketilen yemlerden (dane yemler %12, saman ve kuru otlar %10-15, silajdan %60-70 ve meralardan %60-80) sonuncu ise metabolik su (günlük su gereksiniminin 1/6'nı vücutta meydana gelen olaylar sonucu ortaya çıkan su) ile karşılamaktadır. Sığırlarda su tüketimi tüketmiş olduğu yem miktarı ve özelliği, hava koşulları, süt verimi ve laktasyon gibi faktörlere göre değişim göstermektedir. Su alımını etkileyen en önemli faktör ortam sıcaklığıdır. Ortam sıcaklığı kuru madde alımını da değiştirmektedir. İdeal ortam sıcaklığında 1 kg kuru madde alımı için gerekli su miktarı 3-7 litre iken sıcaklık 35 ºC ve üzerine çıkıldığında alınması gereken su miktarı da 8-15 litreye çıkmaktadır. Su hayvan vücudunda yapı taşı olarak, ısı regülasyonu ve kayganlık verici madde olarak kullanılmaktadır. Bazı hayvanların su tüketimi, sığırlar 25-66 l/gün, süt sığırları 38-110 l/gün, atlar 30-45 l/gün ve koyun ve keçiler 4-15 l/gün su tükettiği bilinmektedir. Bu derlemede hayvancılık işletmelerinde su ayak izinin belirlenmesine ilişkin bilgiler tartışılmıştır.

Anahtar Kelimeler: Hayvancılık, Su Ayak İzi

BIOLOGICAL CONTROL OF BACTERIAL SPECK OF TOMATO (*Pseudomonas syringae* pv. *tomato*) USING COPPER-TOLERANT ANTAGONIST BACTERIA

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ABSTRACT

Bacterial Speck Disease of Tomato, caused by *Pseudomonas syringae* pv. *tomato*, is a bacterial infection that is prevalent in many regions and leads to significant economic losses in tomato production. The disease exhibits as small, dark-colored specks on various parts of the plant. Its management primarily relies on cultural practices, with the supplementary use of copper-based agrochemicals. Although several registered copper-based formulations are available on the market, it is well-documented that the pathogen can rapidly develop resistance due to improper application of these chemicals. For this reason, researchers have increasingly focused on biological control methods as an alternative strategy. In particular, this approach often utilizes beneficial bacteria as antagonistic agents. However, these agents may also be adversely affected by copper applications. This study not only aimed to isolate biological control agents against the pathogen but also evaluated their resistance to copper. To this end, 87 candidate antagonistic bacteria were isolated from healthy tomato plants. Dual culture assays revealed that 29 of these isolates exhibited inhibition zones of varying sizes against the pathogen. Further screening and selection tests were conducted on these antagonists. According to the results, two isolates showed positive results in the potato soft rot test. Twelve isolates demonstrated growth at 37 °C equal to or greater than at 25 °C, while seven isolates did not grow at 37 °C. All antagonistic bacteria tested negative in the tobacco hypersensitivity assay, whereas heat resistance tests demonstrated that six of them were capable of forming endospores. Seventeen isolates produced fluorescent pigments under UV light on King's B medium. In the mechanism of action tests, 10 isolates were DNase-positive, 16 were protease-positive, 1 was chitinase-positive, and 15 were siderophore-positive. Regarding copper resistance, nine antagonists were found to have minimum inhibitory concentrations ranging from 1.08 to 2.16 mM and minimum bactericidal concentrations ranging from 2.16 to 3.74 mM. Considering the results of the dual culture assays, preliminary screenings, mode-of-action tests, and copper resistance, three bacterial isolates (C2NK3, C2EK6, and CBEK3) were selected for pot experiments. For this purpose, combinations of biological control agents, pathogens, and copper applications were evaluated, and assessments conducted on the 24th day after inoculation demonstrated that all antagonist bacterial treatments reduced disease severity with varying effectiveness. However, these positive results must be further validated through multi-year field trials.

Keywords: Antagonistic bacteria, Copper resistance, Biological control, Bacterial speck disease

DOMATES BAKTERİYEL BENEK HASTALIĞINA (*Pseudomonas syringae* pv. *tomato*) KARŞI BAKIRA TOLERANSLI ANTAGONİST BAKTERİLER İLE BİYOLOJİK MÜCADELE

ÖZET

Domates Bakteriyel Benek Hastalığı; *Pseudomonas syringae* pv. *tomato*'nun neden olduğu, birçok bölgede yaygın olarak görülen ve domates üretiminde büyük ekonomik kayıplara yol açan bakteriyel bir hastalıktır. Bitkinin çeşitli kısımlarında koyu renkli ufak benek şeklinde belirtiler oluşturan hastalığın mücadelesi kültürel önlemlere dayanmakta, ayrıca bakırlı tarım ilaçlardan yararlanılmaktadır. Her ne kadar ruhsatlı bakırlı preparatlar piyasada mevcut olsa da hastalık etmeninin bu preparatlara uygun olmayan kullanım nedeniyle kısa sürede dayanıklılık kazandığı bilinmektedir. Bundan dolayı bilim insanları alternatif mücadele yöntemlerden biri olan biyolojik savaş yöntemleri üzerine odaklanmıştır. Özellikle yine bakterilerin savaş ajanı olarak kullanıldığı bu mücadele yönteminde yararlı bakteriler bakırlı preparat uygulanması durumunda etkilenmektedir. Bu çalışmada hastalığa karşı biyolojik savaş ajanlarının araştırılmasının yanında, elde edilen ajanların bakıra dayanıklılıkları da değerlendirmiştir. Bu amaçla; sağlıklı domates bitkilerinden 87 adet antagonist bakteri adayı izole edilmiş ve yapılan ikili kültür testleri ile az ya da çok 29 tanesinin engelleme zonu oluşturduğu bulunmuştur. Daha sonra bu antagonistlere gerek ön eleme gerekse seçim için bazı testler yapılmıştır. Yapılan testlerin sonuçlarına göre; 2 antagonist patates yumuşak çürüklük testinde pozitif sonuç verirken, 12 bakteri 37 ℃'de 25 ℃'deki kadar veya daha iyi bir gelişim göstermiş, 7 bakteri ise 37 ℃'de hiç gelişmemiştir. Tütünde aşırı duyarlılık testine göre antagonist bakterilerin tümü negatif sonuç verirken, yapılan ısı testi ile 6 tanesinin endospor oluşturduğu bulunmuştur. King's B besi yerinde 17 bakterinin UV ışık altında parlayan pigment oluşturduğu bulunmuştur. Antagonist bakterilerin etki mekanizması testlerine göre: 10 bakteri DNase pozitif, 16'sı proteaz pozitif, 1'i kitinaz pozitif, 15'i siderofor pozitif sonuç verdiği saptanmıştır. Bu antagonistlerin bakıra dayanıklılıkları araştırıldığında; 9 antagonistin 1.08−2.16 mM minimum inhibitör konsantrasyon ve 2.16−3.74 mM minimum bakterisidal konsantrasyon değerlerine sahip oldukları bulunmuştur. Gerek ikili kültür, gerek ön değerlendirme/etki mekanizması testleri ve gerekse bakır dayanıklıkları göz önünde bulundurularak bu 9 bakteri içerisinden saksı çalışmaları için 3 bakteri izolatı (C2NK3, C2EK6 ve CBEK3) seçilmiştir. Bunun için biyolojik savaş ajanı, hastalık etmeni ve bakır uygulaması farklı kombinasyonlarda kullanılarak değerlendirilmiş ve inokulasyondan sonra 24. günde yapılan sayımlarda tüm antagonist bakteri uygulamalarının değişen oranlarda hastalık şiddetini azalttığı görülmüştür. Bu olumlu sonuçların özellikle çok yıllık tarla çalışmaları ile desteklenmesi gerekmektedir.

Anahtar Kelimeler: Antagonist bakteri, Bakır dayanıklılığı, Biyolojik mücadele, Bakteriyel benek hastalığı

DETERMINATION OF METHANE CONCENTRATION IN BIOGAS USING LOW-COST MULTIPLE METHANE SENSORS

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ABSTRACT

The quality of biogas generated by biogas plants primarily depends on its methane content, which in turn affects the fuel's energy value and proper combustion characteristics. Current technologies for measuring biogas methane content often involve sophisticated and costly equipment. Conventional methane analysis in biogas relies on laboratory gas chromatography or expensive infrared sensors, posing challenges for on-site, continuous monitoring in small-scale biogas plants. Gas chromatography with thermal conductivity or flame ionization detectors provides precise composition analysis but requires laboratory facilities and skilled technicians. Portable infrared gas analyzers tailored for biogas offer on-site measurements of CH_4 and CO_2. However, such instruments are expensive and may be impractical for small-scale or rural biogas operators. Even simpler handheld gas testers must be frequently calibrated and represent a significant investment. This creates a need for affordable, user-friendly alternatives that can operate in the field.

This study addresses the need for a cost-effective, methane measurement solution by developing a device based on multiple low-cost gas sensors. The system employs dual metal-oxide semiconductor methane sensors (MQ-4 and MQ-9), along with temperature and pressure sensors, all integrated with a microcontroller and housed in a custom-designed 1.2-liter airtight chamber. Since both MQ sensors have an upper detection limit of approximately 10,000 ppm (1% CH_4 by volume), direct measurement of raw biogas (typically containing 50–70% CH_4) would exceed their operational range. To address this, a fixed volume of biogas (10 mL) was injected into the chamber, effectively diluting the sample to maintain methane concentrations within the sensors' measurable limits. After each reading, the chamber was purged with clean air to remove residual gases and ensure accurate and reproducible measurements in subsequent sampling cycles. A calibration procedure was implemented using biogas obtained from laboratory-scale anaerobic bioreactors to determine accurate reference methane concentrations. The procedure was based on a chemical scrubbing method involving the absorption of CO_2 using a sodium hydroxide (NaOH) solution, in conjunction with a gas meter for precise volumetric measurement. Sensor outputs were then linearized via Python-based curve fitting. Data filtering and dual-sensor signal fusion improved measurement stability.

The findings suggest that low-cost sensors, when properly calibrated, can provide reliable methane monitoring for small-scale biogas digesters, enabling operators to continuously track gas quality on-site at minimal cost.

Keywords: Agricultural Biogas Plants, Methane Sensor, Anaerobic Digestion, Bioreactor, Biogas Quality.

BİYOGAZDAKİ METAN KONSANTRASYONUNUN TESPİTİNDE DÜŞÜK MALİYETLİ ÇOKLU METAN SENSÖRLERİNİN KULLANIMI

ÖZET

Biyogaz tesisleri tarafından üretilen biyogazın kalitesi, öncelikle metan içeriğine bağlıdır ve elde edilen yakıtın enerji değerini ve yanma özelliklerini etkiler. Biyogaz metan içeriğini ölçmeye yönelik mevcut teknolojiler genellikle karmaşık ve maliyetli ekipmanları içermektedir. Küçük ölçekli biyogaz tesislerinde geleneksel metan analizi, gaz kromatografisi veya pahalı kızılötesi sensörlerle yapılmakta; yerinde ve sürekli metan izleme için zorluklar oluşturmaktadır. Termal iletkenlik veya alev iyonizasyon detektörlü gaz kromatografisi, hassas bileşim analizi sağlamakla birlikte, laboratuvar olanakları ve uzman teknisyenler gerektirmektedir. Biyogaz için özel olarak tasarlanmış taşınabilir kızılötesi gaz analizörleri, CH_4 ve CO_2'nin yerinde ölçümlerine imkân vermektedir. Ancak, bu tür cihazlar pahalıdır ve küçük ölçekli veya kırsal biyogaz işletmecileri için pratik olmayabilir. Daha basit el tipi gaz test cihazları bile sık sık kalibre edilmeli ve kalibrasyon için önemli bir bütçe ayrılmalıdır. Bu durum, sahada çalışabilecek uygun fiyatlı, kullanıcı dostu alternatiflere olan ihtiyacı ortaya çıkarmaktadır.

Bu çalışma, düşük maliyetli çoklu gaz sensörlerini temel alan bir cihaz geliştirerek, maliyet etkin bir metan ölçüm çözümü ihtiyacını ele almaktadır. Önerilen sistemde, sıcaklık ve basınç sensörleri ile birlikte iki adet metal oksit yarı iletken metan sensörü (MQ-4 ve MQ-9) kullanmaktadır. Sensörlerin tümü bir mikrodenetleyici ile entegre edilmiş ve özel olarak tasarlanmış 1,2 litrelik hava geçirmez bir hazne içine yerleştirilmiştir. Her iki MQ sensörünün de yaklaşık 10.000 ppm (hacimce %1 CH_4) üst algılama sınırına sahip olması nedeniyle, ham biyogazın (tipik olarak %50-70 CH_4 içeren) doğrudan ölçümü, sensörlerin çalışma aralığını aşmaktadır. Bu sorunu çözmek için, ölçüm haznesine sabit bir hacimde biyogaz (10 mL) enjekte edilmiş, bu da metan konsantrasyonlarını sensörlerin ölçülebilir sınırları içinde tutmak için numuneyi etkili bir şekilde seyreltmiştir. Her okumadan sonra, artık gazları uzaklaştırmak ve sonraki numune alma döngülerinde doğru ve tekrarlanabilir ölçümler sağlamak için hazne temiz hava ile temizlenmiştir. Çalışmada laboratuar ölçek anaerobik biyoreaktörlerden elde edilen biyogaz ile doğru referans metan konsantrasyonları elde etmek için, kimyasal yıkama yöntemi (CO_2'nin NaOH ile absorpsiyonu) ve bir gaz sayacı ile birlikte bir kalibrasyon prosedürü uygulanmıştır. Sensör çıktılarına daha sonra Python tabanlı eğri doğrusallaştırma uygulanmıştır. Veri filtreleme ve çoklu sensör sinyallerinin birlikte değerlendirilmesi, ölçüm kararlılığını artırmıştır.

Bulgular, düşük maliyetli sensörlerin, uygun şekilde kalibre edildiklerinde, küçük ölçekli biyogaz reaktörleri için güvenilir metan ölçümü sağlayabileceğini ve işletmecilerin gaz kalitesini yerinde ve minimum maliyetle sürekli olarak takip etmelerine olanak tanıdığını göstermektedir.

Anahtar Kelimeler: Tarımsal Biyogaz Tesisleri, Metan Sensörü, Anaerobik Çürütme, Biyoreaktör, Biyogaz Kalitesi

EFFECT OF CHİTOSAN-BASED NANOCAPSULES ON THE APHİD-MEDİATED TRANSMİSSİON OF POTATO VİRUS Y

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ABSTRACT

Systemic infections in potato-growing areas caused by potato virus Y (*Potyvirus yituberosi*; PVY), making it one of the most significant viral diseases due to its significant impact on yield and quality. PVY infections can lead to yield losses of 50 to 80% in potato plants. In conventional agriculture, the use of various chemical fertilizers, pesticides and other agrochemicals to increase yields and protect crops has shown to have a negative impact on biodiversity, soil fertility and the overall health of the ecosystem. Nanotechnology has become a more prominent topic in the past few years as a sustainable alternative to conventional agricultural inputs. In the present study, thyme essential oil was encapsulated with chitosan, a widely used organic nanoparticle, and lecithin, a natural biopolymer. The effects of this nanoencapsulation on the aphid-mediated transmission of PVY were studied under laboratory conditions. Three additional treatments were applied: thyme essential oil, chitosan + thyme oil nanoparticles, and chitosan nanoparticles alone. In the transmission assay, aphid individuals that had been starved for one hour were placed on potato shoots infected with PVY (*S. tuberosum* cultivar. 'Agria') for a 2.5-minute virus acquisition access period (AAP). The aphids were then transferred to healthy potato plants that had been treated with the nanoparticle formulations with foliar spray 24 hours earlier and allowed to feed overnight. Fifteen days after inoculation with the aphids, the plants were tested for PVY infection using the DAS-ELISA method. The effects of the different treatments on virus titer in the plants were statistically analyzed, and comparisons were made using the Tukey HSD post hoc test. The results show that besides the repellent effect of thyme essential oil against aphids described in the literature, the formulation thyme oil encapsulated with chitosan and lecithin also has a repellent effect against aphids.

Keywords: Potato, Potyvirus, Nanoencapsulation, Insect vector, Chitosan

KİTOSAN BAZLI NANOKAPSÜLLERİN PATATES Y VİRÜSÜNÜN YAPRAK BİTİ ARACILIĞI İLE TAŞINIMI ÜZERİNDEKİ ETKİSİ

ÖZET

Patates üretim alanlarında sistemik enfeksiyonlara yol açarak ciddi verim ve kalite kayıplarına sebep olan Patates Y Virüsü (*Potyvirus yituberosi*; PVY), en önemli viral hastalıklar arasında yer almaktadır. PVY enfeksiyonları, patates bitkilerinde %50 ila %80'e varan oranda verim kaybına yol açabilmektedir. Geleneksel tarımda üretimi artırmak ve bitkileri zararlılardan korumak amacıyla çeşitli kimyasal gübreler, pestisitler ve diğer zirai kimyasalların kullanımı; biyoçeşitlilik, toprak verimliliği ve genel ekosistem sağlığı üzerinde olumsuz etkiler oluşturmaktadır. Bu bağlamda, nanoteknoloji son yıllarda geleneksel uygulamalara sürdürülebilir bir alternatif olarak tarım sektöründe artan bir ilgi görmektedir. Bu çalışmada, yaygın olarak kullanılan organik bir nanopartikül olan kitosan (Kts) ve doğal bir biyopolimer olan lesitin (Ls), kekik uçucu yağı (Ky) ile enkapsüle edilerek (Kts+Ky+LsNP) hazırlanmış ve bu nanoenkapsülasyonunun, laboratuvar koşullarında, PVY'nin yaprak biti aracılığıyla patates bitkisine taşınımı üzerindeki etkileri araştırılmıştır. Üç ek uygulama daha yapılmıştır: kekik esansiyel yağı, kitosan + kekik yağı nanoparçacıkları ve yalnızca kitosan nanoparçacıkları. Taşınım denemesinde, bir saat aç bırakılan yaprak biti bireyleri, 2,5 dakikalık virüs alma süresi (acquisition access period, AAP) boyunca PVY enfekteli patates sürgünleri (*S. tuberosum* cv. 'Agria') üzerine yerleştirilmiş, ardından PVY'den ari olduğu bilinen ve 24 saat önce yapraktan sprey şeklinde nanopartikül uygulanan sağlıklı bitkiler üzerine aktarılmış ve bir gece boyunca beslenmelerine izin verilmiştir. Virüs taşınımı yapılan bu bitkiler, 15 gün sonra DAS-ELISA yöntemi ile PVY yönünden test edilmiştir. Uygulanan farklı formülasyonların, patates bitkilerindeki virüs titrelerine etkileri istatistiksel olarak değerlendirilmiş ve karşılaştırmalar Tukey HSD post hoc testi ile gerçekleştirilmiştir. Elde edilen bulgular doğrultusunda, literatürde yaprak biti kovucu etkisi bilinen Ky uygulamasına ek olarak, Kts+Ky+LsNP formülasyonunun da afitleri uzaklaştırıcı etkisi gösterdiği gözlemlenmiştir.

Anahtar Kelimeler: Patates, Potyvirus, Nanoenkapsülasyon, Vektör böcek, Kitosan

OBTAINING POLYHYDROXYALKANOATE BY CONCENTRATION OF BUTANOLS OF THE RESISTANT STRAIN *PSEUDOMONAS HELMANTICENSIS P1*

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ABSTRACT

Poly-3-hydroxyalkanoates (PHA), produced biosynthetically by Pseudomonas bacteria, are promising substitutes for conventional plastics. Poly-3-hydroxyalkanoates (PHA) are polyesters produced biosynthetically by *Bacillus, Cupriavidus, Pseudomonas*, etc. They have a number of advantages over traditional polymers obtained by refining oil. In particular, they quickly decompose both in natural ecosystems and in the human body without forming toxic products. The study aimed to determine the stability of the polyhydroxyalkanoate-producing strain *Pseudomonas helmanticensis P1* with butanol concentration and without butanol. The toxic effect of butanol was carried out on biofilms of *Pseudomonas helmanticensis P1* and when cultivating the bacteria in suspension in liquid culture media.

Keywords: *Pseudomonas helmanticensis,* Luria-Bertani, *n*-butanol, Hydrogen potential, Oil refining, *mcl*-pha.

EFFECT OF GIBERELLIC ACID-PRODUCING LACTIC ACID BACTERIA ON THE DEVELOPMENT OF GRAPES

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ABSTRACT

One of the main indicators of achieving high and quality yield from agricultural crops is the use of microorganisms that enhance plant growth and development, specifically lactic acid bacteria that synthesize phytohormones. Treating agricultural plants with these bacteria strengthens their growth and development, as the gibberellin synthesized by these microorganisms improves plant growth, enhances soil fertility, increases productivity, and improves product quality. As a result, soils used in agriculture are enriched with beneficial microorganisms.

Keywords: Lactobacillus, Streptobacterium, Grapevine development, Biopreparation, Gibberellin, Grape rhizosphere, Phytohormones, Lactic acid bacteria

EFFECTIVENESS OF USING MICRONUTRIENT AND VITAMIN SUPPLEMENTS IN DAIRY COWS

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ABSTRACT

This article presents the results of a study on the impact of adding microelement-vitamin premixes to the dairy cows' diet for 2 months, focusing on clinical and hematological indicators as well as productivity.

Keywords: Diet, Retinol, Tocopherol, Bentonite, Copper sulfate, Potassium iodide, Manganese Sulfate, Premix, Vitamins, Macro and microelements, Alkaline reserve.

NUTRIENT MEDIA DEVELOPED FOR CULTIVATION AND MULTIPLICATION OF EPIPHYTIC MICROORGANISMS

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ABSTRACT

This article discusses the composition of artificial nutrient media used for the growth of microorganisms. These media typically contain essential nutrients—macro and microelements—dissolved in water, often in amounts sufficient or even greater than what is required for microbial growth and development. For heterotrophic organisms, various organic compounds serve as carbon sources. In microbiological practice, the most commonly used carbon sources are sucrose, glucose, or other hexoses, as well as polyatomic alcohols and carboxylic acids obtained from the oxidation of sugars.

The article also highlights the preparation of an optimal nutrient medium for cultivating epiphytic microorganisms, using a nutrient medium derived from the aerial parts of the Jerusalem artichoke (topinambur) plant.

Keywords: *Azotobacter; Jerusalem artichoke; nutrient medium; soil; fertilizer; Petri dish; gliadin; germination.*

DETERMINATION OF CAST/MspI GENE POLYMORPHISM AND ITS EFFECTS ON 180-DAY WEIGHT IN MEAT PRODUCTION LINE OF KAZAKH SARYARKA LAMBS

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ABSTRACT

The CAST gene has been extensively studied in livestock for meat quality and growth traits. The Saryarka breed is characterized by a hardy constitution that allows for year-round grazing. The aim of this study was to investigate the polymorphism of the CAST gene in lambs of the Saryarka meat production line and to investigate associations between the CAST genotype and live weight in 180-day-old lambs. A total of 60 lambs were genotyped by the PCR-RFLP method. Two genotypes, MM and MN, were identified with frequencies of 0.59 and 0.41, respectively. According tothe association analysis, lambs with the MN genotype produced significantly ($P<0.01$) more live weight (4.48 kg) than lambs with the MM genotype. The study was the first to demonstrate that the Saryarkabreed has a genetic variation of the CAST gene and its effects on lamb live weight. As a result of this study, it can be said that the CAST gene could potentially be a molecular marker for the Saryarka breed to increase lamb production and be integrated into the current selection program for the breed.

Keywords: Saryarka, CAST, MspI, RFLP

LOCATION, STATUS AND STATISTICAL ANALYSIS OF LIVESTOCK IN THE REPUBLIC OF UZBEKISTAN

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ÖZBEKİSTAN CUMHURİYETİ`NDE HAYVANCILIĞIN YERİ, DURUMU VE İSTATİSTİKSEL ANALİZİ

ÖZET

Bu çalışmada, Cumhuriyet genelindeki çeşitli kategorilerdeki tarım işletmelerinde yetiştirilen büyükbaş, küçükbaş ve kümes hayvanlarının sayıları vilayetler bazında analiz edilmiştir. Hayvancılığın sürdürülebilir gelişimini sağlamak amacıyla, hayvan türlerinin sayısının arttırılması artırılması, yürütülen emeğin verimliliği ile doğrudan ilişkilidir. Bu kapsamda, seleksiyon çalışmaları, hayvan ıslahı, soy seçimi, ekonomik ve sosyal önlemler bütüncül şekilde değerlendirilmiş ve hedef odaklı stratejilere temel oluşturmuştur.

Bölgesel doğal, coğrafi ve ekonomik koşullar ile pazar talepleri dikkate alınarak hayvancılığın tüm alt dallarının geliştirilmesi günümüzün öncelikli konularından biri olarak kabul edilmektedir. Gıda ve işleme sanayileri için et, süt, yün, deri, bal, balık, yumurta gibi temel ürünlerin üretimi sağlanmakta olup, bu durum yalnızca sanayi sektörlerinin gelişimini değil, aynı zamanda insan sağlığı için hayati öneme sahip protein açısından zengin ürünlerin üretimini de desteklemektedir.

Anahtar Kelimeler: Cumhuriyet, Hayvancılık, Sığır, Koyun-Keçi, Kümes Hayvanı, Hayvansal ürünler

DGAT1 GENE POLYMORPHISM IN COARSE-HAIRD FAT TAILED LAMBS OF DIFFERENT GENOTYPES

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ABSTRACT

The aim of this study was to investigate the DGAT1 gene polymorphism and its effects on lamb weight in Kazakh purebred (Edilbay) and crossbred lambs (Edilbay x Gissar). A total of 97 blood samples were collected from purebred and crossbred lambs. Animals were genotyped for DGAT1-AluI polymorphism using the polymerase chain reaction-restriction length polymorphism (PCR-RFLP) method. The result of PCR-RFLP showed that purebred lambs had three genotypes (CC, CT and TT) and crossbred lambs had two genotypes (CC and CT). The predominant genotype was CC with a frequency of 0.70 and 0.58 in purebred and crossbred breeds, respectively. The present study was the first to investigate the polymorphism of DGAT1 gene in Kazakh purebred and crossbred lambs.

Keywords: Edilbay, Gissar, DGAT1, Polymorphism, RFLP

USE OF CHLORELLA IN LIVESTOCK (THE CASE OF CATTLE)

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ABSTRACT

The article discusses the use of Chlorella (Chlorella vulgaris) in the feeding of cattle. The effects on weight gain, feed conversion, milk composition, and overall animal health are examined. Data on the biochemical composition of Chlorella, its impact on the digestive system, and the immune status of animals are presented. Experimental data demonstrate the effectiveness of Chlorella as a feed additive for improving productivity and health in cattle.

Keywords: Chlorella, cattle, milk productivity, weight gain, feed conversion, feed additive.

BIOLOGICAL TREATMENT OF WASTEWATER FROM INTENSIVE FISHING PONDS

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ABSTRACT

Biological treatment of unusable water from intensively bred fish ponds in special ponds, that is, converting polluted water into technical water through the Pistia plant and reusing it in agriculture. At the same time, drying the stems and leaves of the Pistia plant, which reproduces in a short time, and adding them to the feed ration of livestock and poultry and using them as feed.

Keywords: Intensive, Pistia, Effluent, Sedge, Technical, Reserve, Industry, Basin, Resource.

THE DEVELOPMENT OF MEAT QUALITIES IN LAMBS OF THE COARSE-WOOL FAT-TAİLED SARYARKA SHEEP BREED (INTERBREED ZHANAARKA)

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ABSTRACT

The study was carried out at the "Zhenis" sheep breeding facility in Kazakhstan's Ulytau region, which is well-known for its purebred livestock. With a focus on the Zhanaarka interbreed, the lambs used in this study were Sararaka breed lambs, which are distinguished by their coarse wool and fat-tailed features. An experimental group of male and female lambs was created during the April lambing season at the "Zhenis" breeding farm. Well-developed, single-born lambs from desirable ewe and ram breeds were among the group. Weighings were taken of each animal in the experimental group at birth, as well as at 1, 2, 3, 4, 5, 6, 7, 12, and 18 months. Male and female lambs born in the same lambing were simultaneously measured for eight major body measurements: oblique body length, chest girth, cannon bone girth, withers height, croup height, chest width, chest depth, and width between shoulder blades. Five Sarara lambs were chosen and put through a controlled slaughter process at four to five months of age in order to assess the meat and fat productivity of these animals. Following a 24-hour fast, the live weight prior to slaughter was determined. Body morphological composition, meat-to-bone ratio, proportions of meat grades and parts, carcass weight without tail fat, tail fat weight, internal fat weight, and slaughter mass were all noted. Additionally, yields of these slaughter products (meat and fat including internal organs) were also noted. In the Kazakhstan-Japan Innovation Center at KazNARU, the genetic structure of the Saryarka sheep breed was also examined in terms of the GDF9 gene.

Anahtar Kelimeler: Saryarka sheep, Selection, Live weight, Meat quality, GDF9, RFLP.

PREPARATION OF BIONANOMATERIALS AS REINFORCING PHASE IN POLYMERIC MATRICES TO FORM NANOCOMPOSITES.

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ABSTRACT

The use of nanomaterials as reinforcing phase in polymeric matrices to form nanocomposites has attracted much research attention due to their ability to improve the mechanical properties of such systems. Hence, biobased materials have been a subject of immense research interest in recent years due to their great potential to produce a variety of biocompatible products. In this study, a suitable approach has been developed to prevent agglomeration of MCC (microcrystalline cellulose) during dispersion by partially or completely covering MCC with octenyl succinic anhydride (OSA) modified starch. This strategy is based on a simple coating technique involving a modest physical treatment, which is convenient and easily available.

The objectives of this work were to develop a new material based on MCC, in the form of colloidal suspension, obtained by hydrolysis with sulfuric acid. The second phase consists in coating the colloidal particles obtained with OSAstarch in order to prepare a bio-based composite material (OSA-Cel), which can be used as stabilizer in the formulation of dispersed systems or as reinforcing filler in a polymeric matrix. The obtained product was characterized in terms of chemical structure, morphology, surface aspects and rheology.

Keywords: microcrystalline cellulose, OSA-starch, composites, surface tension, rheology

USE OF ANTHER CULTURE IN HAPLOID PLANTS PRODUCTION IN STRAWBERRY

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ABSTRACT

Strawberries are the most commercially produced berry plants among other berries in the world. It has been favoured due to its unique taste, high nutritional value, rich in vitamin C, anthocyanin etc., and high raw material potential for processed food. From past to present, breeding studies on strawberries have carried on fruit quality and production yield, disease-resistance, environmental adaptation, postharvest longevity. But some global issues (food scarcity, global warming etc.) and limitations in traditional breeding (being time-consuming, high cost) are restricted the strawberry production and breeding studies. Anther culture is one of the most widely used techniques in plant breeding and genetic research to produce haploid plants. Plants to be obtained will possess a single set of chromosomes in somatic cells. Later those plant also can have their chromosome numbers doubled by applying some treatments. This method enables the homozygous pure line to be obtained in a shorter time compared to traditional methods. However, this depends on various factors such as species, genotype, explant type, nutrient medium, culture conditions, explant age, type of chromosome doubling treatment etc. For strawberry breeding, anther culture could be alternative method to enhance homozygous inbred line. But, its high ploidy level, its complex genetic structure and obtaining high rate of heterozygous progenies by seed propagation are crucial challenges for anther culture studies in strawberry. This review will discuss the current practices, and challenges of anther culture on strawberries, potential applications of haploid and doubled haploid strawberry plants in breeding. This review could be beneficial for studies to be used in genetic studies, marker-assisted selection, genome editing technologies. This study is supported by Çukurova University BAP Coordination Office within the scope of project number FDK-2023-15809.

Keywords: Strawberry, haploid, breeding, anther culture

ÇİLEKTE HAPLOİD BİTKİ ÜRETİMİNDE ANTER KÜLTÜRÜNÜN KULLANIMI

ÖZET

Çilek, dünyadaki diğer üzümsü meyveler arasında ticari olarak en çok üretilen meyvedir. Benzersiz tadı, yüksek besin değeri, C vitamini, antosiyanin vb. açısından zengin olması ve işlenmiş gıda için yüksek hammadde potansiyeli nedeniyle tercih edilmektedir. Geçmişten günümüze çilekler üzerinde yapılan ıslah çalışmaları meyve kalitesi ve üretim verimi, hastalık direnci, çevresel adaptasyon, hasat sonrası uzun raf ömrü üzerinde yoğunlaşmıştır. Ancak bazı küresel sorunlar (gıda kıtlığı, küresel ısınma vb.) ve geleneksel ıslahtaki sınırlamalar (zaman alıcı, yüksek maliyetli olması) çilek üretimi ve ıslah çalışmalarını kısıtlamaktadır. Anter kültürü, haploid bitkiler üretmek için bitki ıslahı ve genetik araştırmalarında en yaygın kullanılan tekniklerden biridir. Elde edilecek bitkiler somatik hücrelerinde tek bir kromozom setine sahip olacaktır. Daha sonra bu bitkilerin kromozom sayıları da bazı işlemler uygulanarak iki katına çıkarılabilir. Bu yöntem, geleneksel yöntemlere kıyasla daha kısa sürede homozigot saf hattın elde edilmesini sağlar. Ancak bu yöntem türe, genotipe, eksplant tipine, besin ortamına, kültür koşullarına, eksplant yaşı, kromozom katlama yöntemi türü gibi vb. çeşitli faktörlere bağlıdır. Çilek yetiştiriciliğinde, anter kültürü homozigot saf hat geliştirmek için alternatif bir yöntem olabilir. Ancak, yüksek ploidi düzeyi, karmaşık genetik yapısı ve tohumla çoğaltım yoluyla yüksek oranda heterozigot yavru elde edilmesi, çilekte anter kültürü çalışmaları için önemli zorluklardır. Bu derlemede çileklerde anter kültürünün mevcut uygulamaları ve zorlukları, haploid ve çift haploid çilek bitkilerinin ıslahta potansiyel uygulamaları tartışılacaktır. Bu derleme genetik çalışmalarda, marker destekli seleksiyonda, genom düzenleme teknolojilerinde kullanılacak çalışmalara katkı sağlayabilir. Bu çalışma, Çukurova Üniversitesi BAP Koordinatörlüğü FDK-2023-15809 nolu proje kapsamında desteklenmektedir.

Anahtar Kelimeler: Çilek, haploid, ıslah, anter kültürü

FULL TEXTS

GROWING GENETICALLY MODIFIED CROPS IN THE WORLD AND TÜRKİYE

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ABSTRACT

With the developments in the second and third quarters of the twentieth century, it became possible to transfer genes to plants by asexual methods without taxonomic restrictions in the fourth quarter. In 1994, the first cultivated plant whose genetic structure was modified by biotechnological methods, the late-ripening tomato plant, was started to be cultivated. In 1996, widespread cultivation of varieties of corn, cotton, soybean and rapeseed whose genetic structure was modified by biotechnological methods was started in 5 countries on an area of 1.7 million hectares. This area increased rapidly and reached 206.3 million hectares in 2023. The number of transgenic plant species whose cultivation is widespread has also increased. The number of countries growing transgenic plants has changed between 6 and 29 in the past period. In 2023, transgenic plants were cultivated in 27 countries worldwide and transgenic plants were traded in 76 countries. Despite the rapid increase in the area of transgenic plants growing in the world, the discussions about the cultivation of these plants and the products obtained from these plants, which started with the beginning of the cultivation of these plants, continue in the world public opinion. Due to these discussions, the cultivation and trade of these plants has been legally prohibited in some countries, and their cultivation in some countries. For this reason, transgenic plant cultivation is carried out in one out of every seven countries in the world. Despite some of the economic and ecological advantages of transgenic plant cultivation, there are ongoing discussions about the possible risks to human health, economy and ecology with the widespread cultivation of these plants. On the other hand, no significant human health and ecological problem has been encountered in the public opinion regarding transgenic plants that have been cultivated, traded and consumed for nearly 30 years.

In this report, the current status and future of transgenic plant cultivation in the world and in our country, and the advantages and risks of transgenic plant cultivation are discussed.

Keywords: Gene, GMO, Transgenic crop, Advantage, Risk

DÜNYADA VE TÜRKİYE'DE GENETİĞİ DEĞİŞTİRİLMİŞ BİTKİ TARIMI

ÖZET

Yirminci yüzyılın ikinci ve üçüncü çeyreğinde sağlanan gelişmelerle dördüncü çeyrekte bitkilere taksonomik sınırlama olmaksızın eşeysel olmayan yöntemle gen aktarılması olanaklı hale gelmiştir. 1994 yılında biyoteknolojik yöntemlerle genetik yapısı değiştirilmiş ilk kültür bitkisi olan geç olgunlaşma özelliği kazandırılmış domates bitkisinin tarımına başlanmıştır. 1996 yılında ise 5 ülkede mısır, pamuk, soya ve kolzanın biyoteknolojik yöntemlerle genetik yapısı değiştirilmiş çeşitlerinin 1.7 milyon hektarlık alanda yaygın tarımına başlanmıştır. Söz konusu alan hızla artarak 2023 yılında 206.3 milyon hektara çıkmıştır. Tarımı yaygınlaşan transgenik bitki türü sayısı da artış göstermiştir. Geçen sürede transgenik bitki yetiştiren ülke sayısı 6 ile 29 arasında değişmiştir. 2023 yılında dünya çapında 27 ülkede transgenik bitki tarımı yapılmış ve 76 ülkede transgenik bitkiler ticarete konu olmuştur. Dünyada transgenik bitki yetiştirme alanı hızla artmasına karşılık, bu bitkilerin tarımının başlamasıyla birlikte dünya kamu oyunda başlayan bu bitkilerin tarımı ve bu bitkilerden elde edilen ürünlerle ilgili tartışmalar devam etmektedir. Bu tartışmalar nedeniyle bazı ülkelerde bu bitkilerin tarımı ve ticareti, bazı ülkelerde ise tarımı yasal olarak yasaklanmıştır. Bu nedenle dünyadaki her 7 ülkenin birisinde transgenik bitki tarımı yapılmaktadır. Transgenik bitki tarımının ekonomik ve ekolojik bazı avantajlarına karşılık, bu bitkilerin tarımının yaygınlaşması ile insan sağlığı, ekonomik ve ekolojik açıdan bazı risklerinin olabileceği konusundaki tartışmalar sürmektedir. Buna karşılık, 30 yıla yakın süredir tarımı, ticareti ve tüketimi yapılan transgenik bitkilerle ilgili kamu oyuna yansımış önemli bir insan sağlığı ve ekolojik sorunla karşılaşılmamıştır.

Bu bildiride, transgenik bitki tarımının dünyada ve ülkemizdeki mevcut durumu, geleceği, transgenic bitki tarımının avantajları ve riskleri tartışılmıştır.

Anahtar Kelimeler: Gen, GDO, Transgenik bitki, Fayda, Risk

1.GİRİŞ

Genomuna biyoteknolojik yöntemlerle aynı türden, başka bir türden veya başka bir organizmadan gen aktarılan organizma Genetiği Değiştirilmiş Organizma (GDO) olarak adlandırılmaktadır. Biyoteknolojik yöntemlerle genomuna gen aktarılmış bitkiye transgenik bitki adı verilmektedir. Aktarılan genin ve düzenleyici gen yapılarının orijinine bağlı olarak; transgenic, sisgenik, intragenik ve subgenik olmak üzere farklı transgenik tipleri bulunmaktadır. Bitkilere gen aktarılmasında kullanılan çok farklı yönetmler mevcuttur. Bunlardan en yaygın kullanılanları; 1) *Agrobacterium tümeaficens* bakterisi aracılığıyla gen aktarma 2) Biyolistik yöntemle gen aktarma 3) Protoplastlara gen aktarma. Bu yöntemlerden Agrobacterium bakterisi aracılığıyla gene aktarma yöntemi en eski vee n yaygın yöntemdir. Aktarılmak istenen genin aktarılmasında bakteri kurye olarak kullanılır. Aktarılacak gen klonlandıktan ve gene düzenleyici dizinler eklendikten sonar oluşturan gen kaseti Agrobacterium bakterisi içinde bulunan Ti plazmitinin T-DNA bölgesine aktarılır. Bakteri T-DNA bölgesine eklenen geni belirli koşullar altında bitki hücresine aktarır ve hücre içine giren gen kromozomlara entegre olur. Agrobacterium aracılığıyla gen aktarma, bakterinin çift çenekli bitkilerde (dikotiledon bitkiler) enfeksiyon yapabildiği için daha çok bitkilere gen aktarmada kullanılmaktadır. Ancak, günümüzde bu yöntemle tek çenekli (monokotiledon) bitkilere de gen aktarılabilmektedir. Biolostik yöntem ise özellikle monokotiledon bitkilere gen aktarma amacıyla geliştirilmiş bir direct gen aktarma yöntemidir. Bu yöntemin esası, yüksek derecede hızlandırılmış mikro-taşıyıcı adı verilen 1-2 µm çapındaki metal (çoğunlukla altın ya da tungsten) partiküller aracılığıyla, bir ateşleme mekanizmasından yararlanılarak DNA'nın hedef dokulara aktarılmasıdır. Mikro-taşıyıcılar makro-taşıyıcı olarak adlandırılan plastik bir silindir üzerinden hedef dokulara doğru bir helyum gazı basıncı ile hızlandırılır. Ateşleme gerek mikro-taşıyıcıların sürtünmesinden doğan sürüklenmeyi, gerekse yüksek basınçlı gaz şokundan doğabilecek hücre parçalanmasını ve sesi engellemek için vakum altında yapılır.

2. TRANGENİK BİTKİ TARIMININ TARİHÇESİ

1983 yılında sürdürülen bir araştırma ile elde edilen antibiyotiğe dayanıklılık geni aktarılmış tütün bitkisi dünyadaki ilk transgenik bitki olmuştur. 1986 yılında, ABD ve Fransa'da herbisite tolerans geni aktarılmış tütün bitkileri tarlaya aktarılan ilk transgenik bitkiler olmuştur. 1987 yılında, Belçika'da Marc Van Montagu ve Jeff Schell *Bacillus thuringiensis* bakterisinden gen aktarılarak böceklere karşı dayanıklı trangenik tütün bitkilerini üretmek üzere dünyadaki ilk transgenik bitki üretim şirketini kurmuşlardır.

Ticari olarak ilk transgenik bitki tarımı 1992 yıllında Çin Halk Cumhuriyeti'nde virüse dayanıklılık geni aktarılmış tütün bitkilerinin yetiştirilmeye başlanması ile başlamıştır (James, 1997). ABD'de ilk transgenik bitki tarımı, 1994 yılında geç olgunlaşma özelliği kazandırılmış ve *FlavrSavr* adıyla tescil edilmiş transgenik bir domates çeşidinin tarımı ile başlamıştır.

1996 yılından itibaren ise transgenik bitkilerin tarımı hızla yaygınlaşmaya başlamıştır. 1996 yılında Çin dışındaki diğer 5 dünya ülkesinde 1.7 milyon ha alan üzerinde transgenik bitki tarımı yapılmasına karşılık, bu alan 2014 yılında 179.4 milyon ha'a yükselmiştir (Çizelge 1).

Çizelge 1. Dünya'da Transgenik Bitki Ekim Alanlarının Değişimi

Yıl	Ekim Alanı (Milyon ha)
1996	1.7
2000	44.2
2010	148.0
2014	179.4
2015	176.8
2016	180.2
2017	186.9
2018	186.9
2019	186.4
2020	189.1
2021	106.2
2022	202.9
2023	205.8
2024	209.8

Kaynak: Anonim, 2025a

2015 yılında ise, % 1.4'lük azalma ile 176.8 milyon ha olmuştur. 2018 yılında, 186.9 milyon ha alanda transgenik bitki tarımı yapılmıştır. 2019 yılında ise 0.5 milyon ha'lık azalma ile 186.4 milyon ha'a düşmüştür. 2020 yılında 189.1'a yükselen transgenik bitki ekim alanı, artış eğilimini 2024 yılına kadar sürdürmüş ve 2024 yılında 209.8 milyon ha'a çıkmıştır. Bu alan, dünyadaki toplam 1.5 milyar hektarlık tarla arazilerinin % 14'ünü oluşturmaktadır.

3. TRANSGENİK BİTKİ TARIMI YAPAN ÜLKELER

1996 yılından ibaren transgenik bitki tarımı yapan ülke sayısı 6 ile 29 arasında değişmiştir. Halen Birleşmiş Milletlere kayıtlı 193 ülke dikkate alındığında, 2024 yılında transgenik bitki tarımı yapan ülke sayısı 27 olmuş ve dünyada her 7 ülkenin birisinde transgenik bitki tarımı yapılmıştır. Bu ülkelerin 11 adedi Amerika kıtasında, 8 adedi Asya kıtasında, 2 adedi Avrupa kıtasında ve 5 adedi Afrika kıtasında, 1 adedi ise Avustralya kıtasında bulunmaktadır.

En fazla transgenik bitki ekim alanı ABD'de bulunmaktadır (Çizelge 2). Nitekim, 2024 yılı rakamlarına göre ABD'de 75.4 milyon ha alan üzerinde transgenik bitki tarımı yapılmıştır. ABD'yi Brezilya ve Arjantin izlemektedir. Transgenik bitki ekim alanlarının % 89'u Amerika kıtasında, % 8.6'sı Asya, % 1.8'i Afrika, % 0.67'si Avustralya kıtasında ve % 0.03'ü Avrupa kıtasında ve bulunmaktadır.

Çizelge 2. Transgenik Bitki Tarımı Yapılan Ülkeler ve Ekim Alanları

Ülke	Ekim Alanı (Milyon ha)	Yetiştirdiği Transgenik Bitkiler
ABD	75.4	Soya, Mısır, Pamuk, Kanola, yonca, Ş. Pancarı
Brezilya	67.9	Soya, Mısır, Pamuk, Şeker kamışı
Arjantin	23.8	Soya, Mısır, Pamuk, Yonca, Buğday
Kanada	11.7	Kanola, Mısır, Soya, Şeker Pancarı
Hindistan	11.2	Pamuk
Paraguay	4.4	Soya, mısır, pamuk
Çin	3.5	Pamuk, Soya, Mısır
Güney Afrika	3.5	Mısır, Soya, Pamuk
Pakistan	1.9	Pamuk
Bolivya	1.8	Soya
Uruguay	1.5	Soya, Mısır
Avustralya	1.4	Pamuk, kanola
Filipinler	0.7	Mısır
Vietnam	0.4	Mısır
Myanbar	0.2	Pamuk
Sudan	0.2	Pamuk
Kolombia	0.2	Pamuk, Mısır
İspanya	<0.1	Mısır
Meksika	<0.1	Pamuk
Honduras	<0.1	Mısır
Endonezya	<0.1	Şeker kamışı, Mısır
Şili	<0.1	Kanola, Mısır, Soya
eSwatini	<0.1	Pamuk
Etiyopya	<0.1	Pamuk
Portekiz	<0.1	Mısır
Bengladeş	<0.1	Patlıcan
Kenya	<0.1	Pamuk

Kaynak: Anaonim, 2025a

4. TRANSGENİK ÇEŞİTLERİ BULUNAN BİTKİ TÜRLERİ

Dünyada halen dört bitki türünün transgenik çeşitlerinin yaygın olarak tarımı yapılmaktadır. Bu türler arasında ise, en fazla ekim alanına sahip tür soya fasulyesidir. Bunu, mısır, pamuk ve kanola izlemektedir (Çizelge 3). Halen toplam transgenik bitki ekim alanının % 99'unda söz konusu dört bitki türüne ait transgenik çeşitler yetiştirilmektedir. Bu dört bitki türü dışında

dışında, yoncanın transgenik çeşidi ABD'de, şeker pancarının trasngenik çeşidi ABD ve Kanada'da, transgenik buğday çeşidi Arjantin'de ve transgenik patlıcan çeşidi Bengladeş'te yetiştirilmektedir.

Çizelge 3. Transgenik Çeşitleri Bulunan Bitki Türleri ve ekim Alanları

Bitki Türü	**Ekim Alanı**	**Toplam Transgenik ekim Alanı İçindeki Oranı (%)**
Soya Fasulyesi	105.1	50.1
Mısır	68.4	32.6
Pamuk	24.2	11.5
Kanola	10.4	5.0
Yonca	1.1	0.50
Şeker Pancarı	0.5	0.2
Şeker Kamışı	0.06	0.02
Buğday	0.05	0.02
Patlıcan	0.003	0.001
Toplam	209.8	100.0

Kaynak: Anonim, 2025a

Transgenik çeşitlerinin tarımı yapılan söz konusu bitki türleri dışında, transgenik çeşitleri bulunan ancak, tarımı henüz yaygınlaşmamış bitki türleri de bulunmaktadır. Nitekim Dünya'da halen aşağıda verilen 32 bitki türünün transgenik çeşitleri için üretim izni alınmıştır(Çizelge 4).

Çizelge 4. Transgenik Çeşitleri İçin Üretim İzni Alınmış Bitki Türleri

Bitki Türü	**Bitki Türü**	**Bitki Türü**	**Bitki Türü**
Yonca	Patlıcan	Soya Fasulyesi	Buğday
Elma	Okaliptüs	Çeltik	Aspir
Kanola	Mısır	Gül	Keten
Fasulye	Kavun	Kabak	Ananas
Karanfil	Papaya	Şeker Pancarı	Petunya
Hindiba	Erik	Şeker Kamışı	Biber
Pamuk	Şalgam	Tavus otu	Tütün
Börülce	Kavak	Patates	Domates

Kaynak: Isaaa, 2025.

5. TRANSGENİK ÇEŞİTLERİN EKİM ALANLARININ TÜRLERİN TOPLAM EKİM ALANI İÇİNDEKİ ORANI

Dünyada transgenik soya ekim alanlarının toplam soya üretim alanları içerisindeki oranı % 74.9 dir (Çizelge 5). Pamukta ise bu oran % 78.4'dır.

Çizelge 5. Transgenik Çeşitlerin Türlerin Toplam Ekim Alanları İçerisindeki Oranları

Bitki	Toplam Ekim Alanı (Milyon ha)	Transgenik Ekim Alanı/ Toplam Ekim Alanı (%)
Soya Fasulyesi	140.5	74.9
Pamuk	30.9	78.4
Kanola	42.9	24.3
Mısır	202.9	33.7

Kaynak: Anonim, 2025a

Ancak, farklı ülkelerde transgenik çeşitlerin toplam ekim alanı içindeki ekim oranı farklılık göstermektedir (Çizelge 6).

Çizelge 6. Transgenik Bitki Yetiştiren Ülkelerde Transgenik Çeşit Ekim Alanının Türün Toplam Ekim Alanı İçindeki Oranı (%)

Ülke	**Soya**	**Mısır**	**Pamuk**	**Kanola**
ABD	93	90	90	93
Kanada	79	96	-	95
Arajantin	99	80	93	-
Günye Africa	92	87	95	-
Avustralya	-	-	99	10
Çin	-	-	86	-
Filipinler		31	-	-
Paraguay	93	50	50	-
Brazilya	89	82	65	-
Uruguay	99	96	-	-
Hindistan	-	-	95	-
Kolombia	-	15	85	-
Meksika	7	-	56	-
Bolivya	91	-	-	-
Pakistan	-	-	88	-
Myanmar	-	-	85	-

Kaynak: James, 2014; Anonim, 2025a.

Çizelgeden anlaşılacağı üzere ABD'de pamuk, mısır ve soyada transgenik oranı % 90'dır. Arjantin de bu açıdan benzerlik göstermektedir.

6. TRANSGENİK ÇEŞİTLERE KAZANDIRILAN ÖZELLİKLER

Halen tarımı yapılan transgenik bitki çeşitleri esas itibarıyla ya herbisitlere dayanıklılık veya bazı böcek türlerine dayanıklılık veyahut ta her iki özelliğe sahip çeşitlerdir. Mevcut transgenik bitki ekim alanlarının % 99'u söz konusu özelliği taşıyan transgenilk bitkilerle ilgilidir. Bunun yanın minör düzeyde tarımı yapılan farklı transgenik özelliklere sahip diğer bazı taransgenik bitkiler de mevcuttur (Çizelge 7)

Çizelge 7. Minör Düzeyde Tarımı Yapılan Transgenik Bitkiler, Özellikleri ve Tarımının Yapıldığı Ülkeler

Bitki Türü ve Çeşit adı	**Donör Tür**	**Aktarılan Gen**	**Kazandırılan Özellik**	**Yetiştiren ülke**
Buğday *HB4*	Ayçiçeği	*hahb-4*	Kurağa dayanıklılık	Arjantin(2020)* Brezilya (2023) Paraguay (2023)
Soya Fasulyesi *Verdaca HB4*	Ayçiçeği	*hahb-4*	Kurağa dayanıklılık	Arjantin (2015) Brezilya (2019) Malezya(2023) ABD (2019)
Mısır *DroughtGard*	Bacillus subtilis	*cspB*	Kurağa Dayanıklılık	Kanada (2010) Japonya (2012) Malezya(2020) ABD(2011)
Okaliptüs *GM Eucalyptus*	Arabidopsis thaliana	*cel1*	Hızlı büyüme	Brezilya (2015)
Fasulye *BRS FC401 RMD*	Fasulye mozaik virisü	*ac1*	Virüse dayanıklılık	Brazilya (2011)
Papaya *Rainbow* *Huanong No.1*	Papaya halkalı leke virüsü ‘’	*prsv_cv* ‘’	Virüse dayanıklık ‘’	ABD (1996) Japonya (2011) Çin(2006)
Patates HiLite Newleaf Y potato	Bacillus thuringiensis Patates Y Virüs	*cry3A* *pvy_cp*	Koleopter böceklerine dayanıklık Patates Y virüsüne dayanıklık	ABD (1998)

Patates *Newleaf Y Russet Burbak Potato*	*Bacillus thuringiensis* Patates Y Virüs	*cry3A* *pvy_cp*	Koleopter böceklerine dayanıklık Patates Y virüsüne dayanıklık	ABD (1999) Kanada(2001)
Patates *İnnate-Acclimate*	*Solanum tuberosum* *Solanum verrucosum* *Solanum venturii*	*asn1,phL,r1,* *vlnv* *ppo5* *rpi-vnt1*	Düşük asparagin, düşük indirgenen şeker, Daha düşük siyah nokta morluğu Geç Patetes yanıklığıu	Kanada (2017) ABD (2016)
Patates *İnnate-Acclimate*	*Solanum tuberosum* *Solanum verrucosum* *Solanum venturii*	*asn1,phL,r1,* *vlnv* *ppo5* *rpi-vnt1*	Düşük asparagin, düşük indirgenen şeker, Daha düşük siyah nokta morluğu Geç Patetes yanıklığıu	Kanada (2017) ABD (2016)
Hindiba *Seed Link*	*Streptomyces hygroscopicus* *Bacillus amyloliquefaciens*	*bar* *barnase*	Glufosinate herbisitine tolerans Erkek kısırlık	ABD (1997)
Karanfil *Moonvelvet*	*Petunia hybrida* *Tütün*	*hfl,cytb5* *surB*	Delfinidin ve derivatlatrının üretim (Mavi renk), Mor ve mavi renkli çiçekler Sulfonilurea herbisitine tolerans	Avustralya (2015) Kolombia (2008) AB (2015) Japonya (2013) Malezya (2012)
Karanfil *Moonique*	*Petunia hybrida* *Viola wittrockiana* *Salvia splendes* *Tütün*	*dfr* *bp40* *sfl* *surB*	Delfinidin ve derivatlatrının üretim (Mavi renk) Delfinidin sentezi Sulfonilurea herbisitine tolerans	Kolomibia (2008) Malezya (2012)

Karanfil *Moonberry*	*Viola wittrockiana* *Petunia hybrida* *Karanfil* *Tütün*	*bp40* *dfr* *dfr-diaca* *surB*	Delfinidin ve derivatlatrının üretim (Mavi renk) Pembe ve kırmuzı renkli pigment Sulfonilurea herbisitine tolerans	Avustralya (2015) Kolombia (2008) AB (2015) Japonya (2013) Malezya (2012)
Karanfil *Moonpearl*	*Viola wittrockiana* *Petunia hybrida* *Karanfil* *Tütün*	*bp40* *dfr* *dfr-diaca* *surB*	Delfinidin ve derivatlatrının üretim (Mavi renk) Pembe ve kırmuzı renkli pigment Sulfonilurea herbisitine tolerans	Kolombia (2008) Malezya (2012)
Agrostis stolonifera *RR Creeping Bentgrass*	*Agrobacterium tümefaciens*	*Cp4 epeps*	Glifosat herbisitine tolerans	ABD (2016)
Keten *CDC Triffid Flax*	*Arabidosisi thaliana*	*Als*	Sulfonilurea herbisitine tolerans	Kanada (1996) ABD (1999)
Patates *Superior New Leaf Potato* *Atlantic New Leaf Potato* *New Leaf Russet Burbank potato*	*Bacillus thringiensis*	*Cry3A*	Koloptera böceklerine dayanıklılık	ABD (1996) Kanada (1997) ABD (1996) Kanada (1995) ABD (1995)
Çeltik *Huahui-1*	*Bacillus thringiensis*	*Cry1Ab, Cry1Ac*	Lepidoptera böceklerine dayanıklılık	Çin (2009)
Mısır *Mavera Maize*	*Corynebacterium glutamicum*	*cordapA*	Lisin içeriğinde artış	Kanada (2006 Japonya (2007)

				ABD (2006)
Mısır *GraINzyme Phytase*	*Echerica coli*	*phy02*	Tek mideli hayvanlarda fitaz enziminin sıcaklığa toleransını ve sindirime karşı hassasiyetini optimize etmek.	ABD (2021)
Çeltik Golden Rice	*Pantoea ananatis* *Mısır*	*crt1* *psy1*	*15-cis-phytoene'nin trans-lycopene katalize edilmesi* *Geranilgenarnil'in phytone dönüşümü*	Filipinler (2021)
Soya *Treus, Plenish*	*Soya* *Soya*	*gm-hra* *gm-fad2-1*	*Sulfonilurea'ya tolarans* *Oleik asitten llinolşeik asit oluşumunu bloke eder ve tohumda oleik asit birikimini sağlar*	Kanada (2009) Japonya (2010) ABD (2010)
Soya *Vistive Gold™*	*Soya* *Soya*	*fat1-A* *FAD2-1a*	*Doymuş yağ oranının azlaması ve 18:1 oleik asit oranının artması* *18:1 olekik asidin 18:2 oleik aside desatuarsyonun azaltma, monodoymuş oleik asit oranını artırma ve doymuş linoleik asit oranını azalktma*	Kanada (2011) Japonya (2013) ABD (2011)
Kolza *InVigor™ x TruFlex™ Roundup Ready™ Canola*	*Agrobacterium tumefaciens strain CP4* *Streptomyces hygroscopicus*	*cp4epsps* *bar*	*Glifosat herbisitine tolerans* *Glufosinate herbisitine tolerans*	Japonya (2015)

	Bacillus amyloliquefaciens	*barnase* *barstar*	*Erkek kısırlık* *Erkek kısırlığı kaldırma*	
Mısır *32138 SPT maintainer*	*Mısır* *Mısır*	*ms45* *zm-aa1*	*Fertliteyi restore eder* *Erkek kısırık*	Brezilya (2015) ABD (2011)
Mısır *InVigor™ Maize*	*Streptomyces hygroscopicus* *Bacillus amyloliquefaciens*	*Bar* *barnase*	*Glufositate herbisitine tolerans* *Erkek kısır*	ABD (1999)
Mısır *32138 SPT maintainer*	*Mısır* *Mısır*	*ms45* *zm-aa1*	*Fertliteyi restore eder* *Erkek kısırık*	Brezilya (2015) ABD (2011)
Mısır *InVigor™ Maize*	*Streptomyces hygroscopicus* *Bacillus amyloliquefaciens*	*Bar* *barnase*	*Glufositate herbisitine tolerans* *Erkek kısır*	ABD (1999)

*) Yetiştirilmeye başlandığı yıl

2023 yılı verilerine göre, transgenik bitki tohumlarının pazar değeri 30.63 milyar dolardır. Bu değer halen dünyadaki 54 milyar dolar değerindeki toplam tohum pazarının % 56.7'sini oluşturmaktadır. 2033 yılında transgenik bitki tohumlarının pazar değerinin 80. 9 milyar dolar olacağı tahmin edilmektedir (Anonim, 2025b).

7. TRANSGENİK BİTKİ TARIMININ AVANTAJLARI

7.1. VERİM ARTIŞI

Transgenik bitki tarımı ile 1996-2020 yılları arasında 979.6 milyon ton daha fazla üretim yapılmıştır. Bu üretimin değeri 263.1 milyar dolardır (Brookes, 2022a). 1996-2020 yılları arasında transgenik bitki yetiştiriciliği ile 183 milyon ha alan tasarrufu yapılmıştır.

Halen tarımı yapılan herbisite toleranslı ve/veya bazı böceklere karşı dayanıklı bitki çeşitleri ile klasik yabancı ot ve böcek kontrol yöntemlerine göre daha etkin mücadele edildiği için verim kayıpları azalmakta ve verimde artış ortaya çıkabilmektedir. Transgenik bitki tarımı yapılan ülkelerde 2020 yılında transgenik çeşit yetiştiriciliğiyle ortaya çıkan verim artışları Çizelge 8'de verilmiştir. Çizelgede izlendiği gibi, herbisite toleranslı soya çeşitleri transgenik olmayan soya çeşitlerine göre verim avantajı sağlamamıştır. Ancak, ABD ve Kanada'da 2009 yılından sonra üretime alınan ve daha yüksek verim potansiyeline sahip herbisite toleranslı soya

çeşitleri transgenik olmayan çeşitlere göre 2020 yılında % 8.9 verim artışı sağlamıştır. Hem herbisite tolerant ve hem de böceğe dayanıklılık özelliğine sahip transgenik soya çeşitleri ise yetiştirildikleri ülkelerin tamamında özellikle böceğe dayanıklılık özellikleri nedeniyle verim artışı sağlamıştır. Herbisite tolerans mısır çeşitleri de Arjantin, Brezilya, Filipinler ve Vietnam dışındaki ülkelerde verim avantajı sağlamamıştır. Arjantin'de hem böceğe dayanıklı ve hem de herbisite tolerans özelliğine sahip olan mısır çeşitleri % 10 verim artışı sağlamıştır. Herbisite tolerant pamuk çeşitleri Meksika, Kolombia ve Vietnam gibi mısır yetiştiriciliğinin daha ekstensif olarak yapıldığı ülkelerde verim artışı sağlamıştır. Geleneksel yetiştiricilikte yabancı ot mücadelesinin daha zor olduğu kanola bitkisinde herbisite toleranslı çeşitler yetiştirildiği tüm ülkelerde verim artışı sağlamıştır. Virüse dayanıklı papaya ve kabak çeşitleri virüs hastalıkları ile mücadelenin güç olması nedeniyle çok önemli verim artışı sağlamıştır. ABD ve Kanada'da herbisite toleranslı şeker pancarı az da olsa verim artışı sağlamıştır. Kurağa dayanıklı mısır ve böceğe dayanıklı patlıcan da 2020 yılında verim artışı sağlayan transgenik bitkiler olmuştur. Geleneksek yetiştiricilikte mücadelesi güç olan böceklere karşı dayanıklı mısır ve pamuk çeşitleri ise yetiştirildikleri ülkelerin tamamında verim artışı sağlamıştır.

Çizelge 8. Transgenik Bitki Tarımı Yapılan Ülkelerde 2020 Yılında Transgenik Çeşit Yetiştiriciliğiyle Ortaya Çıkan Verim Artışları

Transgenik Bitki	**Ülke**	**Verim Artışı (%)**
Herbisite Toleranslı Soya	ABD (2.generasyon çeşitler)	8.9
	Arjantin	0
	Brezilya	0
	Paraguay & Uruguay	0
	Kanada (2.generasyon çeşitler)	8.9
	Güney Afrika	0
	Bolivya	15
Herbisite Tolerant/Böceğe dayanıklı soya	Brezilya	9.4
	Arjantin	7.1
	Paraguay	11.5
	Uruguay	7.0
Herbisite Toleranslı Mısır	ABD	0
	Kanada	0
	Arjantin	3 (Mısır şeridinde)

		22 (Marjinal alanlarda)
	Güney Afrika	0
	Filipinler	5
	Kolombia	0
	Brezilya	3
	Uruguay	0
	Paraguay	0
	Vietnam	5
Herbisite Tolerant/Böceğe dayanıklı Mısır	Arjantin	10.25
Herbisite Toleranslı Pamuk	ABD	0
	Avustralya	0
	Güney Afrika	0
	Arjantin	
	Meksika	16
	Kolombiya	4.0
	Brezilya	1.6
Herbisite Toleranslı Kanola	ABD (Glifosata tolerant)	2
	ABD (Glifosinata tolerant)	7.4
	Kanada(Glifosata tolerant)	2.0
	Kanada(Glifosinata tolerant	7.4
	Avustralya	8.0
Virüse dayanıklı papaya		17
Virüse dayanıklı kabak		100
Herbisite tolerant şeker pancarı	ABD	3.19
	Kanada	3.19
Kurağa dayanıklı mısır	ABD	2.57

Böceğe dayanıklı patlıcan	Bengladeş	19.6
Böceğe Dayanıklı Mısır (Sap kurdu)	ABD	7
	Kanada	7
	Arjantin	5.5
	Filipinler	18
	İspanya	12.6
	Güney Africa	10.6
	Ispanya	12.6
	Uruguay	5.5
	Honduras	24
	Brezilya	11.1
	Kolombia	16
	Paraguay	5.5
	Vietnam	10.2
Böceğe Dayanıklı Mısır (Kök kurdu)	ABD	5
	Kanada	5
Böceğe Dayanıklı Pamuk	ABD	10
	Çin	10
	Avustralya	0
	Arjantin	30
	Güney Africa	24
	Meksika	10.3
	Hindistan	24
	Kolombia	20.7
	Brezilya	2.4
	Pakistan	10
	Maynamar	30

Kaynak: Brookes, 2022a

7.2. ÜRETİM MALİYETİNİN AZALMASI

Herbisite ve/veya böceğe dayanıklı çeşitlerin kullanılması ile miktar ve sayı olarak daha az herbisit ve insektisit kullanılması sonucu birim alandaki üretim maliyetinde azalma ortaya çıkabilmektedir. Nitekim 1996-2020 yılları arasında transgenik çeşit yetiştirilen ülkelerde farklı transgenik bir çeşitlerinin sağladığı üretim maliyeti azalışları Çizelge 9'da verilmiştir. Çizelgede izlendiği gibi genellikle herbisite tolerant çeşitlerin tarımı maliyette azalışa neden olurken, böceğe dayanıklı çeşitlerin tarımı genellikle maliyet artışına neden olmuştur. Ancak, bu çeşitlerin sağladığı verim artışları maliyet artışlarını rahatlıkla karşılamıştır. Kurağa dayanıklı ve virüse dayanıklı çeşitler ise maliyet artışına neden olmakla beraber sağladıkları verim artışları ile klasik çeşitlere göre verimi daha karlı hale getirmişlerdir.

Çizelge 8. Transgenik Çeşit Kullanımında Üretim Maliyeti Azalışları **(**2020)

Transgenik Bitki	**Ülke**	**Üretim Maliyeti Azalışı ($/ha)**
Herbisite Toleranslı Soya	ABD	-15.66
	Arjantin	-19.11
	Brezilya	-32.68
	Kanada	-25.99
	Güney Afrika	-14.42
	Paraguay	-15.10
	Uruguay	-29.01
	Bolivya	-5.96
Herbisite tolerant/Böceğe dayanıklı Soya Fasulyesi	Brezilya	-20.35
	Arjantin	-14.00
	Paraguay	-31.70
	Uruguay	-24.62
Herbisite Toleranslı Mısır	ABD	-32.61
	Kanada	-14.15
	Güney Afrika	-1.13
	Arjantin	-13.25
	Filipinler	+14.17
	Kolombia	-9.82
	Brezilya	+15.19

	Uruguay	-13.25
	Paraguay	+0.36
	Vietnam	+41.67
Herbisite Toleranslı Pamuk	ABD	-6.05
	Avustralya	-32.71
	Güney Afrika	-27.37
	Arjantin	-5.84
	Meksika	-22.82
	Kolombia	-29.47
	Brezilya	-25.86
Herbisite Toleranslı Kanola	ABD (Glifosata tolerant)	-6.75
	ABD (Glifosinate'ye tolerant)	+6.05
	Kanada(Glifosata tolerant)	-30.41
	Kanada (Glifosinate'ye tolerant)	-17.61
	Avustralya (Glifosata tolerant)	+0.89
Böceğe Dayanıklı Mısır (Sap kurduna dayanıklılık)	ABD	+22.88
	Kanada	+2241
	Arjantin	+19.9
	Filipinler	+27.09
	İspanya	+34.33
	Güney Afrika	-1.2
	Uruguay	+19.86
	Honduras	+100
	Portekiz	+44.66
	Brezilya	+42.10
	Kolombia	+5.80

	Paraguay	+16.12
	Vietnam	-15.28
Böceğe Dayanıklı Mısır (Kök kurduna dayanıklı)	ABD	+14.47
	Kanada	+8.85
Böceğe Dayanıklı Pamuk	ABD	+14.48
	Çin	-25.11
	Avustralya	-165.69
	Arjantin	-32.36
	Güney Africa	-13.03
	Meksika	-35.83
	Hindistan	+14.22
	Kolombia	+13.17
	Brezilya	-9.39
	Pakistan	-0.15
	Mayanmar	+10.78
Virüse dayanıklı papaya		+494
Virüse dayanıklı kabak		+736
Herbisite tolerant şeker pancarı	ABD	-44.43
	Kanada	-44.43
Kurağa tolerant mısır	ABD	+24.87
Böceğe dayanıklı patlıcan	Bengladeş	-84.34

Kaynak: Brookes,2022a

7.3. PESTİSİT KULLANIMINDA AZALMA

1996-2020 yılları arasında trangenik bitki yetiştiriciliği ile dünya çapında pestisit kullanımı 748.6 milyon kg (%-7.2) azalmıştır (Çizelge 10). 2020 yılında transgenik bitki yetiştiriciliği ile 15.6 milyon otomobilin bir yılda çıkardığı CO2 kadar CO2 (23.631 milyar kg) emisyonunda azalma sağlanmıştır (Çizelge 11).

Çizelge 10. Transgenik Bitki Kullanımından Kaynaklanan Pestisit Kullanımında Azalma (1996-2020)

Transgenik Bitki	Pestisit Kullanımında Azalma (milyon kg)	Pestisit Kullanımında Azalma (%)
Herbisite Toleranslı Soya	-3.07	-0.1
Herbisite tolerant ve böceğe dayanıklı soya	-30.7	-6.1
Herbisite Toleranslı Mısır	-223.8	-6.2
Herbisite Toleranslı Pamuk	-38.8	-8.4
Herbisite Toleranslı Kanola	-27.3	-18.1
Böceğe Dayanıklı Mısır	-85.4	-45.0
Böceğe Dayanıklı Pamuk	-338.9	-29.9
Herbisite Toleranslı Şeker Pancarı	-0.8	+4.4
Toplam	-748.6	-7.2

Kaynak: Brookes, 2022b

Çizelgede izlendiği gibi, yaygın transgenik bitki tarımının başladığı 1996 yılından 2024 yılına kadar geçen 28 yılda bu bitkilerin tarımı ile dünya çapında pestisit kullanım 748.4 milyon ton , başka bir deyişle % 7.2 azalmıştır. Bu azalma pestisitlerden kaynaklı çevre zararlarının azalmasına yol açmıştır.

7.4. ATMOSFERE SALINAN CO_2 MİKTARINDA AZALMA

Halen yaygın olarak tarımı yapılan böceğe dayanıklı veya herbisite toleranslı transgenik bitkiler tarla trafiğini azalttıkları için yakıt tüketiminde azalmaya ve bu yakıt kaynaklı atmosfere CO_2 çıkışında azalmaya neden olmaktadırlar. Ayrıca, herbisite toleranslı çeşitler ekim öncesi ve ekim sonrası yabancı ot mücadelesi amaçlı toprak işlemeyi gereksiz yaparak, topraktan CO_2 çıkışını engellemektedir.

Çizelge 11. 2020 yılında Transgenik Bitki Tarımının Karbon Bütçesine Etkisi

Ülke/Bitki	**Yakıt Tüketimindeki Azalma Nedeniyle Karbondioksit Çıkışındaki Azalma (milyon kg)**	**Yakıt Tüketimindeki Azalma Nedeniyle ortaya çıkan karbondioksit azalmasına karşılık gelen bir yılda trafikten çekilen otomobil sayısı (X1000)***	**Topraktan Karbondioksit Çıkışının Azalmasından kaynaklanan karbondioksit (milyon kg)**	**Topraktan Karbondioksit Çıkışının Azalması Nedeniyle ortaya çıkan karbondioksit azalmasına karşılık gelen bir yılda trafikten çekilen otomobil sayısı (X1000)***
HT Soya	26 763	17 735	14 613.8	9672.4
HT Kanola	2 848	1 887	992.4	657.5
HT Mısır	6 350	3 435	5 495	3640.8
BD Mısır	1 227	4 208	-	-
BD Pamuk	760	504	-	-
BD Soya	1 199	795	-	-
Toplam	39 147	25 942	21 101.1	13 980.7

Kaynak: Brookes, 2022c

Çizelgede izlendiği gibi, 2020 yılında transgenik bitki tarımı ile yakıt tüketimindeki azalma kaynaklı olarak atmosfere salınan CO_2 miktarı 39,147 milyar kg, herbisite tolerant bitkilerin tarımı ile azalan toprak işleme sonucu ise 21.101 milyar kg CO_2 azalmıştır. Yakıt tüketimindeki azalma nedeniyle azalan CO_2 miktarının 25.942 milyon aracı bir yılda atmosfere saldığı CO_2'e eş değer olduğu hesaplanmıştır. Toprak işlemenin azalması sonucu azalan CO_2 miktarının ise 13.980 aracı bir yılda atmosfere saldığı CO_2'e eş değer olduğu hesaplanmıştır.

8. TRANGENİK BİTKİ TARIMININ RİSKLERİ

Bitki genomuna biyoteknolojik yöntemlerle yeni genlerin eklenmesi, daha önce açıklandığı gibi, söz konusu bitkilerin verimlerinde, besin değerlerinde, bu bitkilerin üretim maliyetlerinde ve bitkisel üretimden kaynaklanan çevre üzerindeki olumsuz etkilerin giderilmesinde bazı olumlu gelişmelere neden olmaktadır. Ancak, transgenik bitkilerin tarımının sayılan bu avantajlı yönlerine karşılık, bu bitkilerin yaygın olarak tarımının yapılması ile bazı çok yönlü

risklerin de ortaya çıkabileceği üzerindeki tartışmalar sürmekte ve dünya kamu oyu bu konuda üç farklı görüş grubuna bölünmüş durumdadır.

Birinci grup: ‘’Transgenik bitkiler klasik bitki ıslahı ile geliştirilen bitkilerden kesinlikle farklı değildir. Bu bitkilerin tarımı ile ortaya çıkabilecek riskler geleneksel yöntemlerle geliştirilen bitki çeşitlerinin tarımında ortaya çıkabilecek risklerden farklı değildir’’. Teknolojiyi geliştiren uluslar arası şirketler, bu şirketler ile yakın ilişki içinde bulunan bilim adamları ve bu şirketlerin bulunduğu ülkelerdir.

İkinci grup: ‘’Transgenik bitkilerin yaygın olarak tarımının yapılması insan sağlığı ve çevre üzerinde büyük tehditler oluşturmaktadır. Transgenik bitkilerin tarımından hemen vazgeçilmelidir’’ (Çevre örgütleri).

Üçüncü grup: ‘’Bu iki cephe arasında yer almakta ve transgenik bitkilerin yaygın olarak yetiştirilmesinin bazı riskleri beraberinde getirebileceği, bu nedenle bu bitkilerin tarımına geçilmeden önce yetiştirilecekleri her çevrede riskleri açısından detaylı olarak araştırılmalı ve tüketiciye seçme hakkı verilmesi açısından bu tip bitkilerden üretilen gıdalarda etiketleme yapılmalıdır’’ (Bağımsız bilim insanları).

Bu tartışmalar sonucu, 1996 yılında başlamış olan Transgenik Bitki Tarımı 2024 yılında Birleşmiş Milletler üyesi 193 ülkeden ancak 27’sinde kabul görmüştür. Bu sayı zaman zaman 29’a kadar çıkmıştır. Avrupa birliği ülkeleri 1998 yılında bu bitkilerin tarımına ve bu bitkilerden elde edilen ürünlerin ithalatına yasak koymuştur. Bu yasak 2004 yılına kadar devam etmiştir.

Transgenik bitkilerin tarımı ile ilgili riskler, temelde bitkilere aktarılan ve bugünkü uygulamasıyla bitkiler dışındaki organizma orijinli (genelde bakteri orijinli) genlerin ürünü olan proteinlerin ve aktarılan gen yapılarının insan ve çevre üzerindeki olası olumsuz etkilerinden kaynaklanmaktadır. Transgenik bitkilerin yetiştirilmesi ve bu bitkilerden elde edilen ürünlerin gıda olarak tüketilmesi ile ilgili riskler üç ana grup altında toplanmaktadır (Kulikov, 2005).

8.1. GIDA OLARAK RİSKLERİ

1)Transgenik bitkilerdeki aktarılan gen veya genlerin ürettiği proteinin bu bitkilerden üretilen gıdaları tüketenlere alerjik ve toksik etki yapması

2) Transgenik Proteinlerin bitki metabolizmasındaki pleitropik etkileri sonucu ortaya çıkabilecek riskler

3) Herbisite toleranslı bitkilerde herbisit ve metabolitlerinin birikmesinden kaynaklanan riskler

4) Bitkilere aktarılan bakteriyel genlerin insan ve hayvanlarda simbiyotik olarak yaşayan bakterilere horizontal olarak transfer olması riski

8.2.EKOLOJİK RİSKLER

1)Dar Bir Genetik Tabandan geliştirilen Transgenik Bitkilerin Tarımının Yaygınlaşması ile Kültür Bitkilerinde Çeşitliliğin Azalması

2) Transgenik Bitkilerden Yabani akrabalarına gen kaçışı sonucu biyoçeşitliliğin azalması ve süper yabancı otların ortaya çıkışı

3)Transgenik bitkilere aktarılan bakteri kökenli genlerin toprak mikroflorasına horiontal olarak geçme riski

4)Toksik Transgenik Proteinlerin Hedef Dışı Organizmaları Olumsuz yönde Etkilemesi

5) Transgenik bitkilerin ürettiği toksik proteinlere hedef organizmaların dayanıklılık kazanması

8.3. SOSYO - EKONOMIK RISKLER

1)Pahalılık

2)Tek tip çeşit ve ilaç kullanımı

3)Tohumluğun her yıl yenilenmesi zorunluluğu

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DETERMINATION OF ALLELOPATHIC EFFECTS OF SORGHUM (*Sorghum bicolor* L.) EXTRACT ON COMMON VETCH (*Vicia sativa* L.)

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ABSTRACT

Allelopathy is defined as the phenomenon in which certain plants suppress or stimulate the growth of other plants through chemical compounds released into their environment. This effect provides a competitive advantage in natural ecosystems and is considered an alternative method for weed control in agricultural production. Sorghum (*Sorghum bicolor* L.) exhibits strong allelopathic properties through its root exudates and plant components. In particular, the inhibitory effects of sorghum extracts on weed germination and growth have been reported in various studies. Vetch (*Vicia sativa* L.) is an important forage crop in agricultural production and is widely used in cropping systems. However, in some cropping systems, vetch may compete with other plants, which can affect its germination and growth due to various environmental factors. In this context, determining how vetch responds to allelopathic effects during its germination and growth process is a key consideration in agricultural planning. This study aimed to investigate the allelopathic effects of sorghum extracts on common vetch. The Erdurmuş sorghum variety was obtained from the West Mediterranean Agricultural Research Institute, while vetch seeds were sourced from commercial suppliers. Sorghum seeds and plant parts were extracted with distilled water, ethanol, and methanol at concentrations of 0%, 5%, and 10%, and applied in controlled conditions to vetch seeds in petri dishes. The experiment was conducted under laboratory conditions (22±2°C) and monitored for 15 days. The parameters evaluated included germination rate (%), root length (mm), shoot length (mm), fresh weight (g), and dry weight (g), with data analyzed using SPSS software. Variance analysis revealed significant differences, and Duncan's multiple comparison test was used for grouping. The study found that the 10% sorghum seed extracts in ethanol and methanol completely inhibited vetch germination. The 5% methanol extract reduced the germination rate to 67.5%, while the 10% methanol extract reduced it to 20%. Root and shoot lengths showed significant reductions with the 10% ethanol and methanol extracts. Fresh and dry weights also significantly decreased with increasing extract concentration. In particular, plant-methanol extracts exhibited a suppressive effect on vetch root and shoot development, while water-based extracts showed

stimulatory effects at certain doses. The results suggest that sorghum's allelopathic components have varying effects depending on different extraction methods and dose levels, significantly inhibiting germination at higher concentrations. These findings highlight the importance of considering allelopathic interactions when cultivating vetch after sorghum. Further studies should focus on investigating the long-term effects on subsequent crops in crop rotation systems following sorghum cultivation.

Keywords: Allelopathy, sorghum, common vetch, germination.

SORGUM (*Sorghum bicolor* L.) EKSTRAKTININ ADİ FİĞ (*Vicia sativa* L.) ÜZERİNDEKİ ALLELOPATİK ETKİLERİNİN BELİRLENMESİ*

ÖZET

Allelopati, bazı bitkilerin çevrelerine salgıladıkları kimyasal bileşenler aracılığıyla diğer bitkilerin büyümesini baskılaması veya teşvik etmesi olarak tanımlanmaktadır. Bu etki, doğal ekosistemlerde rekabet avantajı sağlarken, tarımsal üretimde yabancı ot mücadelesinde alternatif bir yöntem olarak değerlendirilmektedir. Sorgum (*Sorghum bicolor* L.), kök salgıları ve bitkisel bileşenleri ile güçlü allelopatik özellikler sergileyen bir bitkidir. Özellikle sorgum ekstraktlarının yabancı otların çimlenmesi ve büyümesi üzerindeki engelleyici etkileri çeşitli çalışmalarda rapor edilmiştir. Fiğ (*Vicia sativa* L.), tarımsal üretimde önemli bir yem bitkisi olup, ekim sistemlerinde yaygın olarak kullanılmaktadır. Ancak bazı ekim sistemlerinde diğer bitkilerle rekabete girmesi nedeniyle çimlenme ve gelişim süreci farklı çevresel faktörlerden etkilenebilmektedir. Bu bağlamda, fiğin çimlenme ve büyüme sürecinde allelopatik etkilere karşı nasıl tepki verdiğini belirlemek, tarımsal planlamada önemli bir unsur olarak değerlendirilmektedir. Bu çalışmada, sorgum ekstraktlarının adi fiğ üzerinde oluşturduğu allelopatik etkiler araştırılmıştır. Erdurmuş sorgum çeşidi Batı Akdeniz Tarımsal Araştırma Enstitüsü'nden temin edilmiş, fiğ tohumları ise ticari firmalardan sağlanmıştır. Sorgum bitkisinin tohum ve bitkisel aksamları; saf su, ethanol ve methanol ile eksrakte edilip, %0, %5 ve %10'luk konsantrasyon oranlarında petri kaplarındaki fiğ tohumlarına kontrollü bir şekilde uygulanmıştır. Deneme laboratuvar şartlarında (22±2°C) yürütülmüş ve 15 gün boyunca izlenmiştir. Çimlenme oranı (%), kök uzunluğu (mm), sürgün uzunluğu (mm), yaş ağırlık (g) ve kuru ağırlık (g) parametreleri değerlendirilmiş ve elde edilen veriler SPSS programında analiz edilmiştir. Varyans analizi sonucu farklılık tepit edilen değerler Duncan çoklu karşılaştırma testi kullanılarak gruplandırılmıştır. Çalışma sonucunda, %10'luk sorgum tohum-etanol ve tohum-metanol ekstraktlarının fiğde çimlenmeyi tamamen engellediği görülmüştür. %5'lik metanol ekstraktının çimlenme oranını %67.5'ye, %10'luk metanol ekstraktının ise %20'ye düşürdüğü tespit edilmiştir. Kök ve sürgün uzunlukları, %10'luk etanol ve metanol ekstraktlarında belirgin bir azalma göstermiştir. Yaş ve kuru ağırlık değerleri de artan ekstrakt dozu ile önemli ölçüde düşüş göstermiştir. Özellikle, bitki-metanol ekstraktlarının adi fiğin kök ve sürgün gelişimi üzerinde baskılayıcı etkiye sahip olduğu belirlenirken, su bazlı ekstraktların bazı dozlarının teşvik edici etkiler gösterdiği tespit edilmiştir. Çalışma sonuçları, sorgumun allelopatik bileşenlerinin farklı ekstraksiyon yöntemleri ve farklı doz düzeylerine bağlı olarak farklı etki yarattığı ve yüksek konsantrasyonlarda önemli ölçüde çimlenme inhibisyonuna sebep olduğu belirlenmiştir. Bu doğrultuda, sorgum ekstraktlarının adi fiğ üzerinde belirgin allelopatik etkilere sahip olduğu ve belirli dozlarda çimlenme ve büyümeyi baskıladığı belirlenmiştir. Elde edilen bulgular, sorgum ekimi sonrası fiğ yetiştiriciliğinde allelopatik etkileşimlerin dikkate alınması gerektiğini ortaya koymaktadır. Sonraki çalışmalarda, ekim nöbeti içinde sorgumdan sonra gelen bitkiler üzerindeki uzun vadeli etkilerin incelenerek, sürdürülebilir tarımsal üretim stratejilerinin geliştirilmesi gerektiği düşünülmektedir.

Anahtar Kelimeler: Allelopati, sorgum, adi fiğ, çimlenme.

1. GİRİŞ

Tarım sektörü, artan nüfus ve azalan doğal kaynaklar karşısında sürdürülebilirliği sağlamak için yenilikçi ve çevre dostu yöntemlere yönelmektedir (Savcı, 2012). Bu bağlamda verim kayıplarını azaltmak ve tarımda sürekliliği sağlamak için yeni biyolojik mücadele yöntemlerine ihtiyaç duyulmaktadır (Farooq ve ark., 2011; Weston ve ark., 2013). Kimyasal herbisitlerin yoğun kullanımı, toprak mikrobiyal dengesini bozmakta ve dirençli yabancı ot türlerinin yaygınlaşmasına neden olmaktadır (Duke ve ark., 2002; Heap, 2014). Ayrıca bu kimyasallar çevresel toksisite ve gıda güvenliği risklerini de beraberinde getirmektedir (Carpenter ve ark., 2002; Inderjit ve Duke, 2003).

Bu nedenlerle doğal kökenli, biyoaktif bileşiklerin kullanımı tarımsal biyoteknoloji açısından ilgi görmektedir. Allelopati, bir bitkinin çevresine salgıladığı kimyasallar aracılığıyla diğer bitkilerin gelişimini baskılaması ya da teşvik etmesi durumu olarak tanımlanmaktadır (Cheema ve Ahmad, 1988; Reigosa ve ark., 1999). Bu doğal etkileşim, yabancı ot mücadelesinde alternatif yöntemlerin geliştirilmesine olanak tanımaktadır (Xuan ve ark., 2005; Scavo ve ark., 2018). Allelokimyasalların çimlenme, hücre bölünmesi, fotosentez ve protein sentezi gibi birçok fizyolojik süreci etkilediği bilinmektedir (Batish ve ark., 2007; Li ve ark., 2010).

Sorgum (*Sorghum bicolo*r L.), özellikle köklerinden salgıladığı sorgoleone bileşiği ile tanınan, yüksek allelopatik potansiyele sahip bir bitkidir (Dayan ve ark., 2009; Czarnota ve ark., 2001). Yapılan birçok araştırmada sorgumun farklı bitkiler üzerindeki baskılayıcı etkileri deneysel olarak gösterilmiştir (Uddin ve ark., 2013; Cheema ve Ahmad, 1988; Weston ve ark., 2013; Tesio ve Ferrero, 2010). Yapılan çalışmalarda sorgumdan elde edilen ekstraktların; çözücüye, dozuna ve uygulama biçimine göre farklı etki düzeyleri gösterdiği rapor edilmiştir (Inderjit ve Duke, 2003; Macías ve ark., 2007).

Fiğ (*Vicia sativa* L.), azot bağlama yeteneği ile tarım sistemlerinde toprak verimliliğini artıran, yem bitkisi olarak önemli bir türdür. Ancak stres faktörlerine karşı hassas olması nedeniyle dış çevresel etkilere duyarlıdır (Xuan ve ark., 2005; Batish ve ark., 2007). Allelopatik maddelere maruziyetin fiğ gelişimini olumsuz etkileyebileceği yapılan farklı çalışmalarda gösterilmiştir (Inderjit ve Duke, 2003; Hussain ve ark., 2011). Bu nedenle fiğ bitkisi, allelopatik çalışmalar için uygun bir model organizma olarak değerlendirilmektedir (Tefera, 2002; Weston ve ark., 2013).

Son yıllarda yapılan çalışmalar, sorgumun doğal herbisit potansiyelini ortaya koymakta ve bunun sürdürülebilir tarım uygulamalarında kullanımı üzerine yoğunlaşılmaktadır (Duke ve ark., 2002; Xuan ve ark., 2005; Tesio ve Ferrero, 2010; Uddin ve ark., 2013). Bu çerçevede sorgum münavebe sistemlerinde rotasyon bitkisi olarak kullanılmakta ve çevre dostu üretim stratejilerinin geliştirilmesine katkı sağlamaktadır (Reigosa ve ark., 1999; Dayan ve ark., 2009). Bu çalışmada, sorgumun farklı bitki aksamlarından ve çeşitli çözücülerle hazırlanan ekstraktlarının adi fiğ üzerindeki etkileri araştırılmış ve doğal herbisit potansiyeli değerlendirilmiştir.

2. MATERYAL VE METOT

2.1. Araştırma Yeri ve Deneme Koşulları

Deneme, 2024 yılında Sakarya Uygulamalı Bilimler Üniversitesi Ziraat Fakültesi laboratuvarlarında yürütülmüştür. Denemeler, tesadüf parselleri deneme deseninde, faktöriyel düzende dört tekerrürlü olarak gerçekleştirilmiştir. Denemelerde kontrollü ortamda 22±2°C sıcaklık ve %60 nem koşulları sağlanmıştır.

2.2. Bitki Materyalleri

Araştırmada kullanılan sorgum (*Sorghum bicolor* L.) materyali Erdurmuş çeşidi Batı Akdeniz Tarımsal Araştırma Enstitüsü'nden, adi fiğ (*Vicia sativa* L.) ise ticari bir firmadan temin edilmiştir.

2.3. Ekstraktların Hazırlanması

Sorgum bitkisinin tohum ve yeşil aksamları ayrı ayrı 37°C sıcaklıkta etüvde kurutulmuş, ardından öğütülerek toz haline getirilmiştir. Toplam 50 gram kuru materyal, 250 mL'lik; saf su, etanol ve metanol çözücülerinde 72 saat süreyle oda sıcaklığında ekstrakte edilmiştir (Namsi ve ark., 2018). Elde edilen sıvı ekstraktlar önce süzgeçten, ardından filtre kağıdından geçirilmiş ve çözücüsü evaporasyon yöntemiyle uçurularak saf ekstrakt elde edilmiştir. Elde edilen saf ekstraktan %5 ve %10'luk dozlar hazırlanarak, uygulamaya hazır hale getirilmiştir.

2.4. Tohumların Sterilizasyonu

Denemede kullanılan tohumlar ekimden önce yüzey sterilizasyonu yapmak amacıyla sodyum hipokloritte (NaClO %3 çamaşır suyu) 5 dakika bekletilmiştir. Daha sonra beş defa 5 dakika süre ile saf suda yıkanmış ve filtre kağıdı üzerinde oda sıcaklığında kurutulmuştur (Baltepe ve Mert, 1972).

2.5. Denemenin Kurulması ve Gözlemler

Tohumlar, çapları 90 mm olan petri kaplarına whatman kurutma kağıdı arasına yerleştirilmiştir. Her petri kabına 10 adet adi fiğ tohumu yerleştirilmiş ve üzerine 6 ml ekstrakt uygulanmıştır. Kontrol grubuna sadece saf su verilmiştir. Kurulan denemeler kontrollü (22°C +/-2°C) koşullarda 15 gün boyunca günlük takibi yapılmış; çimlenme oranı (%), kök uzunluğu (mm), sürgün uzunluğu (mm), yaş ağırlık (g) ve kuru ağırlık (g) gözlemleri alınmıştır. Ölçümler dijital kumpas ve 0.0001 g hassasiyetindeki terazilerle gerçekleştirilmiştir (Şin ve ark., 2017).

2.6. İstatistiksel Analiz

Elde edilen veriler SPSS 20.0 paket programında varyans analizine tabi tutulmuş, anlamlı fark bulunan uygulamalarda Duncan çoklu karşılaştırma testi uygulanarak gruplandırma yapılmıştır (Düzgüneş ve ark., 1987).

3. BULGULAR VE TARTIŞMA

3.1. Çimlenme Oranı

Sorgum ekstraktı uygulanan adi fiğ bitkisinin çimlenme oranı ortalamaları Tablo 1'de verilmiştir.

Tablo 1. Sorgum ekstraktı uygulanan adi fiğ bitkisinde çimlenme oranı ortalamaları

Ekstrakt dozu	Çimlenme Oranı (%)**						Ortalama
	Bitki			Tohum			
	Etanol	Metanol	Su	Etanol	Metanol	Su	
%0	90.00^{a*}	97.50^{a}	92.50^{a}	85.00^{a}	87.5^{a}	82.50^{a}	89.16
%5	0.00^{c}	67.50^{a}	72.50^{a}	22.50^{ab}	70.00^{a}	75.00^{a}	51.25
%10	0.00^{c}	20.00^{ab}	90.00^{a}	0.00^{c}	0.00^{c}	90.00^{a}	33.33
Ortalama	30.00	61.66	85.00	35.83	52.50	82.50	57.91

* Aynı harfle gösterilen ortalamalar arasındaki farklılık istatistiki açıdan önemli değildir. ** $p \leq 0.01$

Tablo 1 incelendiğinde, sorgum ekstraktlarının çimlenme üzerindeki etkisi istatistiksel olarak önemli bulunmuştur ($p \leq 0.01$). Özellikle tohumdan etanol ve metanol ile elde edilen ekstraktların %10'luk dozları ile bitkiden elde etanolün %5 ve 10'luk dozlarından edilen ekstrakların adi fiğ tohumlarının çimlenmesini tamamen inhibe ettiği tespit edilmiştir. Su bazlı hem bitki hemde tohumdan elde edilen ekstraktlarda ise çimlenme oranı kontrol grubuna yakın değerler göstermiştir. Golubinova ve Ilieva (2014), sorgum toprak üstü aksamından elde edilen ekstraktların yabancı otlar üzerindeki allelopatik etkisini belirlemek amacıyla yürüttüğü çalışmada çimlenme süresini arttırdığı fakat çimlenme hızı ve fide güç indeksini önemli derecede azalttığını bildirmiştir. Çalışmada elde edilen çimlenme üzerine olumsuz etki sonucu gözlemlerimizle uyum göstermektedir.

3.2. Kök Uzunluğu

Sorgum ekstraktı uygulanan adi fiğ bitkisinin kök uzunluğu ortalamaları Tablo 2'de verilmiştir.

Tablo 2. Sorgum ekstraktı uygulanan adi fiğ bitkisinde kök uzunluğu ortalamaları.

Ekstrakt dozu	Kök Uzunluğu (mm)**						Ortalama
	Bitki			Tohum			
	Etanol	Metanol	Su	Etanol	Metanol	Su	
%0	79.08^{ab*}	50.56^{d}	70.02^{bc}	52.43^{d}	46.69^{d}	70.62^{bc}	61.57
%5	0.00^{g}	16.80^{eg}	90.85^{a}	18.00^{ef}	28.10^{e}	57.91^{cd}	35.27
%10	0.00^{g}	8.31^{fg}	48.77^{d}	0.00^{g}	0.00^{g}	45.98^{d}	17.17
Ortalama	26.36	25.22	69.88	23.47	24.93	58.17	38.00

* Aynı harfle gösterilen ortalamalar arasındaki farklılık istatistiki açıdan önemli değildir. ** $p \leq 0.01$

Sorgum bitkisel kısımdan etanol ile ekstrakte edilen %5 ve 10'luk doz ekstraktlar ile sorgum tohumundan ekstrakte edilen etanol ve metanolün %10'luk ekstraktlarının fiğin çimlenmesini tamamen engellemesi sebebiyle kök uzunluğu gözlemi elde edilemmeiştir (Tablo 2). Bunun yanı sıra, sorgum tohumlarından elde edilen %5'lik etanol (18 mm), %5'lik metanol (28.10 mm) ve %10'luk su (45.98 mm) ekstraktları da fiğ köklerinde allelopatik etki oluşturmuştur. Bitki aksamı ve tohumdan elde edilen ekstrakların farklı dozlarının uygulanması sonucu en yüksek kök uzunluğu değeri %5'lik su ekstraktından (90.85 mm) elde edilirken, en düşük kök uzunluğu değeri yine %5'lik bitki metanol ekstraktından elde edilmiştir. Bitki aksamından elde edilen kök uzunluğu değerlerinin tohum ekstraktından elde edilen kök uzunluğu değerlerinden daha düşük olduğu gözlemlenmiştir. Ayrıca bitkisel kısım %5'lik su ekstraktının fiğin kök uzunluğuna olumlu etki yaptığı (90.85 mm), ekstrakt dozunun artması ile kök uzunluğunda olumsuz bir etki ortaya çıktığı belirlenmiştir (48.77 mm). Moosavi ve arkadaşları (2011), sorgum yaprak, gövde ve kök su özütlerinin maş fasulyesinin tohum çimlenmesi ve fide büyümesi üzerindeki etkilerini incelemişlerdir. Çalışmalarında elde ettikleri bulgulara göre, sorgum sapı özütünün maş fasulyesinin kök ve sürgün büyümesi üzerinde engelleyici etkiye sahip olduğunu belirtmişlerdir. Bu bulgu, gözlemlerimizle paralellik göstermektedir.

3.3. Sürgün Uzunluğu

Sorgum ekstraktı uygulanan adi fiğ bitkisinin sürgün uzunluğu ortalamaları Tablo 3'te verilmiştir.

Tablo 3. Sorgum ekstraktı uygulanan adi fiğde sürgün uzunluğu ortalamaları

Ekstrakt dozu	Sürgün Uzunluğu (mm)**						Ortalama
	Bitki			Tohum			
	Etanol	Metanol	Su	Etanol	Metanol	Su	
%0	46.76^{a*}	36.43^{a}	50.00^{a}	49.56^{a}	44.21^{a}	50.78^{a}	46.29
%5	0.00^{c}	26.52^{ab}	52.60^{a}	14.91^{ab}	30.59^{ab}	45.53^{a}	28.35
%10	0.00^{c}	6.31^{b}	42.26^{a}	0.00^{c}	0.00^{c}	40.15^{a}	14.78
Ortalama	15.58	23.08	48.28	21.49	24.93	45.48	29.80

* Aynı harfle gösterilen ortalamalar arasındaki farklılık istatistiki açıdan önemli değildir. ** p≤0.01

Tablo 3 incelendiğinde; sorgum bitkisel kısımdan etanol ile ekstrakte edilen %5 ve 10'luk doz ile sorgum tohumundan ekstrakte edilen etanol ve metanolün %10'luk dozu dışında fiğde sürgün uzunluğunu olumsuz etkileyen uygulama bitki kısmından metanolün %10'luk dozu (6.31 mm) olmuştur. Etanol ekstarkları hem bitki kısmı hem tohumda en düşük sürgün uzunluğu değerlerine sahip olmuştur. Doz ortalamalarına bakıldığında artışa paralel olarak sürgün uzunluğunun azaldığı görülmektedir. Uddin ve arkadaşları (2013) yaptıkları çalışmada, *Sorghum bicolor*'un kök özütü ile karabuğdayın (*Fagopyrum* spp.) kök özütlerinin, bazı geniş yapraklı yabancı otlar üzerindeki etkilerini incelemişlerdir. Çalışmalarında, bu özütlerin karışımının hedef fidelerin çimlenmesini ve büyümesini önemli ölçüde azalttığını belirtmişlerdir. Çalışmamız sonucu önceki yapılan çalışmayla benzerlik göstermektedir.

3.4. Yaş Ağırlık

Sorgum ekstraktı uygulanan adi fiğ bitkisinin yaş ağırlık ortalamaları Tablo 4'te verilmiştir

Tablo 4. Sorgum ekstraktı uygulanan adi fiğde yaş ağırlık ortalamaları

Ekstrakt dozu	Yaş Ağırlık (g)**						Ortalama
	Bitki			Tohum			
	Etanol	Metanol	Su	Etanol	Metanol	Su	
%0	0.997^{ce*}	0.890^{de}	0.771^{ef}	1.339^{ab}	1.211^{bc}	0.952^{de}	1.027
%5	0.00^{ı}	0.744^{ef}	0.444^{gh}	0.324^{h}	0.958^{de}	1.093^{bd}	0.599
%10	0.00^{ı}	0.251^{hı}	0.611^{fg}	0.00^{ı}	0.00^{ı}	1.494^{a}	0.392
Ortalama	0.332	0.638	0.608	0.554	0.723	1.180	0.672

* Aynı harfle gösterilen ortalamalar arasındaki farklılık istatistiki açıdan önemli değildir. ** p≤0.01

Tablo 4'teki verilere göre, %10'luk sorgum bitkisel kısım-etanol karışımı ve sorgum tohumu-etanol/metanol ekstraktları, fiğin çimlenmesini engellemiştir. En belirgin allelopatik etkiyi %10'luk bitki-metanol ekstraktı (0.251 g) göstermiştir. Bu bulgu, Xiong ve ark. (2017) tarafından sorgumun fenolik bileşiklerinin (özellikle metanol bazlı ekstraktların) baklagil çimlenmesini hücre zarı bütünlüğünü bozarak inhibe ettiğini belirten çalışmayla uyumludur. Düşük konsantrasyonlarda (%5), bitki-su (0.444 g) ve tohum-etanol (0.324 g) ekstraktları da fiğ yaş ağırlığı üzerinde allelopatik etkiler göstermiştir. Buna karşılık, %10'luk tohum-su ekstraktı (1.494 g), fiğin yaş ağırlığını artırmıştır. Bu durum, Jabran ve ark. (2015)'ın düşük doz suda çözünür allelokimyasalların bitki büyümesini teşvik edebileceğini öne süren bulgularını desteklemektedir. Sonuçlar, sorgum ekstraktlarının ikili rolünü ortaya koymaktadır: Yüksek konsantrasyonlarda inhibe edici, ancak düşük dozlarda veya sulu ekstraksiyonda uyarıcı etki gösterebilir. Bu ikilik, Einhellig ve Rasmussen (1979)'un allelopatik etkilerin ekstrakt türü, konsantrasyon ve hedef türe bağlı olarak değiştiğini vurgulayan çalışmasıyla örtüşmektedir.

3.5. Kuru Ağrılık

Sorgum ekstraktı uygulanan adi fiğ bitkisinin kuru ağırlık ortalamaları Tablo 5'te verilmiştir

Tablo 5. Sorgum ekstraktı uygulanan adi fiğde kuru ağırlık ortalamaları

Ekstrakt dozu	Kuru Ağırlık (g)**						Ortalama
	Bitki			Tohum			
	Etanol	Metanol	Su	Etanol	Metanol	Su	
%0	0.391^{ab*}	0.429^{a}	0.208^{de}	0.342^{ac}	0.404^{ab}	0.395^{ab}	0.361
%5	0.00^{g}	0.307^{bd}	0.156^{ef}	0.123^{ef}	0.334^{ac}	0.330^{ac}	0.208
%10	0.00^{g}	0.090^{fg}	0.276^{cd}	0.00^{g}	0.00^{g}	0.441^{a}	0.134
Ortalama	0.130	0.275	0.276	0.155	0.246	0.326	0.234

* Aynı harfle gösterilen ortalamalar arasındaki farklılık istatistiki açıdan önemli değildir. ** $p \leq 0.01$

Elde edilen verilere göre bitki kuru ağırlığı en yüksek; bitkisel kısım metanol ekstraktı %0 doz (0.429 g) ile tohum su ekstraktı %10'luk dozda (0.441 g) tespit edilirken, bitki su ekstraktı %0 doz en düşük kuru ağırlığı (0.208 g) sağlamıştır. Bitki kuru ağırlığı verilerine bakıldığında metanol ekstraktının tohum gelişimi üzerinde faydalı etkiler yarattığı ancak etanol ve su ekstraktlarının yüksek dozlarda bitki gelişimini baskılayıcı etkiler gösterdiğini ortaya görülmektedir. Bingöl ve Battal (2017), *Verbascum cheiranthifolium* var. *asperulum* ve *Salvia limbata* bitkilerinin su ve matanolle hazırlanan ekstraktlarının semizotu ve mısır bitkisi üzerine allelopatik etkisini inceledikleri çalışmada mısır bitkisinin çimlenmesi üzerine belirgin olumsuz etki görülmezken semizotu bitkisinin çimlenme parametrelerini önemli derece azalttığını bildirmişlerdir. Elde edilen sonuçlar, Bingöl ve Battal (2017) ile uyumlu olup, ekstrakt türü ve dozunun bitki gelişimi üzerindeki etkilerinin farklılıklar gösterebileceği bu çalışma ile de ortaya konmuştur.

Bitkilerin biyokütle üretimi, uygulanan ekstraktların etkisiyle belirgin şekilde azalmıştır. Etanol ve metanol ekstraktlarının %10'luk dozları yaş ağırlıkta %40, kuru ağırlıkta ise %45'e varan düşüşe neden olmuştur. Bitkisel aksam ve tohum kaynaklı ekstraktlar arasında ise bitkisel aksamdan elde edilenlerin daha güçlü etki yaptığı anlaşılmıştır. Elde edilen sonuçlar, sorgumun doğal herbisit olarak kullanılabileceğini öne süren çalışmalarla paralellik göstermektedir (Cheema ve Ahmad, 1988; Dayan ve ark., 2009; Uddin ve ark., 2013). Ayrıca, allelopatik etki düzeyinin ekstraktın kaynağına (tohum/bitki) ve kullanılan çözücüye bağlı olduğu, bu alanda yapılan diğer çalışmalarda da vurgulanmıştır (Xuan ve ark., 2005).

4. SONUÇ

Bu çalışmada, sorgum bitkisinin tohum ve bitkisel aksamları kullanılarak elde edilen su, etanol ve metanol ekstraktlarının adi fiğ üzerine etkileri araştırılmıştır. Elde edilen veriler, özellikle bitkisel aksamda etanolün %5 ve 10'luk dozu ile tohumdan metanolün %10'luk dozuyla hazırlanan ekstraktların adi fiğin çimlenmesini tamamen durdurduğu, bunların dışındaki uygulamalarda ise başta çimlenme oranı, kök ve sürgün uzunluğu ile biyokütle üretimi olmak üzere incelenen tüm özelliklerde farklı seviyelerde baskılayıcı etkiler oluşturduğu ortaya koymuştur. Bu durum, sorgum ekstraktlarının allelopatik potansiyel taşıdığını ve doğal herbisit olarak değerlendirilebileceğini göstermektedir. Ayrıca, çalışmada kullanılan farklı çözücülerin etkinliğinin değiştiği ve bitkisel aksamın tohumdan daha yüksek etki gösterdiği sonucuna varılmıştır. Bitkisel aksam ve çözücü farkı da allelopatik etki üzerinde belirleyici faktör olarak karşımıza çıkmaktadır. Bu veriler, ekim nöbeti planlamalarında ve örtü bitkisi seçimi süreçlerinde fikir verecek niteliktedir. Gelecekte yapılacak araştırmalarda, farklı bitki türleri, çözücüler ve çevresel koşullar dikkate alınarak sorgumun doğal herbisit potansiyeli daha ayrıntılı incelenmelidir.

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THE EFFECT OF DIFFERENT SALT CONCENTRATIONS ON GERMINATION AND SEEDLING GROWTH OF PERENNIAL FORAGE GRASSES

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ASTRACT

This study was conducted to determine the effect of five different salt concentrations (0 mM NaCl [control], 50 mM NaCl, 100 mM NaCl, 150 mM NaCl, 200 mM NaCl) on germination and seedling growth of different cool season perennial forage grasses species. The following varieties were used as material in the study: the Yükselen cultivar of smooth bromegrass (*Bromus inermis* Leyss), the Nilüfer cultivar of tall fescue (*Festuca arundinecea* Schreb.), the No. 3 line of rescue grass (*Bromus catharticus* Vahl.) developed by selection breeding, the Lidacta cultivar of orchard grass (*Dactylis glomerata* L.) and the Temprano cultivar of perennial ryegrass (*Lolium perenne* L.). The experiment was established at the laboratory of Pasture Plants of the Çukurova University, Faculty of Agriculture, Department of Field Crops in 2025 according to the two-factor (species and salt concentration) completely randomized plot with 4 replications. In this study, germination percentages (%), seedling root lengths (cm), seedling shoot lengths (cm), seedling dry root weight (mg/seedling), seedling dry shoot weight (mg/seedling) and salt tolerance index (%) of cool season perennial forage grasses species at different salt concentrations were investigated. The responses of the cool season perennial forage grass species tested in the study to salt concentrations differed significantly. Increasing salt concentrations negatively affected germination, seedling development and salt tolerance index of the species. However, germination and seedling growth of the tested perennial cool-season forage grasses species could be promoted at low salt concentrations. Orchard grass and tall fescue species are very sensitive to salinity, and salinity tolerant cultivars or varieties should be preferred instead of these species in areas with high salinity. The fact that perennial ryegrass and smooth bromegrass were able to germinate over 50% up to 200 mM NaCl and 150 mM NaCl salt concentrations, respectively, showed that these species were more resistant to high salt concentrations. When germination percentage, seedling growth and salt tolerance index were evaluated together, it was determined that perennial ryegrass was partially advantageous over other species for saline areas.

Keywords: Forage grasses, salt stress, seedling growth, germination

ÇOKYILLIK BUĞDAYGİL YEMBİTKİLERİNİN ÇİMLENME VE FİDE GELİŞİMİ ÜZERİNE FARKLI TUZ KONSANTRASYONLARININ ETKİSİ

ÖZET

Bu araştırma, farklı serin mevsim çokyıllık buğdaygil yembitkisi türlerinin çimlenme ve fide gelişimi üzerine beş farklı tuz konsantrasyonu (0 mM NaCl [kontrol], 50 mM NaCl, 100 mM NaCl, 150 mM NaCl, 200 mM NaCl) uygulamasının etkisini saptamak amacıyla yürütülmüştür. Araştırmada materyal olarak kılçıksız bromun (*Bromus inermis* Leyss) Yükselen çeşidi, kamışsı yumağın (*Festuca arundinecea* Schreb.) Nilüfer çeşidi, seleksiyon ıslahı ile geliştirilmiş parlak bromun (*Bromus catharticus* Vahl.) 3 Nolu hattı, domuz ayrığının (*Dactylis glomerata* L.) Lidacta çeşidi ve çokyıllık çimin (*Lolium perenne* L.) Temprano çeşidi kullanılmıştır. Deneme, 2025 yılında Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Çayır-Mera laboratuvarında iki faktörlü (tür ve tuz konsantrasyonu) tesadüf parselleri deneme desenine göre 4 tekerrürlü olarak kurulmuştur. Araştırmada, serin mevsim çokyıllık buğdaygil yembitkisi türlerinin farklı tuz konsantrasyonlarındaki çimlenme yüzdeleri (%), fide kök uzunlukları (cm), fide sap uzunlukları (cm), fide kök kuru ağırlığı (mg/fide), fide sap kuru ağırlığı (mg/fide) ve tuz tolerans indeksi (%) incelenmiştir. Araştırmada test edilen serin mevsim çokyıllık buğdaygil yembitkisi türlerinin tuz konsantrasyonlarına karşı tepkileri önemli derecede farklılık göstermiştir. Tuz konsantrasyonunun artması, türlerin çimlenmesini, fide gelişimini ve tuza tolerans indekslerini olumsuz yönde etkilemiştir. Ancak, düşük tuz konsantrasyonlarında test edilen çokyıllık serin mevsim buğdaygil yembitkileri türlerinin çimlenmesi ve fide gelişiminin teşvik edilebileceği ortaya çıkmıştır. Domuz ayrığı ve kamışsı yumak türlerinin tuzluluğa çok duyarlı türler olduğu ve tuzluluk oranı yüksek alanlarda söz konusu türler yerine, tuzluluğa toleranslı tür veya varyetelerin tercih edilmesi gerektiği anlaşılmıştır. Çokyıllık çimin 200 mM NaCl, kılçıksız bromun 150 mM NaCl tuz konsantrasyonuna kadar %50 inin üzerinde çimlenebilmesi, söz konusu türlerin yüksek tuz konsantrasyonlarına daha dayanıklı olduğunu göstermiştir. Çimlenme yüzdesi, fide gelişimi ve tuz tolerans indeksi birlikte değerlendirildiğinde çokyıllık çimin tuzlu alanlar için diğer türlerden kısmen avantajlı olduğu belirlenmiştir.

Anahtar Kelimeler: Buğdaygil yembitkileri, tuz stresi, fide gelişimi, çimlenme

1. GİRİŞ

Tuzluluk, özellikle kurak ve yarı-kurak bölgelerde tarımsal üretimi kısıtlayan abiyotik stres faktörleri arasında yer almaktadır (Nawaz ve ark., 2010). Küresel ölçekte 932 milyon hektarlık alan tuzluluk problemiyle karşı karşıyayken, Türkiye'de 1.5 milyon hektarlık alanda hem tuzluluk hem de alkalilik sorunu bulunmaktadır (Sezen, 2021). Tuzluluk, bitkilerde metabolik dengesizliklere yol açarak çimlenme oranının azalmasına, kök ve sürgün gelişiminin gerilemesine, fotosentez kapasitesinin düşmesine ve genel biyokütle üretiminin azalmasına neden olmaktadır (Aydın ve Atıcı, 2015; Al-Ghumaiz ve ark., 2017). Bunların yanında, toprakta bulunan yüksek seviyedeki tuz konsantrasyonu, ozmotik basıncın artmasına ve buna bağlı olarak bitkinin su ve besin maddesi alımını engelleyip bitki büyüme ve gelişmesini sınırlandırmaktadır (Parida ve Das, 2005).

Buğdaygil yembitkileri, hayvancılık için kaliteli ve sürekli yem kaynağı sağlamaları nedeniyle tarımsal üretimin önemli bir bileşenidir. Hayvancılık sektöründe verimli bir yem üretimi sağlamak için yembitkilerinin yetişme koşullarına olan adaptasyonu büyük önem taşımaktadır. Tuzlu topraklarda buğdaygil yembitkisi yetiştiriciliği yapmak, hem hayvan beslenmesi için yeterli miktarda yem üretimini sürdürmek hem de toprak verimliliğini korumak açısından kritik bir konudur (Nawaz ve ark., 2010). Buğdaygil yembitkileri, özellikle kurak ve yarı kurak bölgelerde yüksek adaptasyon yetenekleri sayesinde tercih edilmekte olup, bu türlerin tuza karşı gösterdiği tolerans seviyesi büyük farklılıklar gösterebilmektedir (Al-Ghumaiz ve ark., 2017). Bazı türler düşük tuz seviyelerine dayanabilirken, bazıları yüksek tuz konsantrasyonlarına maruz kaldığında büyüme geriliği, hücresel zararlar ve metabolik bozukluklar gösterebilmektedir (Gupta ve Huang, 2014). Bu nedenle, yem bitkisi üretiminde tuza dayanıklı türlerin belirlenmesi hem üretim sürekliliğini sağlamak hem de yem kalitesini artırmak açısından büyük önem taşımaktadır. Aynı zamanda, tuza dayanıklı yem bitkilerinin belirlenmesi, çiftçilerin sürdürülebilir üretim sistemlerini geliştirmelerine yardımcı olurken, tuzlu alanların tarımsal kullanımını optimize edebilmektedir (Arslan ve ark., 2013).

Farklı tuz konsantrasyonlarının serin mevsim çokyıllık buğdaygil yembitkilerinin çimlenme oranı fide gelişimi gibi morfolojik parametreler üzerindeki etkilerinin incelenmesi, tarımsal üretim sistemleri için önemli bilgiler sunacaktır. Bunun yanı sıra, tuzluluğa toleranslı türlerin belirlenmesi ve uygun yetiştirme stratejilerinin geliştirilmesi, tuzlu alanlarda yembitkisi yetiştiriciliği için uygulanabilir çözümler sağlayacaktır.

Bu araştırma, farklı serin mevsim çokyıllık buğdaygil yembitkileri türlerinin değişen tuz konsantrasyonları altında çimlenme ve erken fide gelişimlerini belirlemek amacıyla yürütülmüştür.

2. MATERYAL ve YÖNTEM

Bu araştırma, Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Çayır-Mera Bitkileri laboratuvarında 2025 yılında yürütülmüştür. Denemede, Karadeniz Tarımsal Araştırma Enstitüsü Müdürülüğünden temin edilen kılçıksız bromun (*Bromus inermis* Leyss) Yükselen çeşidi, Ege Tarımsal Araştırma Enstitüsü Müdürlüğünden temin edilen kamışsı yumağın (*Festuca arundinecea* Schreb.) Nilüfer çeşidi, Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü tarafından seleksiyon ıslahı ile geliştirilmiş parlak bromun

(*Bromus catharticus* Vahl.) 3 Nolu hattı ve Maro Tarım firmasından temin edilen domuz ayrığının (*Dactylis glomerata* L.) Lidacta çeşidi ile çokyıllık çimin (*Lolium perenne* L.) Temprano çeşidi kullanılmıştır. Deneme iki faktörlü tesadüf parselleri deneme desenine göre 4 tekerrürlü olarak kurulmuş ve yürütülmüştür. Denemede, kontrol (distile su) dahil toplamda 5 farklı tuz konsantrasyonu test edilmiştir (0 [kontrol], 50, 100, 150, 200 mM NaCl).

Araştırmada kullanılan serin mevsim çokyıllık yembitkisi türlerinin tohumları çimlenme testinden önce %10 luk sodium hypochlorite (NaClO) çözltesi ile yüzey sterilizasyonundan geçirilmiş ve sterilize edilen tohumlar en az 5 defa distile su ile durulanmıştır. Her bir tür için 25 temsili tohum, 10 cm çapındaki petri kaplarındaki iki katlı filtre kâğıdı üzerine yerleştirilmiştir. Ardından, petri kaplarına 0 (kontrol), 50, 100, 150, 200 mM NaCl konsantrasyonlarındaki önceden hazırlanmış çözeltilerden 10 ml ilave edilmiştir (Irik ve Bikmaz, 2024). Petri kaplarından su kaybını önlemek için parafilm kullanılmıştır. Tuz çözeltisi ilave edilmiş ve parafilm ile kaplanmış petri kapları çimlendirme odasında 20±1 °C'de ve karanlık koşullarda tutulmuştur.

Denemenin 10. gününde kökçüğü en az 2 mm olan tohumlar çimlenmiş olarak kabul edilmiş ve aşağıdaki formülle her türün çimlenme yüzdesi hesaplanmıştır (Atış, 2011).

$$Çimlenme\ yüzdesi\ (\%) = \frac{Çimlenen\ tohum\ sayısı}{Toplam\ tohum\ sayısı} \times 100$$

Denemede her tür için çimlenme yüzdeleri belirlendikten sonra, her türün her bir tekrarlamasından rastgele seçilen 10 fide alınarak, filtre kağıtları yenilenen petri kaplarına yerleştirilmiş ve test edilen her tuz konsantrasyonu için (0, 50, 100, 150, 200 mM NaCl) 10 ml NaCl çözeltisi petri kaplarına ilave edilmiş ve petrilerin etrafı parafilm ile kaplanmıştır. Serin mevsim çokyıllık buğdaygil yembitkisi türlerinin fide özelliklerinden kök ve sap uzunluğunu belirlemek için, denemenin 15. gününde petrilerdeki 10 bitkinin kök ve sap uzunluğu ölçülmüş ve her türün 10 bitkideki kök ve sap uzunluklarının ortalaması alınarak her türün kök ve sap uzunluğu hesaplanmıştır. Fide başına kuru kök ve kuru sap ağırlığını belirlemek için, fidelerin kök ve sapları kesilmiş ve 24 saat 70 °C'de etüvde kurutulmuştur. Etüvde kurutulan örnekler 0.0001 g hassasiyetli terazide tartılmış, her tür için kuru kök ve kuru sap ağırlıkları belirlenmiş ve 10 bitkide belirlenen kuru ağırlıklarının ortalaması alınarak her bir türün fidedeki kuru kök ve kuru sap ağırlığı hesaplanmıştır. Daha sonra, her tür için kök ve sap kuru ağırlıklarının toplamı kullanılarak aşağıdaki eşitlik yardımıyla tuz tolerans indeksi hesaplanmıştır (Kusvuran ve ark., 2015).

$$Tuz\ tolerans\ indeksi = \frac{TKA'daki\ Tx}{TKA'daki\ To} \times 100$$

Burada; TKA'daki T_x = x tuz konsantrasyonundaki kök ve sap toplam kuru ağırlığını, TKA'daki T_0= kontrol uygulamasındaki kök ve sap toplam kuru ağırlığını ifade etmektedir.

Araştırmadan elde edilen veriler R programında homojenite testine tabi tutulmuş ve normal dağılım göstermeyen değerlere varyans analizi öncesi karekök ve açı transformasyonu uygulanmıştır (R Core Team, 2024). Ardından veriler R programında "agricolae" paketi ile varyans analizine tabi tutulmuştur (de Mendiburu, 2023). İstatistiki olarak önemli çıkan özellik ortalamaları Duncan testi ile %5 önem düzeyinde karşılaştırılmıştır (Yurtsever, 2011).

3. BULGULAR ve TARTIŞMA

Araştırma sonuçları, serin mevsim çokyıllık buğdaygil yembitkisi türlerinde incelenen özelliklerin (çimlenme yüzdesi, kök uzunluğu, sap uzunluğu, kök kuru ağırlığı, sap kuru ağırlığı, tuz tolerans indeksi) tümünde tuz konsantrasyonu ve tür faktörü ile tuz konsantrasyonu x tür interaksiyonunun etkisinin istatistiki olarak önemli derecede fark yarattığını ortaya koymuştur ($P<0.001$).

3.1. Çimlenme Yüzdesi

Tuz konsantrasyonunun çimlenme yüzdeleri üzerine etkileri incelendiğinde, tuz konsantrasyonunun artmasıyla çimlenme yüzdeleri linear olarak azalmıştır. Bunun yanında, tuz konsantrasyonunun 100 mM NaCl ve üzerine çıkarılması, kontrol ve 50 mM NaCl seviyesine göre önemli derecede daha düşük çimlenme yüzdesinin ortaya çıkmasına neden olmuştur (Çizelge 1). Uygulanan tuz konsantrasyonuna bağlı olarak çimlenme yüzdesinin azalması birçok araştırmacı tarafından da bilidirilmiştir (Kuşvuran ve ark., 2014a, 2014b; Liu ve ark., 2021; Sharavdorj ve ark., 2021). Nitekim Arslan ve ark. (2013), ortamdaki tuz konsantrasyonunun artması ile ozmotik basıncın arttığını ve tohumun su alımı engellenerek bir nevi kuraklık stresinin ortaya çıktığını bildirmişlerdir. Bunun yanında Javaid ve ark. (2022), artan tuz konsantrasyonuna bağlı olarak embriyoya zararlı iyonların girişi için uygun ortamların sağlandığını ve tohumun çimlenme yüzdesinin azalmasına neden olduğunu bildirmişlerdir.

Çizelge 1. Çokyıllık buğdaygil yembitkilerinin farklı tuz konsantrasyonlarındaki çimlenme yüzdeleri ortalamaları (%)

İncelenen Türler	Tuz Konsantrasyonları (mM NaCl)					
	0 mM	**50 mM**	**100 mM**	**150 mM**	**200 mM**	**Ortalama**
Kılçıksız Brom (*Bromus inermis*)	87.0 ab[2]	76.0 b-d	63.0 e-g	61.0 fg	32.0 j	63.8 B*
Domuz Ayrığı (*Dactylis glomerata*)	75.0 b-e	69.0 d-f	49.0 hı	34.0 j	0.0 k	45.4 D
Çokyıllık Çim (*Lolium perenne*)	88.0 ab	90.0 a	86.0 ab	73.0 c-f	53.0 gh	78.0 A
Parlak Brom (*Bromus catharticus*)	80.0 a-d	78.0 a-d	70.0 c-f	63.0 fg	35.0 j	65.2 B
Kamışsı Yumak (*Festuca arundineceae*)	76.0 b-d	83.0 a-c	69.0 d-f	43.0 ı	0.0 k	54.2 C
Ortalama	81.2 A[1]	79.2 A	67.4 B	54.8 C	24.0 D	

* Aynı sütun içinde benzer büyük harflerle gösterilen Tür ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[1] Aynı satır içinde benzer büyük harflerle gösterilen Tuz konsantrasyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[2] Benzer küçük harflerle gösterilen Tuz konsantrasyonu x Tür interaksiyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

Araştırmada, farklı tuz konsantrasyonlarının ortalaması olarak türlerin çimlenme yüzdesi ortalaması %45.4 ile %78.0 arasında değişmiştir. Çokyıllık çimin çimlenme yüzdesi ortalaması, test edilen diğer türlerin çimlenme yüzdesi ortalamasına göre önemli derecede daha yüksek değer gösterirken, domuz ayrığının çimlenme yüzdesi ortalaması, test edilen diğer türlere göre önemli derecede daha düşük değer göstermiştir. Parlak brom ve benzer istatistiki grupta yer alan kılçıksız bromun çimlenme yüzdesi ortalaması ise çokyıllık çimin çimlenme yüzdesi ortalamasını izlemiştir (Çizelge 1). Maas ve Hoffman (1977), çokyıllık yembitkileri için hazırlamış oldukları tuzluluğa dayanım rehberinde, çokyıllık çimin kamışsı yumak ve domuz ayrığına göre tuzluluğa daha dayanıklı olduğunu, Song ve ark. (2023), kılçıksız brom varyetelerinin tuza dayanımının çok geniş bir genotipik varyasyona sahip olduğunu, Willy ve ark. (2020) parlak bromun tuza orta derecede dayanımının olduğunu ve kabul edilebilir düzeydeki tuz konsantrasyonlarında tohumların çimlenebildiğini bildirmişlerdir. Nitekim yapılan araştırmalarda serin mevsim çokyıllık buğdaygillerin tuzluluğa toleransının türlere bağlı olarak farklılık gösterdiğini ortaya koymaktadır (Khan ve Gulzar, 2003; Tod ve ark., 2021).

Araştırmada, tuz konsantrasyonu x tür interaksiyonun önemli çıkması, tuz konsantrasyonlarının çimlenme yüzdeleri üzerindeki etkisinin türlere bağlı olarak önemli derecede farklılık gösterdiğini ortaya koymaktadır. Nitekim çokyıllık çim ve parlak brom türlerinde 100 mM NaCl tuz konsantrasyona kadar çimlenme yüzdeleri önemli derecede farklılık göstermezken, kılçıksız brom ve domuz ayrığında 100 mM NaCl tuz konsantrasyonunda, kontrol ve 50 mM NaCl tuz konsantrasyonuna göre çimlenme yüzdesi önemli derecede daha düşük değer göstermiştir. Bunların yanında 50 mM NaCl tuz konsantrasyonunda çokyıllık çim en yüksek çimlenme yüzdesi gösterirken, domuz ayrığı ve kamışsı yumak türlerinde 200 mM NaCl tuz konsantrasyonunda çimlenme gözlenmemiştir (Çizelge 1).

3.2. Kök Uzunluğu

Farklı tuz konsantrasyonlarında serin mevsim çokyıllık buğdaygil yembitkilerinin kök uzunluğu değerleri Çizelge 2'de verilmiştir. Çizelge 2'de izlendiği üzere, kök uzunlukları ortalaması, tuz konsantrasyonundaki artışa (kontrolden 200 mM NaCl'ye) bağlı olarak önemli derecede daha düşük değer göstermiştir. Bu durum, artan tuz konsantrasyonuna bağlı olarak türlerin fide gelişiminin zayıfladığını ortaya koymaktadır. Nitekim, birçok araştırıcı artan tuz konsantrasyonuna bağlı olarak fide kök uzunluğunun kontrole göre daha düşük değer gösterdiğini bildirmiştir (Ashraf ve ark., 1986; Kökten ve ark., 2010; Ertekin ve ark., 2022; Zhang ve ark., 2024). Bunun yanında Doğu (2017), tuz stresine bağlı olarak köklerdeki hücre sayısında ve hücre bölünmesinde azalmalar olduğunu ve bu durumunda kök gelişiminin azalmasına neden olduğunu bildirmiştir.

Araştırmada incelene türlerin fide kök uzunluğu ortalaması 1.69 cm ile 3.43 cm arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır (Çizelge 2). Kök uzunluğu ortalaması parlak bromda, test edilen diğer türlere göre önemli derecede daha yüksek değer gösterirken, söz konusu türü benzer istatistiki grupta yer alan çokyıllık çim ve kılçıksız brom türleri izlemiştir. Domuz ayrığında ise fide kök uzunluğu ortalaması, test edilen diğer türlere göre önemli derecede daha düşük değer göstermiştir. Birçok araştırıcı fide kök uzunluğu

değerlerinin türlere göre farklılık gösterdiğini bildirmiştir (Surmen ve Kara, 2018; Kıldış, 2021).

Araştırmada, tuz konsantrasyonu x tür interaksiyonunun önemli olması, tuz konsantrasyonlarının kök uzunluğuna etkisinin türlere bağlı olarak önemli derecede farklılık gösterdiğini ortaya koymaktadır (Çizelge 2). Nitekim, kılçıksız brom, parlak brom ve çokyıllık çimin 0 mM NaCl tuz konsantrasyonu uygulamasında kök uzunlukları, test edilen diğer türlere göre önemli derecede daha yüksek değer gösterirken, 50 mM NaCl tuz konsantrasyonu uygulamasında çokyıllık çim test edilen diğer türlere göre önemli derecede daha yüksek kök uzunluğu ortalaması göstermiştir. Tuz konsantrasyonu 100 mM'a çıkarıldığında, kök uzunluğu ortalaması parlak brom ve benzer istatistiki grupta yer alan çokyıllık çimde en yüksek değer gösterirken, tuz konsantrasyonu 150 mM ve 200 mM'da kök uzunluğu ortalaması parlak bromda test edilen diğer türlere göre önemli derecede daha yüksek değer göstermiştir. Bu durum, parlak bromun kök uzunluğu açısından, artan tuzluluğa bağlı olarak su alım potansiyelini artırmak için kök gelişimini artırdığını ortaya koymaktadır.

Çizelge 2. Çokyıllık buğdaygil yembitkilerinin farklı tuz konsantrasyonlarındaki fide kök uzunlukları ortalamaları (cm)

İncelenen Türler	**Tuz Konsantrasyonları (mM NaCl)**					
	0 mM	**50 mM**	**100 mM**	**150 mM**	**200 mM**	**Ortalama**
Kılçıksız Brom (*Bromus inermis*)	6.30 a[2]	3.35 b-d	2.49 c-e	1.43 f-h	0.63 ıj	2.84 B*
Domuz Ayrığı (*Dactylis glomerata*)	3.94 b	3.23 b-d	1.10 hı	0.20 kl	0.00 l	1.69 D
Çokyıllık Çim (*Lolium perenne*)	5.23 a	5.55 a	3.04 b-d	1.21 gh	0.56 jk	3.12 B
Parlak Brom (*Bromus catharticus*)	5.40 a	3.37 bc	3.72 b	2.82 cd	1.83 ef	3.43 A
Kamışsı Yumak (*Festuca arundineceae*)	2.78 cd	2.48 de	2.51 c-e	1.68 fg	0.00 l	1.89 C
Ortalama	4.73 A[1]	3.59 B	2.57 C	1.47 D	0.60 E	

* Aynı sütun içinde benzer büyük harflerle gösterilen Tür ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[1] Aynı satır içinde benzer büyük harflerle gösterilen Tuz konsantrasyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[2] Benzer küçük harflerle gösterilen Tuz konsantrasyonu x Tür interaksiyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

3.3. Sap Uzunluğu

Tuz konsantrasyonlarının sap uzunluğu üzerindeki etkisi incelendiğinde, sap uzunluğu ortalamsı 50 mM NaCl tuz konsantrasyonunda, test edilen diğer tuz konsantrasyonlarına göre önemli derecede daha yüksek değer göstermiştir. Tuz konsantrasyonunun 100 mM NaCl ve üzerine çıkarılması sap uzunluğu ortalamasının her tuz konsantrasyonu için önemli derecede daha düşük değer göstermesine neden olmuştur (Çizelge 3). Bu durum, tuz konsantrasyonunun 100 mM NaCl'nin üzerine çıkarılmasıyla fide gelişiminin zayıfladığını ortaya koymaktadır. Nitekim, tuz konsantrasyonunun artmasıyla fide sap uzunluğunun azaldığı birçok araştırıcı tarafından rapor edilmiştir (Atış, 2011; Aydın ve Atıcı, 2015; Balcı ve Boydak, 2021). Bunun yanında, düşük tuz konsantrasyonlarında fide sap gelişiminin teşvik edildiği, ancak artan tuz konsantrasyonuna bağlı olarak su ve mineral madde alımının azalmasıyla fide sap gelişiminin azaldığı birçok araştırıcı tarafından da bildirilmiştir (Radic ve ark., 2007; Çolak ve ark., 2008; Pinar ve ark., 2022).

Araştırmada, tuz konsantrasyonlarının ortalaması olarak incelenen türlerin sap uzunlukları ortalaması 2.66 cm ile 6.89 cm arasında değişmiş ve bu değişimin istatistiki olarak önemli olduğu ortaya çıkmıştır (Çizelge 3). Kılçıksız bromun fide sap uzunluğu ortalaması, test edilen diğer türlere göre önemli derecede daha yüksek değer gösterirken, domuz ayrığının fide sap uzunluğu ortalaması test edilen diğer türlere göre önemli derecede daha düşük değer göstermiştir. Bu sonuçlar, parlak bromun tuzluluğa bağlı olarak sap gelişiminin kök gelişimine göre daha fazla etkilendiğini, kılçıksız bromun ise sap gelişiminin kök gelişimine göre tuzluluktan daha az etkilendiğini ortaya koymuştur (Çizelge 2, Çizelge 3). Bu bağlamda, tuzluluğa bağlı olarak türlerin kök ve sap gelişimlerinin farklılık gösterdiği söylenebilir. Nitekim, birçok araştırıcı türlerin fide kök ve sap uzunluğunun tuzluluğa bağlı olarak farklılık gösterdiğini bildirmişlerdir (Arslan ve ark., 2013; Aydın ve Atıcı, 2015; Javaid ve ark., 2022).

Araştırmada tuz konsantrasyonu x tür interaksiyonunun önemli çıkması, tuz konsantrasyonlarının fide sap uzunluğu üzerindeki etkisinin türlere bağlı olarak önemli derecede farklılık gösterdiğini ortaya koymaktadır (Çizelge 3). Nitekim, domuz ayrığının sap uzunluğu ortalaması 0 mM NaCl (kontrol) ve 50 mM NaCl tuz konsantrasyonlarında istatistiki olarak önemli derecede farklı değerler göstermezken, test edilen diğer türlerin sap uzunlukları ortalaması 0 mM NaCl (kontrol) tuz konsantrasyonuna göre 50 mM NaCl tuz konsantrasyonunda önemli derecede daha yüksek değer göstermiştir. Diğer taraftan parlak brom hariç, 100 mM NaCl tuz konsantrasyonundan 200 mM NaCl tuz konsantrasyonuna doğru türlerin sap uzunlukları ortalaması önemli derecede daha düşük değer göstermiştir. Parlak bromun sap uzunluğu ortalaması ise 150 mM NaCl tuz konsantrasyonu ile 200 mM NaCl tuz konsantrasyonunda benzer istatistiki grupta yer almıştır.

Çizelge 3. Çokyıllık buğdaygil yembitkilerinin farklı tuz konsantrasyonlarındaki fide sap uzunlukları ortalamaları (cm)

İncelenen Türler	Tuz Konsantrasyonları (mM NaCl)					
	0 mM	50 mM	100 mM	150 mM	200 mM	Ortalama
Kılçıksız Brom (*Bromus inermis*)	7.97 c-e[2]	11.83 a	7.54 d-f	4.67 ıj	2.43 k-m	6.89 A*
Domuz Ayrığı (*Dactylis glomerata*)	4.09 ıj	5.17 hı	2.79 k	1.27 n	0.00 o	2.66 E
Çokyıllık Çim (*Lolium perenne*)	6.81 e-g	8.90 bc	5.82 gh	4.38 ıj	2.62 kl	5.71 B
Parlak Brom (*Bromus catharticus*)	8.44 cd	9.89 b	5.17 hı	1.94 lm	1.73 mn	5.43 C
Kamışsı Yumak (*Festuca arundineceae*)	4.96 hı	6.48 fg	3.71 j	1.68 mn	0.00 o	3.37 D
Ortalama	6.45 B[1]	8.46 A	5.00 C	2.79 D	1.35 E	

* Aynı sütun içinde benzer büyük harflerle gösterilen Tür ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[1] Aynı satır içinde benzer büyük harflerle gösterilen Tuz konsantrasyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[2] Benzer küçük harflerle gösterilen Tuz konsantrasyonu x Tür interaksiyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

3.4. Kök Kuru Ağırlığı

Serin mevsim çokyıllık buğdaygil yembitkileri türlerinin farklı tuz konsantrasyonlarındaki fide kök kuru ağırlığı ortalamaları Çizelge 4'te verilmiştir. Çizelgede izlendiği üzere, 0 mM (kontrol) NaCl tuz konsantrasyonunda fide kök kuru ağırlığı ortalaması, test edilen diğer tuz konsantrasyonlarındakine göre önemli derecede daha yüksek değer göstermiştir. Ayrıca, 0 mM NaCl tuz konsantrasyonundaki kök kuru ağırlığı ortalamasını sırasıyla benzer istatistiki grupta yer alan 100 mM NaCl (0.33 mg/fide), 50 mM NaCl (0.28 mg/fide) ve 150 mM NaCl (0.26 mg/fide) tuz konsantrasyonları izlemiştir. 200 mM NaCl tuz konsantrasyonunda kök kuru ağırlığı ortalaması ise, 150 mM NaCl tuz konsantrasyonu hariç, test edilen diğer tuz konsantrasyonlarındakine göre önemli derecede daha düşük değer göstermiştir. Benzer sonuçlar, bazı bitki türlerinin fide kök kuru ağırlığının tuz konsantrasyonlarına bağlı olarak önemli derecede farklılık gösterdiğini rapor eden Göçer ve ark. (2021) ve Çirka ve ark. (2022) tarafından da bildirilmiştir.

Farklı tuz konsantrasyonlarının ortalaması olarak, fide kök ağırlığı ortalaması parlak bromda, test edilen diğer serin mevsim çokyıllık buğdaygil yembitkileri türlerine göre önemli derecede daha yüksek değer göstermiş ve söz konusu türü fide kök kuru ağırlığı ortalaması bakımından kılçıksız brom izlemiştir. Ayrıca, benzer istatistiki grupta yer alan kamışsı yumak, domuz ayrığı ve çokyıllık çimin kök kuru ağırlığı ortalamaları test edilen diğer türlerin kök kuru ağırlığı

ortalamalarından önemli derecede daha düşük değer göstermiştir (Çizelge 4). Bu sonuçlar, araştırmada test edilen türlerin tuzluluğa toleranslarınının farklı olduğunu ortaya koymaktadır. Nitekim birçok araştırmacı, bitki türlerinin, hatta aynı türe ait varyetelerin genetik yapılarına bağlı olarak, fide kök kuru ağırlıklarının tuzluluktan önemli derecede etkilendiğini rapor etmiştir (Kıldış, 2021; Özyazıcı ve Açıkbaş, 2021; Alzahrani, 2024; Cui ve ark., 2025).

Çizelge 4. Çokyıllık buğdaygil yembitkilerinin farklı tuz konsantrasyonlarındaki fide kök kuru ağırlığı ortalamaları (mg/fide)

İncelenen Türler	Tuz Konsantrasyonları (mM NaCl)					
	0 mM	**50 mM**	**100 mM**	**150 mM**	**200 mM**	**Ortalama**
Kılçıksız Brom (*Bromus inermis*)	0.39 de[2]	0.27 e-g	0.26 e-g	0.30 ef	0.25 e-g	0.29 B*
Domuz Ayrığı (*Dactylis glomerata*)	0.23 e-h	0.16 f-h	0.13 f-ı	0.18 f-h	0.00 ı	0.14 C
Çokyıllık Çim (*Lolium perenne*)	0.25 e-g	0.19 f-h	0.14 f-ı	0.17 f-h	0.07 hı	0.16 C
Parlak Brom (*Bromus catharticus*)	1.22 a	0.69 c	0.96 b	0.56 cd	0.30 ef	0.74 A
Kamışsı Yumak (*Festuca arundineceae*)	0.12 g-ı	0.10 g-ı	0.14 f-ı	0.11 g-ı	0.00 ı	0.09 C
Ortalama	0.44 A[1]	0.28 B	0.33 B	0.26 BC	0.12 C	

* Aynı sütun içinde benzer büyük harflerle gösterilen Tür ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[1] Aynı satır içinde benzer büyük harflerle gösterilen Tuz konsantrasyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[2] Benzer küçük harflerle gösterilen Tuz konsantrasyonu x Tür interaksiyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

Araştırmada tuz konsantrasyonu x tür interaksiyonunun önemli çıkması, tuz konsantrasyonlarının kök kuru ağırlığı üzerindeki etkisinin türlere bağlı olarak önemli derecede farklılık gösterdiğini ortaya koymaktadır (Çizelge 4). Nitekim, kılçıksız bromun fide kök ağırlığı ortalaması tüm tuz konsantrasyonlarında benzer istatistiki grupta yer alırken, parlak bromda fide kök kuru ağırlığı ortalaması 0 mM NaCl (kontrol) tuz konsantrasyonunda, diğer tuz konsantrasyonlarındakine göre önemli derecede daha yüksek değer göstermiştir. Bunun yanında, kamışsı yumağında fide kök ağırlığı ortalaması tüm tuz konsantrasyonlarında benzer istatistiki grupta yer almıştır.

3.5. Sap Kuru Ağırlığı

Serin mevsim çokyıllık buğdaygil yembitkileri türlerinin farklı tuz konsantrasyonlarında fide sap kuru ağırlığı ortalamaları Çizelge 5'te verilmiştir. Çizelge 5'te izlendiği gibi, fide sap kuru

ağırlığı ortalamaları benzer istatistiki grupta yer alan 0 mM NaCl ve 50 mM NaCl tuz konsantrasyonlarında, test edilen diğer tuz konsantrasyonlarındakine göre önemli derecede daha yüksek değer göstermiştir. Bunun yanında, fide sap kuru ağırlığı ortalaması 200 mM NaCl tuz konsantrasyonunda, test edilen diğer tuz konsantrasyonlarındakine göre önemli derecede daha düşük değer vermiştir. Araştırmadan elde edilen bulgular, fide sap kuru ağırlığı değerlerinin tuz konsantrasyonlarına bağlı olarak önemli derecede farklılık gösterdiğini bildiren birçok araştırıcının bulguları ile uyum içerisinde olduğunu göstermektedir (Atış, 2011; Saud ve ark., 2013; Kuşvuran ve ark., 2018).

Tuz konsantrasyonlarının ortalaması olarak fide sap kuru ağırlığı ortalaması, parlak bromda (1.63 mg/fide) test edilen diğer serin mevsim çokyıllık buğdaygil türlerindekine göre önemli derecede daha yüksek değer göstermiştir (Çizelge 5). Bunun yanında, fide sap kuru ağırlığı ortalaması bakımından parlak bromu sırasıyla farklı istatistiki gruplarda yer alan kılçıksız brom (1.03 mg/fide), çokyıllık çim (0.63 mg/fide), kamışsı yumak (0.38 mg/fide) ve domuz ayrığı (0.26 mg/fide) türleri izlemiştir. Bu sonuç, fide sap kuru ağırlığının serin mevsim çokyıllık buğdaygil yembitkileri türlerine bağlı olarak farklılık gösterdiğini ortaya koymuştur. Nitekim Saud ve ark. (2013), serin mevsim buğdaygil yembitkileri ile yürüttükleri tuzluluk çalışmasında, fide sap kuru ağırlıklarının türlere göre önemli derecede farklılık gösterdiğini rapor etmişlerdir.

Çizelge 5. Çokyıllık buğdaygil yembitkilerinin farklı tuz konsantrasyonlarındaki fide sap kuru ağırlıkları ortalamaları (mg/fide)

İncelenen Türler	Tuz Konsantrasyonları (mM NaCl)					
	0 mM	50 mM	100 mM	150 mM	200 mM	Ortalama
Kılçıksız Brom (*Bromus inermis*)	1.06 de	1.17 d	1.22 d	0.95 d-f	0.76 e-g	1.03 B*
Domuz Ayrığı (*Dactylis glomerata*)	0.41 ı-k	0.38 ı-l	0.34 j-l	0.17 lm	0.00 m	0.26 E
Çokyıllık Çim (*Lolium perenne*)	0.71 f-h	0.76 e-g	0.60 g-j	0.64 g-ı	0.46 h-k	0.63 C
Parlak Brom (*Bromus catharticus*)	2.84 a	2.20 b	1.60 c	0.98 d-f	0.50 g-j	1.63 A
Kamışsı Yumak (*Festuca arundineceae*)	0.62 g-j	0.58 g-j	0.45 h-k	0.25 kl	0.00 m	0.38 D
Ortalama	1.13 A[1]	1.02 A	0.84 B	0.60 C	0.34 D	

* Aynı sütun içinde benzer büyük harflerle gösterilen Tür ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[1] Aynı satır içinde benzer büyük harflerle gösterilen Tuz konsantrasyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[2] Benzer küçük harflerle gösterilen Tuz konsantrasyonu x Tür interaksiyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

Araştırmada tuz konsantrasyonu x tür interaksiyonunun fide sap kuru ağırlığı üzerindeki etkisinin önemli çıkması, tuz konsantrasyonunun fide sap kuru ağırlığı üzerindeki etkisinin türlere bağlı olarak önemli derecede farklılık yarattığını ortaya koymaktadır. Nitekim parlak brom fide sap kuru ağırlığı ortalaması 0 mM NaCl, 50 mM NaCl ve 100 mM NaCl tuz konsantrasyonlarında test edilen diğer türlerin söz konusu tuz konsantrasyonlarındaki fide sap kuru ağırlığı ortalamalarından önemli derecede daha yüksek değer göstermesine rağmen, 150 mM NaCl ve 200 mM NaCl tuz konsantrasyonlarında fide sap kuru ağırlığı bakımından kılçıksız brom ve parlak brom türleri istatistiki olarak birbirinden farklı olmayan değerler göstermiştir.

3.6. Tuz Tolerans İndeksi

Serin mevsim çokyıllık buğdaygil yembitkileri türlerinin farklı tuz konsantrasyonlarındaki tuz tolerans indeksi ortalamaları Çizelge 6'da verilmiştir. Çizelgede izlendiği üzere tuz tolerans indeksi ortalaması 0 mM NaCl ve 50 mM NaCl tuz konsantrasyonlarında istatistiki olarak birbirinden farklı olmayan değerler vermiştir. 100 mM ve daha yüksek NaCl konsantrasyonlarında konsantrasyon arttıkça tuz tolerans indeksi ortalaması önemli derecede daha düşük değer göstermiştir. Bu durum, tuzluluk oranının artmasıyla tuz tolerans indeksinin azaldığını ortaya koymaktadır. Nitekim Atış (2011), tuz konsantrasyonunu artırmamın fide gelişimini olumsuz etkilediğini ve tuz tolerans indeksinin, artan tuz konsantrasyonuna bağlı olarak önemli derecede düşüş gösterdiğini rapor etmiştir.

Araştırmada test edilen türlerin tuz tolerans indeksi ortalaması incelendiğinde, en yüksek tuz tolerans indeksi ortalaması %63.6 ile kılçıksız bromda tespit edilirken, çokyıllık çimin tuz tolerans indeksi ortalaması %62.9 ile kılçıksız bromdan istatistiki olarak farklı olmayan değer göstermiştir. Parlak bromun tuz tolerans indeksi, kamışsı yumak ve domuz ayrığı türleri hariç, test edilen diğer türlere göre önemli derecede daha düşük değer göstermiştir. Bu sonuç, tuz tolerans indeksinin bitki türüne bağlı olarak farklılık gösterdiğini bildiren birçok araştırmacının sonuçlarıyla uyum içerisindedir (Atış, 2011; Kıldış, 2021). Nitekim Al-Ghumaiz ve ark. (2017), birçok halofit bitki türünün tuz tolerans indeksinin yüksek olduğunu, halofit olmayan bitki türlerinin ise belli oranda tuzlulukta gelişim gösterebildiklerini ve tuza tolerans indeksinin bitki türüne bağlı olarak farklılık gösterdiğini rapor etmişlerdir.

Çizelge 6. Çokyıllık buğdaygil yembitkilerinin farklı tuz konsantrasyonlarındaki tuz tolerans indeksi ortalamaları (%)

İncelenen Türler	Tuz Konsantrasyonları (mM NaCl)					
	0 mM	50 mM	100 mM	150 mM	200 mM	Ortalama
Kılçıksız Brom (*Bromus inermis*)	100.0 ab[2]	65.3 c-e	81.0 b-d	45.8 ef	26.0 fg	63.6 A*
Domuz Ayrığı (*Dactylis glomerata*)	100.0 ab	110.2 a	61.3 de	12.6 g	0.0 h	56.8 B
Çokyıllık Çim (*Lolium perenne*)	100.0 ab	99.7 a-c	66.3 c-e	28.7 fg	20.0 g	62.9 A
Parlak Brom (*Bromus catharticus*)	100.0 ab	50.9 d-f	47.5 ef	17.8 g	2.0 h	43.6 B
Kamışsı Yumak (*Festuca arundineceae*)	100.0 ab	99.9 a-c	69.0 c-e	11.9 g	0.0 h	56.2 B
Ortalama	100.0 A[1]	85.2 A	65.0 B	23.3 C	9.6 D	

* Aynı sütun içinde benzer büyük harflerle gösterilen Tür ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[1] Aynı satır içinde benzer büyük harflerle gösterilen Tuz konsantrasyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

[2] Benzer küçük harflerle gösterilen Tuz konsantrasyonu x Tür interaksiyonu ortalamaları arasında Duncan testine göre %5 önem seviyesinde istatistiki olarak anlamlı fark yoktur.

Araştırmada tuz konsantrasyonu x tür interaksiyonunun önemli çıkması, tuz konsantrasyonlarının tuz tolerans indeksi üzerindeki etkisinin türlere bağlı olarak önemli derecede farklılık gösterdiğini ortaya koymuştur. Nitekim, domuz ayrığı, çokyıllık çim ve kamışsı yumak türlerinde tuz tolerans indeksi ortalaması 0 mM NaCl (kontrol) tuz konsantrasyonuna göre 50 mM NaCl tuz konsantrasyonunda istatistiki olarak önemli derecede farklı olmayan değerler verirken, kılçıksız brom ve parlak brom türleri tuz tolerans indeksi bakımından 0 mM NaCl (kontrol) tuz konsantrasyonuna göre 50 mM NaCl tuz konsantrasyonunda önemli derecede daha düşük değer göstermiştir. Diğer taraftan, domuz ayrığı, parlak brom ve kamışsı yumak türlerinin tuz tolerans indeksi 100 mM ve daha yüksek tuz konsantrasyonlarında tuz konsantrasyonu arttıkça önemli derecede daha düşük değer göstermiştir.

4. SONUÇ

Araştırma sonuçları, farklı serin mevsim çokyıllık buğdaygil türlerinin çimlenmesi ve fide gelişimi üzerinde tuz konsantrasyonlarının önemli derecede fark yarattığını ortaya koymuştur. Artan tuz konsantrasyonuna bağlı olarak türlerin hem çimlenmesi hem de fide gelişimi olumsuz etkilenmiştir. Domuz ayrığı ve kamışsı yumak türlerinin tuzluluğa çok duyarlı türler olduğu ve tuzluluk oranı yüksek alanlarda söz konusu türler yerine, tuzluluğa toleranslı tür veya varyetelerin tercih edilmesi gerektiği anlaşılmıştır. Çokyıllık çimin 200 mM NaCl, kılçıksız

bromun 150 mM NaCl tuz konsantrasyonuna kadar %50 inin üzerinde çimlenme yüzdelerinin olması, söz konusu türlerin yüksek tuz konsantrasyonlarında çimlenebileceğini göstermiştir. Ancak çokyıllık çim ve kılçıksız bromun 150 mM NaCl ve daha yüksek tuz konsantrasyonlarında tuz tolerans indekslerinin %50 nin altına düşmesi, türlerin yeteri kadar çimlense dahi ilerleyen dönemlerde türlerin fide gelişiminde sorunlar ortaya çıkacağını göstermektedir. Çimlenme yüzdesi, fide gelişimi ve tuz tolerans indeksi birlikte değerlendirildiğinde çokyıllık çimin tuzlu alanlar için diğer türlerden kısmen avantajlı olduğu ortaya çıkmıştır. Yürütülen bu araştırma, incelenen serin mevsim çokyıllık buğdaygil yembitkisi türleri açısından üreticiye ön bilgi verecek ve ileri seviyede yapılacak araştırmalar için kaynak oluşturacaktır.

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THE EFFECT OF FORAGE TURNIP LEAF EXTRACTS ON GERMINATION AND SEEDLING DEVELOPMENT OF FORAGE COWPEA

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ABSTRACT

Secondary metabolites found in plants function as part of their defense mechanisms. By releasing these secondary metabolites into their surroundings, plants can eliminate them from their own systems while simultaneously influencing the growth of neighboring plants either positively or negatively. This phenomenon is known as allelopathy. In this study, the aimed to determine the effects of extracts obtained from forage turnip (*Brassica rapa* L.) leaves on the germination parameters and seedling development of forage cowpea (*Vigna unguiculata* L. "Ülkem") seeds. Forage turnip leaves were harvested during the flowering period, weighed 500 grams, and soaked in 3 liters of distilled water for 7 hours to prepare the extract. From this extract, four solutions were prepared at concentrations of 25%, 50%, 75%, and 100%. Pure water (PW) was used as the control. The experiment, carried out in triplicates, lasted 21 days under conditions of 25/23 °C temperature, 60% humidity, and a 16/8-hour photoperiod. During the study, the germination rate (%), root and shoot lengths (cm), fresh and dry weights of roots and shoots (g), crude protein content (CP, %), acid detergent fiber (ADF, %), neutral detergent fiber (NDF, %), potassium (K, %), phosphorus (P, %), calcium (Ca, %), magnesium (Mg, %), total phenolics (TP, mg GA g^{-1}), total flavonoids (TF, mg QE g^{-1}), radical scavenging activity (DPPH, %) and condensed tannins (CT, %) were determined. The highest germination rates were obtained from the treatments of 100% DW (100%), 25FT% + 75PW% (100%), and 75FT% + 25PW% (96.67%). In terms of root-shoot lengths and fresh and dry weights, the 25FT+ 75PW% treatment was found to be the most effective. Regarding the seedling's CP, ADF, NDF, K, P, Ca, and Mg contents, the values ranged from 33.00-35.57%, 19.98-26.15%, 22.67-37.51%, 2.87-3.43%, 0.57-0.62%, 1.02-1.14%, and 0.30-0.32%, respectively. There was no significant difference between treatments in terms of secondary metabolites. As a result, the study concluded that fodder turnip extract has an allopathic effect on the germination and

seedling development of forage cowpea, with the 25% fodder turnip extract promoting germination and seedling growth.

Keywords: Allelopathy, Forage turnip, Forage cowpea, Germination, Seedling.

YEM ŞALGAMI YAPRAK EKSTRAKTLARININ YEMLİK BÖRÜLCENİN ÇİMLENME VE FİDE GELİŞİMİ ÜZERİNE ETKİSİ

ÖZET

Bitkilerde bulunan ikincil metabolitler bitkilerin savunma mekanizmalarının bir parçası olarak görev yaparlar. Bitkiler bu ikincil metabolitleri çevrelerine salarak kendi bünyelerinden uzaklaştırırken, diğer bitkilerin gelişimlerini olumlu ya da olumsuz etkileyebilmektedirler. Bu durum allelopati olarak adlandırılmaktadır. Mevcut çalışmada; yemlik börülce "YB" (*Vigna unguiculata* L. "Ülkem") tohumlarının çimlenme parametreleri ile fide gelişimi ve kalitesi üzerinde yem şalgamı "YŞ" (*Brassica rapa* L.) yapraklarından elde edilen özütlerin etkisinin belirlenmesi amaçlanmıştır. Çiçeklenme döneminde hasat eden yem şalgamı yapraklarından 500 gr tartılarak 3 litre saf su içerisinde 7 saat süre ile bekletilmiş ve özüt hazırlanmıştır. Bu özütten %25, %50, %75 ve %100'lük 4 adet yem şalgamı çözeltisi hazırlanmıştır. Kontrol olarak ise saf su (SS) kullanılmıştır. Üç tekrarlı olarak gerçekleştirilen deney 25/23 °C sıcaklık, %60 nem ve 16/8 saat fotoperiyotta 21 gün boyunca devam etmiştir. Çalışmada; çimlenme oranı (%), kök ve gövde uzunlukları (cm), kök-gövde yaş ve kuru ağırlıkları (g), ham protein oranı (%), asit deterjanda çözünmeyen lif (ADF, %), nötr deterjanda çözünmeyen lif (NDF, %), potasyum (K, %), fosfor (P, %), kalsiyum (Ca, %), magnezyum (Mg, %), toplam fenolik (mg GA g^{-1}) toplam flavonoid (mg QE g^{-1}), radikal kovucu aktivite (DPPH, %) ve kondanse tanen (%) içerikleri belirlenmiştir. En yüksek çimlenme oranı %100SS (%100), %25YŞ+75SS (%100) ve %75YŞ+25SS (%96.67) işlemlerinden elde edilmiştir. Kök-gövde uzunlukları ile yaş ve kuru ağırlıkları bakımından %25YŞ+75SS işlemi ön plan acıkmıştır. Çalışmada fidelerin HPO, ADF, NDF K, P, Ca ve Mg içerikleri sırasıyla %33.00-35.57, %19.98-26.15, %22.67-37.51, %2.87-3.43, %0.57-0.62, %%1.02-1.14 ve %0.30-0.32 arasında olmuştur. Çalışmada sekonder metabolitler bakımından işlemler arasında fark olmamıştır. Sonuç olarak; yem şalgamı özütünün soyanın çimlenme ve fide gelişimi üzerinde allelopatik etkisinin belirlendiği çalışmada %25 yem şalgamı özütü yemlik börülcenin çimlenme ve fide gelişimini teşvik ettiği belirlenmiştir.

Anahtar Kelimeler: Allelopati, yem şalgamı, yemlik börülce, çimlenme, fide.

1. GİRİŞ

Ot tipi yem şalgamı olarak da bilinen Lenox, hiç sulanmadan yetiştirilebilen tek yıllık yem bitkisidir. Protein oranı oldukça yüksek olup, hayvan verimini ve kalitesini iyileştirmektedir. Süt verimine ve kalitesine doğrudan etki yapan bitki, üreticinin gelirine de katma değer sağlamaktadır. Bitkinin yağ oranı oldukça yüksek olup, vitaminler ve besin elementleri bakımından da oldukça zengindir (Denen, 2019). Yem şalgamı ile beslenen hayvanların tüyleri parlaklaşır, ayak hastalıkları ve ishal vakalarında belirgin düşüşler olur. Bitkinin yaprakları ve kökü, koyun, keçi, düve, sığır ve süt inekleri tarafından büyük bir iştahla tüketilmektedir (Geren ve ark., 2002; Yavuz, 2022). Yem şalgamı erken dönemde hasada gelmektedir. Bu durum arkasından ekilecek bitki için geniş bir vejetasyon dönemi anlamına gelmektedir. Yem şalgamı ayrıca biyoaktif bileşenlerce oldukça zengindir. (Yavuz ve Gülümser, 2022).

Börülce *(Vigna unguiculata* L. Walp.), tek yıllık ömürlü, otsu karakterde ve sıcak iklim koşullarına uygun bir baklagil türüdür. Hem insan gıdası hem de hayvan yemi olarak değerlendirilen bu bitki, aynı zamanda tarımsal üretimde toprak verimliliğini artırıcı özelliğe sahiptir. Köklerinde simbiyotik olarak yaşayan Rhizobium bakterileri aracılığıyla atmosferdeki serbest azotu bağlayarak toprağın besin değerini zenginleştirir. Pek çok kültür bitkisine kıyasla, kuraklık ve yüksek sıcaklık koşullarına daha dayanıklıdır (Can ve ark., 2021). Börülce; yeşil gübreleme amacıyla, yem bitkisi olarak ve doğrudan tüketim için yaygın şekilde kullanılır. Hayvancılıkta ise yeşil ve kuru ot formu, silaj (özellikle sorgum ve darı ile karışık) ve kuru tohumları yem olarak değerlendirilmektedir. Besin değeri açısından zengin olan börülcenin yeşil kısmı %14-21, tohumları ise %18-26 oranında ham protein içermektedir (Adeyanju ve ark., 2007; Ali ve ark., 2004). Bunun yanı sıra, doğal meralarda otlatma yoluyla da hayvan beslenmesinde kullanılabilmektedir.

Bitkiler tarafından sentezlenen ikincil metabolitler, bitkilerin çevresel stres etmenlerine karşı geliştirdiği savunma mekanizmalarının bir parçası olarak işlev görürler. Bu bileşiklerin birçoğu bitki için toksik olabileceğinden, bitkiler bu maddeleri çevrelerine salgılayarak bünyelerinden uzaklaştırma yoluna gider (Duke, 1991). Bu kimyasallar, çevredeki diğer bitkiler üzerinde doğrudan veya dolaylı etkiler meydana getirerek onların büyüme, gelişme ve fizyolojik süreçlerini etkileyebilir. Bu tür bileşikler allelokimyasallar, bu bileşiklerin neden olduğu etkileşimler ise allelopati olarak tanımlanır. Allelopatik etkiler bitki türüne bağlı olarak bazı bireylerde baskılayıcı, bazı bireylerde ise uyarıcı sonuçlar doğurabilir. Etkinin derecesi ve yönü; salgılanan bileşiğin kimyasal özellikleri, yoğunluğu ve diğer bitkilerle temas süresi gibi faktörlere bağlı olarak değişebilir. Ancak yapılan çalışmalarda, bu kimyasalların çoğunlukla olumsuz etkilere yol açtığı gözlemlenmiştir. Bu etkiler; bitki gelişiminde yavaşlama, fotosentezde azalma, besin elementlerinin alımında düşüş, yaprak sararması (klorozis), morfolojik deformasyonlar, yaprak dökülmesi, kurumalar ve hatta bitki ölümüne kadar ilerleyen sonuçlar doğurabilir (Rice, 1984).

Yukarıdaki açıklamalar ışığı altında bu çalışmada; yem şalgamı yapraklarından elde edilen özütlerden hazırlanan farklı solüsyonlarının yemlik börülcenin çimlenme ile fide gelişimi ve kalitesi üzerindeki alleloptik etkilerinin belirlenmesi amaçlanmıştır.

2. MATERYAL VE METOT

Araştırma, Bilecik Şeyh Edebali Üniversitesi'nin Tarımsal Uygulama ve Araştırma alanındaki laboratuvarda gerçekleştirilmiştir. Çalışmada allelopati materyali olarak yem şalgamının (*Brassica rapa* L.) "Lenox, çimlenme materyali olarak ise yemlik börülcenin (*Vigna unguiculata* L.) "ülkem" çeşitleri kullanılmıştır. Yem şalgamı %50 çiçeklenme döneminde hasat edilmiş ve yapraklarından 500 gram örnek alınarak 3 litre saf su içinde 7 saat süreyle bekletilerek özüt elde edilmiştir. Daha sonra bu özütlerden %100, %75, %50 ve %25 oranında 4 farklı solüsyon hazırlanmıştır. Solüsyonlar saf su ile hazırlanmış olup, kontrol grubu olarak yine saf su (%100 saf su) kullanılmıştır. Çimlenme ve fide gelişimi; plastik kaplar içerisinde ve iki kat kurutma kâğıdı üzerinde üçer tekrarlı (25x4) olarak gerçekleştirilmiştir. Laboratuvar koşulları ise;16 saat aydınlık/8 saat karanlık fotoperiyotta ve 25±1˚C olarak ayarlanmıştır. Çalışmaya 21 gün boyunca devam edilmiştir.

2.1. Çimlenme Oranı (%): ((Çimlenen tohum sayısı/Toplam tohum sayısı) × 100) (Kayacetin ve ark., 2018).

2.2. Kök-Gövde Yaş ve Kuru Ağırlığı (g): Hasat edilen örneklerin yaş ağırlıkları belirlendikten sonra, 60 °C'de sabit ağırlığa gelene kadar kurutulmuş ve tartılarak kuru ağırlıklar belirlenmiştir (Işık ve Çalıseki, 2017; Leblebici ve ark., 2024)

2.3. Ham Protein Oranı (HPO), Asit Deterjanda Çözünmeyen lif (ADF), Nötr Deterjanda Çözünmeyen Lif (NDF) ve Besin Elementleri (%): Örnekler, 60 °C'de sabit ağırlığa ulaşana kadar kurutulmuş ve ardından 1 mm elek çapına sahip bir değirmende öğütülerek analiz için hazırlanmıştır. Sonrasında bu örneklerin HPO, ADF, NDF, potasyum (K), kalsiyum (Ca), magnezyum (Mg) ve fosfor (P) içerikleri, Near Infrared Reflectance Spectroscopy (NIRS) (Foss 6500) cihazı ve IC-0904FE yazılımı kullanılarak belirlenmiştir.

2.4. Toplam Fenolik İçeriği (mg GA g^{-1}): Ekstraktların toplam fenolik içeriği, Folin-Ciocalteu Reaktifi (FCR) kullanılarak, Singleton ve ark. (1999) metoduna göre belirlenmiştir. Çalışma için, örnek çözeltilerinden 0.2 ml alınarak üzerine 9 ml distile su eklenmiş ve ardından 0.2 ml Folin-Ciocalteu reaktifi ilave edilmiştir. Bu karışım, 3 dakika süreyle bekletildikten sonra, 0.6 ml %20 sodyum karbonat (Na_2CO_3) eklenmiş ve toplam hacim 10 ml'ye tamamlanmıştır. Karışım, oda sıcaklığında karanlık ortamda 2 saat inkübe edildikten sonra, 760 nm'de absorbans ölçümü yapılmıştır. Standart kalibrasyon eğrisini oluşturmak için saf suda çözülmüş gallik asit kullanılmıştır. Gallik asit, ana stok çözeltisi olarak 0.1 mg ml^{-1} konsantrasyona getirilmiş ve seyreltme yöntemiyle yedi farklı konsantrasyon elde edilmiştir. Kontrol çözeltisi olarak, örnek çözeltisi kadar (0.2 ml) saf su ilave edilmiştir. Gallik asit standart eğrisine dayanarak, tüm bitki ekstraktlarındaki toplam fenolik madde miktarı, mg gallik asit eşdeğeri (GAE g^{-1}) olarak hesaplanmıştı

2.5. Toplam Flavonoid İçeriği (mg QE g^{-1}): Quercetin stok çözeltisi, 200 mg L^{-1} konsantrasyona hazırlanmış ve bu çözeltiden seyreltme yöntemiyle beş farklı konsantrasyon elde edilmiştir. Bitki ekstraktlarının her birinden 1 ml, aynı miktarda %2'lik $AlCl_3$ çözeltisiyle karıştırılarak oda sıcaklığında 10 dakika bekletilmiştir. Ardından, numunelerin 415 nm'deki absorbansları ölçülmüştür. Aynı prosedür, standart Quercetin için de uygulanmış ve örneklerin

flavonoid içerikleri Quercetin eşdeğeri (mg QE g^{-1}) olarak hesaplanmıştır (Arvouet-Grand ve ark., 1994).

2.6. Radikal Kovucu Aktivite İçeriği (DPPH, %): Serbest radikal süpürme aktiviteleri, 2,2-difenil-1-pikrilhidrazil (DPPH) radikali kullanılarak belirlenmiştir (Gezer ve ark., 2006). DPPH çözeltisi, 4 mg DPPH'in 100 ml metanolde çözündürülmesiyle hazırlanmıştır. Ekstraktlar, ana stok çözeltilerinden farklı konsantrasyonlarda seyreltildi. Her bir örnek için, 3.2 ml DPPH radikali çözeltisi ve farklı konsantrasyonlardaki ekstrakttan 200 µl eklenmiştir. Karışımlar, oda sıcaklığında karanlık ortamda 30 dakika inkübe edildikten sonra, spetofotometre cihazı ile 517 nm'de absorbans ölçümü yapılmıştır. Standart olarak, askorbik asit ve bütillenmiş hidroksi toluen (BHT) kullanılmıştır. Kontrol için, deney tüpüne örnek çözeltisi kadar çözücü ilave edilmiştir. Her bir deneme üç tekerrürlü olarak yapılmıştır. DPPH radikali süpürme yüzdesi aşağıdaki formül ile hesaplanmıştır.

%DPPH radikal süpürücü aktivitesi = [(Akontrol–Aekstrak) / Akontrol] × 100.

2.7. Kondanse Tanen İçeriği (%): 0.01 gr öğütülmüş örnek tartılarak üzerine 6 ml tanen çözeltisi eklenmiş ve karışım bir tüpe konarak vortex ile iyice karıştırılmıştır. Örnekler, kaynar suda 1 saat bekletildikten sonra çıkarılıp 1 saat boyunca 100 °C'de tutulmuş, sonrasında soğutulmuştur. Soğuduktan sonra, 550 nm'de absorbans ölçümü yapılmıştır (Bate-Smith, 1975). Kondanse tanen içeriği, aşağıdaki formül kullanılarak hesaplanmıştır.

Absorbans (550 nm x 156,5 x seyreltme faktörü)/ Kuru ağırlık (%).

2.8. Verilerin Değerlendirilmesi: Elde edilen sonuçlar MSTAT-C paket programı kullanılarak ve tesadüf parseller deneme desenine göre analizine tabi tutulmuş, grup ortalamaları arasındaki farklılıkların karşılaştırılmasında ise Duncan testi kullanılmıştır.

3. BULGULAR VE TARTIŞMA

Tablo 1'de yem şalgamının farklı oranlardaki özütleri ile sulanan soya tohumlarının bazı fenolojik ile kalite özellikleri verilmiştir. İşlemler arasında istatistiksel olarak çimlenme oranı (ÇO), gövde uzunluğu (GU), gövde yaş ağırlığı (GY), gövde kuru ağırlığı (GK) ve asit deterjanda çözünmeyen lif (ADF) bakımından önemli ($p<0.05$), kök uzunluğu (KU), kök yaş ağırlığı (KY), kök kuru ağırlığı (KK) ve nötr deterjanda çözünmeyen lif (NDF) bakımından çok önemli ($p<0.01$) farklılık olmuştur. Çalışmada ham protein oranı (HPO), potasyum (K), fosfor (P), kalsiyum (Ca) magnezyum (Mg), toplam flavonoid (TFL), toplam fenolik (TFN) radikal kovucu aktivite (DPPH) ve kondanse tanen (KT) bakımından ise farklılık olmamıştır (Tablo 1).

Tablo 1. Yemlik börülce tohumlarında belirlenen bazı fenolojik ve kalite özellikleri

Özellikler	%100YŞ	%75YŞ+25S	%50YŞ+50S	%25YŞ+75S	%100S	*Ortalama*
ÇO (%)*	89.99b	96.67a	90.00b	100.00a	100.00a	***95.13***
KU (cm)**	10.61b	8.68c	10.54b	12.63a	10.80b	***10.65***
GU (cm)*	7.75a	7.05ab	5.49c	7.96a	6.36bc	***6.92***
KY (g)**	4.13b	4.05b	2.90c	5.89a	5.96a	***4.59***
KK (g)**	0.63bc	0.60bc	0.58c	0.85a	0.69b	***0.67***
GY (g)*	7.88c	9.09c	9.27c	21.48a	12.41b	***12.03***
GK (g)*	1.09c	1.14c	1.32c	2.26a	1.78b	***1.52***
HPO (%)	33.00	34.89	34.79	35.57	34.97	***34.64***
ADF (%)*	26.03a	26.15a	25.68a	19.98b	22.17ab	***24.00***
NDF (%)**	37.51a	37.24a	36.58a	22.67b	32.49a	***33.30***
K (%)	3.43	3.43	3.37	2.87	2.99	***3.22***
P (%)	0.62	0.62	0.61	0.59	0.57	***0.60***
Ca (%)	1.02	1.02	1.06	1.14	1.14	***1.07***
Mg (%)	0.32	0.31	0.31	0.32	0.30	***0.31***
TFL (mg QE g^{-1})	0.51	1.16	0.86	0.46	0.34	***0.67***
TFN (mg GA g^{-1})	18.22	15.48	16.79	17.86	12.83	***16.24***
DPPH (%)	57.75	56.23	69.30	74.29	53.27	***62.17***
KT (%)	0.97	1.06	1.15	1.14	1.25	***1.11***

**: p<0.01; *: p<0.05: Aynı sütunda aynı harfle gösterilen ortalamalar arasında fark yoktur (p<0.001). YŞ: yem şalgamı; S: Saf su; ÇO: Çimlenme oranı; KU: Kök uzunluğu; GU: Gövde uzunluğu; KY: Kök yaş ağırlığı; KK: Kök kuru ağırlığı; GY: Gövde yaş ağırlığı; GK: Gövde kuru ağırlığı; HPO: Ham protein oranı; ADF: Asit deterjanda çözünmeyen lif oranı; NDF: Nötr deterjanda çözünmeyen lif oranı; K: Potasyum; P: Fosfor; Ca: Kalsiyum; Mg: Magnezyum; TFN: Toplam fenolik; TFL: Toplam flavonoid; DPPH: Radikal kovucu aktivite; KT: Kondanse tanen

En yüksek çimlenme oranı aynı istatistiksel grupta yer alan %100SS (%100), %25YŞ+75SS (%100) ve %75YŞ+25SS (%100) işlemlerinden elde edilmiştir. Yem şalgamı özütünün en yüksek seviyesi yemlik börülce tohumları üzerinde toksik bir etki yaptığı ve çimlenme oranını düşürdüğü görülmüştür. Yem şalgamı ekstraktlarının %75 ve %25 oranlardaki özütleri ise çimlenmeyi teşvik etmiştir. Bu durum farklı seviyelerde yem şalgamı özütünün yemlik börülce üzerinde olumlu allelopatik etki yaptığını göstermektedir. Leblebici ve ark. (2024) yem şalgamı özütlerinin mürdümük tohumları üzerinde allelopatik etkisini belirlemek amacıyla yürüttükleri çalışmada; %25 oranında yem şalgamı özütünün tohumların çimlenmesini teşvik ettiğini tespit etmişlerdir. En uzun kök ve gövde uzunluğu ile kök ve gövde yaş ağırlıkları %25 yem şalgamı ile sulanan işlemlerden elde edilmiştir. Yem şalgamı yüksek miktarda sekonder metabolit içermektedir (Yavuz ve Gülümser, 2022; Leblebici ve ark., 2024). Bu sayede kendinden sonra gelen bitkinin gelişimi üzerinde etkili olabilmektedir.

Tablo 1 incelendiğinde; yem şalgamı özütü ile sulanan soya tohumlarının HPO %33.00-35.57 arasında değişmiştir. En düşük ADF ve NDF %25 yem şalgamı özütü ile sulanan yemlik börülce fidelerinde tespit edilmiştir. En yüksek ADF ve NDF ise aynı istatistiksel diğer

işlemlerde elde edilmiştir. Çalışmada börülce fidelerinin K, P, Ca ve Mg içeriklerinin sırasıyla %2.87-3.43, %0.57-0.62, %1.02-1.14 ve %0.30-0.32 arasında değişmiştir (Tablo 1).

Sekonder matabolitler bitkilerin hayatta kalabilmeleri açısından önem ihtiva etmektedir. Nitekim bitkiler stres koşullarında biyaoktif bileşenler salgılayarak hayatta kalabilmektedirler(Mammadov, 2014). Çalışmada yem şalgamı yaprak özütleri ile sulanan yemlik börülce fidelerinde TFL, TFN, DPPH ve KT içerikleri belirlenmiştir. Tüm özellikler arasında işlemler arasında önemli farklılıklar olmamıştır. Bu durum bitkilerin herhangi bir strese maruz kalmadığının bir göstergesi olabilir, ancak gelişime olumlu katkı sunmadığı da bir gerçektir. Nitekim çimlenme ve bazı fide gelişim parametreleri bunu göstermiştir. Mevcut çalışmada işlemlerin TFL, TFN, DPPH ve KT içerikleri sırasıyla 0.34-1.16 mg QE g^{-1}, 12.83-18.22 mg GA g^{-1}, %53.27-69.30 ve %0.97-1.25 arasında olmuştur (Tablo 1). Gürkan ve ark. (2025) yem şalgamı ekstraktlarının soyanın çimlenme ve fide gelişimi üzerindeki etkilerini inceldikleri çalışmada, %25 yem şalgamı ekstraktının soya üzerinde etkili olduğun belirlemişlerdir. Nitekim yem şalgamı ekstarkatının oranındaki artışlara bağlı olarak soya fidelerinde stres ortaya çıkmış ve sekonder metabolitlerde artış tespit edilmiştir.

SONUÇ

Bu çalışmada, yem şalgamı ekstraktlarının, yemlik börülce tohumlarının çimlenmesi, fide morfolojisi ve fide kalitesi üzerindeki allelopatik etkilerini ortaya koymayı amaçlamıştır. Çalışmadan elde edilen bulgular, yem şalgamı ekstraktlarının konsantrasyona bağlı olarak soya bitkisi üzerinde çift yönlü allelopatik etkiler oluşturduğunu göstermektedir. Gene olrak yüksek düzeylerde uygulanan ekstraktlar çimlenme oranı, kök ve gövde uzunluğu ile genel fide gelişimini olumsuz yönde etkilemiştir. Buna karşılık, daha düşük özellikle de %25 yem şagmı ekstrak uygulanması çimlenme yüzdesi ve fide gelişim parametrelerinde anlamlı bir artışa yol açmış ve olumlu allelopatik özellik sergilemiştir. Bu etkilerin, yem şalgamı yapraklarında doğal olarak bulunan flavonoid ve fenolik bileşikler gibi sekonder metabolitlerin varlığına bağlı olarak geliştiği değerlendirilmektedir. Sonuç olarak, %25 oranındaki yem şalgamı ekstraktının yemlik börülce tohumlarının çimlenmesi ve fide gelişimini destekleyici etkide bulunduğu, bu eşiğin üzerindeki konsantrasyonların ise olumsuz allelopatik etkiler yarattığı belirlenmiştir.

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REDUCTION OF GREENHOUSE GAS EMISSIONS IN FIELD CROPS PRODUCTION SYSTEMS

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ABSTRACT

The increase in the proportions of greenhouse gases such as carbon dioxide and methane in the atmospheric composition is causing an increase in the surface temperatures of our planet and climatic problems. This review addresses the current status of greenhouse gas (GHG) emissions from field crop cropping systems and focuses on key factors affecting greenhouse gas emissions, such as crop type, management practices, and soil conditions. In this context, challenges and opportunities for reducing GHG emissions in field crop cropping systems are assessed. Field crop cultivation accounts for a very large share of crop area, production, and energy use among crop groups worldwide. In this respect, field crops are important carbon dioxide (CO_2) sinks. They also release oxygen through photosynthesis, but also emit significant amounts of methane (CH_4) and nitrous oxide (N_2O) during growth and decomposition. In recent years, with the increasing severity of global warming, there has been an increasing interest and on examining the emission and absorption of GHG and reducing these emissions in field crop production systems to help mitigate the effects of global warming. The greenhouse gas emissions of different cultivation systems and processes vary. Conventional tillage systems release more greenhouse gases such as CO_2 and N_2O than reduced or zero tillage systems. Similarly, rotation, residue management, increasing carbon sequestration and controlling nitrogen fertilizer use can contribute to reducing GHG emissions. As a result, in this study, the contribution and importance of sustainable management practices in agricultural processes based on field crops for reducing greenhouse gas emissions and sustainable use of ecological resources are emphasized.

Keywords: Global warming, greenhouse gases, field crops, agricultural activities.

TARLA BİTKİLERİ ÜRETİM SİSTEMLERİNDE SERA GAZI EMİSYONLARININ AZALTILMASI

ÖZET

Atmosfer bileşiminde karbondioksit ve metan gibi sera gazlarının oranlarının yükselişi gezegenimizin yüzey sıcaklıklarında artışa ve iklimsel sorunlara yol açmaktadır. Bu derlemede, tarla bitkileri ekim sistemlerinden kaynaklanan sera gazı emisyonu (SGE)'na ilişkin mevcut durum ele alınmış ve ürün türü, yönetim uygulamaları ve toprak koşulları gibi SGE'yi etkileyen temel faktörlere odaklanılmıştır. Bu kapsamda tarla bitkileri ekim sistemlerinde SGE azaltılmasına yönelik zorluklar ve fırsatlar değerlendirilmiştir. Tarla bitkileri yetiştiriciliği tüm dünyada ürün grupları arasında ekiliş alanı, üretim ve enerji kullanımı bakımından çok büyük bir paya sahiptir. Bu bakımdan tarla bitikleri önemli karbondioksit (CO_2) yutakları arasındadır. Aynı zamanda fotosentez yoluyla oksijen de salarlar. Ancak büyüme ve ayrışma sırasında önemli miktarda metan (CH_4) ve azot oksit (N_2O) salınımına neden olurlar. Son yıllarda küresel ısınmanın etkilerini hafifletmeye yardımcı olmak için tarla bitkisi üretim sistemlerinde SGE ve emilimini incelemeye ve bu emisyonları azaltmaya yönelik ilgi artmıştır. Farklı yetiştirme sistem ve süreçlerinin SGE değişkenlik göstermektedir. Azaltılmış veya sıfır toprak işleme sistemlerinde, geleneksel toprak işleme sistemlerine göre CO_2 ve N_2O gibi sera gazlarının salınımı daha düşüktür. Benzer şekilde, münavebe, kalıntı yönetimi, karbon bağlamanın artırılması ve kontrolü azotlu gübre kullanımı SGE azaltılmasına katkı sağlayabilir. Sonuç olarak bu çalışmada ekolojik kaynakların sürdürülebilir kullanımı için, tarla bitkileri temelli tarımsal süreçlerde SGE azaltmanın yollarına değinilmiş ve sürdürülebilir yönetim uygulamalarının katkısı ve önemi vurgulanmıştır.

Anahtar Kelimeler: Küresel ısınma, sera gazı, tarla bitkileri, tarımsal faaliyetler.

1. GİRİŞ

Toplumların gelişmesine bağlı olarak artan insan kaynaklı sera gazı emisyonu (SGE) küresel ısınmaya katkıda bulunmuş ve Dünya'nın iklimini önemli ölçüde etkilemiştir (Yuan ve ark., 2024). Bu nedenle, SGE'yi azaltmak küresel ısınmanın etkilerini hafifletmek ve gezegeni korumak için çok önemlidir. Hükümetler Arası İklim Değişikliği Paneli (IPCC) raporlarına göre sanayi devriminden sonra küresel ortalama sıcaklık 1.1 °C artmış, ve bu artışın yüzyılın sonuna kadar 2.6-4.8 °C'yi bulması öngörülmektedir (Hayhoe ve ark., 2017). Yaşanan gelişmeler ve bilimsel tespitler de bu öngörüleri doğrulamakladır. Dünya Meteoroloji Örgütü (WMO) tarafından, 2024'ün 175 yıllık gözlem kayıtlarındaki en sıcak yıl olduğu bildirilmiştir. 2024 yılında ortalama küresel ortalama yüzey sıcaklığı 1850-1900 ortalamasının 1.55 °C ± 0.13 °C üzerinde gerçekleşmiştir. Bir önceki en sıcak yıl ise 1.45 °C ± 0.12 °C' lik bir anomali ile 2023 olarak kaydedilmiştir. Üstelik geçtiğimiz on yılın (2015-2024), kayıtlardaki en sıcak on yıl olduğu bildirilmiştir (WMO, 2025). WMO raporunda ayrıca deniz seviyesindeki uzun vadeli yükselme değerinin, uydu kaydının başlangıcından bu yana iki katından fazla artığı ve buna göre 1993 ile 2002 arasında yılda 2.1 mm iken 2015 ile 2024 arasında yılda 4.7 mm'ye ulaştığı bildirilmektedir. Raporda deniz suyu sıcaklığı ile ilgili veriler de endişe vericidir. Zira rapora göre; 2024 yılı yılında ölçülen okyanus sıcaklığı, 2023 yılına ait önceki rekoru aşarak 65 yıllık gözlemsel kayıtlardaki en yüksek seviyeye ulaşmıştır, üstelik son sekiz yılda her yıl rekor kırarak artmaya devam etmektedir. Ayrıca okyanuslarda son yirmi yılda (2005-2024) gerçekleşen ısınmanın, 1960-2005 döneminde gerçekleşen ısınmanın iki katından fazla olduğu bildirilmektedir.

Tüm bunların oluşmasında, insan faaliyetleri ve bu faaliyetler sonucu oluşan SGE önemli paya sahiptir. Tarım da büyük oranda insan kontrolünde gerçekleşen ve SGE'si yüksek bir sektördür. Tarımsal sistemler ve faaliyetler toplam emisyonun %30'undan (16 milyar ton CO_2 eşd.) sorumludur. Çitlik faaliyetleri ve üretimle ilgili süreçlerin payı ise %14'tür (12 milyar ton CO_2 eşd.). Tarım aynı zamanda arazi bozulmasını da tetikler ve bu bir taraftan emisyona neden olurken diğer taraftan toprakta karbon tutulumunu azaltmaktadır. Zira toprak en önemli karbon yutaklarından biridir. Arazi bozulması aynı zamanda milyarlarca insanın gıda üretim imkanlarını kısıtlamaktadır.

Son yıllarda küresel ısınmanın etkilerini hafifletmeye yardımcı olmak için, tarla bitkileri üretiminde sistemlerinde toplam ve net SGE'yi azaltmaya yönelik ilgi ve çabalar aratmaktadır (Xing ve Wang, 2024). Yüksek emisyon değerlerine rağmen tarım iklim değişiğini yavaşlatmada en önemli ve etkili sektörlerden biri olabilir. Tarla bitkileri üretim sistemlerinin hem karbon bağlama hem de emisyon oluşturma potansiyeli oldukça yüksektir. Bu nedenle olumsuz çevresel etkilerinin belirlenmesi ve bu etkilerin azaltılmasına yönelik yöntem ve sistemlerin değerlendirilmesi faydalı olacaktır. Bu kapsamda yapılacak eylem ve değerlendirmeler iklim değişikliği ile mücadele alanında oldu kadar sürdürülebilir tarım için de elzemdir. Zira tarımsal üretim, özellikle bitkisel üretim hava ve iklimle ilişkilidir ve iklimsel istikrara bağlıdır. İklimde olası bir istikrarsızlık, örneğin yağış rejiminde ve miktarındaki değişim öncelikle tarımı etkileyecektir Tarım, su ihtiyacı çok yüksek olan bir sektördür ve dünyada toplam kullanılabilir suyun % 72 gibi yüksek bir oranını kullanmaktadır (Anonim, 2023). Bu yüzden daha az suyla daha fazla üretime olanak sağlayacak girişimlere, yatırımlara ve iklimsel sorunlara adaptasyonu yüksek tarım sitemlerinin desteklenmesine ihtiyaç vardır.

2. TARLA BİTKİLERİ ÜRETİM SİSTEMLERİ

Tarla bitkileri belirli ekolojik koşullarda gıda ve yem üretimi ve farklı endüstrilerin veya sektörlerin ihtiyaçlarını karşılamak amacıyla tarla ortamında kültürü yapılan bitkilerdir. Tarla bitkileri üretim sistemleri ise yetiştirilecek ürünü ve bu ürününün yetiştiriciliğinde uygulanan toprak işleme, ekim nöbeti, ekim, gübreleme, sulama, yabancı ot mücadelesi, hasat ve harman gibi direk veya dolaylı konuları içerir. Tarla bitkileri temelde tahıllar, yemeklik baklagiller, endüstri bitkileri ve yem bitkileri olarak dört ana grupta toplanan çok geniş bir ürün grubuna sahiptir. Tarla bitkileri tüm dünyada ekim alanı ve üretim bakımından bitkisel üretimin en büyük kolunu teşkil eder. Türkiye'de tarla bitkileri 16.8 milyon ekim alanı ve 75.5 milyon ton üretim miktarına sahiptir. Türkiye'de toplam tarım arazisi 38.62 milyon ha kadardır ve bu alanın % 43.5'i, her yıl işlenmen alanların ise %70'i tarla bitkilerinden oluşmaktadır (Anonim, 2024a). Bu ölçek aynı zamanda tarla bitkileri üretim süreçlerinde oluşan SGE potansiyeline de işaret etmektedir. Üstelik tarla bitkileri sebze meyve ve mera alanlarıyla kıyaslandığında toprak işlemenin çok daha yoğun yapıldığı ve ilaçlama, hasat ve harman gibi süreçlerde çok daha fazla enerjiye ihtilaç duyulan bir alandır.

Teknoloji ve mekanizasyon alanında ki gelişmelerin sonucunda tarla bitkileri üretiminde her geçen yıl insan gücüne bağımlık azalmakta makina kullanımı artmaktadır. Yine son yıllarda ilim değişikliğinin de etkisiyle hastalık ve zararlılarla mücadele kapsamında yürütülen faaliyetlerde ve sulama işlemlerinde artışlar yaşanmaktadır. Tüm bu süreçler daha verimli bir üretim için gerekli görülse de daha fazla SGE ve kimyasal kirliliğe neden olabilir. Dolayısıyla tarla bitkileri üretim sistemlerinin çevresel boyutunun incelenmesi ve kontrol edilmesi doğal kaynaklar üzerindeki potansiyel olumsuz etkilerinin azaltılması için gereklidir.

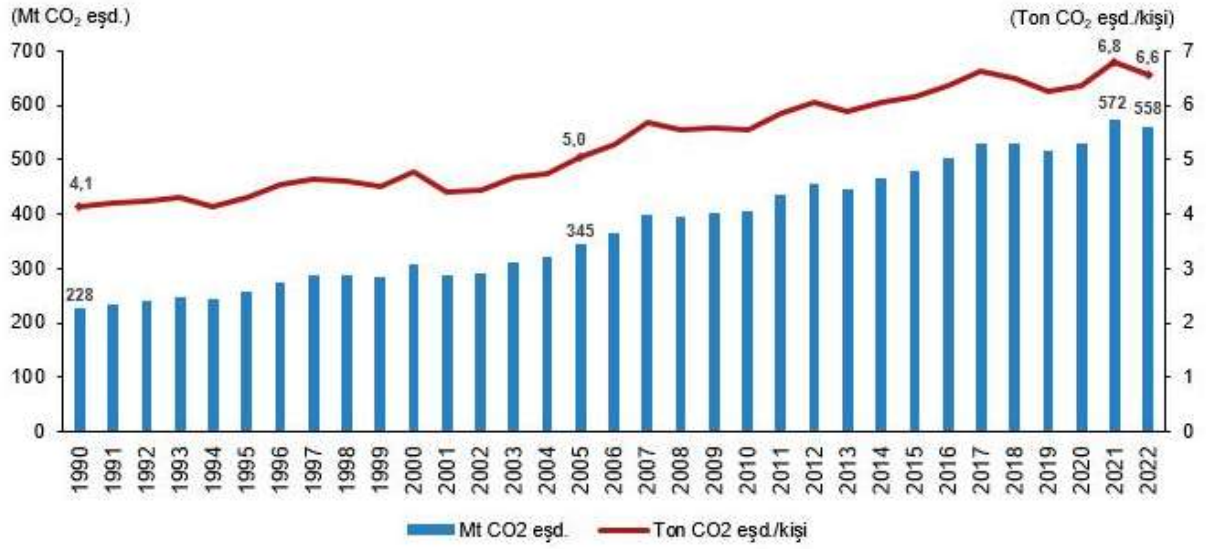
3. TARLA BİTKİLERİ ÜRETİM SİSTEMLERİNİN SERA GAZI EMİSYONLARI

2022 yılı sera gazı envanteri sonuçlarına göre, Türkiye'de toplam SGE 558.3 milyon ton (Mt) CO_2 eşd., kişi başı SGE ise 6.6 ton CO_2 eşd. olarak hesaplanmıştır (Şekil 1). Toplam SGE içinde en büyük payı %71.8 (700.6 Mt CO_2 eşd.) ile enerji kaynaklı emisyonlar alırken bunu sırasıyla %12.8 (71.5 Mt CO_2 eşd.) ile tarım, %12.5 (69.9 Mt CO_2 eşd.) ile endüstriyel işlemler ve ürün kullanımı ve %2.9 (16.3 Mt CO_2 eşd.) ile atık sektörü takip etmektedir (Şekil 2). Tarım sektörü kaynaklı emisyonlar 2022 yılında, 1990 yılına göre %37.9 artış göstermiştir. (Anonim, 2024b).

Küresel ısınmanın sonuçlarının giderek belirgin hale gelmesi ve tarımın SGE'de ki önemli katkısı, sürdürülebilir tarımsal üretim ve kalkınma için endişeye neden olmaktadır. Tarla bitkileri üretimi üretim ve hasat sonrası süreçlerde neden olduğu SGE ile çok yönlü ve büyük ölçekli etkilere sahiptir. Tarımsal faaliyetler en önemli sera gazları olan CO_2 , CH_4 ve N_2O ve bunun yanında su buharı ve kloroflorokarbonların (CFCs) salınımında etkilidir (Snyder ve ark., 2009). Bu gazların birikmesi, Dünya'nın yüzey sıcaklığında artışa ve böylece küresel ısınmaya yol açar. Karbondioksit en önemli sera gazıdır ve büyük oranda fosil yakıtların yanması ve ormansızlaşmadan kaynaklanır (Nunes, 2023). CH_4 ve N_2O ile kıyaslandığında, CO_2 büyük oranda tarımsal süreçlerde tekrar döngüye girer. Bitkiler fotosentez yoluyla büyük miktarda CO_2 bağlarlar ve tarım toprakları içerdikleri organik materyal ve canlılarla önemli bir karbon yutağıdır. Ancak kullanım ve çürüme nedeniyle bağlanan miktar tekrar salınır. Bu döngü sebebiyle bitkisel üretimde net CO_2 salınımı düşüktür. Net salınımının sebebi ise genellikle

işleme ve nakliye süreçlerinde kullanılan enerjidir (Kayıkçıoğlu ve Okur, 2012). IPCC'ye göre, metan başlıca hayvancılık ve pirinç tarlası emisyonlarından kaynaklanır ve üstelik küresel ısınma potansiyeli açısından karbondioksitten 28 kat daha güçlüdür (Thakur ve Solanaki, 2022). N_2O emisyonu başlıca gübre ve endüstriyel atıklardan kaynaklanır ve benzer şekilde karbondioksitten daha güçlü bir sera etkisine sahiptir. Sentetik kimyasallardan kaynaklanan CFCs, ise en güçlü sera gazları arasında kabul edilmektedir (Walling ve Vaneeckhaute, 2020; Xing ve Wang, 2024).

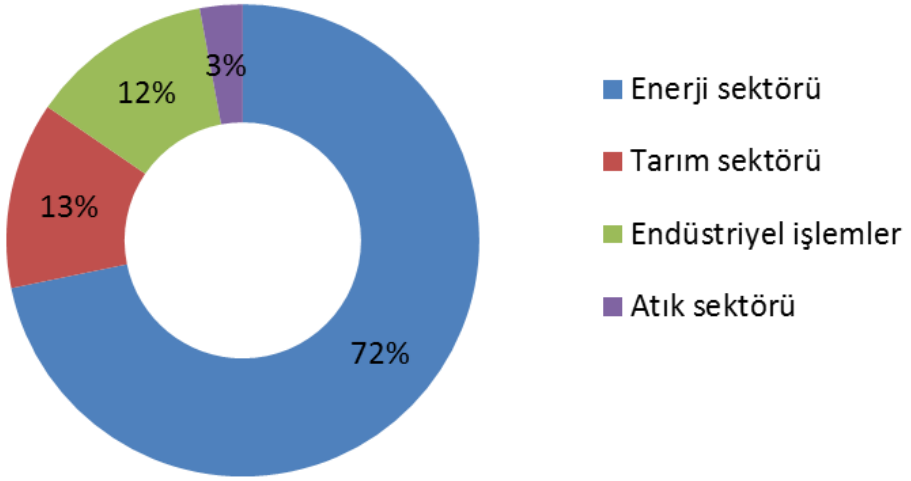
Tarla bitkileri üretim sistemlerinde oluşan sera gazlarının incelenmesi, tarımsal faaliyetlere bağlı SGE'yi azaltmak için stratejiler belirlemek açısından kritik öneme sahiptir. Ekim sistemlerinin SGE'si yetiştirilen ürün türlerine, gübre ve pestisit kullanımı, toprak ve su kaynaklarıyla ilgili yönetim uygulamaları dahil olmak üzere çeşitli faktörlere bağlı olarak değişir (Xing ve Wang, 2024). Bu kapsamda farklı üretim süreçlerinin, meydana gelen emisyon ve genel çevresel etki bakımından karşılaştırılarak incelemesi önemlidir. Geleneksel üretimde, verimi en üst düzeye çıkarmak için sentetik gübrelerin, pestisitlerin kullanılması ve mono kültür yetiştiriciliğin hakim olması toprakta fiziksel ve kimyasal bozulmaya zemin oluştururken (Altıeri ve ark., 2017), organik sistemlerde uygulanan ekim nöbeti, karışık ekim, ve örtü bitkisi gibi uygulamalar toprak verimliliğini artırmak, hastalık ve zararlıları baskılamak ve erozyonu azaltmak gibi sürdürülebilirlik için önemli katkılar sağlar (Durham ve Mizik 2021).



Şekil 1. Türkiye'nin toplam ve kişi başı sera gazı emisyonu, 1990-2022 (Anonim, 2024b).

Tarla bitkileri üretim sistemlerinde oluşan SGE'de topraktaki mikrobiyal aktivitelerin ve bitkilerin metabolik süreçlerinin rolü büyüktür. Sera gazları hem bitki büyümesi hem de ayrışma sırasında üretilir. Toprak mikroorganizmaları organik maddeleri ayrıştırarak metan ve azot oksit üretirken, karbondioksit redoks reaksiyonları yoluyla salınır (Zheng ve ark., 2024). Toprakta bulunan bakteriler ve mantarlar mikrobiyal aktiviteyi önemli ölçüde etkiler. Bakteriler

öncelikle organik maddeyi ayrıştırarak CO_2 açığa çıkartırken, mantarlar daha dirençli organik maddeleri ayrıştırarak metan salınımına neden olurlar (Ren ve ark., 2020). Ayrıca tarımda gübreleme emisyonlara önemli ölçüde katkıda bulunur, çünkü kimyasal gübrelerin aşırı kullanımı, ekosistem hasarına ve N_2O emisyonlarını teşvik eden yüksek azot kalıntısına yol açabilir (Bai ve ark., 2023). Bu nedenle, tarla bitkisi sistemlerinde SGE'nin azaltılması için, bitki yetiştirmede ki tüm süreçlerin gözden geçirilmesi ve tarla yönetimi uygulamalarının optimizasyonu acil bir ihtiyaçtır. Bunun yanında, tarla bitkisi sistemlerinin sürdürülebilir gelişimi için küresel ısınmayla mücadelede daha etkili çözümler sağlayacak sistematik bilimsel araştırma ve teknolojik yeniliklerin devamlılığı da kritik önemdedir (Xing ve Wang, 2024).



Şekil 2. Türkiye'de 2022 yılında sektörlerin toplam SGE'de ki payları (Anonim, 2024b).

Tarla bitkisi sistemlerinde, ürünler arasında SGE bakımından belirgin farklılıklar vardır. Tahıl ürünleri tarımsal üretimde önemli bir rol oynar ve SGE üzerinde önemli bir etkiye sahiptir (Shah ve ark., 2024). Örneğin pirinç ve buğdayın emisyon değerleri göz önüne alındığında, ürün seçiminin SGE'yi azaltmada önemli bir rol oynadığı açıktır. Nitekim pirinç ve buğdayın SGE'si farklılıklar gösterir. Genellikle nemli ortamlarda yetiştirilen pirinç, yüksek sulama ve gübreleme ihtiyacıyla toprakta daha fazla CH_4 üretimine neden olur. Bu nedenle pirinç tarlaların SGE spektrumunda CH_4 emisyonunu açısından önemli bir kaynaktır Buna karşılık, çoğunlukla kurak alanlarda yetiştirilen buğdayın, pirince oranla CH_4 salınımına katkısı çok düşüktür. Ancak buğday büyüme döngüsü sırasında daha yüksek N_2O emisyonları üretebilir (Ghimire ve ark., 2016; Maraseni ve ark., 2018).

4. TARLA TARIMI SİSTEMLERİNDE SERA GAZI EMİSYONLARININ AZALTILMASI

Tarım kaynaklı emisyonların büyük bir çoğunluğunun yanlış veya hatalı uygulamalardan kaynakladığı, bu itibarla büyük oranda azaltılmasının mümkün olduğu temel hareket noktası olmalıdır. Tarla tarımı sistemlerinde SGE'yi azaltmak için en önemli strateji, mevcut koşullarda en uygun üretim sistemlerini ve materyallerini kullanmak ve agronomik süreçleri iyi şekilde yönetmekten geçmemektedir. İkim değişikliği ile mücadele tüm bu alanlarda dinamik ve

kendini yenileyen mekanizmaları gerekli kılmaktadır. Bu kapsamda değişen koşullarda daha etkin ve verimli üretim için yeni çeşitlerin denemesi, ekim zamanlarının değiştirilmesi, mevcut üretim desenlerinde ve ekim nöbeti sistemlerinde değişikliğe gidilerek su tüketimi ve girdi ihtiyaçları daha düşük ürünlerin tercih edilmesi öncelikle başvurulabilecek yöntemlerdir. Bununla birlikte iklim değişikliği ile mücadele süreçlerinde tarla tarımı sistemlerinde kimyasal kullanımını azaltıcı organik uygulamaların sisteme dahil edilmesi, ıslahta yeni yaklaşımların benimsenmesi, toprak ve su korumaya yönelik tarımsal uygulamaların ve yetiştiricilik sistemlerinin uygulanması, verimli sulama sistemleri ve hassas tarım teknolojilerinin yaygınlaştırılması, sorunların ve çözümlerin olabildiğince lokal düzeyde ele alınması, yerel genotiplerin ve uygulamaların korunması ve sürecin genelini dikkate alan entegre çözümlerin benimsenmesi önemli bir potansiyele sahiptir. Tüm bu süreçte finansal desteklemeler, eğitim faaliyetleri, sosyal destekler, teknolojik gelişmeler ve bilimsel çalışmalar başarı için belirleyici rollere sahiptir.

Emisyon azaltma önlemlerinin genel etkisini değerlendirirken, farklı stratejilerin SGE'yi nasıl etkilediğini dikkate almak önemlidir. Ürünlerle ilgili bilinçli seçimler yaparak ve bilimsel gübreleme ve tasarruflu sulama uygulamaları ile, tahıl ürünlerinden kaynaklanan SGE etkili bir şekilde azaltılabilir ve böylece hem tarımsal üretkenliğe hem de çevre korumaya katkıda bulunulabilir. Bitkilerin büyümeleri sırasında yayılan sera gazı miktarı, ekim ve yönetim aşamaları boyunca farklı bitki türleri arasında değişir (Qian ve ark., 2023). Bu farklılık analiz edilerek, sahada her bitki SGE'yi etkili bir şekilde azaltmaya yönelik üretim senaryoları ve yönetim stratejileri, geliştirilebilir (Tian ve ark., 2023). Ayrıca bu alandaki tespit ve çalışmaklar hükümetlerin ve ilgili kurumların tarımsal emisyon azaltma çabalarını teşvik ederek bu konuda politikalar belirlemeleri için bilimsel kanıtlar da sağlayabilir. Bilimsel esaslara dayalı politikalar çiftçileri emisyon azaltma önlemlerini benimsemeye yönlendirilebilir. Nihayetinde tarla bitkisi sistemlerindeki SGE araştırılması, çevrenin korunmasına ve sürdürülebilir tarımsal uygulamaların geliştirilmesine destek olabilir.

Toplam SGE'nin azaltılması açısından tarla bitkisi üretim sistemlerinde, karbon bağlamanın ve yutaklarının geliştirilmesi önemlidir. Bu da genel anlamda üretim sürecinde enerji kullanımını veya fosil yakıtlara bağımlılığı azaltarak, toprağın organik madde içeriğini artırarak, mikrobiyal aktivitesini teşvik ederek, agregat stabilitesini iyileştirerek ve toprağı erozyona karşı daha dayanıklı hale getirerek ve elbette ürün verimini de artırarak elde edilebilir. Bunun yanında, tarım alanlarında azot döngüsünü teşvik edici uygulamalar, azotlu gübre kullanımının ve N_2O emisyonlarının azaltılması açısından önemlidir (Guenet ve ark., 2021). Azot kullanımı ve sistemleri optimize edilerek, organik ve biyolojik gübreler kullanarak, ve azot kullanımını iyileştirerek toprakta azot kaybı dolayısıyla da N_2O emisyonları düşürülebilir (Pan ve ark., 2022).

Bu kapsamda etkili olabilecek bir diğer yöntem de organik gübrelerin uygulanmasıdır. Yavaş salınımlı, uzun süreli etkileri ve toprak iyileştirme özellikleriyle organik gübreler, toprak verimliliğini artırır, toprak kalitesini iyileştirir, aşırı azot ve fosfor gübre kullanımını azaltır ve azot oksit ve metan emisyonlarını düşürür (Bryan ve ark., 2013). Organik gübrelerin kullanımı ayrıca toprak mikroorganizmalarının büyümesini ve aktivitesini teşvik ederek azot döngüsüne ve organik maddenin ayrışmasına yardımcı olur (Kangogo ve ark., 2021).

Gübreleme yönetimi, SGE'yi azaltırken aynı zamanda ürün verimini ve kalitesini artırdığı için tarla bitkisi sistemlerinin kritik bir yönüdür. Gübreleme yönetimini optimize etmede ilk dikkate alınması gereken husus, toprağın besin durumunun belirlenmesi olmalıdır. Toprak testi, toprağın besin içeriğini değerlendirmek ve uygun gübrelerin ve uygulama şekillerinin belirlenmesinde değerli bir araçtır. Bilimsel gübreleme uygulamalarını ürünle ve büyüme aşamalarının özel ihtiyaçlarıyla uyumlu hale getirerek, besin israfı ve N_2O emisyonu en aza indirilebilir. Organik gübreler, biyogübreler ve yeşil gübreleme yöntemlerinin kullanılması, kimyasal gübrelerin çevresel etkisini hafifletmeye, toprak verimliliğini iyileştirmeye ve SGE'yi daha da azaltmaya yardımcı olabilir. Ek olarak, gübrelemenin zamanlaması ve sıklığı gübreleme yönetimini optimize etmede çok önemlidir. Ürün büyüme gereksinimlerine ve mevsimsel özelliklere dayalı uygun zamanlamaya ve sıklığa uymak, gübre kullanım verimliliğini artırabilir ve emilmeyen besinlerin çevreye kaybını azaltabilir ve sonuçta gaz emisyonlarında bir azalmaya yol açabilir (Xing ve Wang, 2024).

Makul gübre uygulamaları ile birlikte, ekim nöbeti ve uygun ürünlerin ekimi CH_4 ve N_2O emisyonlarını etkili bir şekilde azaltabilir ve çevresel etkiyi hafifletebilir. Ekim nöbeti toprak dokusunu iyileştirmek, organik madde içeriğini artırmak, böylece gübre ihtiyacını ve azot salınımını azaltmak gibi faydalı sonuçlar içerir. Araştırmalar, ekim nöbetinin toprak organik madde içeriğini ve mikroorganizma aktivitesini önemli ölçüde artırdığını, toprak yapısını iyileştirdiğini, amonyağın gaz halde uçmasını engellediğini, SGE'yi azalttığını ve böylece tarım arazilerinde kirliliğinin azaltılmasına ve çevrenin korunmasına katkıda bulunduğunu göstermiştir (Ozor ve Nnaji, 2011; Fosu-Mensah ve ark., 2012).

Karışık ekim gibi uygulamalar da toplam karbon bağlama potansiyelini arttırır, toprak yapısını ve verimliliğini iyileştirir, toprak bozulmasını yavaşlatır, CH_4 ve N_2O emisyonlarını azaltır (Martin ve ark., 20214). Karışık ekim, aynı araziye aynı anda iki veya daha fazla ürün ekerek verimliliğini artırmayı hedefler ve bu aynı zamanda ve gübrelerin salınımını yavaşlatmaya yardımcı olur. Karışık ekim ayrıca zararlıların ve hastalıkları baskılayarak pestisitlere olan ihtiyacın azalmasına ve tarımsal faaliyetlerin daha düşük çevresel etkiye sahip olmasına yol açar. Bu itibarla hem münavebe hem de karışık ekim arazi kullanım verimliliğinin arttırılması, gübre kullanımının ve SGE'nin azaltılması açısından oldukça etkili olabilecek uygulamalardır.

Tarla tarımında en yüksek emisyon kaynaklarından biride toprak işleme aşmasıdır. Toprak işlemenin düzenlenmesi ve azaltılması enerji ihtiyacını düşürerek ve beraberinde toprak üzerindeki olumlu etkileri nedeniyle SGE'nin azaltılmasında önemli bir yere sahiptir. Azaltılmış veya sıfır toprak işleme gibi koruma amaçlı sistemler, enerji kullanımını, gübre ve pestisit kullanımını azaltır, toprak işleme sıklığını azaltır ve toprak ekosistemlerinin bütünlüğünü ve istikrarını korur. Hasat atıklarının geri dönüşümü, karışık ekim ve organik gübrelerin uygulanması, emisyonları etkili bir şekilde azaltabilir (Srivastava ve ark., 2026). Tarımsal atıkların geri dönüşümü toprağın organik madde içeriğini artırır, su ve besin tutma kapasitesini geliştirir ve kimyasal gübrelere olan ihtiyacı azaltır (Moniruzzaman, 2025) ve ayrıca toprak mikroorganizmalarının büyümesini teşvik ederek toprak ekosisteminin restorasyonuna ve sağlığına katkıda bulunur.

Tarla bitkileri üretiminde emisyon azaltıcı sitemlerin geliştirilmesi ve uygulanması aşamalarında maliyet-fayda analizinin yapılması önemlidir. Emisyon azaltıcı önlemlerin

rasyonalitesi ve uygulanabilirliği açısından ulaşılmak istenen hedefle azaltma için gerekli ekipman yatırımı, işletme, bakım ve enerji tüketim masraflarının kıyaslanması kritik önemdedir (Yang ve ark., 2020). Uygulanan önlemlerin faydaları azaltılan sera gazı miktarıyla ölçülür. Bu bağlamda, kimyasal gübrelerin yerine biyogübrelerin kullanılması belirli üretim ve nakliye maliyetlerini artırabilir, ancak toprak azot emisyonlarında uzun vadeli azalmalara yol açarak SGE'yi düşürür (Stephan ve Stephan, 2016).

Tarla bitkileri sisteminde emisyon azaltma önlemlerinin çevresel ve sosyal etkilerini değerlendirirken, çok çeşitli etkilerin dikkate alınması esastır. Tarla bitkileri sisteminde azaltma önlemlerinin uygulanması, hava kirletici emisyonlarında bir azalmaya da yol açabilir, böylece hava kalitesini iyileştirebilir ve hem insanlara hem de diğer organizmalara verilen zararı en aza indirebilir (Ruiz-García ve ark., 2021). Tarla bitkileri sisteminde emisyon azaltma önlemlerinin çevresel ve sosyal etkileri, yalnızca SGE ile ilişkili çevresel riskleri azaltmayı değil, aynı zamanda sosyo-ekonomik gelişmeyi ve sürdürülebilir kalkınmayı teşvik etmeyi de içerir. Sosyal etkiler, azaltma stratejilerinin değerlendirilmesinde eşit derecede önemlidir. SGE'yi düşürmek, toplum için genel çevre kalitesini iyileştirebilir, doğal afetlerin sosyal ilerleme üzerindeki potansiyel etkisini azaltabilir, yeşil bir ekonominin büyümesini teşvik edebilir, iş fırsatları yaratabilir ve sakinlerin yaşam kalitesini artırabilir. Dahası, azaltma önlemlerinin benimsenmesi sürdürülebilir tarım uygulamalarını destekleyebilir, tarımsal üretkenliği artırabilir, çiftçilerin gelirlerini artırabilir ve sürdürülebilir kırsal kalkınmaya katkıda bulunabilir. Bu nedenle, gelecekte tarımsal üretimde çevre ve toplum için de faydalar sağlayan yeşil, düşük karbonlu üretim modeli oluşturmak için araştırmalara, azaltma önlemlerinin güçlendirilmesi ve yaygınlaştırılmasına odaklanılmalıdır.

5. SONUÇ

Tarım ve özellikle tarla tarımı sistemleri direk iklim ve hava olaylarına bağlıdır. Bu nedenle iklim değişikliğinin olası etkilerinden ilk ve en fazla etkilenecek sektör hiç şüphesiz tarımdır. Ancak ilginç bir şekilde tarım, iklim değişikliğine neden olan uygulamalar ve sistemleri de içirmektedir. Diğer taraftan tarım önemli bir karbon yutak kaynağıdır. Bu itibarla tarım, iklim değişikliği konusunda hem sorunun hem de çözümün önemli bir parçasıdır. Tarla tarımını sistemleri gerek emisyon kaynağı, gerekse iklim değişikliği ile mücadele alanında çok kritik konumdadır. Zira ölçeği nedeni ile hem olumsuz hem de olumlu etkilerinin boyutu oldukça yüksektir. Tarımsal faaliyetler içerisinde tarla tarımı sistemleri geniş ekim alanı, yüksek miktarda gübre, ilaç ve enerjinin kullanımına sahiptir. Sonuç olarak tarla tarımı üretim sistemlerinde mevcut uygulamaların gözden geçilmesi çevre etki değerlerinin analiz edilmesi ve sara gazı emisyonlarını azaltıcı yeni yaklaşımların ve uygulamaların geliştirilmesi ikim değişikliği ile mücadele, sürdürülebilir tarımsal üretim ve gıda arz güvenliği açısından önemli faydalar sağlayacaktır.

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EFFECTS OF DIFFERENT NITROGEN DOSES ON YIELD AND QUALITY CHARACTERISTICS OF SAGE (*Salvia officinalis* L.) UNDER THE ECOLOGICAL CONDITIONS OF ESKİŞEHİR

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ABSTRACT

This study was conducted in 2023 to determine the effects of different nitrogen doses on the yield and quality characteristics of sage (*Salvia officinalis* L.) under the ecological conditions of Eskişehir. The field experiment was carried out using a randomized complete block design with three replications, applying five different nitrogen doses (0, 5, 10, 15, and 20 kg N/da). Plant height, fresh herb yield, fresh leaf yield, dry leaf yield, essential oil content, and essential oil yield were examined in the study. The findings showed that increasing nitrogen doses significantly enhanced plant height, fresh herb yield, fresh leaf yield, and dry leaf yield. The highest plant height (38.50 cm) and fresh herb yield (736.62 kg/da) were obtained from the 20 kg/da nitrogen dose, while the highest fresh leaf yield (527.93 kg/da) and dry leaf yield (165.30 kg/da) were observed at the 15 kg/da nitrogen dose. The highest essential oil content (2.68%) was recorded at the 0 kg/da nitrogen dose. When the essential oil yield values were examined, the highest value (4.18 L/da) was determined at the 15 kg/da nitrogen dose. When the results obtained from the study were evaluated, it was seen that 15 kg N/da nitrogen application could be recommended to obtain the highest dry leaf and essential oil yield.

Keywords: *Salvia officinalis,* fertilizer, nitrogen, essential oil, yield

FARKLI AZOT DOZLARININ ESKİŞEHİR EKOLOJİK KOŞULLARINDA TIBBİ ADAÇAYI (*Salvia officinalis* L.)' BİTKİSİNİN VERİM VE KALİTE ÖZELLİKLERİ ÜZERİNE ETKİLERİ

ÖZET

Bu çalışma, farklı azot dozlarının Eskişehir ekolojik koşullarında tıbbi adaçayı (*Salvia officinalis* L.) bitkisinin verim ve kalite özellikleri üzerine etkilerini belirlemek amacıyla 2023 yılında yürütülmüştür. Tarla denemesi 5 farklı azot dozu (0, 5, 10, 15 ve 20 kg N/da) kullanılarak tesadüf blokları deneme desenine göre üç tekerrürlü olarak yürütülmüştür. Denemede bitki boyu, yaş herba verimi, yaş yaprak verimi, kuru yaprak verimi, uçucu yağ oranı ve uçucu yağ verimi incelenmiştir. Elde edilen bulgulara göre, azot dozlarının artışıyla birlikte bitki boyu, taze herba verimi, taze yaprak verimi ve kuru yaprak verimi önemli ölçüde artmıştır. En yüksek bitki boyu (38.50 cm) ve taze herba verimi (736.62 kg/da) 20 kg/da azot dozundan elde edilirken, en yüksek taze yaprak verimi (527.93 kg/da) ve kuru yaprak verimi (165.30 kg/da) 15 kg/da azot dozunda gözlemlenmiştir. En yüksek uçucu yağ oranı (%2.68) 0 kg/da azot dozunda belirlenmiştir. Uçucu yağ verimi değerleri incelendiğinde ise en yüksek değer (4.18 L/da) 15 kg/da azot dozunda tespit edilmiştir. Çalışmadan elde edilen sonuçlar değerlendirildiğinde en yüksek kuru yaprak ve uçucu yağ verimi elde etmek için 15 kg N/da azot uygulamasının önerilebileceği görülmüştür.

Anahtar Kelimeler: *Salvia officinalis*, gübre, azot, uçucu yağ, verim

1. GİRİŞ

Tüm dünyada giderek artan beslenme ve sağlıklı yaşam ilişkisi konusundaki farkındalığa paralel olarak tıbbi aromatik bitkilere olan talep de artış göstermiş ve göstermeye de devam etmektedir. Artan taleple birlikte tüm dünyada tıbbi aromatik bitkilerin ticaret hacminde de artış gözlenmektedir. Adaçayı yaprağı ve uçucu yağı ülkemizin önemli dış satım ürünlerinden biridir. Ülkemizde iç ve dış ticarete konu olan adaçaylarından *Salvia tomentosa* Mill. ve *Salvia fruticosa* Mill. doğal floramızda bulunmakta olup, çoğunlukla doğal floradan toplanarak ticarete sunulurken, doğal floramızda bulunmayan *Salvia officinalis* türü tarla koşullarında üretilerek ticarete sunulmaktadır (Bayraktar ve ark., 2017; Elmas, 2021).

Tıbbi adaçayının (*Salvia officinalis*) mensup olduğu Lamiaceae familyası yaklaşık 245 cins ve 7886 türe sahiptir. Lamiaceae familyasına ait türler soğuk kutup bölgeleri hariç dünyanın hemen hemen her tarafında yayılış göstermektedir. Lamiaceae familyasının (Scutellaria 360 tür, Stachys 300 tür, Plectranthus 300 tür, Hyptis 280 tür, Thymus 220 tür ve Nepeta 200 tür) en büyük cinsi olan *Salvia*, 900'ün üzerindeki tür ve 11 alt türe sahip olduğu tespit edilmiştir (Wu et all, 2020; Abdelhalima and Hanrahan, 2021). Tıbbi adaçayı (*Salvia officinalis*) türü, *Salvia officinalis* spp. *lavandulifolia* Gams, *Salvia officinalis* spp. *minor* Gams ve *Salvia officinalis* spp. *major* Gams olmak üzere üç alt türe sahiptir (Ceylan, 1996). *Salvia officinalis* L. bitkisi uzun yıllardır değişik hastalıkların tedavisinde ve enfeksiyonların önlenmesinde kendisinden faydalanılan çok yıllık bir tıbbi aromatik bitkidir. Ayrıca bitki gıda, kozmetik ve farmasötik endüstrisinde de değişik şekillerde kullanılmaktadır. *Salvia officinalis* bitkisinin yapraklarından ekstrakte edilen uçucu yağ, güçlü ve çok yönlü kullanımı olan doğal bir sekonder metabolittir (Bonesi et al., 2017, Jakovljević ve ark., 2019; Özçoban ve Gedikoğlu, 2024). Yapılan birçok çalışma uçucu yağ oranlarının ve kompozisyonunun üretimin bölgenin iklim ve toprak koşullarının yanı sıra agro-teknik uygulamalara ve kullanılan ekstraksiyon teknolojisine bağlı olarak değiştiğini göstermiştir (Gedikoğlu ve ark., 2019; Özçoban ve Gedikoğlu, 2024). *Salvia officinalis* bitkisinde uçucu yağ oranı %1.0-2.5 arasında değişmekte ve uçucu yağın ana bileşenleri dikkate alındığında tıbbi adaçayı bitkilerinin çoğunluğu thujone grubunda yer almaktadır (Başer, 2002; Topçu, 2006; Başyiğit ve Baydar, 2017; Katar ve ark., 2018; Elmas, 2021).

Son yıllarda artan adaçayı iç ve dış talebi dikkate alındığında, talep edilen miktar ve kalitede sürekli ürün temin edebilmek için adaçayının yetiştiriciliğinin yapılması büyük önem taşımaktadır. Bu nedenle adaçayı yetiştiriciliğinde verim ve kalite üzerinde etkili olan iklim ve toprak istekleri ile birlikte en uygun üretim tekniklerinin belirlenmesini konu edinen çalışmalar oldukça büyük önem taşımaktadır. Ürünün verim ve kalitesi üzerinde etkili olan en önemli agro-teknik uygulamalardan biri de azotlu gübre uygulamasıdır (Madandoust and Mahmood Fooladchang, 2018). Azotlu gübrelerin miktarı ve uygulama yöntemleri verim ve kalite üzerinde etkili olduğu gibi ekolojik sistem üzerindeki etkisi ile birlikte ürünün maliyeti üzerinde de oldukça önemli bir etkiye sahiptir (Elmas, 2021).

Bu çalışmanın amacı Eskişehir ekolojik koşullarında farklı azot dozlarının tıbbi adaçayı (*Salvia officinalis*) bitkisinin verim ve kalitesi üzerindeki etkisini belirlemektir.

2. MATERYAL VE METOD

Araştırmada bitki materyali olarak Atatürk Bahçe Kültürleri Merkez Araştırma Enstitüsü Müdürlüğü'nden temin edilen tohumlardan Eskişehir Orman Fidanlık Müdürlüğünün seralarında üretilen Tıbbi adaçayı bitkisinin fideleri kullanılmıştır.

Çalışmanın yürütüldüğü Eskişehir İlinin uzun yıllar ve 2023 yılına ait aylar itibariyle yağış ve sıcaklık değerleri Çizelge 1'de verilmiştir. Çizelge 1 incelendiğinde denemenin yürütüldüğü 2023 yılında uzun yılların 22.7 mm üzerinde bir yağış aldığı görülmektedir.

Uzun yıllara ait yıllık ortalama sıcaklıkları ile çalışmanın yürütüldüğü 2023 yılına ait ortalama sıcaklıklar ise hemen hemen birbirine yakın olup, uzun yılların ortalama sıcaklığı 10.9 °C iken, 2023 yılında ise 11.1 °C olarak tespit edilmiştir. Aynı şekilde aylık ortalama sıcaklıklar bakımından da uzun yıllara ait değerler ile 2023 yılına ait değerlerin birbirlerine yakın olduğu Çizelge 1'de görülmektedir.

Çizelge 1. Eskişehir İlinin Deneme Yılına ve Uzun Yıllara Ait İklim Verileri*

AYLAR	Ortalama sıcaklık (°C)		Aylık toplam yağış miktarı (mm)	
	Uzun yıllar	**2023**	**Uzun yıllar**	**2023**
Ocak	0.2	0.1	30.6	33.2
Şubat	1.4	1.7	26.1	27.5
Mart	5.1	5.3	27.6	33.3
Nisan	9.9	10.0	43.1	43.5
Mayıs	15.0	14.9	40.0	41.5
Haziran	19.2	18.9	23.7	28.4
Temmuz	22.2	22.0	13.1	14.4
Ağustos	22.0	22.1	9.2	11.2
Eylül	17.3	17.6	18.1	18.1
Ekim	11.8	12.2	32.8	33.7
Kasım	5.6	6.1	34.0	35.6
Aralık	1.6	2.0	40.5	41.3
Toplam/Ortalama	10.9	11.1	338.8	361.5

* * Eskişehir Meteoroloji Genel Müdürlüğü Verileri

Denemenin yürütüldüğü tarlaya ait toprağın özelliklerini belirlemek amacıyla alınan örnekler Orman Toprak ve Ekoloji Araştırma Enstitüsü Müdürlüğü Toprak Analiz Laboratuvarı'nda analiz edilmiş olup, toprak özelliklerini gösteren değerler çizelge 2'de verilmiştir. Çizelge 2'de görüldüğü gibi deneme tarlasının toprak pH'sı 7.6 olup, hafif alkali bir toprak özelliği göstermektedir. % 1.7 organik madde içeren toprağımız organik madde bakımından fakir bir topraktır. Yararlanılabilir potasyum ve fosfor düzeyleri sırasıyla 240 kg/da ve 4 kg/da'dır. Kireç oranı ise % 8.46 olarak belirlenmiştir. Toprağın tuz içeriği ise % 0.34 olarak belirlenmiştir.

Çizelge 2. Deneme yeri toprağının bazı kimyasal ve fiziksel özellikler

Strüktürü	Kireç (%)	Tuz (%)	Yararlanılabilir fosfor (P_2O_5) (kg da^{-1})	Yararlanılabilir Potasyum (K_2O) (kg da^{-1})	pH	Organik Madde (%)
Tınlı*	8.46	0.34	4.0	240	7.6	1.7

***Analiz Orman, Toprak ve Ekoloji Araştırma Enstitüsü Müdürlüğü laboratuvarında yapılmıştır.*

25.02.2023 tarihinde Eskişehir Orman Fidanlık Müdürlüğü'nün seralarında viyollere (1/3 oranında kum + 2/3 oranında torf içeren) ekilen tıbbi adaçayı tohumlarından elde edilen fideler kullanılarak 18.04.2023 tarihinde deneme plantasyonu Eskişehir Orman Fidanlık Müdürlüğü'nün tarlasında kurulmuştur. Viyollerde yaklaşık 7 hafta süreyle gelişen ve şaşırtılacak olgunluğa ulaşan fideler 18.04.2023 tarihinde bitki sıklığı 50 × 20 cm olacak şekilde dikimleri yapılmıştır (Koç, 2000; Koç, 2006; Başyiğit ve Baydar, 2017; Tuğlu ve Baydar, 2019; Elmas 2021). Deneme tesadüf blokları deneme desenine göre 3 tekerrürlü olarak kurulmuş ve her tekerrürde 5 parsel (0 kg N/da, 5 kg N/da, 10 kg N/da, 15 kg N/da ve 20 kg N/da) bulunmaktadır (Koç, 2000; Koç, 2006). Azotlu gübreler 3 porsiyona bölünerek ilk porsiyon 18 Nisan 2023 uygulanırken, ikinci porsiyon 15 Haziran 2023 tarihinde ve üçüncü porsiyon ise 01 Ağustos 2023 tarihinde uygulanmıştır. Her parsel 4 sıra bitki içermekte olup, 2 m × 4 m= 8 m^2 alana sahiptir. Bitki plantasyonlarında özellikle ilkbaharda sorun oluşturan yabancı otlar çapayla temizlenmiştir. Plantasyona suya ihtiyaç durumu dikkate alınarak 15-20 gün aralıklarla damlama sulama sistemiyle su verilmiştir (Elmas, 2021). Plantasyona başka herhangi bir gübre uygulaması yapılmamıştır. Bu çalışmada kullanılan materyaller plantasyonun 1. yılından elde edilmiş bitki materyalleridir. Bitkiler 27.09.2023 tarihinde toprak yüzeyinden 5-10 cm yükseklikten biçilerek hasat edilmiştir. Hasat edilen taze bitkiler tartılarak taze herba verimleri (kg/da) belirlenmiştir. Hasat edilen taze bitkilerin yaprakları saplarından ayrılarak taze yaprak verimleri tespit edilmiştir. Taze yapraklar 35-38 °C'de 48 saat süreyle etüvde kurutularak kuru yaprak verimleri belirlenmiştir. Kurutulmuş yapraklardan alınan örneklerin uçucu yağ oranları su distilasyonu yöntemiyle tespit edilmiştir. Uçucu yağların distilasyonu için kurutulmuş 100 g yaprak örnekleri 2000 ml'lik balonlara yerleştirildikten sonra 1000 ml saf su eklenerek 3 saat boyunca distilasyon işlemi gerçekleştirilmiştir. Distilasyon işlemi tamamlandıktan sonra clevenger aparatının dereceli kısmından yağ miktarı okunarak % olarak belirlenmiştir (Kılıç, 2008).

Denemeden elde edilen bitki boyu (cm), taze herba verimi (kg/da), taze yaprak verimi (kg/da), kuru yaprak verimi (kg/da), uçucu yağ oranı (%) ve uçucu yağ verimine (l/da) ait veriler TARIST paket programı kullanılarak, tesadüf blokları deneme desenine göre varyans analizine tabi tutularak incelenen özelliklerin önemlilik düzeyleri tespit edilmiştir. Önemli çıkan uygulamalar arasındaki farklılıklar hesaplanan LSD değerine göre gruplandırılmıştır (Kayaalp ve Keser, 2017).

3. BULGULAR

Eskişehir ekolojik koşullarında farklı azot dozlarının tıbbi adaçayında bitki boyu (cm), taze herba verimi (kg/da), taze yaprak verimi (kg/da) üzerine etkilerine ait bulgu Çizelge 3'te ve drog yaprak verimi (kg/da), uçucu yağ oranı (%) ve uçucu yağ verimi (l/da) değerlerine ait bulgular ise Çizelge 4'de verilmiştir.

3.1. BİTKİ BOYU (cm)

Denemede uygulanan farklı azot dozları bitki boyu üzerinde istatistiki anlamda (%1) önemli bir farklılık oluşturmuştur. Bitki boyu değerleri 29.66-38.50 cm arasında değişmiştir. En yüksek bitki boyu 38.50 cm ile 20 kg N/da uygulamasından elde edilirken, en düşük bitki boyu ise 29.66 cm ile kontrol parselinde elde edilmiştir. Azot dozlarının ortalaması olarak ise 35.28 cm bitki boyu tespit edilmiştir (Çizelge 3).

Çizelge 3: Değişen azot dozlarının tıbbi adaçayı (*Salvia officinalis* L.) bitkisinin bitki boyu (cm), taze herba verimi (kg/da) ve taze yaprak verimi (kg/da) üzerine etkisi

N Dozları (kg/da)	Bitki boyu (cm)	Taze herba verimi (kg/da)	Taze yaprak verimi (kg/da)
0 kg	29.66^{d}	404.70^{c}	295.64^{c}
5 kg	34.58^{c}	449.04^{c}	325.51^{c}
10 kg	36.50^{b}	589.45^{b}	428.62^{b}
15 kg	37.16^{ab}	722.60^{a}	527.93^{a}
20 kg	38.50^{a}	736.62^{a}	527.66^{a}
Ortalama	35.28	580.48	421.08
F değeri	35.19**	76.88**	36.29**
V.K.	2.37	4.26	6.15

3.2. TAZE HERBA VERİMİ (kg/da)

Çalışmada kullanılan farklı azot dozları taze herba verimi üzerinde istatistiki anlamda (%1) önemli bir farklılığa neden olmuştur. Taze herba verimi değerleri 404.70-736.62 kg/da arasında değişmiştir. En yüksek taze herba verimi 736.62 kg/da ile 15 kg N/da dozuyla aynı grupta yer

alan 20 kg N/da uygulamasından elde edilirken, en düşük taze herba verimi ise 404.70 kg/da olarak kontrol parselinde belirlenmiştir. Azot dozlarının ortalaması olarak ise 580.48 kg/da taze herba verimi elde edilmiştir (Çizelge 3).

3.3. TAZE YAPRAK VERİMİ (kg/da)

Çalışmada kullanılan farklı azot dozları taze yaprak verimi üzerinde istatistiki anlamda (%1) önemlilik düzeyinde farklılık göstermiştir. Taze yaprak verimi değerleri 295.64 - 527.93 kg/da arasında değişmiştir. En yüksek taze yaprak verimi 527.93 kg/da ile 20 kg N/da dozuyla aynı grupta yer alan 15 kg N/da uygulamasından elde edilirken, en düşük taze yaprak verimi ise 295.64 kg/da olarak kontrol parselinden elde edilmiştir. Farklı azot dozlarının ortalaması olarak ise 421.08 kg/da taze yaprak verimi bulunmuştur (Çizelge 3).

3.4. KURU YAPRAK VERİMİ (kg/da)

Çalışmada kullanılan farklı azot dozları kuru yaprak verimi üzerinde istatistiki anlamda (%1) önemlilik düzeyinde farklılık göstermiştir. Kuru yaprak verimi değerleri 103.12-165.30 kg/da arasında değişmiştir. En yüksek kuru yaprak verimi 165.30 kg/da ile 20 kg N/da dozuyla aynı grupta yer alan 15 kg N/da uygulamasından elde edilirken, en düşük kuru yaprak verimi ise 103.12 kg/da olarak kontrol parselinden elde edilmiştir. Farklı azot dozlarının ortalaması olarak ise 135.91 kg/da kuru yaprak verimi tespit edilmiştir (Çizelge 4).

Çizelge 4: Değişen azot dozlarının tıbbi adaçayı (*Salvia officinalis* L.) bitkisinin kuru yaprak verimi (kg/da), uçucu yağ oranı ve uçucu yağ verim üzerine etkisi

N Dozları (kg/da)	Kuru yaprak verimi (kg /da)	Uçucu yağ oranı (%)	Uçucu yağ verimi (L/da)
0 kg	103.12^{c}	2.68^{A}	2.76^{B}
5 kg	110.96^{c}	2.36^{B}	2.62^{B}
10 kg	141.11^{b}	2.53^{A}	3.57^{A}
15 kg	165.30^{a}	2.52^{A}	4.18^{A}
20 kg	159.03^{a}	2.33^{B}	3,71^{A}
Ortalama	135.91	2.48	3.37
F değeri	36.36**	1.36*	8.05*
V.K.	4.90	6.90	9.93

**: %1 düzeyinde anlamlı ve *: %5 düzeyinde anlamlı V.K.: Varyans Katsayısı

3.5. UÇUCU YAĞ ORANI (%)

Çalışmada kullanılan farklı azot dozları uçucu yağ oranı üzerinde istatistiki anlamda (%5) önemli bir farklılık göstermiştir. Uçucu yağ oranı değerleri 2.33-2.68 % arasında değişmiştir. En yüksek uçucu yağ oranı 2.68 % kontrol dozundan elde edilirken en düşük uçucu yağ oranı ise 2.33 % ile 5 kg N/da dozuyla aynı grupta yer alan 20 kg N/da uygulamasından elde

edilmiştir. Azot dozlarının ortalama uçucu yağ oranı ise 2.48 % olarak belirlenmiştir (Çizelge 4).

3.6. UÇUCU YAĞ VERİMİ (L/da)

Çalışmada kullanılan farklı azot dozları uçucu yağ verimi üzerinde istatistiki anlamda (%5) önemli bir farklılık göstermiştir. Uçucu yağ verimi değerleri 2.62-4.18 L/da arasında değişmiştir. En yüksek uçucu yağ verimi 4.18 L/da ile 10 ve 20 kg N/da ile aynı grupta yer alan15 kg N/da dozundan elde edilirken en düşük uçucu yağ verimi ise 2.62 L/da ile kontrol dozuyla aynı grupta yer alan 5 kg N/da uygulamasından elde edilmiştir. Azot dozlarının ortalama uçucu yağ verimi ise 3.37 L/da olarak belirlenmiştir (Çizelge 4).

4. TARTIŞMALAR

Bilindiği gibi azot, su ile birlikte bitkisel üretimde yokluğu en fazla çekilen besin elementi olarak karşımıza çıkmaktadır. Bu nedenle azot, bitkisel üretimde bitkilerin büyüme ve gelişimini kontrol eden en önemli besin elementi olarak bilinmektedir (Gardiner ve Miller, 2008; Fageria, 2009; Bolat ve Kara, 2017). Azotun tıbbi aromatik bitkilerde verim ve kalite üzerine etkisini belirlemek amacıyla yapılan çalışmaların birçoğunda uçucu yağ oranları hariç diğer parametrelerin üzerinde özellikle yetersiz organik madde içeriğine sahip topraklarda artan azot dozları belirli bir düzeye kadar artışlara neden olduğu bildirilmiştir (Nurzynska-Wierdak, 2013; Özyiğit ve ark., 2016; Can, 2020; Can ve Katar, 2020). Benzer şekilde bu çalışmadan elde edilen bitki boyu (cm), taze herba verimi (kg/da), taze yaprak verimi (kg/da), drog yaprak verimi (kg/da) ve uçucu yağ verimi (l/da) değerlerinde de azalan azot miktarına paralel olarak bir azalış tespit edilmiştir. Azot, bitkilerin uygun şekilde büyüyüp gelişebilmesi için gerekli olan yeni hücre oluşumunun temel yapıtaşları olan proteinler, amino asitler, nükleik asitler, enzimler, klorofil, ATP, ADP gibi organik bileşiklerin önemli bir bileşenidir. Bu nedenle azot yetersizliğinde büyüme ve gelişme için mutlak gerekli olan proteinler, amino asitler, nükleik asitler, enzimler, klorofil, ATP, ADP gibi birçok organik bileşik yeterince üretilememekte ve dolayısıyla da bitkiler yeterince hücre üretememektedir. Azalan azot dozlarına paralel olarak azalan bitki boyu (cm), taze herba verimi (kg/da), taze yaprak verimi (kg/da), drog yaprak verimi (kg/da) ve uçucu yağ verimi (l/da) değerleri azot yetersizliği nedeniyle sap uzamasında meydana gelen azalışla, bitkilerin sahip olduğu düşük yaprak sayısı ve düşük yaprak alanı değerleriyle ve sürgün büyümesinde/uzamasında meydana gelen azalışla açıklanabilir (Hughes et al., 1989; Sarmadnia, 1993; Saeedfar et al., 2015). Dolayısıyla uygun bir büyüme ve gelişme gösteremeyen bitkilerden de hedeflenen yüksek verimin elde edilmesi mümkün olmamaktadır (Güzel ve ark., 2004; Gardiner and Miller, 2008; McCauley et al., 2009; Bolat ve Kara, 2017).

Diğer taraftan bitkilerin büyüme ve gelişme döneminde karşılaştıkları biyotik ve abiyotik stres koşulları bitkilerde Süperoksit Dismutaz, Katalaz, Glutatyon Peroksidaz gibi antioksidan enzimlerini, uçucu yağ oranlarını ve Absisik Asit içeriğini önemli ölçüde artırdığı yapılan birçok çalışmayla ortaya konmuştur. Çalışmadan elde edilen, azalan azot miktarlarına bağlı olarak artan uçucu yağ oranları ise azot eksikliğinin bitki üzerinde oluşturduğu stres durumunun uçucu yağ üretimini teşvik etmiş olmasıyla açıklamak mümkündür (Aliabadi Farahani et al., 2009a; Aliabadi Farahani et al., 2009b; Saeedfar et al., 2015).

5. Sonuç

Çalışmadan elde edilen veriler birlikte değerlendirildiği zaman Eskişehir ekolojik koşullarında tıbbi adaçayı üretmek için en yüksek drog yaprak 15 kg/da azot dozu ile gübreleme önerilirken, en yüksek uçucu yağ verimi elde edebilmek için ise 10 kg/da azot dozu ile gübreleme önerilmektedir. Çalışmanın tek yıllık olması yani plantasyonun ilk yılından elde edilen veriler dikkate alındığında bu konuda başka çalışmaların da yapılmasına da ihtiyaç duyulmaktadır.

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EFFECT OF DIFFERENT NITROGEN DOSES ON YIELD AND QUALITY PARAMETERS OF ROSEMARY (*Rosmarinus officinalis* L.) PLANT IN ESKIŞEHIR ECOLOGICAL CONDITIONS

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ABSTRACT

This study was conducted in 2023 under the ecological conditions of Eskişehir. The experiment was established in a randomized block design with three replications. Five different nitrogen doses (0, 5, 10, 15, and 20 kg/da) were tested. The aim of this study was to determine the effects of different nitrogen doses applied to rosemary (*Rosmarinus officinalis* L.) on plant height (cm), fresh herb yield (kg/da), dry herb yield (kg/da), dry leaf yield (kg/da), essential oil ratio (%), and essential oil yield (L/da). According to the results, as nitrogen doses increased, a significant increase was observed in plant height, fresh herb yield, and dry herb yield. The highest plant height (67,75 cm), fresh herb yield (1682.19 kg/da), dry herb yield (655.00 kg/da), and dry leaf yield (435.92 kg/da) were obtained at a nitrogen dose of 20 kg/da. The essential oil ratio varied among nitrogen doses, with the highest essential oil ratio (0.81%) obtained at 0 kg/da nitrogen dose. Essential oil yield, calculated based on dry herb yield, was determined as 5.37 L/da at the nitrogen dose of 20 kg/da. In conclusion, while the application of 20 kg/da nitrogen resulted in the highest increase in biomass production for rosemary cultivation under Eskişehir ecological conditions, a decrease in essential oil content was observed.

Keywords: *Rosmarinus officinalis*, nitrogen, yield

FARKLI AZOT DOZLARININ ESKİŞEHİR EKOLOJİK ŞARTLARINDA BİBERİYE (*Rosmarinus officinalis* L.) BİTKİSİNİN VERİM VE KALİTE PARAMETRELERİ ÜZERİNE ETKİSİ

ÖZET

Bu araştırma Eskişehir ekolojik koşullarında 2023 yılında yürütülmüştür. Deneme tesadüf blokları deneme desenine göre üç tekerrürlü olarak kurulmuştur. Denemede 5 farklı azot dozu (0, 5, 10, 15 ve 20 kg/da) çalışılmıştır. Bu çalışmanın amacı biberiye (*Rosmarinus officinalis* L.) bitkisine uygulanan farklı azot dozlarının bitki boyu (cm), yeşil herba verimi (kg/da), kuru herba verimi (kg/da), kuru yaprak verimi (kg/da), uçucu yağ oranı (%) ve uçucu yağ verimi (L/da) üzerine etkisini belirlemektir. Araştırmaya göre, azot dozlarının artışıyla birlikte bitki boyu, yeşil herba verimi ve kuru herba veriminde belirgin bir artış gözlemlenmiştir. En yüksek bitki boyu (67,75 cm), yaş herba verimi (1682,19 kg/da), kuru herba verimi (655,00 kg/da) ve kuru yaprak verimi (435,92 kg/da) 20 kg/da azot dozunda elde edilmiştir. Uçucu yağ oranı azot dozları arasında değişiklik gösterirken, en yüksek uçucu yağ oranı (%0,81) 0 kg/da azot dozunda elde edilmiştir. Uçucu yağ verimi kuru herba verimi üzerinden 20 kg/da azot dozunda 5.37 L/da olarak belirlenmiştir. Sonuç olarak, Eskişehir ekolojik şartlarında biberiye tarımı için 20 kg/da azot uygulaması, biyokütle üretiminde en fazla artış sağlarken, uçucu yağ oranında azalma gözlemlenmiştir.

Anahtar kelime: *Rosmarinus officinalis*, azot, verim

1. GİRİŞ

Lamiaceae familyasına ait olan biberiye (*Rosmarinus officinalis*) bitkisi çok yıllık önemli bir tıbbi aromatik bitkidir. Rosmarinus cinsinin dünyanın farklı bölgelerinde yayılış gösteren *R. officinalis, R. eriocalyx, R. laxiflorus* ve *R. lavandulaceus* türleri bulunmaktadır. Bu türlerden kültürü yapılan en önemli biberiye türü olan *Rosmarinus officinalis*'in *erectus, humilis* ve *albiflorus* varyeteleri bulunmaktadır (Angioni et al., 2004; Sönmez, 2008; Yıldırım, 2018). Rosmarinus ismi, bitkiye deniz kenarlarında çok yaygın bulunmasından ve deniz iklimini çok sevmesinden dolayı verilmiş olabileceği dair kayıtlar bulunmaktadır (Baydar, 2005). Biberiye bitkisi Türkçe'de kuşdili, hasalbal, hasalban, akpüren, akpürün ve zeytin çiçeği gibi farklı isimlerle bilinmektedir (Baytop, 1999; Begumet al., 2013; Başkaya ve ark., 2016). Biberiye bitkisi İspanya başta olmak üzere Akdeniz'in sahil bölgelerinde yer alan ülkelerin doğal florasında yayılış göstermektedir (Elhaak et al., 2015; Katar et al., 2019). Bitki, ülkemizde Akdeniz ve Ege sahil kuşağında doğal yayılış göstermekte olup, Çanakkale, Mersin, Hatay ve Adana illerimizde yoğun bir şekilde doğal florada yer almaktadır (Katar et al., 2019). Türkiye'de bitki sahil kuşağından başlayarak 1000 m'ye kadar farklı rakımlarda doğal florada yayılış göstermektedir (Baydar, 2005). Bitkinin yetiştiriciliği Fransa, İspanya, Portekiz, Yunanistan, ABD, bazı Afrika ülkeleri ve Meksika gibi ülkelerde yapılmaktadır. Türkiye'de odun dışı orman ürünleri kategorisinde değerlendirilen bitki çoğunlukla Adana ve Mersin bölgesinde doğal vejetasyondan toplanarak iç ve dış pazarlara arz edilmektedir (Baydar, 2005; Kırıcı, 2015; Başkaya ve ark., 2016).

Biberiye bitkisinin drog olarak değerlendirilen kısımları yaprakları ve çiçekleridir. Çoğunlukla taze veya kurutulmuş haldeki çiçekli dalları ürün olarak piyasaya arz edilmektedir. Biberiye bitkisi tanen (%8), acı madde ve uçucu yağ (%0,1-2,5) içermektedir (Baytop, 1999). Biberiye bitkisinin en önemli sekonder metaboliti yaprak ve çiçeklerde yoğunlaşan uçucu yağıdır. Biberiye bitkisinin renksiz veya açık sarı renkli uçucu yağ oranı %0,1-2,5 arasında değişmektedir (Çetin,1996; Kırpık, 1998; Baytop, 1999; Kırıcı ve Inan, 2002; Gülbaba et al., 2002; De Mastro et al. 2004; Başkaya et al., 2016; Katar et al., 2019). Yapılan çalışmalar biberiye bitkisinin uçucu yağ oranı ve bileşenlerinde önemli düzeyde farklılıkların olduğu tespit edilmiştir. Bu farklılıklar, bitkinin genotipi/kemotipi, çevre ve agronomik koşullar, hasat zamanı, depolama süresi, bitkinin yaşı, hasat edilen organ ve hasat döneminde bitkinin bulunduğu gelişim dönemi gibi birçok faktörün etkisiyle oluştuğu tespit edilmiştir (Usai ve ark., 2011; Singh and Guleria, 2012; Başkaya ve ark. 2016). Biberiye bitkisinin kuru yapraklarında yapılan bir analizde; %5,7 nem, %4,5 protein, %17,7 yağ, %19 ham lif, %47,4 karbonhidrat, %6,0 kül, %1,5 kalsiyum, %0,7 fosfor, %0,03 demir, %0,004 sodyum, %1 potasyum, 175 IU/100 g vitamin A, 0,51 mg/100 g vitamin B, 61,3 mg/100 g vitamin C ve 440 kalori/100 g enerji içerdiği tespit edilmiştir (Farooqi et al., 2005; Sasikumar, 2012).

Tıbbi aromatik bitkilerin tarımında hedeflenen verim ve kalitede ürünün elde edilebilmesi için yüksek genotipik potansiyele sahip üretim materyalinin seçilmesi, yetiştirilecek bitki türü için uygun iklim ve toprak koşullarında üretimin yapılması ve yine üretim materyalinin sahip olduğu verim ve kalite potansiyelini ortaya çıkaracak agroteknik uygulamalar büyük öneme sahiptir (Singh and Guleria, 2012; Başkaya ve ark. 2016). Bilindiği gibi ürünün verim ve kalitesi üzerinde etkili olan en önemli yetiştiricilik uygulamalarından birisi gübrelemedir. Bitkilerin uygun bir şekilde büyüyüp gelişebilmeleri için en az 17 bitki besin maddesine ya da

elementine ihtiyaç bulunmaktadır (White, 2006; Gardiner ve Miller, 2008; Fageria, 2009; Bolat ve Kara, 2017). Bitkinin ihtiyacı olan makro ve mikro besin elementlerinin uygun miktarlarda topraktan ya da yapraktan bitkiye sağlanmasına gübreleme denmektedir. Karbon, hidrojen, oksijen, azot, potasyum kalsiyum, fosfor, magnezyum ve kükürt makro besin elementi grubu içerisinde değerlendirilmektedir (Bolat ve Kara, 2017). En önemli makro bitki besin elementi olan azot başta amino asit ve proteinlerin yapısında yer alarak bitki büyüme ve gelişiminde önemli bir fonksiyona sahiptir (Robertson and Groffman, 2007; Fowler et al., 2013; Martínez-Dalmau et al., 2021). Tarımsal üretimin üzerinde en önemli abiyotik stres koşullarından olan azot, su ile birlikte kıtlığı en fazla çekilen bitki besin elementi olarak karşımıza çıkmaktadır. Bu nedenle azot yetersizliği daha çok bitki büyümesini kontrol eden besin elementi olarak bilinmektedir. Bilindiği gibi azot toprağın ana kayasında ve ana kayadan gelen anorganik ana materyalde bulunmamaktadır ve azotun doğadaki kaynağı atmosferdir. Atmosfer ile birlikte bir miktar azot doğada hidrosfer ve canlılarda yer almaktadır. Toprakta var olan azotun ana kaynağı organik maddelerdir. Topraktaki organik maddelerin süreç içerisinde ayrışması ile ortaya çıkan azottan bitkiler faydalanabilmektedir (Çepel, 1996; Kantarcı, 2000; Boşgelmez ve ark., 2001; Gardiner ve Miller, 2008; Fageria, 2009; Bolat ve Kara, 2017). Bitkisel üretimde bitkilerin ihtiyacı olan azotun toprakta organik maddelerin ayrışmasıyla oluşan azotla karşılanamayan kısmının toprağa gübreleme yoluyla verilmesi hedeflenen verim ve kaliteye ulaşılmasında büyük bir öneme sahiptir (Gardiner ve Miller, 2008; Fageria, 2009; Bolat ve Kara, 2017).

Bu çalışmanın amacı Eskişehir ekolojik koşullarında değişen azot dozları uygulamasının biberiye (*Rosmarinus officinalis* L.) bitkisinin verim ve kalitesi üzerine etkisini belirlemektir.

2. Materyal ve Metot

Araştırmada bitki materyali olarak Atatürk Bahçe Kültürleri Merkez Araştırma Enstitüsü Müdürlüğü'nden ve piyasadan temin edilen biberiye fideleri Eskişehir Orman Fidanlık Müdürlüğünün tarlasında 3 yıl yetiştirilerek kış soğuklarına tolerans göstererek doğal seleksiyon sonucunda kalan 5 bitkiden alınan çelikler Eskişehir Orman Fidanlık Müdürlüğünün seralarında köklendirilerek kullanılmıştır.

Çalışmanın yürütüldüğü Eskişehir ilinin uzun yıllar ve 2023 yılına ait aylar itibariyle yağış ve sıcaklık değerleri Çizelge 1'de verilmiştir. Çizelge 1 incelendiğinde denemenin yürütüldüğü 2023 yılında uzun yılların 22.7 mm üzerinde bir yağış alındığı görülmektedir.

Uzun yıllara ait yıllık ortalama sıcaklıkları ile çalışmanın yürütüldüğü 2023 yılına ait ortalama sıcaklıklar ise hemen hemen birbirine yakın olup, uzun yılların ortalama sıcaklığı 10.9 °C iken, 2023 yılında ise 11.1 °C olarak tespit edilmiştir. Aynı şekilde aylık ortalama sıcaklıklar bakımından da uzun yıllara ait değerler ile 2023 yılına ait değerlerin birbirlerine yakın olduğu Çizelge 1'de görülmektedir.

Çizelge 1. Eskişehir İlinin Deneme Yılına ve Uzun yıllara Ait İklim Verileri*

AYLAR	Ortalama sıcaklık (°C)		Aylık toplam yağış miktarı (mm)	
	Uzun yıllar	**2023**	**Uzun yıllar**	**2023**
Ocak	0.2	0.1	30.6	33.2
Şubat	1.4	1.7	26.1	27.5
Mart	5.1	5.3	27.6	33.3
Nisan	9.9	10.0	43.1	43.5
Mayıs	15.0	14.9	40.0	41.5
Haziran	19.2	18.9	23.7	28.4
Temmuz	22.2	22.0	13.1	14.4
Ağustos	22.0	22.1	9.2	11.2
Eylül	17.3	17.6	18.1	18.1
Ekim	11.8	12.2	32.8	33.7
Kasım	5.6	6.1	34.0	35.6
Aralık	1.6	2.0	40.5	41.3
Toplam/Ortalama	10.9	11.1	338.8	361.5

* * Eskişehir Meteoroloji Genel Müdürlüğü Verileri

Denemenin yürütüldüğü tarlaya ait toprağın özelliklerini belirlemek amacıyla alınan örnekler Orman Toprak ve Ekoloji Araştırma Enstitüsü Müdürlüğü Toprak Analiz Laboratuvarı'nda analiz edilmiş olup, toprak özelliklerini gösteren değerler Çizelge 2'de verilmiştir. Deneme tarlasının toprak pH'sı 7.8, hafif alkali bir toprak özelliği göstermektedir. Organik madde %1.9, yararlanılabilir potasyum ve fosfor düzeyleri sırasıyla 240 kg/da ve 14 kg/da'dır. Kireç oranı ise % 7.3 olarak belirlenmiştir. Toprağın tuz içeriği ise %0.25 olarak belirlenmiştir.

Çizelge 2. Deneme yeri toprağının bazı kimyasal ve fiziksel özellikler

Strüktürü	Kireç (%)	Tuz (%)	Yararlanılabilir fosfor (P_2O_5) (kg da^{-1})	Yararlanılabilir Potasyum (K_2O) (kg da^{-1})	pH	Organik Madde (%)
Tınlı*	7.3	0.25	14.0	240	7.8	1.9

***Analiz Orman, Toprak ve Ekoloji Araştırma Enstitüsü Müdürlüğü laboratuvarında yapılmıştır.*

Deneme plantasyonunu oluşturmak için 04.04.2020 tarihinde alınan çelikler Eskişehir Orman Fidanlık Müdürlüğü'nün seralarında köklendirildikten sonra viyollere (1/3 oranında kum + 2/3 oranında torf içeren) alınan fideler yaklaşık 1 yıl boyunca fidanlıkta büyütülmüş ve 15.04.2021 tarihinde Eskişehir Orman Fidanlık Müdürlüğü'nün deneme tarlasında fideler parsellere 100 x 40 cm sıklıkta dikilmiştir. Deneme tesadüf blokları deneme desenine göre 4 tekerrürlü olarak kurulmuş ve her tekerrürde 5 parsel (0 kg N/da, 5 kg N/da, 10 kg N/da, 15 kg N/da ve 20 kg N/da) bulunmaktadır. Azotlu gübrelerin ilk uygulaması 08 Nisan 2023 tarihinde, ikinci uygulaması 18 Haziran 2023 tarihinde ve üçüncü uygulaması ise 03 Ağustos 2023 tarihinde yapılmıştır. Her parsel, 4 sıra bitki olacak şekilde 4.0 × 4.0 m= 16 m^2 alana sahiptir. Bitkiler, gelişme döneminde yabancı otlardan çapayla temizlenmiştir. Bitkilerin ihtiyaç durumu dikkate alınarak 15-20 gün aralıklarla damlama sulama sistemiyle su verilmiştir. Bitkilere azotun dışında herhangi bir gübre uygulaması yapılmamıştır. Bu çalışmada kullanılan materyaller plantasyonun 3. yılından elde edilmiş bitki materyalleridir. Bitkiler 30.09.2023 tarihinde toprak yüzeyinden 30-35 cm yükseklikten biçilerek hasat edilmiştir. Hasat edilen taze bitkiler tartılarak taze herba verimleri (kg/da) belirlenmiştir. Taze herba örnekleri 35-38 °C'de 48 saat süreyle etüvde kurutularak kuru herba ve kuru yaprak verimleri belirlenmiştir. Kuru herbadan alınan örneklerin uçucu yağ oranları su distilasyonu yöntemiyle tespit edilmiştir. Uçucu yağların distilasyonu için kurutulmuş 100 g yaprak örnekleri 2000 ml'lik balonlara yerleştirildikten sonra 1000 ml saf su eklenerek 3 saat boyunca distilasyon işlemi gerçekleştirilmiştir. Distilasyon işlemi tamamlandıktan sonra clevenger aparatının dereceli kısmından yağ miktarı okunarak % olarak belirlenmiştir (Kılıç, 2008).

Denemeden elde edilen bitki boyu (cm), taze herba verimi (kg/da), kuru herba verimi (kg/da), kuru yaprak verimi (kg/da), uçucu yağ oranı (%) ve uçucu yağ verimine (l/da) ait veriler TARIST paket programı kullanılarak, tesadüf blokları deneme desenine göre varyans analizine tabi tutularak incelenen özelliklerin önemlilik düzeyleri tespit edilmiştir. Önemli çıkan uygulamalar arasındaki farklılıklar hesaplanan LSD değerine göre gruplandırılmıştır (Kayaalp ve Keser, 2017).

3. BULGULAR

Eskişehir ekolojik koşullarında farklı azot dozlarının biberiye bitkisinde bitki boyu (cm), taze herba verimi (kg/da), kuru herba verimi (kg/da) üzerine etkilerine ait bulgu Çizelge 3'te ve kuru yaprak verimi (kg/da), uçucu yağ oranı (%) ve uçucu yağ verimi (l/da) değerlerine ait bulgular ise Çizelge 4'de verilmiştir.

3.1. BİTKİ BOYU (cm)

Çalışmada kullanılan farklı azot dozları bitki boyu üzerinde istatistiki anlamda (%1) önemli bir farklılık oluşturmuştur. Bitki boyu değerleri 55.75-67.75 cm arasında değişmiştir. En yüksek bitki boyu 67.75 cm ile 20 kg /da azot uygulamasından elde edilirken, en düşük bitki boyu ise 55.75 cm ile kontrol parselinden elde edilmiştir. Azot dozlarının ortalaması olarak bitki boyu 61.20 cm olarak belirlenmiştir.

3.2. TAZE HERBA VERİMİ (kg/da)

Araştırmada kullanılan farklı azot dozları biberiye bitkisinin taze herba verimi üzerinde %1 önemlilik düzeyinde farklılığa neden olduğu belirlenmiştir. Taze herba verimi değerleri 1370.80-1682.19 kg/da arasında değişmiştir. En yüksek taze herba verimi 1682.19 kg/da ile 15 kg N/da dozuyla aynı grupta yer alan 20 kg N/da uygulamasından elde edilirken, en düşük taze herba verimi ise 1370.80 kg/da olarak kontrol parselinden elde edilmiştir. Uygulamaların ortalaması olarak ise 1560.38 kg/da taze herba verimi belirlenmiştir.

3.3. KURU HERBA VERİMİ (kg/da)

Denemede kullanılan farklı azot dozları kuru herba verimi üzerinde istatistiki anlamda (%1) önemlilik düzeyinde farklılık göstermiştir. Kuru herba verimi değerleri 455.36-655.00 kg/da arasında değişim göstermiştir. En yüksek kuru herba verimi 655.00 kg/da ile 20 kg/da azot dozu uygulamasından elde edilirken, en düşük kuru herba verimi ise 455.36 kg/da olarak kontrol parselinden elde edilmiştir. Farklı azot dozlarının ortalaması olarak ise 569.30 kg/da kuru herba verimi belirlenmiştir.

Çizelge 3: Değişen azot dozlarının Biberiye (*Rosmarinus officinalis* L.) bitkisinin bitki boyu (cm), taze herba verimi (kg/da) ve kuru herba verimi (kg/da) üzerine etkisi

N Dozları (kg/da)	Bitki boyu (cm)	Taze herba verimi (kg/da)	Kuru herba verimi (kg/da)
0 kg	55,75c	1370,80d	455,36c
5 kg	58,75d	1535,37c	571,85b
10 kg	61,00c	1576,96bc	581,01b
15 kg	62,75b	1636,57ab	583,26b
20 kg	67,75a	1682,19a	655,00a
Ortalama	61,2	1560,38	569,30
F değeri	103,27**	22,34**	8,43**
V.K.	11,13	12,57	6,74

3.4. KURU YAPRAK VERİMİ (kg/da)

Denemede kullanılan farklı azot dozları kuru yaprak verimi üzerinde istatistiki anlamda (%1) önemlilik düzeyinde farklılığa neden olmuştur. Kuru yaprak verimi değerleri 294.73-435.92 kg/da arasında farklılık göstermiştir. En yüksek kuru yaprak verimi 435,92 kg/da ile 20 kg/da azot uygulamasından elde edilirken, en düşük kuru yaprak verimi ise 294.73 kg/da olarak 10 ve 15 kg/da azot uygulamasıyla aynı grupta yer alan kontrol parselinden elde edilmiştir. Farklı azot dozlarının ortalaması olarak ise 338.97 kg/da kuru yaprak verimi elde edilmiştir.

3.5. UÇUCU YAĞ ORANI (%)

Çalışmada kullanılan farklı azot dozları uçucu yağ oranı üzerinde istatistiki anlamda (%1) önemli bir farklılık göstermiştir. Uçucu yağ oranı değerleri % 0.57-0.81 arasında değişmiştir. En yüksek uçucu yağ oranı % 0.81 kontrol dozundan elde edilirken en düşük uçucu yağ oranı ise % 0.57 ile 20 kg/da azot uygulamasından elde edilmiştir. Azot dozlarının ortalama uçucu yağ oranı değeri ise % 0.72 olarak belirlenmiştir.

3.6. UÇUCU YAĞ VERİMİ (L/da)

Denemede kullanılan farklı azot dozları uçucu yağ verimi üzerinde istatistiki anlamda (%1) önemli bir farklılık göstermiştir. Uçucu yağ verimi değerleri 3.75-5.37 L/da arasında değişmiştir. En yüksek uçucu yağ verimi 5.37 L/da ile 20 kg/da azot dozundan elde edilirken en düşük uçucu yağ verimi ise 3.75 L/da ile kontrol uygulamasından elde edilmiştir. Azot dozlarının ortalama uçucu yağ verimi ise 4.42 L/da olarak belirlenmiştir.

Çizelge 4: Değişen azot dozlarının Biberiye (*Rosmarinus officinalis* L.) bitkisinin kuru yaprak verimi (kg/da), uçucu yağ oranı ve uçucu yağ verim üzerine etkisi

N Dozları (kg/da)	Kuru yaprak verimi (kg /da)	Uçucu yağ oranı (%)	Uçucu yağ verimi (L/da)
0 kg	294,73c	0,81a	3,73c
5 kg	310,43bc	0,71b	4,69b
10 kg	318,39bc	0,75c	4,76b
15 kg	335,36b	0,73d	4,78b
20 kg	435,92a	0,57e	5,37a
Ortalama	338,97	0,72	4,42
F değeri	23,46**	163,74**	0,25**
V.K.	5,19	1,50	5,81

****: %1 düzeyinde anlamlı ve *: %5 düzeyinde anlamlı V.K.: Varyans Katsayısı**

4. TARTIŞMA

Azot, su ile birlikte bitkisel üretimde yokluğu en fazla çekilen besin elementi olarak karşımıza çıkmaktadır. Bu nedenle azot, bitkisel üretimde bitki büyümesini kontrol eden en önemli besin elementi olarak bilinmektedir (Gardiner ve Miller, 2008; Fageria, 2009; Bolat ve Kara, 2017). Azot uygulamasının aromatik bitkilerin verimleri üzerindeki etkisini belirlemek amacıyla yapılan çalışmalarda çoğunlukla uçucu yağ oranı hariç diğer parametrelerin (bitki boyu (cm), taze herba verimi (kg/da), drog herba verimi (kg/da), taze yaprak verimi (kg/da), drog yaprak verimi (kg/da) ve uçucu yağ verimi (l/da) gibi) hemen hemen tümünde özellikle yetersiz organik madde içeriğine sahip topraklarda artan azot dozları belirli bir düzeye kadar bu parametrelerde artışa neden olduğu tespit edilmiştir (Nurzynska-Wierdak, 2013; Özyiğit ve ark., 2016; Can, 2020; Can ve Katar, 2020). Bu çalışmadan elde edilen veriler de bu bulgulara paralellik arz etmektedir. Azalan azot miktarına paralel olarak azalan bitki boyu (cm), taze herba verimi (kg/da), drog herba verimi (kg/da), drog yaprak verimi (kg/da) ve uçucu yağ verimi (l/da), bitkilerin yeterince büyüyüp gelişebilmesi için mutlak gerekli olan proteinler, amino asitler, nükleik asitler, enzimler, klorofil, ATP, ADP gibi organik bileşiklerin önemli bir bileşeni olan azotun eksikliğinin yetersiz hücre oluşumuna ve buna bağlı olarak yetersiz sap uzamasına, daha düşük yaprak sayısına, yaprak alanına ve sürgün büyümesine/uzamasına neden olmasıyla açıklanabilir (Hughes et al., 1989; Sarmadnia, 1993; Saeedfar et al., 2015). Diğer bir ifade ile azot yetersizliğinde büyüme ve gelişme için mutlak gerekli olan yeni hücre oluşumunun temel yapıtaşları olan proteinler, amino asitler, nükleik asitler, enzimler, klorofil, ATP, ADP gibi birçok organik bileşiklerin yeterince üretilememiş olması ile açıklanabilir. Azot eksikliği nedeniyle yeterli miktarda yeni hücre üretme kabiliyeti olmayan bitkilerin yeterli miktarda ürün üretmesi de mümkün değildir (Güzel ve ark., 2004; Gardiner and Miller, 2008; McCauley et al., 2009; Bolat ve Kara, 2017).

Diğer taraftan bitkilerin büyüme ve gelişme döneminde karşılaştıkları biyotik ve abiyotik stres koşulları bitkilerde süperoksit dismutaz, katalaz, glutatyon peroksidaz gibi antioksidan enzimlerini, uçucu yağ oranlarını ve absisik asit içeriğini önemli ölçüde artırdığı yapılan birçok çalışmayla ortaya konmuştur. Bu çalışmadan elde edilen, azalan azot miktarlarına bağlı olarak artan uçucu yağ oranları ise azot eksikliğinin bitki üzerinde oluşturduğu stres durumunun uçucu yağ üretimini teşvik etmiş olmasıyla açıklamak mümkündür (Aliabadi Farahani et al., 2009a; Aliabadi Farahani et al., 2009b; Saeedfar et al., 2015).

5. SONUÇ

Çalışmadan elde edilen veriler ile birlikte değerlendirildiğinde Eskişehir ekolojik koşullarında biberiye üretiminde en yüksek kuru yaprak ve uçucu yağ verimi elde etmek için 20 k/da azot uygulamasının uygun olacağı tespit edilmiştir. Yürütülen çalışmanın tek yıllık olması ve kullanılan en yüksek azot dozundan en yüksek verimlerin alınmış olması bu konuda daha kesin önerilerde bulunulabilmesi için özellikle çok yıllık ve daha yüksek dozlar da kullanılarak denemelerin yürütülmesinde fayda bulunmaktadır.

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A STUDY ON THE INVESTIGATION OF MORPHOLOGICAL AND ANATOMICAL CHARACTERISTICS OF SOME ORNAMENTAL PLANTS GEOPHYSICS DISTRIBUTED IN KIRŞEHİR REGION

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ABSTRACT

In this study, the morphological and anatomical structures of some geophytes (*Crocus ancyrensis* (Herb.) Maw (Iridaceae), *Galanthus elwesii* Hook.f. (Amaryllidaceae) and *Muscari neglectum* Guss. ex Ten. (Asparagaceae)), which are ornamental plants with medical and economic importance and are distributed in the Kırşehir region, were examined; the obtained findings were compared with the literature data. Plant materials were collected from localities in the Kırşehir region during the flowering period in March–April 2024. Morphological data were obtained from fresh samples by measurement and observation, and anatomical data were obtained by examining stem and leaf preparations stored in 70% alcohol under a microscope. The source called "Flora of Turkey" was used for the diagnoses.

In the species *C. ancyrensis* (Iridaceae), corms are in two structures placed on top of each other, the lower one is a hollow old corm and the upper one is a newly formed corm. Corms are 14.82–18.4 × 10.35–13.62 mm in size. Tunics are reticulate, leaves are 2–5, linear and 0.5–1 mm wide. Flowers are bright yellow, blunt-tipped and 1.5–3 × 0.9–1.3 cm in size. Style is three-part and anthers are 8–13 mm long. In *G. elwesii* (Amaryllidaceae), the bulb is globose-ovate and 15.02–20.62 × 9.09–13.58 mm in size. Leaves are linear or narrowly lanceolate, rolled inwards. Scape is 44.49–55.36 mm long. Anthers are 4.08–5.23 mm, filaments are 0.85–2.21 mm long. The capsule is ovoid-spherical in shape, 11-16 × 10-14 mm in size. In the species *M.neglectum* (Asparagaceae), the bulb is ovate in size 22.34-32.44 × 13.61-19.51 mm. The number of leaves is 5-7 and it is in a linear-ribbon-lanceolate form. The inflorescence is in the form of a cluster 27.97-45.11 × 13.74-16.13 mm, dark blue in color and with white lobes at the ends. The capsule is 7-9 × 8-10 mm in size, circular-ovoid.

According to the cross-section of the species *C. ancyrensis* (Iridaceae), the stem is slightly wavy, the epidermis consists of circular cells and is covered with cuticle. The cortex is narrow and the vascular bundles are spread over the stem. The pith region is fragmented. The leaf has a horn-like cross-section. The midrib is distinct and the vascular bundles are located in the center and arms. The mesophyll is bifacial; there is a double-row palisade parenchyma and a spongy parenchyma underneath. Stomata are only a few on the upper surface. According to the cross-section of the species *G. elwesii* (Amaryllidaceae), the epidermis consists of circular cells

in the stem section and is covered with cuticle. The cortex is not distinct. The parenchyma cells are polygonal in shape and there are intercellular spaces between them. The leaf is spindle-shaped and the mesophyll is unifacial. The epidermis consists of square/circular cells and stomata are present on both surfaces. According to the cross-section of the species *M. neglectum* (Asparagacea), the stem is regularly circular in shape. There are parenchyma cells under the epidermis and a sclerenchyma ring afterwards. The vascular bundles are regularly arranged and the tracheids are distinct. The leaf cross-section is crescent-shaped. The mesophyll is unifacial, the parenchyma cells are circular and contain intermittent spaces. Stomata are present on both surfaces.

Keywords: Ornamental plants, medicinal plants, morphology, anatomy, *Crocus*, *Galanthus*, *Muscari*

KIRŞEHİR YÖRESİNDE YAYILIŞ GÖSTEREN SÜS BİTKİSİ NİTELİĞİNDEKİ BAZI GEOFİTLERİN MORFOLOJİK VE ANATOMİK ÖZELLİKLERİNİN İNCELENMESİ ÜZERİNE BİR ARAŞTIRMA

ÖZET

Bu araştırmada, Kırşehir yöresinde yayılış gösteren tıbbı ve ekonomik önemi olan, süs bitkisi niteliğindeki bazı geofitlerin (*Crocus ancyrensis* (Herb.) Maw (Iridaceae), *Galanthus elwesii* Hook.f. (Amaryllidaceae) ve *Muscari neglectum* Guss. ex Ten. (Asparagaceae)) morfolojik ve anatomik yapıları incelenmiş; elde edilen bulgular literatür verileriyle karşılaştırılmıştır. Bitkisel materyaller çiçeklenme dönemlerinde 2024 yılında Mart–Nisan aylarında Kırşehir yöresindeki lokalitelerden toplanmıştır. Morfolojik veriler taze örneklerden ölçüm ve gözlemle, anatomik veriler ise %70'lik alkolde saklanan gövde ve yaprak preparatlarının mikroskop altında incelenmesiyle elde edilmiştir. Teşhisler için "Flora of Turkey" adlı kaynaktan yararlanılmıştır.

C. ancyrensis (Iridaceae) türünde kormlar üst üste yerleşmiş iki yapıda olup, alttaki boşluklu eski korm ve üstteki yeni oluşmuş korm şeklindedir. Kormlar 14,82–18,4 × 10,35–13,62 mm boyutlarındadır. Tünikler ağsı yapıda olup, yapraklar 2–5 adet, şeritsi ve 0,5–1 mm genişliğindedir. Çiçekler parlak sarı renkte, küt uçlu ve 1,5–3 × 0,9–1,3 cm boyutlarındadır. Stilus üç parçalı anterler ise 8–13 mm uzunluğundadır. *G. elwesii* (Amaryllidaceae) türünde soğan küremsi-yumurtaması 15,02–20,62 × 9,09–13,58 mm boyutlarındadır. Yapraklar şerit ya da dar mızraksı, içe doğru dürülmüştür. Sıkapoz 44,49–55,36 mm uzunluğundadır. Anterler 4,08–5,23 mm, filamentler 0,85–2,21 mm uzunluğundadır. Kapsül ovoit–küremsi formda, 11–16 × 10–14 mm boyutlarındadır. *M.neglectum* (Asparagaceae) türünde soğan yumurtaması 22,34–32,44 × 13,61–19,51 mm boyutlarındadır. Yaprak sayısı 5–7 olup, şeritsi-şeritsi mızraksı formdadır. Çiçek kurulu salkım şeklinde 27,97–45,11 × 13,74–16,13 mm, koyu mavi renkte ve uçları beyaz lobludur. Kapsül 7–9 × 8–10 mm boyutlarında, dairesel–yumurtamsıdır.

C. ancyrensis (Iridaceae) türünün enine kesitine göre gövde hafif dalgalı, epidermis dairesel hücrelerden oluşur ve üzeri kutikula ile kaplıdır. Korteks dar olup iletim demetleri gövdeye yayılmıştır. Öz bölgesi parçalanmıştır. Yaprak boynuzsu enine kesite sahiptir. Orta damar belirgin olup iletim demetleri merkez ve kollarda yer alır. Mezofil bifasiyaldir; çift sıralı palizat parankiması ve altında sünger parankiması mevcuttur. Stomalar yalnızca üst yüzeyde az sayıda bulunur. *G. elwesii* (Amaryllidaceae) türünün enine kesitine göre gövde kesitinde epidermis dairesel hücrelerden oluşur ve kutikula ile kaplıdır. Korteks belirgin değildir. Parankima hücreleri poligonal şekilli ve aralarında hücre arası boşluklar vardır. Yaprak mekik şeklinde olup mezofil unifasiyaldir. Epidermis karesel/dairesel hücrelerden oluşur, her iki yüzeyde stomalar bulunur. *M. neglectum* (Asparagacea) türünün enine kesitine göre gövde düzgün dairesel şekildedir. Epidermisin altında parankima hücreleri ve devamında skleranкima halkası bulunur. İletim demetleri düzgün sıralanmıştır ve trakeidler belirgindir. Yaprak enine kesiti hilal şeklindedir. Mezofil unifasiyaldir, parankima hücreleri dairesel ve aralıklı boşluklar içerir. Stomalar her iki yüzeyde bulunur.

Anahtar Kelimeler: Süs bitkileri, tıbbi bitkiler, morfoloji, anatomi, *Crocus*, *Galanthus*, *Muscari*

1.GİRİŞ

Ülkemiz; yer aldığı coğrafik konum, çok kısa mesafelerde dahi değişebilen arazi topoğrafyası ve çok farklı ekolojik koşulları sayesinde biyoçeşitlilik yönünden dünyanın en önemli gen merkezlerinden birisi konumundadır. Bu zengin biyoçeşitlilik içerisinde önemli gruplardan birini de geofitler oluşturur. Geofit olarak adlandırılan ve yaşamlarının büyük bölümünü toprak altında geçiren bitki topluluğu, ülkemizin floristik çeşitliliğinde önemli bir yer tutmaktadır. Geofitlerin gövdeleri korm, yumru, rizom, soğan şeklinde metamorfoza uğramış ve toprak seviyesinin altında yer almaktadır. Geofitlerin önemli bir kısmı, doğanın canlandığı ilkbahar aylarında çiçek açarak bu mevsimin gelişini müjdelemektedirler (Avcu ve ark., 2016).

Kökeni Anadolu toprakları olan geofitler günümüzde Avrupa'daki birçok bahçede süs bitkisi olarak yetiştirilmektedir. Geofitler, yalnızca estetik amaçlarla süs bitkisi olarak değil, aynı zamanda ilaç ve gıda alanlarında da değerlendirilmektedir. Bu etkileyici zenginliğinin bir yansıması olarak, geofitler Türkiye florasının yaklaşık %15'ini oluşturmaktadır. Anadolu'da doğal olarak yetişen bu bitkilerin büyük bir kısmı; Liliaceae, Amaryllidaceae, Ranunculaceae, Iridaceae, Primulaceae, Araceae, Geraniaceae ve Orchidaceae familyalarına ait türler ile temsil edilmektedir (Başköse ve ark., 2013).

Kırşehir, İç Anadolu bozkır florası içerisinde önemli bir konuma sahip olup, Anadolu'da endemik bitki türlerinin doğal olarak yetiştiği değerli alanlardan biridir. Bu alanda yayılış gösteren bitki çeşitliliği ile ilgili çalışmalar hali hazırda devam etmekte olup, araştırmalar sonuçlandıkça flora ile ilgili bilgiler güncellenmektedir (Aktoklu ve Arslan, 2012).

Geofitlerin, özellikle bazı türlerinin, çok yüksek bir süs bitkisi potansiyeli vardır. Birçok geofit türü kültüre alınmış ve hatta ıslah çalışmaları ile günümüzde binlerce çeşit geliştirilmiştir. Kırşehir florasında doğal olarak yayılış gösteren ve bu çalışmanın da bitkisel materyalini oluşturan türlere ait ayrıntılı bilgi aşağıda türler bazında verilmiştir.

Iridaceae (süsengiller) familyasına ait *Crocus* L. Dünyada Orta ve Güney Avrupa, Kuzey Afrika ve Güneybatı Asya'dan Batı Çin'e kadar birçok bölgede yayılış göstermektedir. *Crocus* cinsi, Plants of the World Online'a göre Dünya genelinde güncel olarak 250 kabul edilmiş türe sahiptir. Türkiye *Crocus* türlerinin varlığı açısından oldukça zengindir. Türkiye çiğdemlerinin 156 tür ve 56 alt türü bulunmaktadır. Bu türlerin 55 tanesi ise endemiktir. Cins son yıllarda, fazla sayıda tanımlanan yeni türlerinin etkisiyle hızlı bir taksonomik genişleme göstermektedir, Bu sebeple de farklı çalışmalarda tür sayıları farklı olabilmektedir. Ülkemiz endemik türlerinden biri olan *Crocus ancyrensis* (Herb.) Maw Türkçe ismiyle Ankara Çiğdemi olarak bilinmekte olup Türkiye' de Batı ve Orta Karadeniz bölgesi, Orta ve Yukarı Kızılırmak Bölgesi, yukarı Fırat bölgesinde doğal olarak yayılış göstermektedir. Dünyada ise Almanya ve Büyük Britanya'ya taşınmıştır (Kravkaz ve ark., 2006; POWO, 2023; Bizim Bitkiler, 2013).

Çiğdemler otsu, çok yıllık, yaprak ve çiçekleri mevsimlik olan bitkilerdir. Çiğdemler genel olarak beyaz, sarı ve mavi olmak üzere değişik renk tonlarında çiçek açmaktadır. Türlerin bazıları ilkbahar aylarında çiçek açarken bazıları sonbahar aylarında çiçek açmaktadırlar.. Araştırmamızın materyalini oluşturan *Crocus ancyrensis* ise Şubat- Mart aylarında 1000- 1600 metre rakımlarda ormanlık, kayalık ve fundalıklarda sarı renkte çiçek açan ayrıca cormu besin olarak tüketilen bir türdür. *Crocus ancyrensis* türünü diğer türlerden ayıran özellikler

soğanlarının ağsı yapıda olması, periantların sarı olması ve üçlü stillerinin olmasıdır (Kravkaz ve ark., 2006).

Galanthus elwesii Hook.f., Amaryllidaceae (nergisgiller) familyasına ait *Galanthus* cinsinin bir üyesi olup, Kardelen adıyla bilinmektedir. *Galanthus* cinsi, Plants of the World Online veritabanına göre Dünyada 23 kabul edilmiş türe sahiptir (POWO, 2023). Bu cinsin 19 türü ve 6 alt türü bulunmakta, bunlardan 5 tanesi Türkiye endemiği olarak öne çıkmaktadır (Bizim Bitkiler, 2013). *Galanthus elwesii* Arnavutluk, Bulgaristan, Yunanistan, Türkiye, Ukrayna ve eski Yugoslavya topraklarında doğal olarak bulunurken; Avusturya, Almanya, Büyük Britanya, İrlanda ve bazı Amerika Birleşik Devletleri eyaletlerine taşınmış materyaller aracılığıyla yayılış göstermektedir. Türkiye'de ise bu tür; Çatalca, Ergene, Asıl Ege, İç Anadolu, Yukarı Sakarya, Orta Kızılırmak, Antalya ve Adana bölümlerinde doğal olarak yayılış göstermektedir (Baktır, 1996).

Galanthus elwesii çoğunlukla 800-1000 m ile 1600 m arasındaki dağlarda, subalpin meralarda bulunur. Tür ülkemizde süs bitkisi olarak ihraç edilen çiçek soğanları arasında ilk sıralarda yer almaktadır. Bunun sebebi baharın müjdecisi bu çiçeklerin dış pazarda fazlaca talep edilmesidir. Geofitlerde genel olarak tohumdan yeni soğanların oluşması için geçen süre oldukça uzundur. Örneğin kardelen bitkisinin tohumdan yeni yumru oluşturabilecek olgunluğa gelmesi için geçen süre yaklaşık olarak 4 ila 5 yıl arasındadır. Dolayısıyla bu bitkilerin çoğaltılmasında vejetatif yöntemler yani yavru soğanlar kullanılmaktadır. Kardelen gibi ticaret hacmi büyük olan geofitlerin sürekli sökülmesi nesillerini tehlike altına sokmaktadır. Nesli bilinçsizce toplamadan dolayı tehlike altına giren geofitlerin korunması için uluslararası anlaşmalar yapılmış ve bazı geofit türlerinin toplanması yasaklanmıştır (Baktır, 1996; Nasırcılar ve Karagüzel, 2006; Zeybekoğlu, 2024).

Asparagaceae (kuşkonmazgiller) familyasının *Muscari* cinsine ait olan *Muscari neglectum* Guss.Ex Ten. ülkemizde Arapüzümü olarak bilinmektedir. *Muscari* cinsi, Plants of the World Online (POWO) veri tabanına göre 84 kabul edilmiş türe sahiptir. Tür Dünya genelinde doğal olarak doğu Avrasyada yayılış göstermekte ve diğer birçok bölgeye de taşınarak kendine geniş bir yayılış alanı bulmaktadır (POWO, 2023). Türkiye'de 37 türü mevcut olup bu türlerden 26 tanesi endemiktir. Ülkemizde Istranca, Çatalca-Kocaeli,Güney Marmara, Batı ve Orta Karadeniz, Ege, İç Batı Anadolu, Yukarı Sakarya, Yukarı Kızılırmak ve Fırat, Adana, Antalya bölümünde yayılış göstermektedir (Bizim Bitkiler, 2013). Muscari türleri otsu formda, ilkbaharda çiçeklenen ve genel olarak çok yıllık soğanlı bitkilerdir. Deniz seviyesi ile 2300 m yükseklikler arasında; çam korulukları, makilikler, çalılıklar ve çayırlıklarda; taşlık kireç taşı yamaçlar ve nadiren kayalık kumluk alanlarda gözlenebilirler. Çiçekler toplu şekilde salkım şeklinde koyu mavi, uçlarına doğru beyazdır. Tepede biriken çiçekler daha açık renkli olabilmektedir. Muscari cinsine ait birçok bitki türü geleneksel halk tıbbında ve gıda amaçlı olarak kullanılmaktadır (İlçim ve ark., 2020).

Farklı ekolojilerde bitki türlerinin hem floral hem de vejetatif aksamlarında bazı farklılıklar meydana gelebilmektedir. Çalışma konusu türler daha önce tanımlanmış ve bilim dünyasına kazandırılmış bilindik türlerdir. Bu çalışma ise Kırşehir ekolojisinin mevcut türler üzerine herhangi bir etkisinin olup olmadığını belirlemek için yapılmıştır. Bu çalışmanın amacı Kırşehir'de doğal olarak yayılış gösteren *Crocus ancyrensis, Galanthus elwesii, Muscari*

neglectum türlerinin bazı morfolojik ve anatomik özelliklerini ortaya koyarak bölgenin florasına ilişkin literatüre katkı sağlamak ve yapılacak diğer çalışmalara kaynak oluşturmaktır.

2.GELİŞME

2.1.Materyal ve Yöntem

Araştırma Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesinde yürütülmüştür. Çalışma konusunu oluşturan bitkisel materyaller çiçeklenme dönemlerinde belirtilen lokalitelerden toplanmıştır (Tablo 1.). Toplanan örneklerin bir kısmı preslere alınarak, gölgeli ve hava akımı olan bir ortamda kurumaya bırakılmış ve her tür için herbaryum örneği hazırlanmıştır.

Tablo 1. İncelenen türlerin toplanıldığı lokaliteler

No	Tür	Lokalite	Toplanma Tarihi
1	*Crocus ancyrensis* (Herb.) Maw	Kırşehir, Kervansaray Dağı	29.03.2024
2	*Galanthus elwesii* Hook.f.	Kırşehir, Kervansaray Dağı	29.03.2024
3	*Muscari neglectum* Guss.Ex Ten.	Kırşehir, Mucur, Köme mevki	01.04.2024

Peak Visor veri tabanındaki verilere göre Kervansaray Dağı, Kırşehir merkezinin güneydoğusunda, 39°11′32″ K, 34°13′53″ D koordinatlarında ve deniz seviyesinden 1682 m yüksekliğiyle ilin belirgin yükseltilerinden biri olarak karşımıza çıkmaktadır. Kervansaray Dağları'nda 50 familyaya ait yaklaşık 250 türe ulaşmış ve bunların 27'si endemik olarak tanımlanmıştır (ÇŞİDB, 2023). Mucur, Köme ise Mucur ilçesi sınırları içinde, ilçe merkezine yaklaşık 21 km uzaklıkta, 935 m rakımlı platolarda konumlanmıştır (Kırşehir İl Kültür ve Turizm Müdürlüğü,2025).

2.1.1.Bitki Örneklerinin Toplanması

Türlere ait bitki örnekleri Mart-Nisan ayları arasında toplanılmıştır. Toplanan örneklerin bitkinin bütün özelliklerini temsil etmesine dikkat edilmiştir. Ayrıca örneklerin toplanması esnasında teşhis için gerekli olan örneklere ait bazı önemli morfolojik özelliklerin fotoğrafları da çekilmiş ve gözlenen özellikler tespit edilmiştir.

2.1.2.Örneklerin Korunması ve Saklanması

Toplanan örneklerin bir kısmı preslere alınarak nemsiz, gölgeli ve hava akımı olan bir ortamda kurumaya bırakılmıştır. Örneklerin sağlıklı bir şekilde kuruması için kuruma kağıtları belirli aralıklarla değiştirilmiştir. Daha sonra kuruyan örneklerin teşhisleri yapılarak her bir örnek için herbaryum örneği hazırlanmıştır.

Araştırmanın anatomik çalışmalarında kullanılmak üzere toplanan örnekler temizlenmiş, yaprak ve skapus kısımlarından alınan numuneler ,%70 'lik alkol içeren cam kavanozlar içerisine konularak ışık almayan bir yerde saklanmıştır.

2.1.3.Örneklerin Teşhisleri

Alınan örneklerin teşhislerinde, Flora of Turkey isimli eserden yararlanılmıştır (Davis, 1984; Davis, 2000).

2.1.4.Örneklerin Morfolojik Olarak İncelenmesi

Tür örneklerinin yapraklı ve çiçekli dönemlerinde yapılan gözlemlerde kök, gövde, yaprak, soğan, çiçek gibi organların morfolojik şekilleri ve özellikleri fotoğraf ve mikroskop görüntüleri ile belirlenmiş ve ölçümleri yapılmıştır.

2.1.5.Örneklerin Anatomik Olarak İncelenmesi

Anatomik incelemelerde alkol içerisinde fiske edilen bitki materyalleri kullanılmıştır. Türlerin gövde ve yaprak anatomisinde bu kısımlardan bir parça strafor içerisine yerleştirilerek jilet yardımı ile enine kesitler alınmış ve saf su damlatılmış lam üzerine yerleştirilip üzeri lamel ile kapatılıp mikroskop altında incelenmiştir.

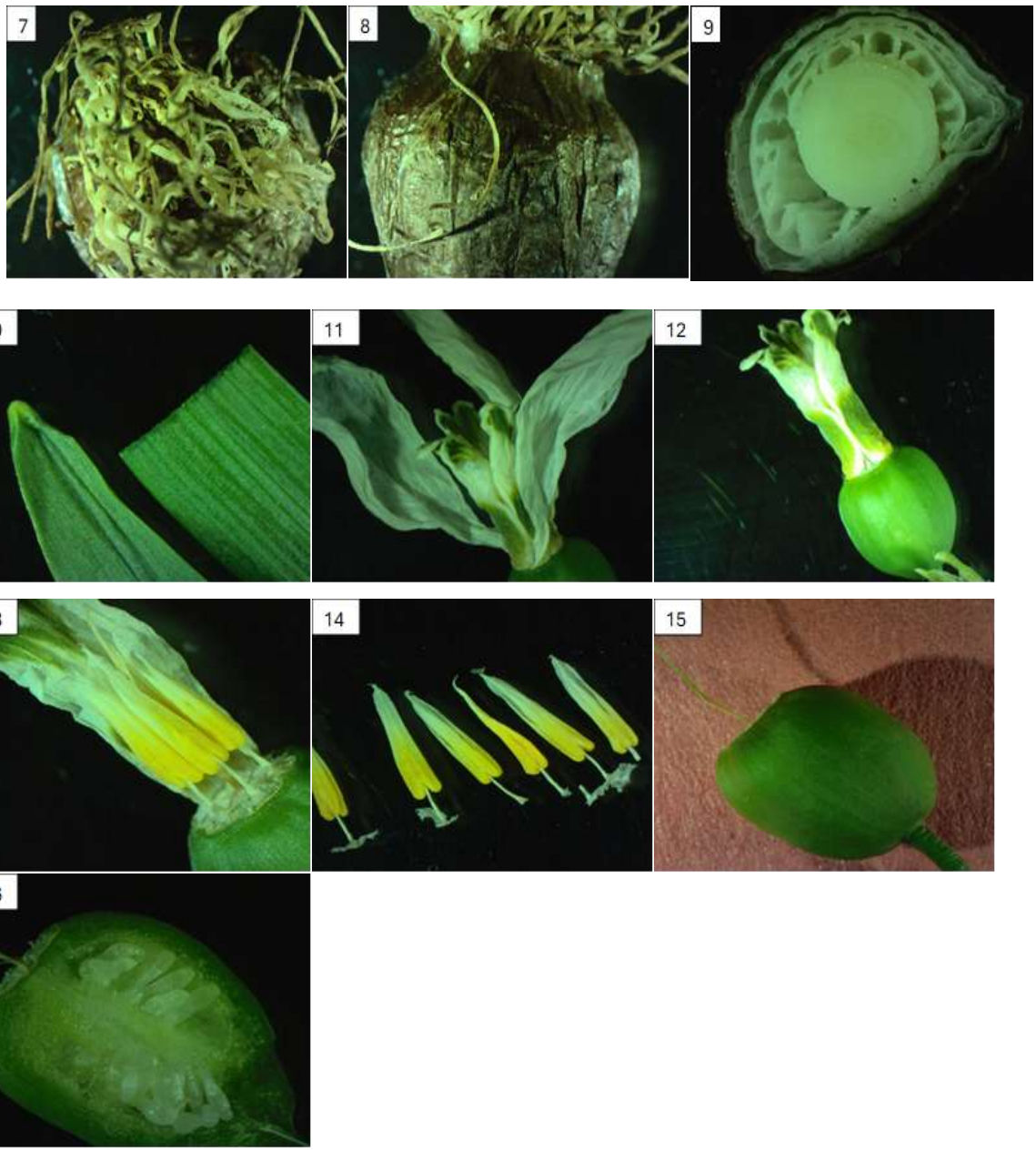
2.2.Bulgular

2.2.1.Morfolojik Bulgular

Crocus ancyrensis türünde kormus yumurtamsı ya da basık küremsi, 14,82-18,4 × 10,35-13,62 mm aralığındadır (Şekil 2,3). Tünik ağsı liflidir (Şekil 1). Yapraklar 2-5 adet, şeritsi, 0.5-1 mm genişliğindedir (Şekil 4). Çiçeklenme ve yapraklanma eşzamanlıdır. Brakte mevcuttur. Perigon tüpü sarı renkli ve tüysüzdür. Çiçek segmentleri 1.5-3 × 0.9-1.3 cm, küt uçlu veya yuvarlağımsı olup parlak sarı renklidir. Çoğunlukla tabanda ve perigon tüpünde morumsu renktedir. Stamenler 3 adettir. Filamentler 2-4 mm olup tüysüzdür. Anterler 8-13 mm uzunluğunda olup sarı renklidir (Şekil 5). Stilus portakal rengi veya kırmızımsı-portakal rengi olup 3 parçaya ayrılmıştır (Şekil 6).

Şekil (1),(2),(3) *Crocus ancyrensis* corm mikroskop görüntüleri , (4) *Crocus ancyrensis* yaprak mikroskop görüntüsü , (5) *Crocus ancyrensis* anter mikroskop görüntüsü ,(6) *Crocus ancyrensis* stilus mikroskop görüntüsü.

Galanthus elwesii türünde soğanlar küremsi ya da yumurtamsı, 15,02−20,62 × 9,09-13,58 mm aralığındadır (Şekil 7,8,9). Yapraklar şerit şeklinde ya da daralan ters mızraksı, tomurcukta içe doğru dürülmüş, tepede küt, mumludur (Şekil 10). Sıkapoz 44,49-55,36 mm'dir. Dış periant segmentleri dışbükey, obovat ya da spatulat, 15-26 ×7-10 mm, iç periant segmentleri yassı, dar oblong-spatulat, 10,1-22,68 × 3,75-8,72 mm, tabanda ve tepede yeşil lekeler bulunur, lekeler bazen merkezde birleşir (Şekil 11,12). Filamentler 0,85-2,21 mm, anterler 4,08-5,23 mm aralığındadır (Şekil 13,14). Kapsül ovoit ilâ küremsiye kadar, 11-16 × 10-14 mm'dir.



Şekil (7), (8), (9) *Galanthus elwesii* türünün soğan yapısının mikroskop görüntüleri , (10) *Galanthus elwesii* türünün yaprak mikroskop görüntüsü , (11),(12) *Galanthus elwesii* türünün dış ve iç periant mikroskop görüntüleri , (13),(14) *Galanthus elwesii* filament ve anter mikroskop görüntüleri , (15),(16) *Galanthus elwesii* ovaryum mikroskop görüntüleri.

Muscari neglectum türünde soğan yumurtamsı ve 22,34 - 32,44 × 13,61 - 19,51 mm aralığındadır (Şekil 17,18,19). Yapraklar 5-7 adettir. Yapraklar şeritsi ila şeritsi mızraksı, 6 - 40 cm x 2-8 mm olup parlak yeşil renklidir (Şekil 20).. Sıkapa ve yapraklar genellikle aynı

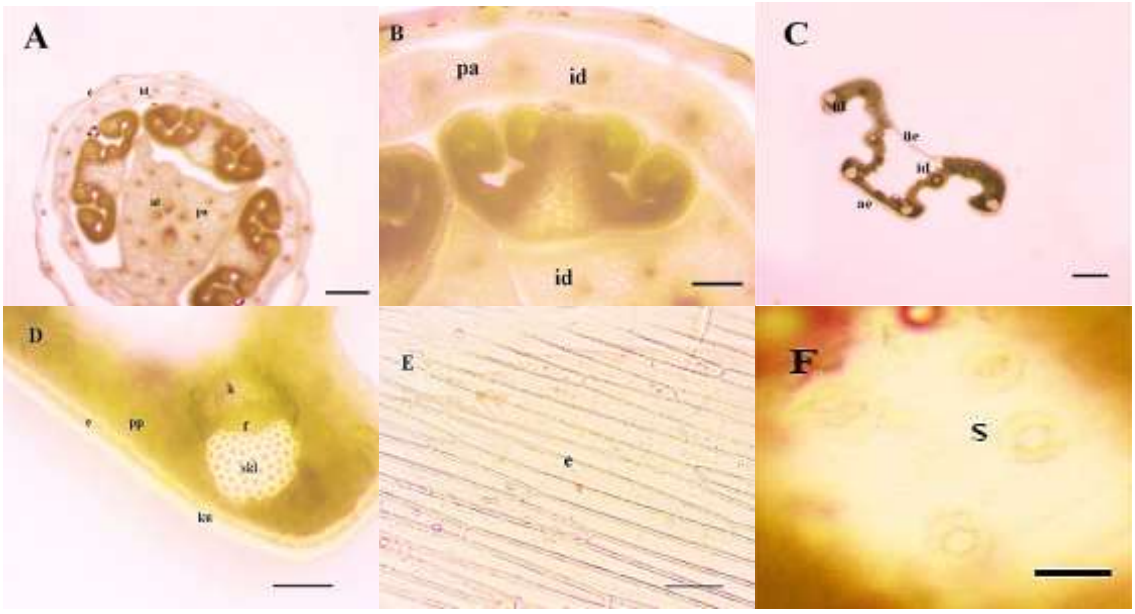
uzunluktadır. Çiçek kurulu sıkı, 27,97 - 45,11 x 13,74 - 16,13 mm ve 34 - 58 adet çiçek barındırır. Çiçekler koyu mavi renkli olup uçları beyaz lobludur. Bu loblar tırtıklı bir yapıya sahiptir (Şekil 21). Fertil çiçekler kokulu, yumurtamsı ila dikdörtgenimsi-testimsi olup koyu mavi ila siyahımsı mavi renklidir (Şekil 22). Stamenler iki sıralı olup tüpün ortasının hemen altındadır (Şekil 23). Steril çiçeklerin sapı yatay ya da yükselicidir. Bunlar en çok 33 adet olup fertil çiçeklerden daha küçüktür ve renkleri daha soluktur. Meyve zamanı çiçek kurulu uzar ve gevşer. Kapsül genişçe yumurtamsı ila dairesel olup 7-9 x 8-10 mm'dir.

Şekil (17), (18), (19) *Muscari neglectum* soğan yapısının mikroskop görüntüleri, (20) *Muscari neglectum* türünün yaprak mikroskop görüntüsü , (21) *Muscari neglectum* çiçek kurulu mikroskop görüntüsü, (22) *Muscari neglectum* çiçek mikroskop görüntüsü , (23) *Muscari neglectum* çiçek boyuna kesit mikroskop görüntüsü, (24) *Muscari neglectum* anter yapısı mikroskop görüntüsü.

2.2.2.Anatomik Bulgular

Crocus ancryensis türünün gövde enine kesitine göre gövde hafif dalgalı-kıvrımlı şekillidir (Şekil 25-A). Gövdenin en dışında dairesel ve silindirik şekilli epidermis hücreleri

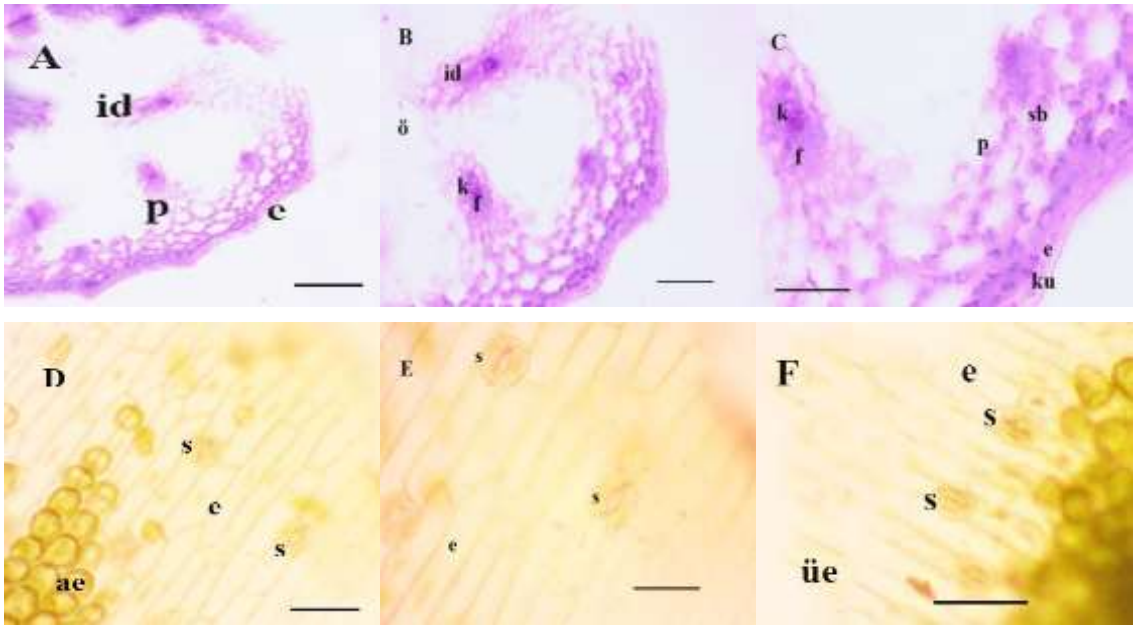
görülmektedir. Epidermis üzeri kutikula tabakası ile kaplıdır. Epidermisin hemen altında daralmış bir korteks görülmektedir. İletim demetleri merkezde 4 büyük olmak üzere gövde geneline dağılmıştır (Şekil 25-B) . Öz bölgesi bütünlüğünü kaybetmiş olup parçalanmıştır. *Crocus ancyrensis* 'in yaprak enine kesitine göre orta kısımda karesel bir orta damar alanı bulunup kenarlara doğru kollar oluşmuştur (Şekil 25-C). Yaprak enine kesitinin genel görünümü boynuzsudur. Yaprağın orta damar kısmında 4 adet iletim demeti bulunmakta olup yan kollarda 2'şer adet iletim adeti yerleşmiştir. Hem alt hem üst yüzeyde kalın bir kutikula tabakası epidermis hücrelerinin üzerini kaplamaktadır. Epidermis üzerinde tüyler yok denecek kadar azdır. Epidermis hücreleri dikdörtgensel veya karesel şekillidir (Şekil 25-E). Bu epidermis hücrelerinin zaman zaman konveks şekil almıştır. Epidermisin iç çeperlerinin kalınlaştığı görülmektedir. Mezofil bifasiyaldir. 2 sıra palizat parankimasının altında sünger parankiması vardır. Her bir iletim demetinin üzerinde kubbe şeklinde sklerankima hücreleri yer almaktadır (Şekil 25- D). Yaprağın alt yüzeyinde stomaya rastlanmamıştır. Sadece üst yüzeyde stoma gözlemlenmiş olup çok az sayıdadır (Şekil 25-F).



Şekil 25. *Crocus ancyrensis*'in kesitleri. A-B gövde enine kesiti, C-F yaprak enine kesiti, e:epidermis, id: iletim demeti, pa: parankima, ae: alt epidermmiş, üe: üst epidermis, ku: kutikula, pp: palizat parankiması, k: ksilem, f: floem, skl: sklerenkima, s: stoma.

Galanthus elwesii'nın gövde kesitine göre en dışta dairesel şekilde epidermis hücreleri olup üzeri kutikula tabakası ile kaplıdır (Şekil 26- A). Belirli bir korteks alanı yoktur. Gövdenin genelinde parankima hücreleri poligonal şekildedir (Şekil 26-B). Parankima hücrelerinin arasında hücre arası boşluklar çok geniştir (Şekil 26-C). Merkeze doğru zaman zaman parankima hücrelerinin kaybolduğu görülmektedir. Kollateral iletim demetleri gövde geneline dağılmıştır. *Galanthus elwesii* ' nin yaprak enine kesitine göre yaprak mekik şeklindedir.

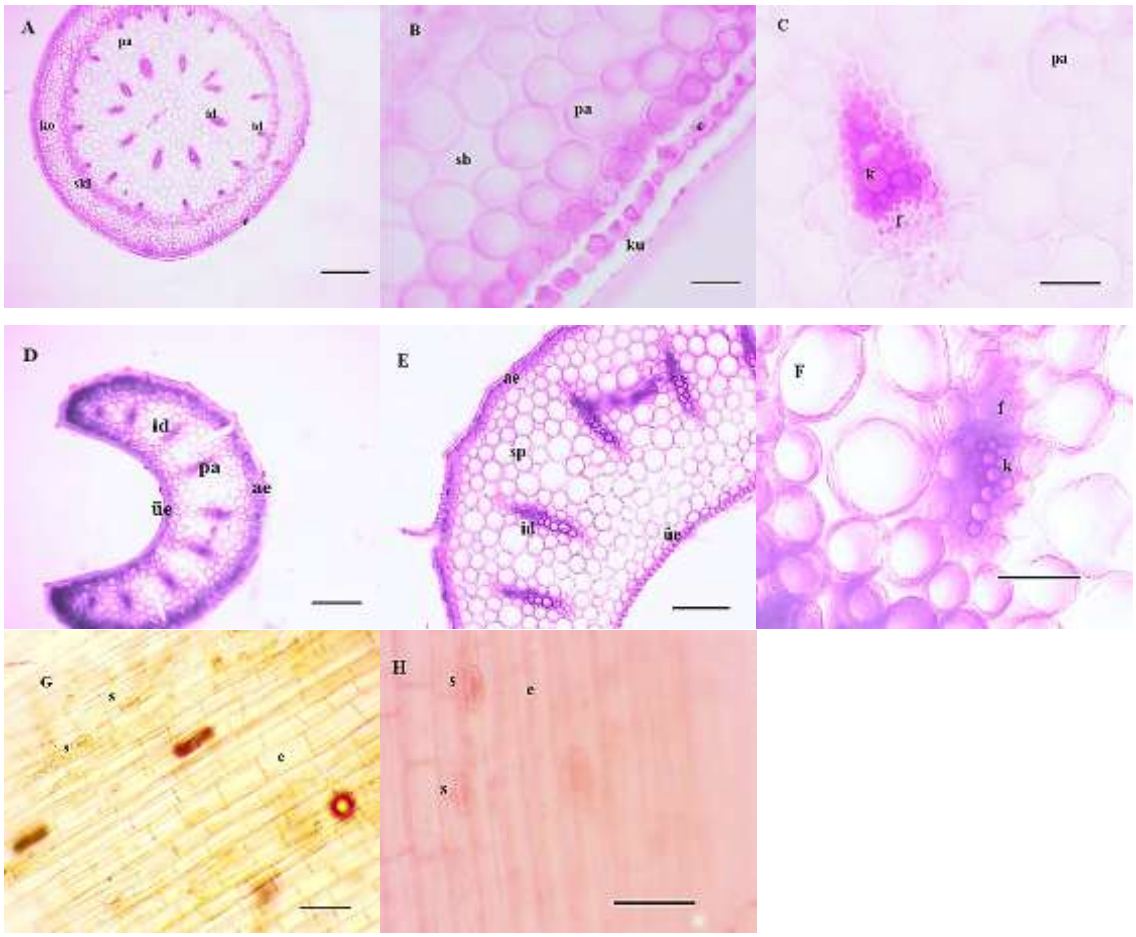
Epidermis hücreleri karesel veya dairesel şekillidir (Şekil 26-D) İnce bir kutikula tabakası epidermis üzerini kaplamaktadır. Epidermis üzerinde az sayıda örtü tüyü mevcuttur. Belirgin bir orta damar bölgesi yoktur. Epidermisin hemen altında dairesel şekilli sünger parankiması hücreleri görülmektedir. Mezofil unifasiyaldir. Mezofilde bir iki sıra palizat parankiması merkeze doğru ise sünger parankiması hücreleri görülmektedir. Yaprağın hem alt hem de üst yüzeyinde stomalara rastlanmıştır (Şekil 26-E-F).



Şekil 26. *Galanthus elwesii*'nin kesitleri. A-C gövde enine kesiti,D-F yaprak enine kesiti,

e: epidermis, p: parankima, id: iletim demeti, ö: öz, k: ksilem, f: floem, ku: kutikula, sb: salgı doku. s: stoma, ae: alt epidermis, üe: üst epidermis.

Muscari neglectum'un gövde kesitine göre gövde düzgün dairesel şekillidir (Şekil 27-A). En dıştaki epidermis hücreleri karesel veya dairesel şekilli olup üzeri kalın bir kutikula tabakası ile kaplıdır (Şekil 27-B). Epidermisin alt yüzeylerinde hücre çeperi kalınlaşması görülmektedir. Epidermisin hemen altıda 6-7 sıralı parankima hücrelerinden sonra devamlı bir halka halinde sklerankima tabakası görülmektedir. Merkeze doğru çok farklı büyüklükteki parankima hücreleri arasında boşluklar bulunmaktadır. Merkezdeki iletim demetleri düzgün bir sıra halinde dağılmıştır(Şekil 27-C).. Sklerankima halkasının hemen altındaki iletim demetleri de düzgün bir sıra oluşturmaktadır. İletim demetlerinde trakeidler çok belirgindir (Şekil 27-F).*Muscari neglectum*'un yaprak enine kesitine göre yaprak hilal şeklindedir (Şekil 27-D). Epidermis hücreleri karesel veya dairesel şekillidir (Şekil 27-E). Mezofil dairesel şekilli parankima hücrelerinden oluşur. Mezofil unifasiyaldir. Çok kalın bir kutikula tabakası epidermisin üzerini örter. Orta damar bölgesi belirgin değildir. Şekilli parankima hücreleri arasında boşluklar vardır. Hem alt hem de üst yüzeyde stomalara rastlanmıştır (Şekil 27-G-H).



Şekil 27. *Muscari neglectum*'un kesitleri. A-C gövde enine kesiti. D-H yaprak enine kesiti, e: epidermis, ko: kollenkima, skl: sklerankima, id: iletim demeti, pa: parankima, ku: kutikula, sb: salgı boşluğu, f: floem, k: ksilem, ae: alt epidermis, üe: üst epidermis, sp: süger parankiması, s: stoma.

2.3.Tartışma

Çalışılan türler ait oldukları familyaların genel özelliklerini göstermektedir. *C. ancyrensis* gövdesinde iletim demetleri merkezde 4 büyük olmak üzere gövde geneline dağılmıştır. *Crocus pulchellus* Herbert türünde 7 adet iletim demetleri, gövde orta kısmında yer almaktadır (Özdemir ve Akyol, 2005). *C. ancyrensis* yaprak enine kesiti oldukça karakteristiktir. Orta damar bölgesi kareseldir ve karenin köşe kısımlarına denk gelen bölgelerde 4 adet iletim demeti bulunmaktadır. Mezofil yanlara doğru kıvrılarak iki kolu meydana getirmektedir. Yaprağın alt yüzeyinde stomaya rastlanmamıştır. Kandemir (2011) *C. ancyrensis* türünde iletim demetlerini alt iki köşede iki adet olarak belirlemiştir. *C. olivieri* J.Gay ve *Crocus abantensis* T. Baytop et Mathew türlerinin yapraklarının kesit şekli *C. ancyrensis* ile benzerlik göstermektedir (Uslu ve ark. 2022). *G. elwesii* gövde ve yaprak anatomik bulgular ilk defa literatüre kazandırılmıştır. *G. elwesii* yaprağında 2-3 sıralı palizat parankiması merkeze doğru ise sünger parankiması

hücreleri görülmekte olup yaprak mezofili bifasiyaldir. Yaprakların her iki yüzeyinde de stomalara rastlanmıştır (Amfistomatik yaprak). Demetler kollateraldir. Bol miktarda hava boşluğu mezofilde bulunmaktadır. *G. fosteri* var. *fosteri* and *G. fosteri* var. *antepensis* taksonlarında bifasiyal mezofil, kollateral demetler ve amfistomatik yaprak tipi ve bol miktarda hava boşluğu rapor edilmiştir (Kandemir ve Akçin 2006). *G. peshmenii* A.P. Davis & C.D. Brickell mezofilinde de büyük hava boşlukları bulunmaktadır (Davis ve Barnett 1997).

3.SONUÇ

Yapılan bu çalışma ile Kırşehir yöresinden toplanan *C. ancyrensis*, *G. elwesii*, *M. neglectum* türleri ile ilgili bazı morfolojik ve anatomik değerler aydınlatılmaya çalışılmıştır. Elde edilen bulgular literatür ile uygunluk göstermiş, bulunan farklılıklar belirtilmiştir. Ülkemizin biyolojik zenginliğine katkıda bulunan bu türlerin bilinçli bir şekilde in-situ ve ex-situ muhafazasının yapılması ve bu bitkilerin gelecek nesillere aktarılması önem arz etmektedir.

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EFFECT OF GLYCINE BETAINE PRIMING APPLICATION ON GERMINATION AND SEEDLING DEVELOPMENT IN SAFFLOWER SEEDS UNDER DROUGHT STRESS

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ABSTRACT

This study was conducted to investigate the effects of glycine betaine (GB) priming on the drought stress tolerance of safflower (*Carthamus tinctorius* L.) OLAS variety seeds. Drought stress is a physiological condition that arises when the water required for plant growth, development, and productivity becomes insufficient. This stress factor adversely affects seed germination, early seedling development, and overall plant vigor, thereby playing a direct and critical role in determining the success of plant populations and agricultural productivity. In the experiment, seeds were pre-treated with 20 mg/l glycine betaine for different durations (control, 1, 2, 3 and 4 h) and then subjected to different concentrations of PEG (polyethylene glycol) (Control, -0.25, -0.50, -0.75, -1.00 MPa) for germination testing. The experiment was conducted in the Field Crops Laboratory of the Faculty of Agriculture at Sakarya University of Applied Sciences, using factorial completely randomized design arrangement with three replications. The results showed that increasing PEG concentration caused a decline in germination rate, germination vigor, seedling and root length, total fresh and dry weights, water content (WC), and relative water content (RWC). However, glycine betaine priming applied for different durations partially alleviated these adverse effects, enhancing the tolerance of plants to drought stress. These findings suggest that glycine betaine pretreatment could be an effective approach to promote uniform germination and seedling emergence of safflower under drought conditions.

Keywords: Safflower, Glycine Betaine, Priming, PEG.

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ASPİR TOHUMLARINDA GLİSİN BETAİN PRİMİNG UYGULAMASININ KURAKLIK STRESİ ALTINDA ÇİMLENME VE FİDE GELİŞİMİNE ETKİSİ

ÖZET

Bu araştırma, aspir (*Carthamus tinctorius* L.) OLAS çeşidi tohumlarında glisin betain (GB) ile yapılan priming uygulamasının kuraklık stresine karşı etkisini incelemek amacıyla gerçekleştirilmiştir. Kuraklık stresi, bitkilerin büyüme, gelişme ve verimlilik süreçlerinde ihtiyaç duyduğu suyun yetersizliği sonucu ortaya çıkan fizyolojik bir durumdur. Bu stres faktörü, tohumların çimlenmesi, erken dönem fide gelişimi ve genel bitki canlılığı üzerinde olumsuz etkiler oluşturmakta; dolayısıyla bitki popülasyonlarının gelişimi ve tarımsal verimlilik üzerinde doğrudan belirleyici rol oynamaktadır. Çalışmada, tohumlar 20 mg/l glisin betain ile farklı sürelerde (kontrol, 1, 2, 3 ve 4 saat) ön işleme tabi tutulmuş ve ardından farklı seviyelerde PEG (polietilen glikol) konsantrasyonları (kontrol, -0.25, -0.50, -0.75, -1.00 MPa) altında çimlenme testine alınmıştır. Deneme, tesadüfi parselleri faktöriyel deneme desenine göre üç tekerrürlü olarak Sakarya Uygulamalı Bilimler Üniversitesi Ziraat fakültesinin tarla bitkileri laboratuvarında yürütülmüştür. Elde edilen sonuçlara göre, artan PEG konsantrasyonunun çimlenme hızı, çimlenme gücü, fide ve kök uzunluğu, toplam yaş ve kuru ağırlık, su içeriği (WC) ve bağıl su içeriği (RWC) gibi parametrelerde düşüşe neden olduğunu göstermiştir. Ancak, tohumlara uygulanan farklı sürelerde glisin betain priming işlemi, bu olumsuz etkileri kısmen hafifleterek bitkilerin kuraklık stresine karşı daha dayanıklı hale gelmesini sağlamıştır. Elde edilen bulgular, glisin betain ile yapılan ön işlemin, aspir tohumlarının kuraklık koşullarında uniform çimlenme ve çıkışlarına etkili bir yöntem olabileceğini ortaya koymaktadır.

Anahtar Kelimeler: Aspir, Glisin Betain, Priming, PEG.

1. GİRİŞ

Aspir (*Carthamus tinctorius* L.) yüksek adaptasyon kabiliyeti, agronomik özellikleri, biyolojik aktif bileşen içeriği ve tohumlarında bulunan kaliteli yağ asitleri kompozisyonu ile dikkat çeken önemli bir yağ bitkisidir. Hem gıda sanayisinde hem de kozmetik endüstrilerinde kullanım potansiyeli sayesinde ekonomik değeri giderek artmaktadır. Özellikle linoleik asit açısından zengin tohum yağı, aspirin dünya genelinde yaygın olarak yetiştirilmesine neden olan başlıca faktörlerden biridir. Ayrıca, yarı kurak iklim koşullarına uyum sağlayabilmesi, düşük girdi gereksinimi ve alternatif ürün olma potansiyeli ile sürdürülebilir tarımsal üretim sistemlerinde önemli bir yer tutmaktadır (Delshad ve ark., 2018). Toplam yağ asitlerinin yaklaşık %90'ını oluşturan yüksek oranda doymamış yağ asitleri içermektedir. Bu yağ asitlerinin başlıcaları linoleik (%71–75) ve oleik (%16–20) asitlerdir. Aspir bitkisi, abiyotik stres faktörlerine karşı yüksek tolerans göstermektedir. Özellikle tuzluluk ve kuraklık gibi çevresel stres koşullarında, aspir bitkisinin fizyolojik ve moleküler adaptasyon mekanizmaları sayesinde verim kayıpları minimize edilebilmektedir. Su stresi, tarımsal üretimde küresel ölçekte en önemli abiyotik kısıtlayıcı faktörlerden biri olarak kabul edilmekte olup, bitkisel gelişim, biyokütle üretimi ve verim üzerinde ciddi düzeyde olumsuz etkiler oluşturmaktadır. (Mahajan ve Tuteja, 2005). Tuzluluk ve kuraklık bitkisel üretimi etkileyen iki önemli çevresel faktördür. Su ve toprak tuzluluğu kurak ve yarı kurak bölgelerde bitkisel üretimi sınırlayabilen önemli stres faktörlerinden biridir. Kuraklık, iyon adsorpsiyon süreci sırasında su emilimini azaltır. Su, tohumlardaki maddelerin çimlenmesinde ve metabolizmasında önemli bir faktördür (Serrano ve ark., 1999; Murillo- Amador ve ark., 2002). Özellikle çimlenme sürecinin başlangıcında su potansiyelinin düşük olması, tohumun su almasını bozar ve çimlenmeyi geciktirir (Hardegree ve Emmerich, 1990). Tohum ön işlemleri (priming), çeşitli bitki türlerinde hem optimal hem de stres koşullarında çimlenme performansını ve fide gelişimini artırmada etkili bir agronomik uygulama olarak öne çıkmaktadır. Glisin betain (GB), diğer adıyla trimetilglisin, bitkilerde ozmoprotektan olarak işlev gören doğal olarak oluşan bir bileşiktir. Glisin aminoasidinin bir türevi olan bu bileşik, kuraklık ve tuzluluk gibi çeşitli çevresel stres faktörlerine karşı organizmaların toleransını artırmadaki rolüyle bilinmektedir (Ashraf ve Foolad, 2007). Tüm bitkiler, abiyotik stres koşullarının olumsuz etkilerini dengelemek amacıyla yeterli düzeyde glisin betain (GB) sentezleyememektedir. Bu durum göz önüne alındığında, stres toleransını artırmak için önerilen yaklaşımlardan biri, glisin betain gibi osmolotik modülatörlerin dışsal olarak uygulanması yoluyla bitkilerde bu bileşiğin içsel konsantrasyonunun artırılmasıdır. Prolin ve glisin betain gibi uyumlu çözücülerin stres öncesinde, stres süresince ya da stres sonrasında bitkilere eksojen olarak uygulanması, bu bileşiklerin endojen seviyelerinin yükseltilmesine katkı sağlamakta ve bu durum, genellikle stres koşullarında bitki büyümesi ve verimliliğinde iyileşmelerle sonuçlanmaktadır. Çeşitli çalışmalarda, glisin betainin dışsal uygulanmasının, abiyotik stres altındaki bitkilerin büyüme ve fizyolojik performansı üzerinde olumlu etkiler oluşturduğu rapor edilmiştir (Makelan ve ark., 1996; Agboma ve ark., 1997; Ashraf ve Foolad, 2007). Buğday (*Triticum aestivum* L.), bezelye (*Pisum sativum* L.), ayçiçeği (*Helianthus annuus* L.) ve pamuk (*Gossypium hirsutum* L.) gibi türlerde, fide çıkışını hızlandırmak ve kuraklık stresine toleransı artırmak amacıyla hidropriming, osmo-priming ve hormonal priming gibi farklı priming teknikleri başarıyla uygulanmıştır. Benzer şekilde, şeker pancarı (*Beta vulgaris* L.), mısır (*Zea mays* L.), soya fasulyesi (*Glycine max* L.) ve aspir (*Carthamus tinctorius* L.) gibi diğer bitki türlerinde de tohum priming uygulamalarının

çimlenme ve erken gelişim üzerindeki olumlu etkileri çeşitli çalışmalarda rapor edilmiştir (Koçak Şahin., 2024; MacDonald & Mohan., 2025; Mylsamy ve ark., 2025). Aspir diğer yağ bitkileriyle karşılaştırıldığında kuraklık ve tuzluluk gibi abiyotik stres koşullarına karşı daha yüksek tolerans göstermektedir. Ancak, çimlenme ve erken fide gelişimi dönemlerinde bu stres faktörlerine karşı duyarlılığı artmaktadır. Özellikle çimlenme aşamasında tuz stresi, çimlenme oranını ve fide gelişimini olumsuz etkilemektedir. Bu durum, aspir bitkisinin erken gelişim evrelerinde tuzluluk ve kuraklık stresine karşı hassas olduğunu göstermektedir (Fatahiyan ve ark., 2025).

Bu çalışmanın amacı, aspir bitkisinde çimlenme döneminde uygulanan glisin betain (GB) ön uygulamasının kuraklık stresine karşı dayanıklılık üzerine etkilerini araştırmaktır.

2. MATERYAL ve YÖNTEM

Araştırma 2025 yılında Sakarya Uygulamalı Bilimler Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Laboratuvarında tesadüf parselleri faktöriyel deneme deseninde ve 3 tekerrürlü olarak kurulmuştur. Bu çalışmada bitki materyali olarak, Trakya Tarımsal Araştırma Enstitüsü Müdürlüğü'nden temin edilen OLAS aspir (*Carthamus tinctorius* L.) çeşidi kullanılmıştır. Denemede kullanılan cam petri kapları ve kurutma kağıtları, sterilizasyon amacıyla etüvde 175 °C'de 30 dakika süreyle bekletilmiştir. Tohumlara ön muamele amacıyla biyostimülant olarak glisin betain (GB) uygulanmıştır. Çimlendirme öncesinde, kontaminasyon riskini en aza indirmek için tohumlar %3'lük sodyum hipoklorit (NaClO) çözeltisinde 15 dakika süreyle çalkalanmış ve ardından üç kez saf su ile durulanmıştır. Denemede tohumlar, 20 mg/l konsantrasyonunda glisin betain çözeltisi ile farklı sürelerde (kontrol, 1, 2, 3 ve 4 saat) ön işleme tabi tutulmuştur. Ön muamele sonrası, farklı seviyelerdeki polietilen glikol (PEG 6000) çözeltileri (kontrol, -0.25, -0.50, -0.75 ve -1.00 MPa) altında çimlendirme testleri gerçekleştirilmiştir. Her tekerrürde 50 adet tohum kullanılmış ve deneyler sabit 23 ± 1 °C sıcaklıktaki çimlendirme ortamında yürütülmüştür.

Kuraklık stresini simüle etmek amacıyla, su potansiyelinin hesaplanmasında aşağıdaki denklemden yararlanılmıştır (Michel ve Kaufmann, 1973).

$$\Psi H = (-1.18 \times 10^{-2}) \times C - (1.18 \times 10^{-4}) \times C + (2.67 \times 10^{-4}) \times C \times T + (8.39 \times l0^{-7}) \times C^2T$$

(ψ: su potansiyeli, MPa; C: PEG 6000 konsantrasyonu, g L^{-1}; T: sıcaklık, °C).

Bu denklem kullanılarak 1 L distile suya eklenmesi gereken PEG 6000 miktarları belirlenmiş ve kontrol ile –0.25, –0.50, –0.75 ve –1.00 MPa su potansiyeline sahip çözeltiler hazırlanmıştır.

Bu araştırmada çimlenme hızı (%), çimlenme gücü (%), kök uzunluğu (mm), fide uzunluğu (mm), yaş ağırlığı (g), kuru ağırlığı (g), bağıl su içeriği (%) ve su içeriği (g/g) gözlemler ISTA (2010) kurallarına göre 4. ve 14. günde alınmıştır. hesaplanmıştır. Bağıl su içeriği (RWC) Weatherley (1950), ve su içeriği (WC), Wu ve diğerleri (2013) gözlemler sırasıyla verilen formüllerden hesaplanmıştır:

RWC (%)=[(Yaş ağırlık- Kuru ağırlık/ Tam turgor ağırlığı – Kuru ağırlığı)]×100

WC (g/g) = (Yaş ağırlık- Kuru ağırlık)/ Kuru ağırlık

Denemeden elde edilen veriler varyans analizine (ANOVA) tabi tutulmuştur. Tüm istatistiksel analizler MSTAT-C paket programı kullanılarak gerçekleştirilmiştir. Elde edilen ortalamalar arasındaki farkların belirlenmesinde, anlamlılık düzeyine göre Duncan çoklu karşılaştırma testi uygulanmış ve sonuçlar gruplandırılarak yorumlanmıştır.

3. BULGULAR VE TARTIŞMA

Bu çalışmada incelenen tüm özelliklere ait varyans analizi sonuçları Tablo 3.1'de sunulmuştur. Elde edilen bulgulara göre, GB uygulama süresi ile PEG seviyeleri arasındaki etkileşim, tüm özellikler açısından %1 anlamlılık düzeyinde istatistiksel olarak önemli bulunmuştur ($P < 0.01$).

Tablo 3.1: PEG stresi altında farklı GB uygulamalarıyla aspir özelliklerinin varyans analizi sonuçları.

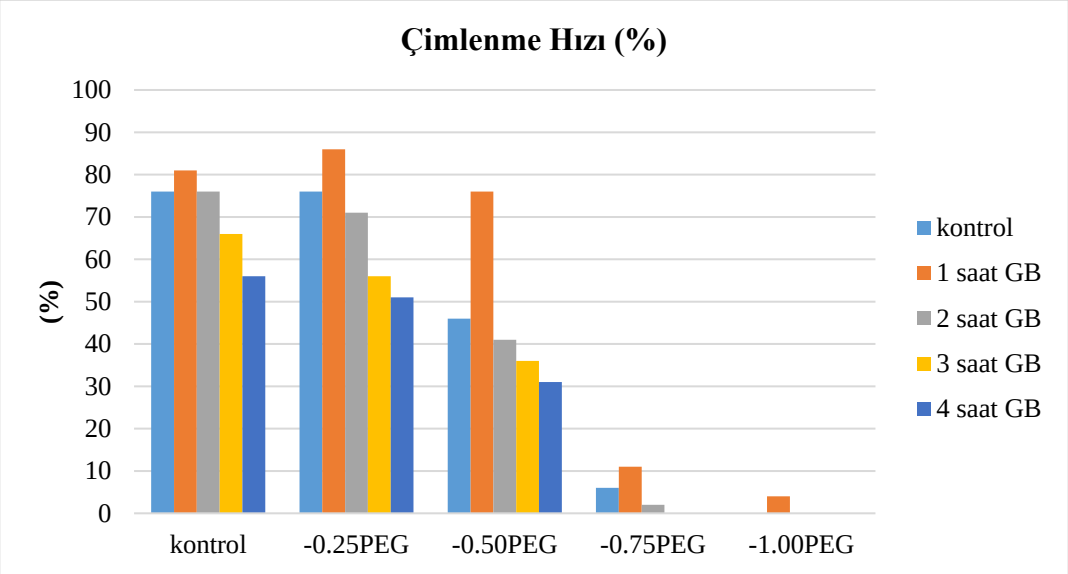
V.K	SD	Gözlemlerin Kareler Ortalaması							
		Çimlenme Hızı (%)	Çimlenme Gücü (%)	Fide Uzunluğu (mm)	Kök Uzunluğu (mm)	Toplam Yaş Ağırlığı (g)	Toplam Kuru Ağırlığı (g)	Bağıl Su İçeriği (RWC)(%)	Su içeriği (WC) (g/g)
(GB)	4	1282.08**	1747.62**	0.023	3.29**	0.008**	0.00025**	25.41**	4.62**
(P)	4	17274.18**	20591.82**	22.66**	80.4**	0.254**	0.004**	22838.23**	261.03**
(GB) × (P)	16	163.53**	131.67**	0.206**	4.19**	0.005**	0.00006**	104.09**	2.68**
Hata	50	0.76	0.74	0.043	0.042	0.0000001	0.0000001	0.141	0.001
Genel	74	------	------	------	------	------	------	------	------
CV%		2.30	1.96	2.20	9	0.35	2.79	0.88	0.77

** P <0.01 seviyesinde önemli, * P <0.05 seviyesinde önemli olduğunu göstermektedir.

Glisin Betain uygulama süresi (GB), PEG (P)

Çimlenme Hızı (%)

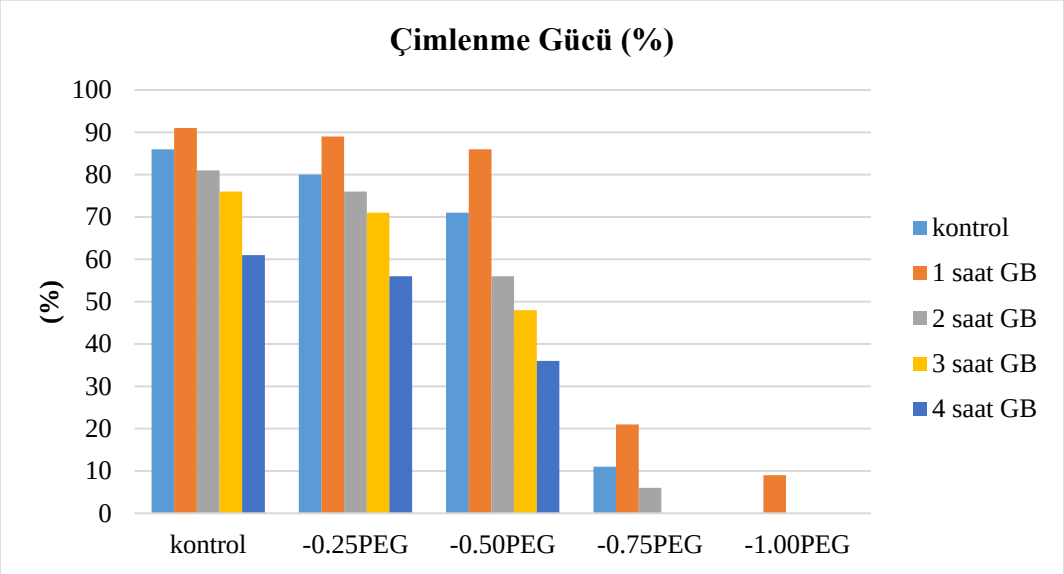
Grafikte, farklı GB ön uygulama sürelerinin (kontrol, 1, 2, 3 ve 4 saat) PEG ile oluşturulan kuraklık koşulları altında aspir tohumlarının çimlenme hızına etkisi gösterilmektedir. Elde edilen sonuçlara göre GB × PEG interaksiyonunun genel ortalamalarında en yüksek çimlenme hızı %86 olarak 1 saat GB uygulamasında ve –0.25 Mpa polietilen glikol dozunda gözlemlenmiştir ve 4 saat ön uygulama ve –0.75 Mpa polietilen glikol dozunda çimlenme gerçekleşmemiştir (Şekil 3.1).



Şekil 3.1: GB ön uygulama süresinin PEG stresi altında çimlenme hızına etkisi

Çimlenme Gücü (%)

Şekil 3.2'de, farklı glisin betain (GB) ön uygulama sürelerinin (kontrol, 1, 2, 3 ve 4 saat) PEG ile oluşturulan kuraklık stresi koşulları altında aspir tohumlarının çimlenme gücü üzerindeki etkisi gösterilmektedir. Uygulamadan 14 gün sonra elde edilen bulgulara göre, GB × PEG etkileşiminin genel ortalamalarında en yüksek çimlenme gücü %91 ile 1 saatlik GB uygulaması ve kontrol grubunda kaydedilmiştir. Öte yandan, 4 saatlik GB uygulaması ile –0.75 MPa PEG konsantrasyonunun birlikte uygulandığı koşullarda çimlenme gerçekleşmemiştir. Elde edilen sonuçlara göre, artan PEG dozları aspir tohumlarının çimlenmesini olumsuz yönde etkilemiştir. Özellikle –0.75 ve –1.00 MPa seviyelerindeki PEG uygulamalarında çimlenme gözlenmemiştir. Bu durum, yüksek osmotik basıncın tohumun su alımını engelleyerek çimlenme sürecini durdurabileceğini ortaya koymaktadır. Benzer şekilde, Kaya ve ark. (2006) ve Farooq ve ark. (2009) yaptıkları çalışmalarda, artan PEG konsantrasyonlarının bitki tohumlarında çimlenme oranını ve çimlenme hızını önemli ölçüde düşürdüğünü bildirmişlerdir. Ayrıca, çimlenme ortamına uygulanan PEG'nin, hücre içi su potansiyelini azaltarak metabolik aktiviteleri baskıladığı belirtilmiştir (Bewley ve ark., 2013).

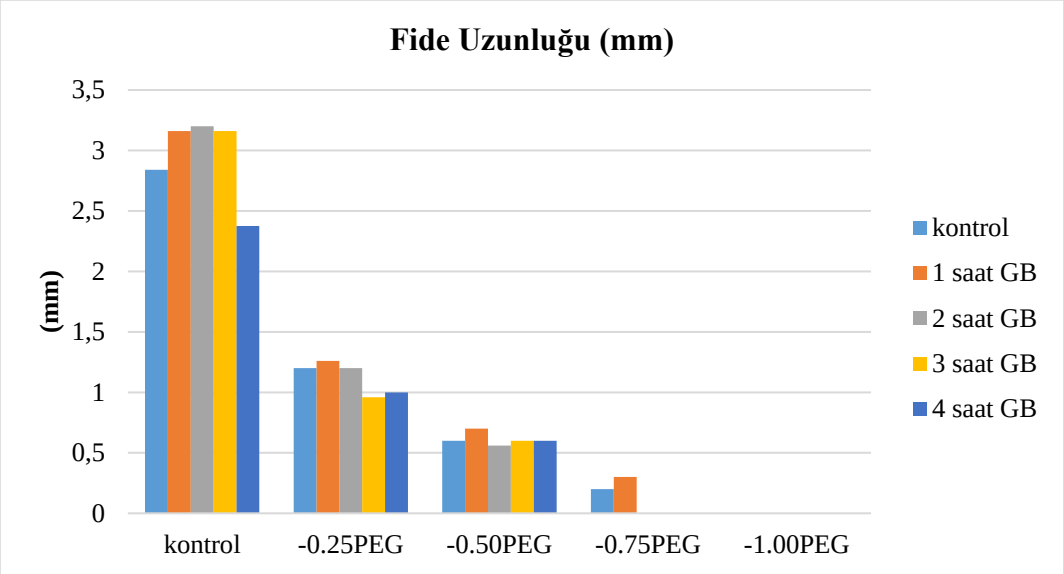


Şekil 3.2: GB ön uygulama süresinin PEG stresi altında çimlenme gücüne etkisi

Fide Uzunluğu (mm)

Şekil 3.3'te, farklı glisin betain (GB) ön uygulama sürelerinin ve PEG ile oluşturulan kuraklık stresinin aspir fide boyu üzerindeki etkileri gösterilmektedir. Elde edilen bulgulara göre, en uzun fide boyu (3.20 mm) kontrol grubunda ve 2 saatlik GB ön uygulamasında gözlemlenmiştir. Bununla birlikte, –0.75 MPa PEG dozunda 3 ve 4 saatlik GB ön uygulamalarında, ayrıca –1.00 MPa PEG uygulamasında çimlenme gerçekleşmemiştir. Grafik verileri incelendiğinde, artan PEG konsantrasyonlarının fide boyunda belirgin bir azalmaya neden olduğu görülmektedir. Bu durum, PEG'in oluşturduğu osmotik stresin hücre bölünmesi ve uzamasını sınırlayarak fidelerin gelişimini olumsuz etkilediğini göstermektedir. Ancak 1 saatlik GB ön uygulamasının, yüksek PEG seviyelerinde dahi diğer uygulama sürelerine kıyasla daha iyi fide gelişimi sağladığı belirlenmiştir.

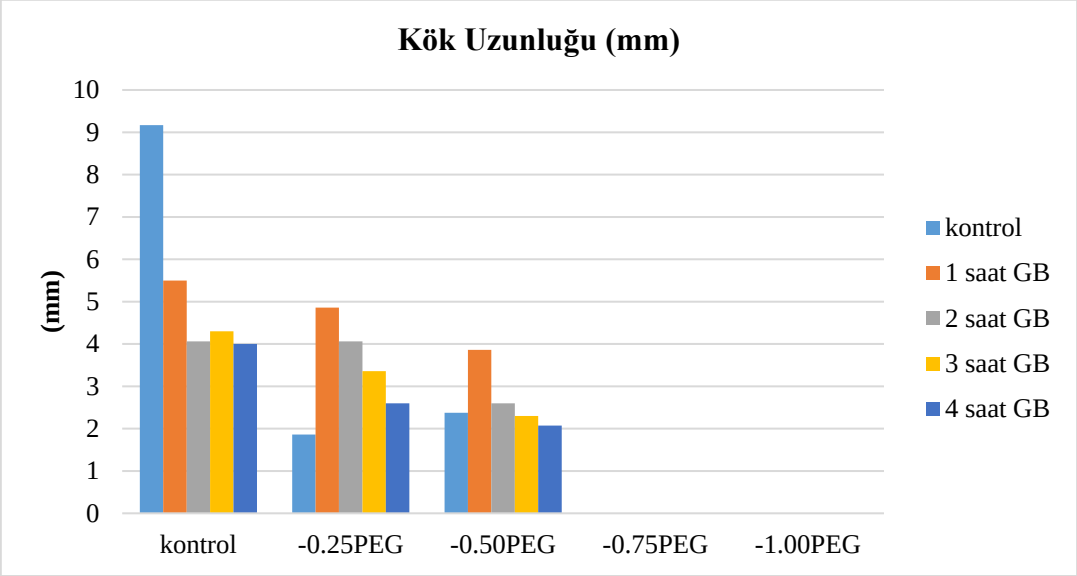
Bu sonuçlar, glisin betainin uygun süre ve dozlarda uygulanmasının osmotik stres koşullarında bitki fide gelişimini destekleyebileceğini göstermektedir. Benzer şekilde, Zhang ve ark. (2013) GB'nin antioksidan savunmayı artırarak ve ozmotik dengeyi düzenleyerek kuraklık stresine karşı koruyucu rol oynadığını bildirmiştir. Ayrıca, Noreen ve ark. (2010) ve Farooq ve ark. (2008) gibi araştırmacılar da glisin betain uygulamasının fide gelişimini iyileştirdiğini ve bitkilerin stres koşullarına karşı dayanıklılığını artırdığını vurgulamışlardır.



Şekil 3.3: GB ön uygulama süresinin PEG stresi altında fide uzunluğuna etkisi

Kök Uzunluğu (mm)

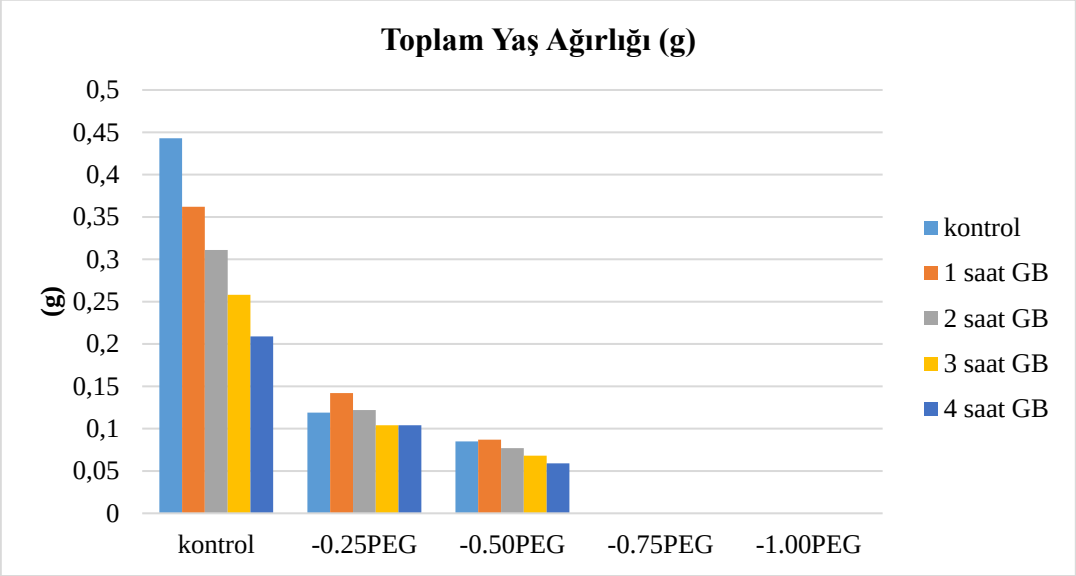
Şekil 3.4'te, farklı glisin betain (GB) ön uygulama sürelerinin ve polietilen glikol (PEG) ile oluşturulan kuraklık stresinin aspir tohumlarının kök uzunluğu üzerindeki etkileri gösterilmektedir. Ortalama değerlere göre, en uzun kök gelişimi kontrol grubunda gözlemlenmiş, en kısa kök uzunluğu ise kontrol grubunun –0.25 MPa PEG uygulamasında kaydedilmiştir. Genel eğilim incelendiğinde, artan PEG konsantrasyonlarının kök gelişimini belirgin biçimde sınırlandırdığı görülmektedir. Bununla birlikte, grafik verileri 1 saatlik GB ön uygulamasının diğer sürelerle karşılaştırıldığında daha uzun kök gelişimi sağladığını ortaya koymaktadır. Bu bulgu, GB'nin stres koşulları altında ozmotik düzenleyici olarak görev yaparak su dengesini koruduğu ve kök gelişimini desteklediği yönündeki literatür ile örtüşmektedir. Agboma ve ark. (1997) ve Ashraf ve Foolad. (2007) glisin betainin kök sisteminin gelişimini artırarak bitkilerin kuraklık koşullarına karşı dirençlerini yükselttiğini bildirmişlerdir. Ayrıca, Kaya ve ark. (2006) GB uygulamasının kök uzunluğu üzerindeki pozitif etkilerini farklı bitki türlerinde göstermiştir.



Şekil 3.4: GB ön uygulama süresinin PEG stresi altında kök uzunluğuna etkisi

Toplam Yaş Ağırlığı (g)

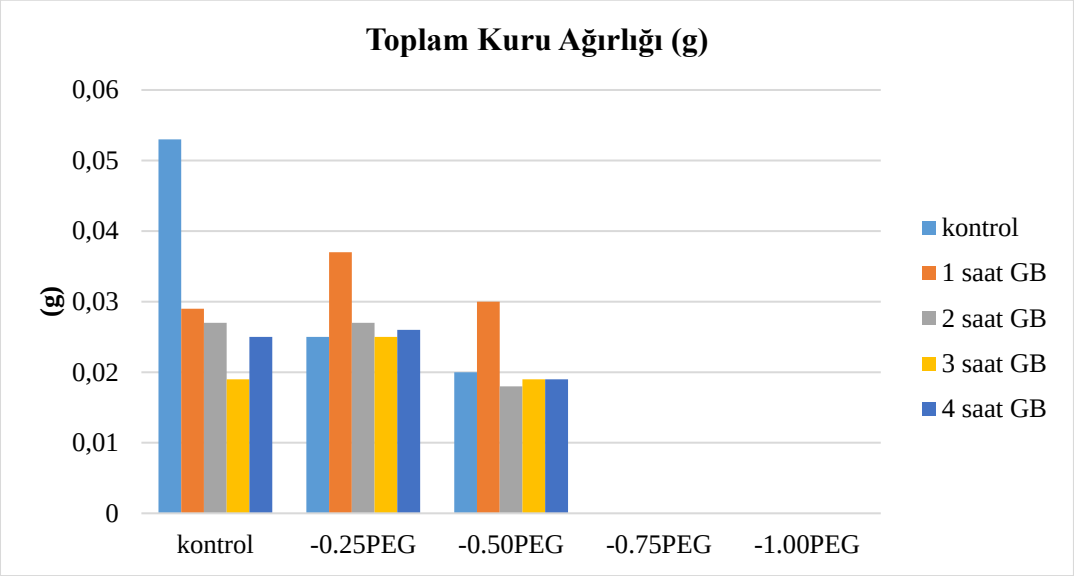
Elde edilen bulgulara göre, en yüksek toplam yaş ağırlığı 0.44 g ile kontrol grubunda kaydedilirken, en düşük değer 0.059 g olarak –0.50 MPa PEG uygulaması ve 4 saatlik GB ön uygulaması kombinasyonunda gözlemlenmiştir (Şekil 3.5). Genel olarak artan PEG konsantrasyonları, aspir fidelerinin biyokütle üretimini olumsuz yönde etkilemiştir. Bu durum, yüksek osmotik stresin hücresel su dengesini bozarak metabolik faaliyetleri yavaşlatmasıyla ilişkilendirilmektedir. Öte yandan, 1 saatlik GB ön uygulaması, diğer sürelerle karşılaştırıldığında özellikle orta düzeydeki PEG uygulamalarında daha yüksek yaş ağırlığı değerleri sağlamıştır. Bu bulgu, glisin betainin ozmotik dengeyi düzenleyerek su alımını artırdığı ve fizyolojik stres tepkilerini hafiflettiğini gösteren önceki çalışmalarla uyumludur (Ashraf ve Foolad, 2007; Wahid ve ark., 2007). Ayrıca, Hanif ve ark. (2023) yaptıkları çalışmada, glisin betain kaplı çinko oksit nano-parçacıklarının, PEG ile indüklenen kuraklık stresi altında kişniş bitkilerinin morfolojik parametrelerini ve yaş ağırlığını önemli ölçüde artırdığını bildirmişlerdir. Benzer şekilde, 2024 yılında yayımlanan bir araştırmada, glisin betain ile yapılan tohum ve kök ön uygulamalarının, buğday fidelerinde kuraklık toleransını artırarak büyümeyi ve antioksidatif savunmayı iyileştirdiği gösterilmiştir (Baroi ve ark., 2024).



Şekil 3.5: GB ön uygulama süresinin PEG stresi altında toplam yaş ağırlığına etkisi

Toplam Kuru Ağırlığı (g)

Toplam kuru ağırlık açısından elde edilen bulgular, en yüksek değerin 0.053 g ile kontrol grubunda kaydedildiğini göstermiştir (Şekil 3.6). Buna karşılık, en düşük toplam kuru ağırlık değeri 0.018 g olarak, –0.50 MPa PEG ile uygulanan kuraklık stresi altında ve 2 saatlik glisin betain (GB) ön uygulamasında gözlemlenmiştir. Artan PEG konsantrasyonlarına bağlı olarak tohumların toplam kuru madde birikimi anlamlı düzeyde azalmış; bu durum, kuraklık stresinin bitki büyümesi ve biyokütle üretimi üzerindeki olumsuz etkisini ortaya koymuştur. GB ön uygulaması belirli düzeylerde bu olumsuz etkileri hafifletmiş olsa da, yüksek düzeyde PEG uygulamalarında biyokütle üretimi belirgin şekilde düşmüştür. Acar ve ark. (2020), buğdayda PEG ile oluşturulan kuraklık stresinin bitki kuru ağırlığını önemli ölçüde azalttığını ve GB ön uygulamasının bu etkiyi kısmen hafiflettiğini rapor etmiştir. Demirtaş ve ark., (2023) ise ayçiçeğinde benzer şekilde yüksek PEG dozlarının toplam kuru ağırlık üzerinde baskılayıcı etkiler gösterdiğini ve 1 saatlik GB uygulamasının kök ve gövde biyokütlesi üzerinde olumlu etkiler yarattığını bildirmiştir.

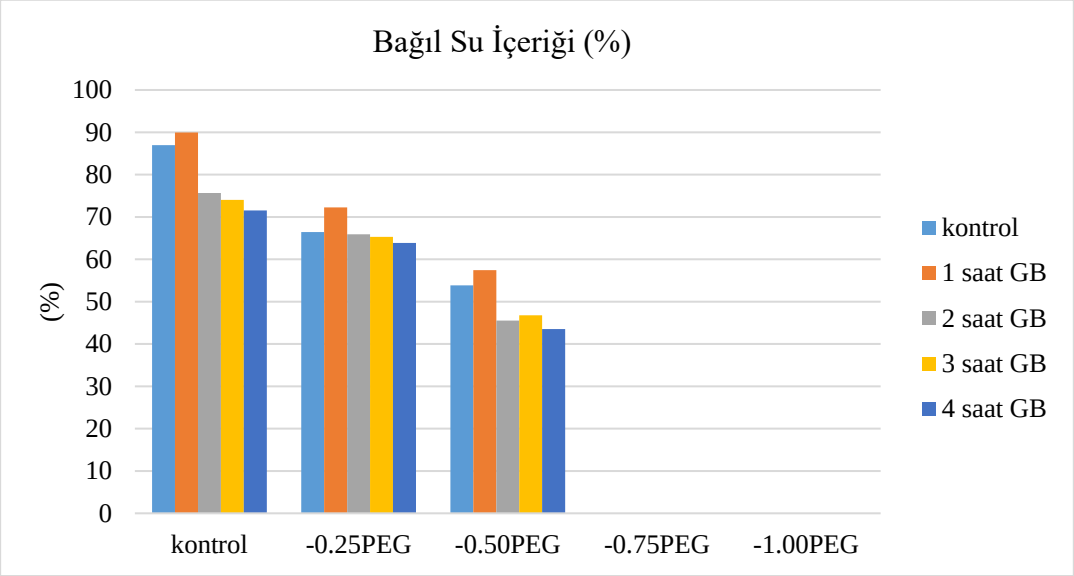


Şekil 3.6: GB ön uygulama süresinin PEG stresi altında toplam kuru ağırlığına etkisi

Bağıl Su İçeriği (%)

Bitkilerde bağıl su içeriği (RWC), fizyolojik durumun belirlenmesinde yaygın olarak kullanılan önemli bir parametredir. RWC'nin %90–100 aralığında olması, bitkinin su bakımından sağlıklı olduğunu ve herhangi bir stres altında olmadığını göstermektedir. Buna karşılık, bu oranın %50'nin altına düşmesi, şiddetli su stresine işaret eder ve hücre düzeyinde hasar riskinin yüksek olduğunu gösterir (Barrs ve Weatherley, 1962).

Çalışmamızda elde edilen bulgulara göre, en yüksek bağıl su içeriği %89.95 ile kontrol + 1 saat glisin betain (GB) ön uygulamasında ölçülmüştür. En düşük RWC değeri ise %43.53 oranıyla –0.50 MPa PEG + 4 saat GB uygulamasında tespit edilmiştir (Şekil 3.7). Bu durum, –0.50 MPa ve üzeri PEG konsantrasyonlarının bitkilerde şiddetli su stresine neden olduğunu göstermektedir. Bununla birlikte, 1 saatlik GB ön uygulaması, bu stresin etkilerini kısmen de olsa hafifleterek diğer stres gruplarına kıyasla daha yüksek RWC değerlerinin korunmasına katkı sağlamıştır. Bu sonuçlar, GB'nin osmotik stres koşullarında koruyucu etkisi olabileceğini desteklemektedir. Chen ve ark. (2008), glisin betainin (GB) stres koşullarında bağıl su içeriği üzerindeki olumlu etkisini kanıtlamışlardır.

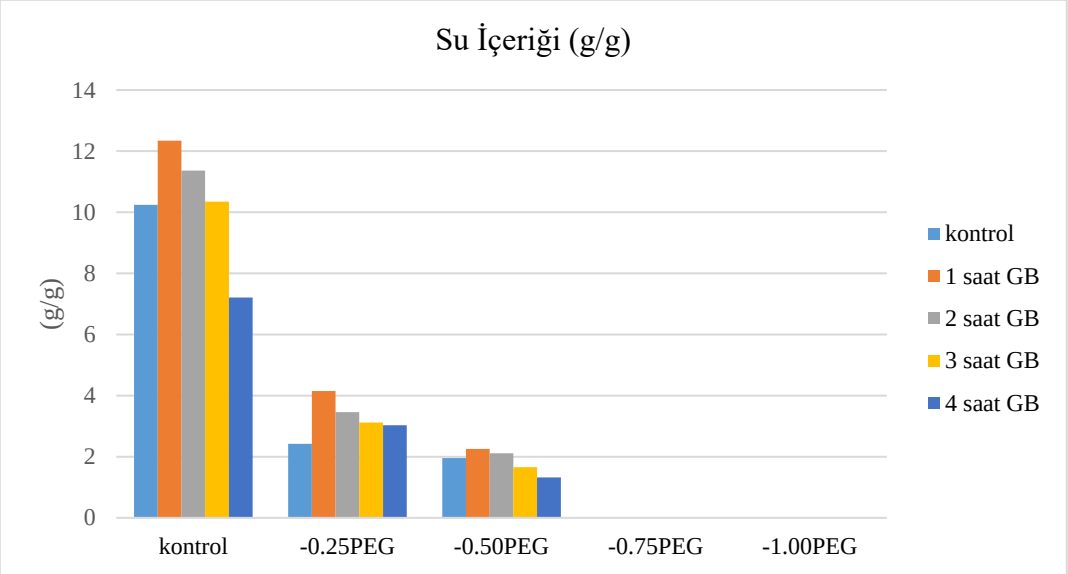


Şekil 3.7: GB ön uygulama süresinin PEG stresi altında bağıl su içeriğine etkisi

Su İçeriği (g/g)

Bitkilerin fizyolojik durumunu ve çevresel stres koşullarına verdiği tepkileri değerlendirmede su içeriği (WC, g/g) önemli bir göstergedir. Su içeriği, bitkilerin su tutma kapasitesini ve hücre içi turgor durumunu yansıtarak, özellikle kuraklık veya osmotik stres gibi suya bağlı çevresel etkilere karşı tolerans seviyelerinin belirlenmesinde kullanılır (Sade ve ark., 2012). Bu çalışmada, aspir (*Carthamus tinctorius* L.) bitkisinde su içeriği ortalamalarının 12.34 ile 1.32 g/g arasında değiştiği belirlenmiştir. Şekil 3.8'de de görüldüğü üzere, en yüksek su içeriği değeri kontrol + 1 saat glisin betain (GB) ön uygulaması yapılan grupta ölçülmüştür. Buna karşın, PEG dozunun artırılmasıyla su içeriğinde belirgin bir azalma gözlemlenmiştir. Bu durum, PEG'in ortamdaki ozmotik potansiyeli düşürerek bitki köklerinin su alımını sınırlandırmasıyla açıklanabilir. PEG-6000, hücre zarından geçemeyecek kadar büyük bir polimer olduğundan, ortamın su potansiyelini düşürerek yapay bir su stresi oluşturur (Verslues ve ark., 2006). Glisin betain uygulamasının ise PEG kaynaklı stres koşullarında su içeriği üzerinde olumlu bir etkisi olduğu görülmüştür. GB, hücre içi osmotik dengeyi koruyan ve hücre zarlarını stabilize eden bir osmolittir. Bu özellikleri sayesinde, bitkinin suyu daha etkin tutmasını sağlar ve su stresinin zararlarını azaltır (Chen ve Murata, 2008). Çalışmamızda, özellikle 1 saatlik GB ön uygulamasının en yüksek WC değerine sahip grup olması, GB'nin su tutma kapasitesini artırarak aspir bitkisinde osmotik stres toleransını yükseltebileceğini göstermektedir.

1.



Şekil 3.8: GB ön uygulama süresinin PEG stresi altında su içeriğine etkisi

SONUÇ

Bu çalışmada, farklı sürelerde uygulanan glisin betain (GB) ön uygulamalarının, polietilen glikol (PEG) ile oluşturulan kuraklık stres koşulları altında aspir (*Carthamus tinctorius* L.) tohumlarının çimlenme ve erken gelişim parametreleri üzerindeki etkileri incelenmiştir. Bulgular, artan PEG konsantrasyonlarının çimlenme hızı, çimlenme gücü, fide ve kök uzunluğu, toplam yaş ve kuru ağırlık ile bağıl su ve su içeriği gibi fizyolojik parametreleri anlamlı şekilde olumsuz etkilediğini göstermektedir. Bununla birlikte, özellikle 1 saatlik GB ön uygulaması, tüm PEG düzeyleri altında genel olarak en yüksek performansın elde edildiği uygulama süresi olmuştur. En yüksek çimlenme hızı (%86) ve çimlenme gücü (%91), sırasıyla –0.25 MPa PEG dozunda ve kontrol koşullarında 1 saat GB uygulamasıyla elde edilmiştir. Aynı süre, fide ve kök uzunluğu ile toplam yaş ve kuru ağırlıkta da olumlu etkiler göstermiştir. Ayrıca, bağıl su içeriği (%89.95) ve su içeriği (12.34 g/g) en yüksek düzeyde yine 1 saatlik GB uygulamasında gözlemlenmiştir. Bu bulgular, glisin betainin osmotik stres koşullarında su alımını kolaylaştırarak fizyolojik dengeyi desteklediğini ve bitki gelişimini iyileştirdiğini ortaya koymaktadır. Sonuç olarak, glisin betainin özellikle kısa süreli (1 saat) ön uygulamaları, PEG ile oluşturulan yapay kuraklık koşullarında aspir bitkisinin çimlenme ve erken gelişim sürecini destekleyerek kuraklık stresine karşı toleransını artırmada etkili olmuştur. Bu nedenle, glisin betainin uygun süre ve dozlarda tarımsal uygulamalara entegre edilmesi, kuraklık stresine karşı dirençli bitki üretiminde önemli bir strateji olabilir.

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INVESTIGATION OF THE EFFECTS OF CHITOSAN PRIMING ON SOYBEAN (*GLYCINE MAX* L.) SEEDS AGAINST SALT STRESS

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ABSTRACT

This study was conducted to determine the effects of chitosan priming on salt stress tolerance of soybean (*Glycine max* L.) KRİSTAL variety seeds. The seed germination stage is one of the most sensitive phases in the plant life cycle and is highly susceptible to environmental stress factors, particularly salt stress. Germination under high salinity conditions negatively affects both water uptake and metabolic activation processes, leading to a decrease in germination rate, germination speed, and seedling vigor. Therefore, enhancing plant resistance to salt stress during the seed stage is of critical importance for the sustainability of agricultural productivity. In this study, the seeds were pre-treated with 30 mg/l chitosan for different durations (control, 2, 4, and 6 h) and then subjected to different salt concentrations (control, 3, 6, and 9 dS/m) for germination. The experiment was conducted in the Field Crops Laboratory of the Faculty of Agriculture at Sakarya University of Applied Sciences, using factorial completely randomized design arrangement with three replications. The results indicated that increasing salt concentrations led to a general decrease in germination rate, germination vigor, seedling length, root length, total fresh weight, total dry weight, and relative water content (RWC). However, chitosan pretreatment mitigated these adverse effects and enhanced plant tolerance to salt stress. These findings suggest that chitosan priming could be an effective strategy for improving salt stress resistance in soybean seeds.

Keywords: Priming, Chitosan, Soybean, Salt stress

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KİTOSAN İLE PRİMİNG UYGULAMASININ SOYA (*GLYCINE MAX* L.) TOHUMLARININ TUZ STRESİNE KARŞI ETKİLERİNİN İNCELENMESİ

ÖZET

Bu çalışma, soya (*Glycine max* L.) KRİSTAL çeşidinin tohumlarında kitosan ile priming uygulamasının tuz stresine karşı etkilerini belirlemek amacıyla gerçekleştirilmiştir. Tohum çimlenme evresi, bitkilerin yaşam döngüsündeki en hassas aşamalardan biridir ve çevresel stres faktörlerine, özellikle tuz stresine karşı son derece duyarlıdır. Tohumun yüksek tuzluluk koşullarında çimlenmesi, hem su alımını hem de metabolik aktivasyon süreçlerini olumsuz etkileyerek çimlenme oranı, çimlenme hızı ve fide canlılığında düşüşe yol açmaktadır. Bu nedenle, tohum aşamasında uygulanan tuz stresine karşı bitkisel dayanıklılığın artırılması, tarımsal verimliliğin sürdürülebilirliği açısından kritik öneme sahiptir. Çalışmada, tohumlar 30 mg/l kitosan ile farklı sürelerde (kontrol, 2 saat, 4 saat ve 6 saat) ön işlemden geçirilmiş ve ardından farklı tuz konsantrasyonlarda (kontrol, 3, 6, 9 dS/m) çimlenmeye alınmıştır. Deneme, tesadüfi parselleri faktöriyel deneme desenine göre üç tekerrürlü olarak Sakarya Uygulamalı Bilimler Üniversitesi Ziraat fakültesinin tarla bitkileri laboratuvarında yürütülmüştür. Elde edilen sonuçlara göre, artan tuz konsantrasyonu çimlenme hızı, çimlenme gücü, fide uzunluğu, kök uzunluğu, toplam yaş ağırlık, toplam kuru ağırlık ve bağıl su içeriği (RWC) gibi özelliklerde genel bir azalmaya neden olmuştur. Ancak, kitosan ile yapılan ön uygulama, bu olumsuz etkileri azaltarak bitkilerin tuz stresine karşı daha toleranslı hale gelmesini sağlamıştır. Sonuçlar, kitosan priming uygulamasının, soya tohumlarının tuz stresine karşı dayanıklılığını artırmada etkili bir yöntem olabileceğini göstermektedir.

Anahtar Kelimeler: Priming, Kitosan, Soya, Tuz stresi

1. GİRİŞ

Soya fasulyesi (*Glycine max* L.), dünya genelinde hem insanlar hem de hayvanlar için önemli bir protein ve yağ kaynağı olarak yetiştirilen ekonomik değeri yüksek bir baklagildir. Küresel bitkisel yağ üretiminin %55'ini, toplam yağ tohumu üretiminin ise %53'ünü karşılamaktadır. (Pratap ve ark. 2016; Liu ve ark. 2020). Tohumları %35 oranında protein, %21 oranında yağ içerir ve çeşitli mineraller (Fe, Cu, Mn, Zn vb.) ile B1, B2, B6 vitaminleri ve izoflavonlar bakımından zengindir. Aynı zamanda yüksek biyolojik azot fiksasyon kapasitesiyle toprak verimliliğine katkı sağlar (Shereen ve Ansari, 2001). Gıda endüstrisinin dışında; ilaç, kozmetik, boya, mürekkep ve pestisit gibi birçok sanayi kolunda da kullanılmaktadır. (Pratap ve ark., 2012) Günümüzde artan insan nüfusu, hayvansal yem ihtiyacı ve endüstriyel talep doğrultusunda, soya fasulyesi üretimi dünya çapında hızla artmaktadır. Soya fasulyesi, küresel ölçekte dördüncü en önemli tahıl ürünü olup en kârlı tarım ürünlerinden biridir (Ferreir ve ark., 2017; Ahmed ve ark., 2021). Tüm bu avantajlarına rağmen, soya fasulyesi kuraklık ve tuzluluk gibi çevresel streslere karşı hassastır. Soya fasulyesi, 2-5 dS/m (1,28 g/l - 3,2 g/l) tolerans eşiğine sahip tuzluluğa duyarlı bitki olarak sınıflandırılmaktadır (Taufiq ve ark., 2020).

Tuzluluk, dünya genelindeki tarımsal üretimi tehdit eden başlıca abiyotik stres faktörlerinden biridir. Özellikle NaCl kaynaklı tuzluluk, ozmotik ve iyonik stres yoluyla bitki çimlenmesini, büyümesini ve verimini olumsuz etkiler (Cho ve ark., 2021). Bu stres; su alımında azalma, sodyum toksisitesi, enzim ve protein aktivitesinde bozulma, hormon dengesizlikleri, hücre duvarı hasarı ve besin alımında (özellikle K ve N) yetersizlik gibi fizyolojik sorunlara yol açar. Ayrıca reaktif oksijen türlerinin (ROS) üretimini artırarak oksidatif stres meydana getirir. Bu durum, lipid peroksidasyonu, DNA mutasyonları, protein bozulmaları ve gen ekspresyonunda değişiklikler ile sonuçlanır (Mushtaq ve ark., 2022). Tuzluluğun etkisiyle bitkilerde kök gelişimi, yaprak alanı, bitki boyu ve tohum verimi azalırken; fotosentez, membran stabilitesi ve metabolik süreçler de zarar görür (Sinaga ve ark., 2023; Yunita ve ark., 2023). Dünyada yaklaşık 932 milyon hektar tarım arazisi tuzluluk tehdidi altındadır ve bu sorun, iklim değişikliği ve yanlış tarım uygulamalarıyla giderek büyümektedir (Fagodiya vd., 2022). Türkiye'de ise tarım alanlarının %1,7'si bu durumdan etkilenmektedir (Kaplan ve Kara, 2014; Çakmakcı ve ark., 2016).

Tohum çimlenmesi, bitki yaşam döngüsünün en hassas evrelerinden biri olup, özellikle tuzlu koşullarda başarılı çimlenme, bitki gelişiminde kritik öneme sahiptir (Acikbaş ve ark., 2021; Açıkbaş ve Özyazıcı, 2022). Yüksek tuz konsantrasyonları, tohumların su alımını engelleyerek çimlenme oranını düşürmekte; düşük seviyeler ise tohumun uykuda kalmasına neden olabilmektedir (Zuffo ve ark., 2020). Çimlenme ve erken fide gelişimi, bitki büyümesinin tuzluluğa en duyarlı evreleri arasında yer alır. Bu süreçteki başarı, yalnızca çevresel koşullar ve tuzun türüyle değil, aynı zamanda bitki türü, çeşidi ve tuz yoğunluğu ile de yakından ilişkilidir. Genotipler arası farklılıkların tanımlanması da, tuz stresine dayanıklı çeşitlerin geliştirilmesi açısından büyük önem taşımaktadır (Özyazıcı ve Açıkbaş, 2021).

Tohum çimlenmesi ve bitki gelişiminin önemi, sürdürülebilir tarım, ekosistem restorasyonu ve küresel gıda güvenliği açısından kritik olup, bu süreçlerde karşılaşılan zorluklar yenilikçi çözümlere olan ihtiyacı ortaya koymaktadır. Bu bağlamda, çevre dostu ve biyolojik olarak parçalanabilir özellikleriyle öne çıkan kitosan, bitki gelişimini destekleyen potansiyel bir ajan

olarak dikkat çekmektedir (Pichyangkura ve Chadchawan, 2015; Malerba ve Cerana, 2016; Crini, 2019; Shahrajabian ve ark., 2021). Kitosan, kitinin deasetillenmiş formu, kabukluların atıklarından, farklı mantar kaynaklarından ve son zamanlarda çiftlik böceklerinden elde edilebilen doğal bir biyopolimerdir. Kitosan yalnızca biyouyumlu ve biyolojik olarak parçalanabilir bir polimer olmakla kalmaz, aynı zamanda neredeyse her zaman biyolojik atıkların geri dönüştürülmesiyle üretilir (Iber ve ark., 2022; Chatterjee ve ark., 2022). Kitosanın çok çeşitli bitki türlerinde çimlenme, büyüme, çiçeklenme ve abiyotik stres toleransı üzerindeki uyarıcı etkilerini gösteren birçok çalışma bulunmaktadır (Abdel-Mawgoud ve ark., 2010; Pichyangkura ve Chadchawan, 2015; Malerba ve Cerana, 2016; Shahrajabian ve ark., 2021). Kitosan, tohumların su ve besin alımını artırarak çimlenme oranlarını ve erken fide gelişimini olumlu yönde etkiler. İçerdiği amino ve hidroksil grupları sayesinde ağır metallerle şelat oluşturarak toksik etkileri azaltır. Aynı zamanda doğal bir uyarıcı gibi davranarak, bitkilerde savunma sistemlerini aktive eden antimikrobiyal bileşiklerin sentezini teşvik eder. Jel benzeri yapısı nem emilimini artırırken, kök gelişimini destekleyerek besin alım kapasitesini güçlendirir (Rom´an-Doval ve ark., 2023). Kitosanın biyouyumluluğu, toksik olmaması ve ekosistem üzerinde kalıcı bir zarar bırakmaması, onu sentetik kimyasallara sürdürülebilir bir alternatif haline getirmektedir (Riseh ve ark., 2024).

Priming dediğimiz tohum astarlama, çimlenme sırasında tohumlardaki metabolik süreçleri uyarmak ve farklı çevre koşullarındaki performanslarını iyileştirmek için kullanılan bir tekniktir (Prajapati ve ark., 2020). Kitosanla tohum astarlama, stres altında büyümeyi destekleyen indolasetik asit ve serbest amino asitlerin birikimini artırmaktadır. Tuzluluk stresi, büyüme parametrelerinde, çözünür şekerlerde, çözünür proteinlerde, prolin ve malondialdehit içeriğinde bir azalmaya neden olurken; kitosan işlemi morfolojik özellikleri iyileştirmektedir (Attia ve ark., 2021; Bakhoum ve ark., 2022).

Bu çalışma, tuzluluk stresi altında soya fasulyesi genotipinin çimlenme yanıtlarını değerlendirmeyi ve kitosan ile yapılan ön işlem (priming) uygulamasının farklı tuz konsantrasyonlarına karşı tolerans geliştirmedeki etkisini belirlemeyi amaçlamaktadır.

2. MATERYAL ve YÖNTEM

Bu araştırma, 2025 yılında Sakarya Uygulamalı Bilimler Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Laboratuvarında, tesadüf parsellerine dayalı faktöriyel deneme deseninde ve üç tekerrürlü olarak kurulmuştur. Bitki materyali olarak, Trakya Tarımsal Araştırma Enstitüsü Müdürlüğü'nden temin edilen KRİSTAL soya (*Glycine max* L.) çeşidi kullanılmıştır. Çimlendirme için kullanılan cam petri kapları ve kurutma kâğıtları, 175 °C sıcaklıktaki etüvde 30 dakika bekletilerek sterilize edilmiştir. Tohumlara ön uygulama amacıyla biyostimülant olarak kitosan uygulanmıştır. Çimlendirme öncesinde kontaminasyon riskini en aza indirmek amacıyla tohumlar %3'lük sodyum hipoklorit (NaClO) çözeltisinde 15 dakika süreyle çalkalanmış, ardından üç kez saf su ile durulanmıştır. Tohumlar, 30 mg/l derişimindeki kitosan çözeltisi ile farklı sürelerde (kontrol, 2, 4 ve 6 saat) ön işlemden geçirilmiştir. Bu işlemin ardından, farklı tuz konsantrasyonlarına (kontrol, 3, 6 ve 9 dS/m) maruz bırakılarak çimlendirme testleri gerçekleştirilmiştir. Her tekerrürde 50 tohum kullanılmış olup, denemeler 23 ± 1 °C sabit sıcaklıktaki çimlendirme ortamında yürütülmüştür. Çimlenme oranı (%),

çimlenme gücü (%), kök uzunluğu (mm), fide uzunluğu (mm), toplam yaş ağırlık (g), toplam kuru ağırlık (g) ve bağıl su içeriği (%) parametrelerine ilişkin gözlemler, ISTA (2010) kurallarına göre 5. ve 8. günlerde yapılmıştır. Bağıl su içeriği (RWC), Weatherley (1950) tarafından önerilen formül ile;

RWC (%) = [(Yaş Ağırlık – Kuru Ağırlık) / (Tam Turgor Ağırlığı – Kuru Ağırlık)] × 100

Denemeden elde edilen veriler varyans analizine (ANOVA) tabi tutulmuştur. Tüm istatistiksel analizler MSTAT-C paket programı kullanılarak gerçekleştirilmiş; anlamlılık düzeyine bağlı olarak ortalamalar arasındaki farkların belirlenmesinde Duncan çoklu karşılaştırma testi uygulanmış ve elde edilen sonuçlar gruplandırılarak yorumlanmıştır.

3. BULGULAR VE TARTIŞMA

Bu çalışmada incelenen tüm özelliklere ilişkin varyans analizi sonuçları Tablo 3.1'de verilmiştir. Elde edilen verilere göre, kitosan uygulama süresi ile tuz seviyeleri arasındaki etkileşim, tüm parametreler açısından %1 düzeyinde istatistiksel olarak yüksek derecede anlamlı bulunmuştur ($P < 0.01$).

Tablo 3.1: Tuz stresi altında farklı kitosan uygulamalarıyla soya özelliklerinin varyans analizi sonuçları.

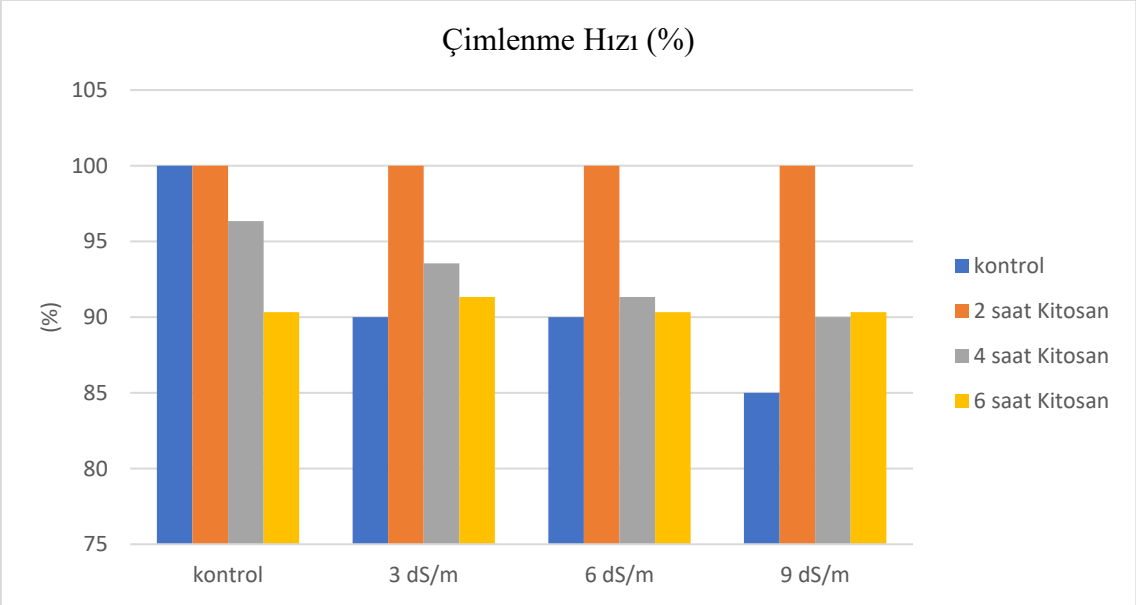
V.K	SD	Gözlemlerin Kareler Ortalaması						
		Çimlenme Hızı (%)	Çimlenme Gücü (%)	Fide Uzunluğu (mm)	Kök Uzunluğu (mm)	Toplam Yaş Ağırlığı (g)	Toplam Kuru Ağırlığı (g)	Bağıl Su İçeriği (RWC)(%)
Kitosan	3	3.305**	15.79**	14.07**	39.79**	0.354**	0.046**	158.91*
Tuz	3	252.40**	77.74**	19.16**	4.03**	0.131**	0.041**	789.76**
Kitosan × Tuz	9	1.9**	5.37**	0.788**	6.93**	0.222**	0.007**	506.88**
Hata	32	0.167	0.375	0.048	0.017	0.0000015	0.0000013	49.99
Genel	47	------	------	------	------	------	------	------
CV%		0.42	0.63	3.99	1.5	0.15	0.66	9.02

** P <0.01 seviyesinde önemli, * P <0.05 seviyesinde önemli olduğunu göstermektedir.

Çimlenme Hızı (%)

Şekil 3.1'de, farklı sürelerde uygulanan kitosan ön işlemlerinin (kontrol, 2, 4 ve 6 saat), çeşitli tuz stresi düzeyleri (0, 3, 6 ve 9 dS/m) altında soya tohumlarının çimlenme hızına etkisi gösterilmektedir. Analiz sonuçlarına göre, kitosan × tuz etkileşimi genel ortalamalar açısından istatistiksel olarak anlamlı bulunmuş ve en yüksek çimlenme hızı %100 ile kontrol grubunda ve 2 saatlik kitosan uygulamasına tabi tutulan 3, 6 ve 9 dS/m tuz konsantrasyonlarında elde edilmiştir. En düşük çimlenme hızı %85 oranında 9 dS/m tuz konsantarsyonunda ve kontrol grubunda gözlemlenmiştir. Bu sonuçlar, kitosanın tohum çimlenmesi üzerindeki olumlu etkilerini desteklemektedir. Benzer şekilde, daha önce yapılan çalışmalarda da kitosan uygulamalarının çimlenme oranını artırdığı ve bitkilerin tuz stresi gibi olumsuz çevresel

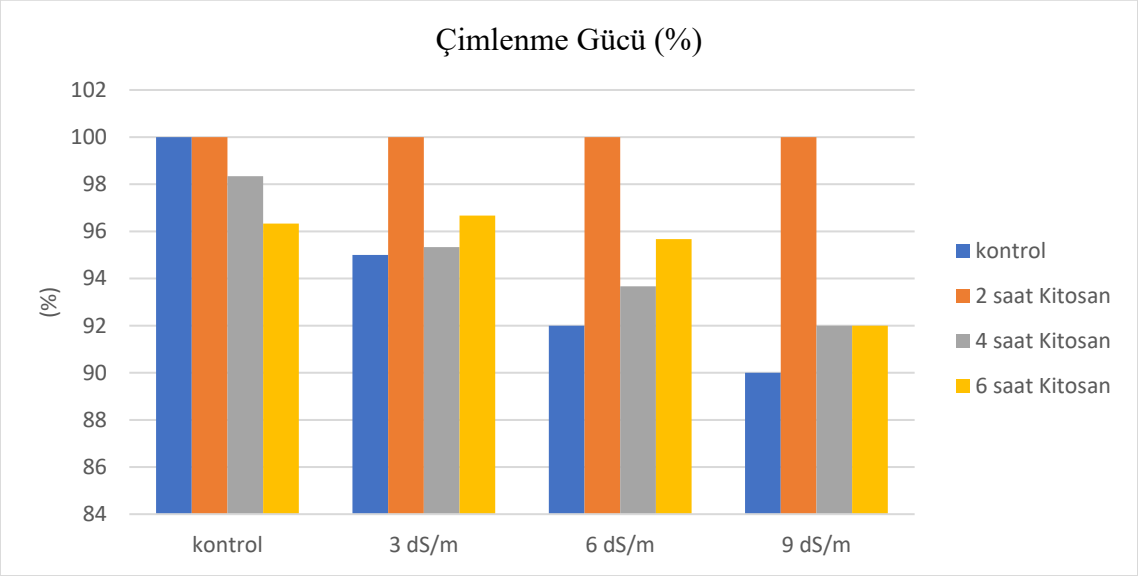
koşullara karşı dayanıklılığını yükselttiği bildirilmiştir (Guan ve ark., 2009; Farouk ve ark., 2011; El-Tarabily ve ark., 2021). Kitosanın bu etkisi, su alımını iyileştirme, hücre zarlarını stabilize etme ve stresle ilişkili fizyolojik mekanizmaları destekleme yeteneği ile ilişkilendirilmektedir.



Şekil 3.1: Kitosan ön uygulama süresinin Tuz stresi altında çimlenme hızına etkisi

Çimlenme Gücü (%)

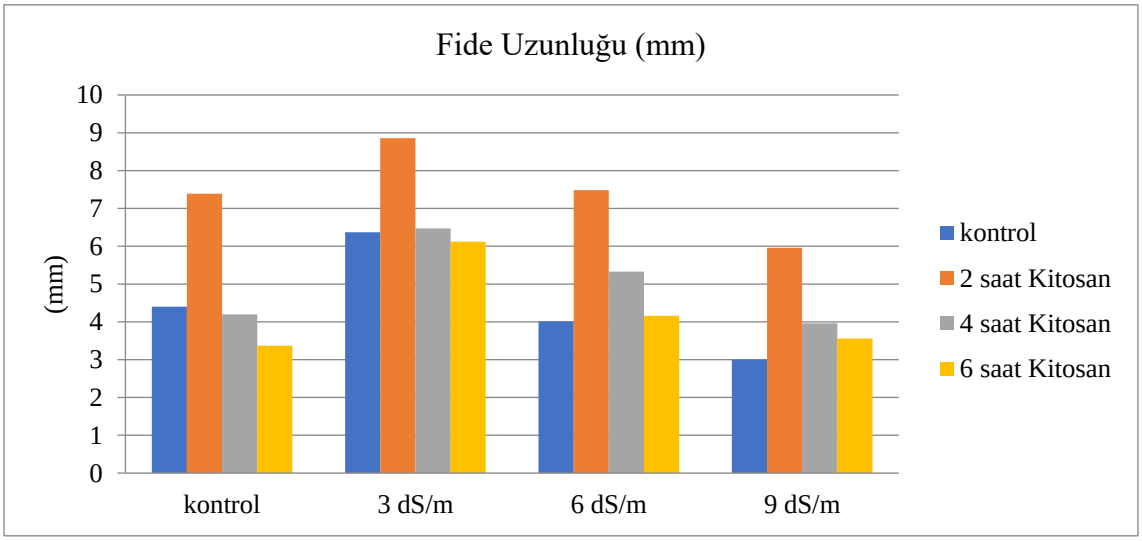
Şekil 3.2'de, farklı kitosan ön uygulama sürelerinin (kontrol, 2, 4 ve 6 saat) tuz stres koşulları altındaki soya tohumlarının çimlenme gücü üzerindeki etkileri sunulmaktadır. Denemenin 8. gününde elde edilen verilere göre, kitosan ve tuz etkileşiminin genel ortalamaları değerlendirildiğinde, en yüksek çimlenme gücünün (%100) hem kontrol grubunda hem de 2 saatlik kitosan ön işlemesine tabi tutulan 3, 6 ve 9 dS/m tuz konsantrasyonlarında gerçekleştiği belirlenmiştir. Buna karşın, kontrol grubunda çimlenme gücünün en düşük değeri %90 olarak tespit edilmiştir. Bu bulgular, artan tuz konsantrasyonlarının çimlenme performansı üzerinde baskılayıcı bir etki yarattığını ortaya koymaktadır. Ancak, 2 saat süreyle kitosan ile ön işleme tabi tutulan tohumların tüm tuz seviyelerinde %100 çimlenme gücü göstermesi, kitosanın tuz stresine karşı çimlenme üzerinde koruyucu bir etki sağladığını göstermektedir. Literatürde de benzer şekilde, kitosan uygulamalarının çimlenme ve fide gelişimi üzerinde olumlu etkiler sağladığı, özellikle tuz stresine karşı bitkisel dayanıklılığı artırdığı bildirilmektedir (Guan ve ark., 2009; Farouk ve ark., 2011; El-Tarabily ve ark., 2021).



Şekil 3.2: Kitosan ön uygulama süresinin Tuz stresi altında çimlenme gücüne etkisi

Fide Uzunluğu (mm)

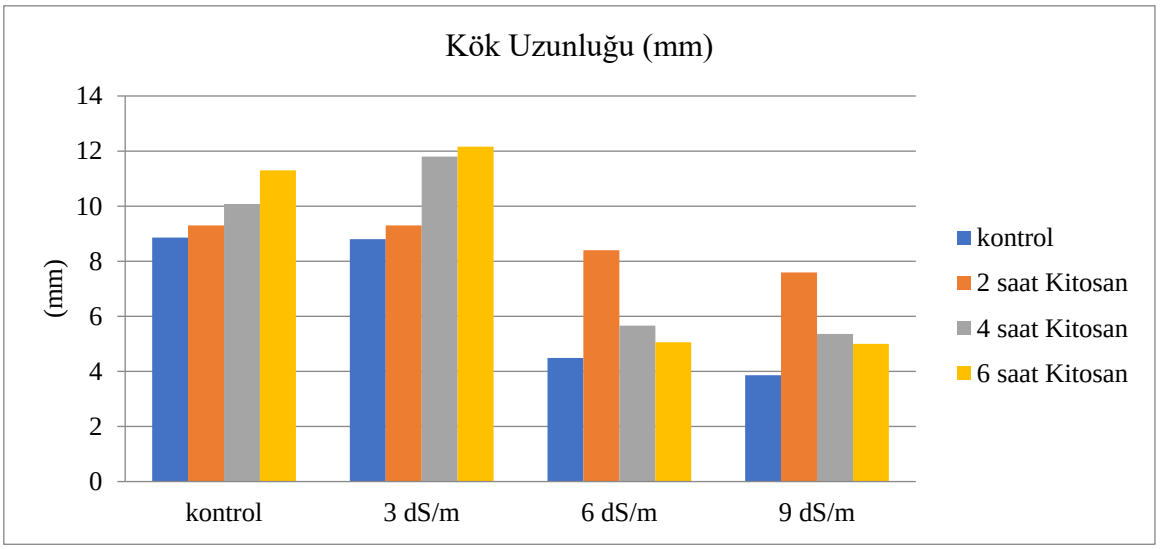
Elde edilen verilere göre, en uzun fide boyu (8.86 mm) 2 saatlik kitosan ön uygulaması ve 3 dS/m tuz konsantrasyonu kombinasyonunda gözlemlenmiştir (Şekil 3.3). Buna karşın, 9 dS/m tuz seviyesinde ve kitosan uygulanmayan (kontrol) grupta fide boyunun en düşük düzeyde kaldığı belirlenmiştir. Grafik verilerinin incelenmesi sonucunda, artan tuz konsantrasyonlarının fide boyunda anlamlı bir azalmaya yol açtığı görülmektedir. Bu durum, yüksek tuz konsantrasyonlarının bitki hücrelerinde osmotik stres oluşturarak hücre bölünmesi ve hücre uzamasını sınırladığı, dolayısıyla vegetatif büyümeyi olumsuz etkilediği şeklinde değerlendirilebilir (Munns ve Tester, 2008). Bununla birlikte, 2 saat süreyle uygulanan kitosan ön işlemesinin, özellikle yüksek tuz seviyelerinde, diğer uygulama sürelerine göre daha iyi fide gelişimi sağladığı tespit edilmiştir. Bu bulgu, kitosanın stres koşullarında bitkisel büyüme parametreleri üzerinde düzenleyici bir etki oluşturduğunu ve ozmotik dengeyi destekleyerek tuz stresine karşı toleransı artırdığını ortaya koymaktadır (Guan ve ark., 2009; Ali ve ark., 2014; El-Tarabily ve ark., 2021).



Şekil 3.3: Kitosan ön uygulama süresinin Tuz stresi altında fide uzunluğuna etkisi

Kök Uzunluğu (mm)

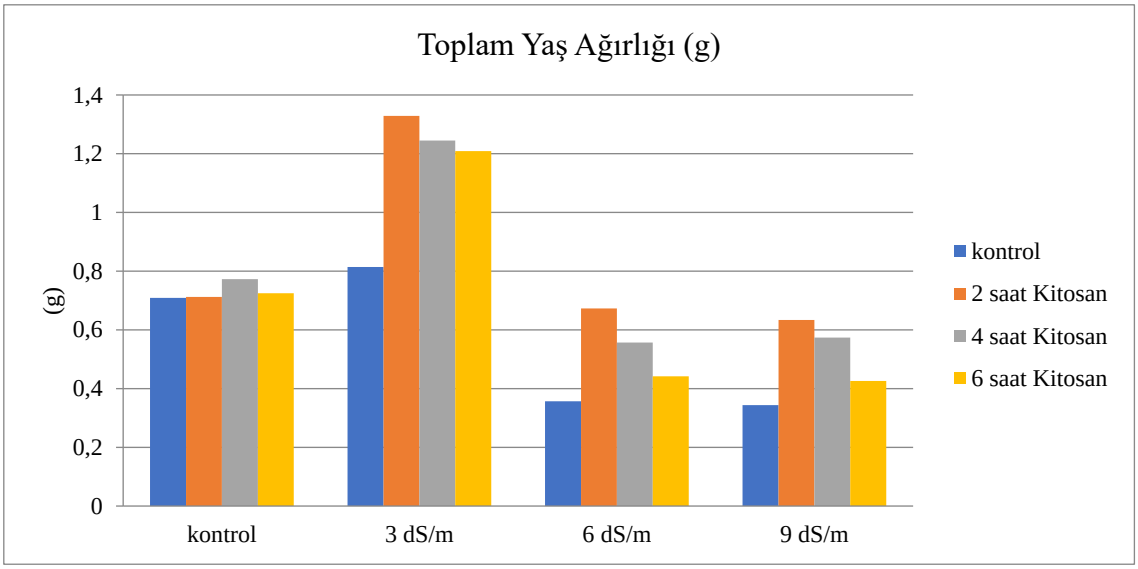
Şekil 3.4'te, farklı kitosan ön uygulama sürelerinin ve tuz kaynaklı stresin soya tohumlarının kök uzunluğu üzerindeki etkileri sunulmaktadır. Ortalama değerlere göre, en uzun kök gelişimi (12.16 mm), 6 saatlik kitosan ön uygulaması ve 3 dS/m tuz konsantrasyonu kombinasyonunda gözlemlenmiştir. Buna karşılık, en kısa kök uzunluğu (3.86 mm), kontrol grubunda 9 dS/m tuz uygulamasında kaydedilmiştir. Genel eğilim incelendiğinde, artan tuz konsantrasyonlarının kök gelişimini anlamlı düzeyde sınırladığı görülmektedir. Tuz stresinin, hücre bölünmesi ve uzamasını engelleyerek kök uzamasını baskıladığı bilinmektedir (Munns ve Tester, 2008; Yeo, 1998). Bununla birlikte, özellikle 2 saatlik kitosan ön uygulaması, yüksek tuz seviyelerinde bile diğer uygulama sürelerine kıyasla daha uzun kök gelişimini desteklemiştir. Bu durum, kitosanın hücre zarlarının stabilizasyonunu sağlayarak iyon dengesini koruması ve bitkisel büyümeyi teşvik edici etkisiyle açıklanabilir (Guan ve ark., 2009; El-Tarabily ve ark., 2021). Kitosanın antioksidan savunma sistemini aktive ederek tuz stresine karşı dayanıklılığı artırdığı da önceki çalışmalarla doğrulanmıştır (Ali ve ark., 2014; Abdel-Aziz ve ark., 2016).



Şekil 3.4: Kitosan ön uygulama süresinin Tuz stresi altında kök uzunluğuna etkisi

Toplam Yaş Ağırlığı (g)

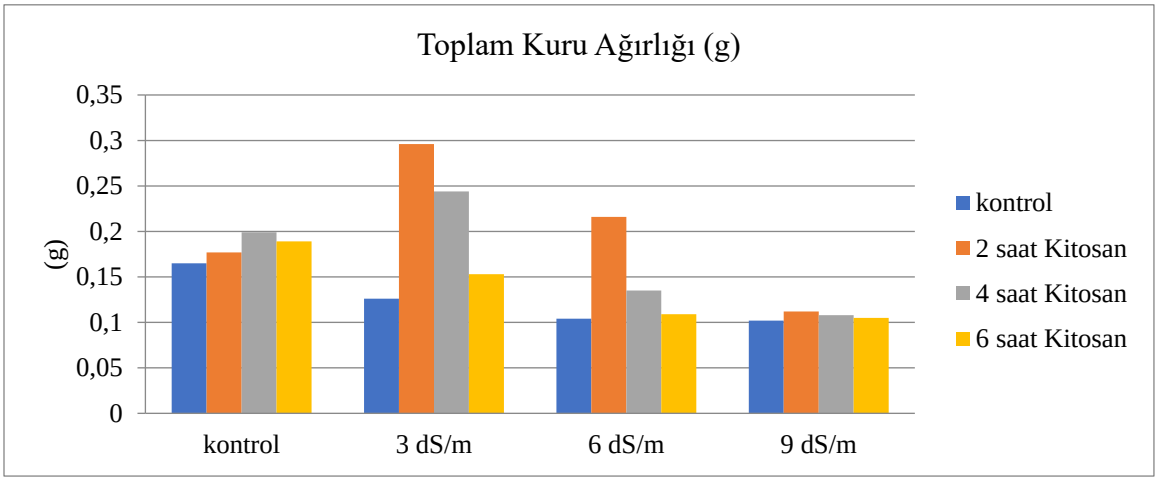
Şekil 3.5'te, farklı kitosan ön uygulama sürelerinin ve tuz stresinin soya fidelerinin toplam yaş ağırlığı üzerindeki etkisi gösterilmektedir. Elde edilen bulgulara göre, en yüksek toplam yaş ağırlığı (1.32 g), 2 saatlik kitosan ön uygulaması ve 3 dS/m tuz konsantrasyonu kombinasyonunda kaydedilmiştir. Buna karşın, en düşük yaş ağırlığı değeri (0.344 g), 9 dS/m tuz uygulamasında ve herhangi bir kitosan uygulaması yapılmayan kontrol grubunda gözlemlenmiştir. Genel olarak, artan tuz konsantrasyonları, soya fidelerinin yaş biyokütle üretimini anlamlı şekilde azaltmıştır. Bu durum, tuz stresinin bitkilerde hücre içi ozmotik dengeyi bozarak su alımını sınırlandırması ve metabolik aktiviteleri yavaşlatmasıyla ilişkilendirilmektedir (Acosta-Motos ve ark., 2017). Bununla birlikte, 2 saatlik kitosan uygulaması, özellikle orta ve yüksek tuz dozlarında (3, 6 ve 9 dS/m) diğer uygulamalara kıyasla daha yüksek yaş ağırlığı değerlerinin elde edilmesini sağlamıştır. Bu sonuçlar, kitosanın stres koşulları altında bitkisel büyümeyi teşvik edici etkilerini desteklemektedir. Kitosan, osmotik dengenin korunmasına, su alımının artırılmasına ve stres kaynaklı hasarların azaltılmasına katkı sağlayarak biyokütle üretimini olumlu yönde etkilemektedir (Ali ve ark., 2014; Khan ve ark., 2020).



Şekil 3.5: Kitosan ön uygulama süresinin Tuz stresi altında toplam yaş ağırlığına etkisi

Toplam Kuru Ağırlığı (g)

Şekil 3.6'da sunulan verilere göre, toplam kuru ağırlık açısından en yüksek değer 0.296 g ile 2 saatlik kitosan ön uygulaması ve 3 dS/m tuz konsantrasyonu kombinasyonunda elde edilmiştir. Buna karşın, en düşük toplam kuru ağırlık değeri (0.102 g), kontrol grubunda ve 9 dS/m tuz konsantrasyonunda kaydedilmiştir. Artan tuz düzeylerinin, tohumların toplam kuru madde birikimini anlamlı ölçüde azalttığı gözlemlenmiştir. Bu durum, tuz stresinin osmotik dengesizlik, iyon toksisitesi ve su yetersizliği gibi etkilerle bitki büyümesini ve biyokütle üretimini kısıtladığını göstermektedir (Munns ve Tester, 2008; Parida ve Das, 2005). Bununla birlikte, özellikle 2 saatlik kitosan ön uygulaması, orta düzeydeki tuz stresi koşullarında kuru madde birikimini destekleyerek osmotik stresin etkilerini hafifletmiştir. Ancak, yüksek tuz konsantrasyonlarında (özellikle 9 dS/m) biyokütle üretiminde gözlenen düşüş, kitosanın bu seviyelerdeki tuz stresini tam olarak telafi edemediğini ortaya koymaktadır. Bu bulgu, kitosan uygulamasının etkili olduğu stres aralığının sınırlı olabileceğini ve optimal uygulama koşullarının belirlenmesi gerektiğini düşündürmektedir.

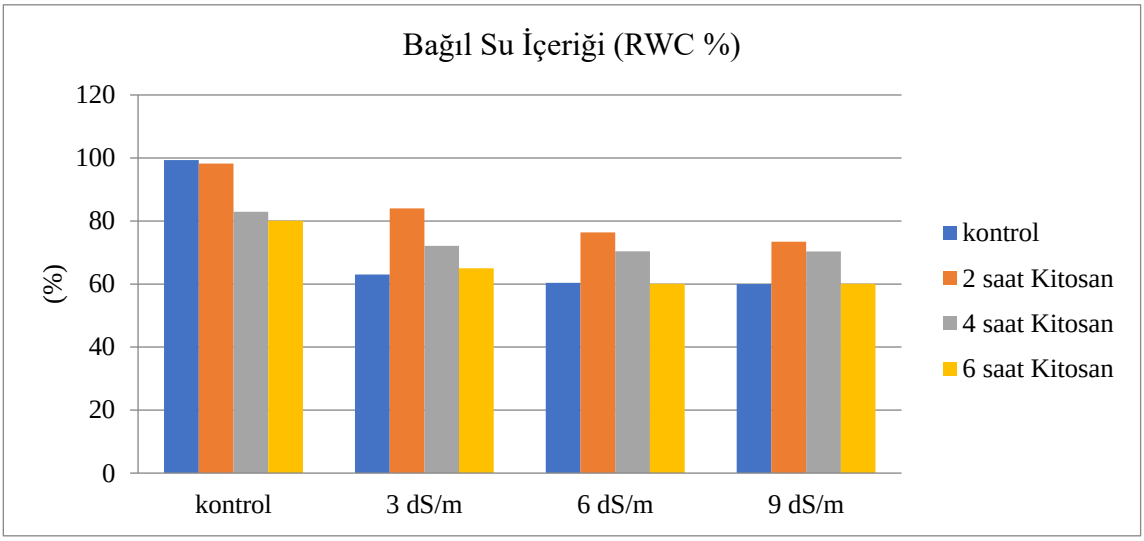


Şekil 3.6: Kitosan ön uygulama süresinin Tuz stresi altında toplam kuru ağırlığına etkisi

Bağıl Su İçeriği (%)

Bitkilerde bağıl su içeriği (Relative Water Content, RWC), bitkinin su durumunu ve fizyolojik dengesini değerlendirmede temel göstergelerden biridir. Yüksek RWC değerleri (%90–100), hücrelerin turgor basıncını koruduğunu, metabolik süreçlerin sağlıklı şekilde sürdüğünü ve bitkinin herhangi bir su stresi altında olmadığını göstermektedir. Buna karşın, RWC değerinin %50'nin altına düşmesi, bitkinin ciddi düzeyde su stresine maruz kaldığını, hücre zarı bütünlüğünün bozulabileceğini ve fotosentetik kapasitenin önemli ölçüde azalabileceğini işaret etmektedir (Barrs ve Weatherley, 1962; Yamasaki ve Dillenburg, 1999). Bu nedenle, RWC parametresi, çevresel stres koşullarına verilen fizyolojik tepkilerin izlenmesinde güvenilir bir belirteç olarak yaygın şekilde kullanılmaktadır.

Bu çalışmada elde edilen sonuçlara göre, en yüksek bağıl su içeriği (RWC) %99.35 ile stres uygulanmayan kontrol grubunda belirlenmiştir. Buna karşılık, en düşük RWC değeri %60.00 ile 9 dS/m tuz konsantrasyonuna maruz bırakılan ve kitosan uygulanmamış kontrol grubunda gözlemlenmiştir (Şekil 3.7). Tuz stresinin artan düzeylerde bağıl su içeriğini önemli ölçüde azalttığı görülmektedir. Bu durum, yüksek tuzluluk seviyelerinde meydana gelen osmotik stresin, hücre içi su potansiyelini düşürerek su alımını sınırlandırmasıyla açıklanabilir (Munns ve Tester, 2008). Ancak dikkat çekici şekilde, 2 saatlik kitosan ön uygulamasına tabi tutulan tohumlarda tüm tuz seviyelerinde bağıl su içeriği görece yüksek değerlerde kalmıştır. Bu bulgu, kitosanın osmotik dengeyi koruyarak membran stabilitesini artırabileceğini ve su kaybını azaltabileceğini göstermektedir (Gornik ve ark., 2008; Ali ve ark., 2021). Dolayısıyla kitosan, bitkilerin tuz stresine karşı fizyolojik adaptasyonlarını destekleyen etkili bir biyostimülant olarak değerlendirilebilir.



Şekil 3.7: Kitosan ön uygulama süresinin Tuz stresi altında bağıl su içeriğine etkisi

SONUÇ

Bu çalışmada, farklı sürelerde uygulanan kitosan ön işlemlerinin, çeşitli tuz stres düzeyleri altında soya tohumlarının çimlenme ve erken dönem fide gelişimi üzerindeki etkileri değerlendirilmiştir. Elde edilen veriler, tuz stresinin bitkisel fizyoloji ve büyüme parametreleri üzerinde baskılayıcı bir etki yarattığını açıkça ortaya koymuştur. Özellikle yüksek tuz konsantrasyonları (6 ve 9 dS/m), çimlenme hızı, fide ve kök uzunluğu, yaş ve kuru biyokütle ile bağıl su içeriği gibi fizyolojik göstergelerde anlamlı düşüşlere neden olmuştur. Ancak dikkat çekici bir şekilde, 2 saatlik kitosan ön uygulaması tüm tuz dozlarında hem çimlenme gücü hem de fide gelişimi parametrelerinde olumlu etkiler sağlamıştır. Bu uygulama, özellikle %100 çimlenme oranı ve en yüksek fide boyu (8.86 mm), yaş ağırlık (1.32 g) ve kuru ağırlık (0.296 g) gibi sonuçlarla öne çıkmış; ayrıca RWC'nin stresli koşullarda bile yüksek düzeylerde kalmasına katkı sağlamıştır. Bu bulgular, kitosanın bitkisel hücre zarlarını stabilize etme, ozmotik dengeyi koruma, su alımını destekleme ve antioksidatif savunma sistemlerini aktive etme potansiyelini vurgulamaktadır. Sonuç olarak, kitosan uygulaması, özellikle 2 saatlik ön işlem süresiyle, soya bitkisinin tuz stresine karşı dayanıklılığını artırmakta etkili bir yaklaşım olarak değerlendirilebilir. Bu biyopolimerin tarımsal uygulamalarda düşük maliyetli ve çevre dostu bir biyostimülant olarak kullanılabilirliği, sürdürülebilir bitki üretimi açısından önem taşımaktadır. Ancak, kitosan uygulamalarının etkili olduğu stres aralıklarının daha net belirlenebilmesi için farklı türler, dozlar ve uygulama sürelerini içeren ileri düzey çalışmaların yürütülmesi gerekmektedir.

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DETERMINATION OF PARTHENOGENETIC ACTIVATION CAPACITY OF BOVINE OOCYTES MATURED IN VITRO IN CULTURE MEDIA USING ROYAL JELLY AS A PROTEIN SOURCE

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ABSTRACT

Fetal calf serum and other chemical compounds are widely used as protein sources in the culture medium for in vitro nuclear maturation of bovine oocytes. After the transfer of embryos obtained from in vitro matured oocytes using fetal calf serum and other chemicals as a protein source in a culture medium, different physiological and metabolic syndromes can be encountered both in the fetal period and in the postnatal period. This situation has led to the search for different sources of protein in the culture medium for in vitro maturation. In this context, it has been tested as a royal jelly protein source in the culture medium during the in vitro maturation phase and successful results have been obtained. It is also of great importance to determine the capacity to obtain embryos from in vitro matured oocytes in environments using royal jelly. The aim of this study was to determine the division capacities of in vitro matured bovine oocytes in culture media with and without royal jelly as a protein source. In this context, the material of the study consisted of ovaries obtained after slaughter from different cattle breeds. The ovary was transferred to the laboratory under appropriate conditions. A total of 239 oocytes with suitable characteristics for in vitro maturation from these ovaries were obtained. These oocytes were subjected to in vitro maturation in culture media with and without royal jelly (control group) as a protein source. The parthenogenetic activation protocol was applied to mature oocytes that were subjected to in vitro maturation in culture media using different protein sources. The division rates of oocytes matured in culture media containing and not containing (control group) royal jelly as a protein source after parthenogenetic activation were determined as 35.5% and 42.4%, respectively ($P>0.05$). These results showed that the capacities to obtain embryos from in vitro matured oocytes in culture media with and without royal jelly were similar. In summary, this study has shown that embryos can be successfully obtained when royal jelly is used as a protein source in the culture medium during in vitro maturation.

Keywords: Bovine, oocyte, in vitro maturation, protein source, royal jelly

PROTEİN KAYNAĞI OLARAK ARI SÜTÜ KULLANILAN KÜLTÜR ORTAMLARINDA İN VİTRO OLGUNLAŞTIRILAN SIĞIR OOSİTLERİNİN PARTHENOGENETİK AKTİVASYON KAPASİTELERİNİN BELİRLENMESİ

ÖZET

Sığır oositlerinin in vitro nükleer olgunlaştırılmalarında kültür ortamında protein kaynağı olarak fötal buzağı serumu ve diğer kimyasal bileşikler yaygın bir şekilde kullanılmaktadır. Kültür ortamında protein kaynağı olarak fötal buzağı serumu ve diğer kimyasallar kullanılarak in vitro olgunlaştırılan oositlerden elde edilen embriyoların transferi sonrasında hem fötal dönemde hem de doğum sonrası dönemde farklı fizyolojik ve metabolik sendromlar ile karşılaşılabilinmektedir. Bu durum in vitro olgunlaştırmada kültür ortamında protein olarak farklı kaynakların arayışını ortaya çıkarmıştır. Bu kapsamda in vitro olgunlaştırma aşamasında kültür ortamında arı sürü protein kaynağı olarak denenmiş ve başarılı sonuçlar elde edilmiştir. Arı sütü kullanılan ortamlarda in vitro olgunlaştırılan oositlerden embriyo elde etme kapasitelerinin belirlenmeside büyük önem taşımaktadır. Bu çalışmada da, protein kaynağı olarak arı sütü kullanılan ve kullanılmayan kültür ortamlarında in vitro olgunlaştırılan sığır oositlerinin bölünme kapasitelerinin belirlenmesi amaçlanmıştır. Bu kapsamda çalışmanın materyalini farklı sığır ırklarından kesim sonrası elde edilen ovaryumlar oluşturmuştur. Ovaryumla uygun şartlarda laboratuvara transfer edilmiştir. Bu ovaryumlardan in vitro olgunlaştırma için uygun özelliklere sahip toplam 239 adet oosit elde edilmiştir. Bu oositler, protein kaynağı olarak arı sütü kullanılan ve kullanılmayan (kontrol grubu) kültür ortamlarında in vitro olarak olgunlaştırmaya tabi tutulmuşlardır. Farklı protein kaynağı kullanılan kültür ortamlarında in vitro olgunlaştırmaya tabi tutulan oositlerden olgunlaşanlara parthenogenetic aktivasyon protokolü uygulanmıştır. Parthenogenetik aktivasyon sonrası protein kaynağı olarak arı sütü içeren ve içermeyen (kontrol grubu) kültür ortamlarında olgunlaşan oositlerin bölünme oranları sırasıyla %35,5 ve %42,4 olarak belirlenmiştir ($P>0,05$). Bu sonuçlar, arı sütü kullanılan ve kullanılmayan kültür ortamlarında in vitro olgunlaştırılan oositlerden embriyo elde edilme kapasitelerinin benzer olduğunu göstermiştir. Özetle, bu çalışma in vitro olgunlaştırmada kültür ortamında protein kaynağı olarak arı sütünün kullanılması durumunda da başarılı bir şekilde embriyoların elde edilebileceğini ortaya koymuştur.

Anahtar Kelimeler: Sığır, oosit, in vitro olgunlaştırma, kültür ortamı, protein kaynağı, arı sütü

1.GİRİŞ

Hayvancılıkta üretim etkinliğinin artırılmasının yanısıra hayvan ıslahına yardımcı olabilecek yeni biyoteknolojiler geliştirilirken bir kısım teknolojiler de son yıllarda uygulama alanlarına yayılmaya başlamıştır. Bu biyoteknolojiler arasında kızgınlık senkronizasyonu, suni tohumlama, in vitro embriyo üretimi, klonlama Multıple Ovulasyon Embriyo Transferi (MOET) bulunmaktadır. Bu üreme biyoteknolojilerinin amacı, seçilmiş erkek ve dişilerden elde edilen döllerin sayısını artırmak ve generasyonlar arası süreyi kısaltarak çiftlik hayvanlarında genetic ilerlemeyi hızlandırmaktır.

Suni tohumlama ile erkeklere ait genetic ilerleme hızı artırılmıştır. Özellikle dişi sığırlarda yılda bir döl alınması nedeniyle generasyonlar arası süre daha uzun olmaktadır. Bu nedenle dişi sığırlarda generasyonlar arası süre kısaltılarak genetik ilerleme hızının artırılması için üreme biyoteknolojilerine daha fazla ihtiyaç duyulmaktadır. Dişilerde yılda birden fazla döl elde edilmesi için geliştirilen biyoteknolojilerden biriside in vitro embriyo üretimi teknolojisidir.

İn vitro embriyo üretimi; in vitro olgunlaştırma, in vitro fertilizasyon ve in vitro kültür aşamalarından oluşmaktadır. Ayrıca bu teknoloji ile üretilmiş buzağıların doğum ağırlıkları in vivo üretilmiş buzağılara göre daha yüksek olduğu tespit edilmiştir. Doğum ağırlığının artmasına paralel olarak yaşama gücüde artmaktadır (Kruip ve Dendaas,1997).

İn vitro olgunlaştırmada kültür ortamının kompozisyonu, oositlerin metabolizasmasını buna bağlı olarak da gelişimlerini etkilemektedir (Barnet ve Bavister, 1996). Bu nedenle in vitro olgunlaştırmada kültür ortamına ilave edilen protein kaynağı önemlidir. İn vitro olgunlaştırma aşamasında kültür ortamına ilave edilen protein kaynağı, oositlerin hem metefaz II aşamasına ulaşma oranlarını hem de fertilizasyon sonrası gelişimi etkilemektedir (Bavister, 1995). İn vitro olgunlaştırmada kullanılan protein kaynağı olasıl etkisini morula/blastosist aşamasına ulaşmada göstermektedir (Van de Sandt ve ark., 1990). Kültür ortamında protein kaynağı olarak serum, serum albumin, polivinil alkol (PVA) yaygın olarak kullanılmaktadır. Serum ve serum albumin gibi çeşitli yollarla canlılarlardan elde edilen protein kaynaklarında hastalık etkeni bulunma ve protein kaynaklarının bünyelerinde çeşitli patojenleri barındırm riski kültür ortamlarında kullanımlarını sınırlandırmaktadır (McEvoy ve ark., 2000). Bu durum külür ortamlarında risk barındırmayan protein kaynakları arayışını hızlandırmıştır. Şirin ve Kuran (2021) yaptıkları çalışmada in vitro olgunlaştırmada kültür ortamında arı sütünü protein kaynağı olarak başarılı bir şekilde kullanmışlardır. Bu çalışmada oositleri in vitro olgunlaşmaya tabi tutulmuşlar ve bu süreç sonunda protein kaynağı olarak arı sütü kullanılan kültür ortamında oositlerin olgunlaştığını tespit etmişlerdir. Arı sütünün in vitro olgunlaştırmada başarılı bir şekilde kullanılmasından sonra bu oositlerin embriyo oluşturma kapasitelerinin belirlenmesi gerekliliği ortaya çıkmıştır.

Bu çalışmada, kültür ortamında protein kaynağı olarak arı sütü kullanılarak olgunlaştırılan oositlerin partheneogenetik aktivasyon sonrası embriyo oluşturma kapasitelerinin belirlenmesi amaçlanmıştır.

2. MATERYAL ve METOT

Araştırma materyalini, kesim sonrası farklı sığır ırklarından elde edilen ovaryumlar oluşturmuştur.

Kesim sonrası elde edilen ovaryumlar 37 ^{0}C'de fosfat tamponlu tuz çözelitisi (PBS) içerisinde laboratuvara transfer edilmiştir. Laboratuvara getirilen ovaryumlar üzerinde bulunan 5-8 cm çapındaki follikül içersindeki oositler 18 g çapındaki şırınga yardımı ile toplanmışlardır. Follikül içi sıvı içerisinde bulunan oositler mikroskop altında incelenerek sitoplazması düzgün olanlar seçilmiştir. İki farklı kültür ortamı hazırlanmıştır. Bunlardan birincisi 9 ml bikarbonat tamponlu kültür medium içerisine 1 ml fötal buzağı serumu (FCS), 100 µl penisilin-streptomisin ve 20 µl sodyum pürüvat ilave edilerek hazırlanmıştır. Diğer kültür ortamı ise 9 ml bikarbonat tamponlu kültür medium içerisine protein kaynağı olarak %10 arı sütü, 100µl penisilin-streptomisin ve 20 µl sodyum pürüvat ilave edilerek hazırlanmıştır. Her iki kültür ortamı kullanmadan önce 39 ^{0}C'de %5 CO_2 ve % 95 nemli ortamda 2 saat süreyle gazlanmıştır. Daha sonra seçilen oositler bu kültür ortamları içerisine eşit sayıda transfer edilmiştir. Kültüğr ortamına transfer edilen oositler 22 saat süreyle 39 ^{0}C'de %5 CO_2 ve % 95 nemli ortamda olgunlaştırmaya tabi tutulmuşlardır. 22 saat süreyle olgunlaştırmaya tabi tutulan oositlerden metafaz-II aşamasına ulaşanlar mikroskop altında tespit edilerek her iki ortamda olgunlaşan oositlerin oranları belirlenmiştir. Her iki kültür ortamında olgunlaşan oositlerin parthenogenetik aktivasyon sonrası bölünme oranlarının tespit edilmesi için aşağıdaki protocol uygulanmıştır. Buna göre her iki gruptada olgunlaşan oositler önce 100 ml Hepes tamponlu kültür mediumuna % 7 oranında ethanol katılarak oda sıcaklığında 5 dakika süreyle bekletilmişlerdir. Bu işlemi takiben olgunlaştırılmış oositler iki defa Hepes tamponlu kültür mediumunda yıkanmışlardır. Ethanol ile aktivasyonu takiben 1.5 ml Hepes tamponlu kültür medium içerisine 10 µl cycloheximide ve 10 µl cytohalasin-B çözülerek ilave edilmiştir. Her iki gruptaki olgunlaştırılmış oositler 6 saat süreyle 39 ^{0}C'de %5 CO_2 ve % 95 nemli ortamda aktivasyona tabi tutulmuşlardır. 48. saat sonunda ise her iki gruptaki oositlerin bölünme oaranları mikroskop altında tespit edilerek kayıt altına alınmıştır.

3. BULGULAR ve TARTIŞMA

İki farklı kültür ortamında olgunlaştırılan oositlerin olgunlaşma oranları Tablo 1'de verilmiştir. Protein kaynağı olarak arı sütü ilave edilen kültür ortamında olgunlaştırılan oositlerin % 78'i olgunlaşırken protein kaynağı olarak fötal buzağı serumu kullanılan kültür ortamında olgunlaştırılan oositlerin ise % 77 oranında olgunlaştığı tespit edilmiştir. Gruplar arasında isitatistiksel olarak bir farklılık tespit edilmemiştir ($P>0.05$). Bu sonuçlar arı sütünün in vitro olgunlaştırmada protein kaynağı olarak kullanılabileceğini de ortaya koymuştur. Bununla birlikte Fukui ve Ono (1989) yaptıkları çalışmada in vitro olgunlaşma oranını % 59, Lonergan ve ark., (1996) % 64, Ali ve Sirard (2002) ise % 69 olarak tespit etmişlerdir. Çalışmamızda her iki kültür ortamında tespit edilen in vitro olgunlaşma oranları ise bu çalışmalarda elde edilen oranlardan daha yüksek olduğu görülmektedir. Ocana-Quenro ve ark., (1998) in vitro olgunlaştırma oranını % 78, Geshi ve ark., (2000) % 77 olarak oalrak tespit etmişlerdir. Bu çalışmalardaki in vitro olgunlaşma oranları ise çalışmamızdaki oranlar ile benzerlik göstermektedir.

Tablo 1. İki farklı kültür ortamında olgunlaştırılan oositlerin nükleer olgunlaşma oranları

Kültür Ortamı	İncelenen Oosit Sayısı	Kumulus Ekspansiyon Oranları (%)	Nükleer Olgunlaşma Derecesi (%)			
			Metefaz-I	Anafaz-I	Telefaz-I	Metafaz-II
FCS İlaveli	172	97	20	2	1	77
Arı Sütü İlaveli	179	94	19	2	1	78

İki farklı protein kaynağı kullanılan kültür ortamında olgunlaştırılan oositlerin parthenogenetik aktivasyon sonrası bölünme oranları Tablo 2'de verilmiştir. Buna göre protein kaynağı olarak arı sütü kullanılan kültür ortamında olgunlaştırılan oositlerin parthenogenetik aktivasyon sonrası bölünme oranı % 36 iken, protein kaynağı olarak fötal buzağı serumu kullanılan kültür ortamlarında olgunlaştırılan oositlerin bölünme oranı ise % 42 olarak tespit edilmiştir. Gruplar arasında bölünme oranları bakımından istatistiksel bir farklılık tespit edilmemiştir ($P>0.05$). Bu sonuçlar kültür ortamında protein kaynağı olarak arı sütü kullanılarak olgunlaştırılan oositlerden de benzer oranlarda embriyo elde edilebileceğini ortaya koymuştur. Bununla birlikte Otoi ve ark., (1996) yaptıkları çalışmada parthenogenetik aktivasyon sonrası bölünme oranını % 45, Matsushida ve ark., (2004) ise yaptıkları çalışmada % 68 olarak tespit etmişlerdir. Bu iki çalışmada elde edilen parthenogenetik aktivasyon sonrası bölünme oranları çalışmamızda elde edilen oranlarda daha yüksektir. Bu duruma rağmen çalışmamızda elde edilen bölünme oranları arı sütü kullanılan kültür ortamlarında in vitro olgunlaştırılan sığır oositlerinin başarılı bir şekilde bölünebileceği, yani embriyo oluşturma kapasitelerinin bulunduğunu ortaya koymuştur.

Tablo 2. İki farklı kültür ortamında olgunlaştırılan oositlerin parthenogenetik aktivasyon sonrası bölünme oranları

Kültür Ortamı	Olgunlaştırılan Oosit Sayısı	Bölünen Oosit Sayısı	Bölünme Oranı (%)
FCS İlaveli	59	25	42
Arı Sütü İlaveli	61	22	36

4.SONUÇLAR

İn vitro olgunlaştırmada kültür ortamında serum ve serum albümin gibi canlılardan elde edilen protein kaynaklarının kullanımı hem kültür ortamına patojen aktarma riski hem de elde edilen embriyoların gelişimi ve doğum sonrası dönemde ortaya çıkabilecek çeşitli metabolik ve fizyolojik sendromlar sonrası buzağı kayıplarına yol açma riski bulunmaktadır. Bu risk sonrası

kültür ortamlarında daha güvenilir ve bu riskleri minimuma indirecek alternatif protein kaynakları arayışı hızlanmıştır. Bu arayışlar sonrasında arı sütü in vitro olgunlaştırmada kültür ortamında başarılı bir şekilde kullanılmıştır. Fakat in vitro olgunlaştırılan oositlerin embriyo oluşturma kapasiteleri büyük önem taşımaktadır. Bu nedenle bu çalışmada in vitro olgunlaştırmada kültür ortamında protein kaynağı olarak arı sütü kullanılması durumunda embriyo oluşturma yani bölünme kapasitelerinin belirlenmesi ihtiyacı ortaya çıkmıştır. Yapılan bu çalışmada in vitro olgunlaştırmada protein kaynağı olarak arı sütü kullanılan kültür ortamlarında olgunlaştırılan oositlerin parthenogenetik aktivasyon sonrasında başarılı bir şekilde bölündükleri tespit edilmiştir. Bu duruma bağlı olarak in vitro olgunlaştırmada kültür ortamında protein kaynağı olarak arı sütü kullanımı sonucunda olgunlaştırılan oositlerden başarılı bir şekilde embriyoların elde edilebileceğini ortaya koymuştur.

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DETERMINATION OF GROWTH PERFORMANCE OF LAMBS AND FERTILITY CHARACTERISTICS OF KARAYAKA SHEEP RAISED IN TOKAT

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ABSTRACT

The Karayaka breed is a local genetic resource cultivated in the Black Sea region. Although the Karayaka breed has a low fertility rate, its meat quality is one of our best breeds. The most important source of income in sheep breeding in Türkiye is lamb sales. Therefore, fertility in sheep and growth characteristics of lambs have a significant impact on the income obtained. In order to improve incomes, breeding programs in herds need to be carried out. It is known that the number of breeding programs carried out in sheep breeding in our country is very limited. For this reason, the "National Sheep and Goat Breeding Project of Türkiye" has been implemented throughout the country by the General Directorate of Agricultural Research and Policies, which is affiliated to the Ministry of Agriculture and Forestry. Within the scope of this project, the "Project for Breeding of Karayaka Breed in Tokat Province" has been started to be implemented. In this study, it was aimed to determine the fertility characteristics of Karayaka sheep and the average live weights of lambs in various periods within the scope of the project. The animal material of this study consists of the herds in this project. Data were collected from 26797 Karayaka lambs of 28325 Karayaka sheep which were born during 2020 to 2024 birth season. In this study, live weights in various periods, daily live weight gains, survival rates of lambs and some fertility traits of Karayaka sheep were examined. The average birth weight, 60th day and 90th day (weaning) weights and daily live weight gains of lambs were determined as 3.90 kg, 22.97 kg, 26.81 kg and 262.07 g, respectively. The average survival rate in lambs was 0.97. The infertility rate, birth rate, twins, fecundity and litter size in Karayaka sheep were 8%, 92%, 6%, 1.06 and 1.14, respectively. These results show that although the averages have fluctuated over the years depending on environmental factors, they have improved compared to the beginning of the project. In addition, the variation among the data showed that improvements would be achieved in terms of the characteristics emphasized through breeding studies.

Keywords: Sheep, Karayaka, Lamb, Breeding, Fertility, Growth Characteristics

TOKAT İLİNDE YETİŞTİRİLEN KARAYAKA KOYUNLARININ BAZI DÖL VERİM ÖZELLİKLERİ ve KUZULARIN BÜYÜME ÖZELLİKLERİNİN BELİRLENMESİ

ÖZET

Karayaka ırkı karadeniz bölgesinde yetiştiriciliği yapılan yerli bir gen kaynağımızdır. Döl verimi düşük olmasına rağmen et kalitesi en iyi ırklarımızdan birisidir. Türkiye'de, koyun yetiştiriciliğinde en önemli gelir kaynağını kuzu satışları oluşturmaktadır. Bu nedenle koyunlarda döl verimi ve kuzuların büyüme özellikleri elde edilen gelir üzerine önemli miktarda etki etmektedir. Gelirlerin iyileştirilmesi için sürülerde ıslah programlarının yürütülmesi gerekmektedir. Ülkemizde ise koyun yetiştiriciliğinde ıslah programlarının yürütüldüğü işletme sayısının çok sınırlı olduğu bilinmektedir. Bu nedenle, Tarım ve Orman Bakanlığına bağlı olan Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü tarafından ülke genelinde "Halk Elinde Hayvan Islahı Ülkesel Projesi" uygulamaya alınmıştır. Bu proje kapsamında ise Tokat İlinde Karayaka Irkının Halk Elinde Islahı Projesi" uygunlamaya başlamıştır. Bu çalışmada, proje kapsamında Karayaka koyunlarının döl verim özellikleri ile kuzuların çeşitli dönemlerdeki canlı ağırlıklarına ait ortalamaların belirlenmesi amaçlanmıştır. Bu çalışmanın hayvan materyalini ise bu projede yer alan sürüler oluşturmaktadır. Bu çalışmada 2020-2024 yılları arasında 28360 baş anaç hayvana ait toplam 26797 veri kullanılmıştır. Bu kapsamda kuzuların çeşitli dönem canlı ağırlıkları, günlük canlı ağırlık artışları, yaşama güçleri ve Karayaka koyunlarının bazı döl verim özellikleri incelenmiştir. Kuzuların ortalama doğum ağırlığı, 60.gün ve 90.gün (sütten kesim) ağırlıkları ile günlük canlı ağırlık artışları sırası ile 3.90 kg, 22.97 kg, 26.81 kg ve 262.07 gr olarak tespit edilmiştir. Kuzularda yaşama gücü ortalaması ise 0.97 olarak gerçekleşmiştir. Karayaka koyunlarında döl verim özelliklerinden kısırlık oranı, doğum oranı, ikizlik oranı, koç altı koyun başına kuzu sayısı ve doğuran koyun başına kuzu sayısı sırasıyla % 8, % 92, % 6, 1.06, 1.14 olarak gerçekleşmiştir. Bu sonuçlar, ortalamaların yıllar itibariyle çevresel faktörlere bağlı olarak dalgalanma göstermiş olmasına rağmen projenin başlangıcına göre iyileştiği ortaya konulmuştur. Ayrıca veriler arasındaki varyasyon ıslah çalışmaları ile üzerinde durulan özellikler bakımından iyileşmeler sağlanacağını da göstermiştir.

Anahtar Kelimeler: Koyun, Karayaka, Kuzu, Islah, Döl Verimi, Büyüme Özellikleri

1.GİRİŞ

Karayaka koyun ırkı Karadeniz Bölgesinde yetiştiriciliği yapılan yerli bir ırkımızdır. Döl verimi düşük fakat et kalitesi yüksektir (Akçapınar ve ark., 2005). Karayaka koyun ırkı Sinop'tan Giresun'a kadar uzanan Karadeniz sahili ile Amasya, Tokat il ve ilçelerinde yetiştirilen genelliklede Doğu ve Orta Karadeniz bölgesinin hakim bir ırkıdır. Karayaka koyunu yazın yayla, kışın ise sahil kesimine yakın yerlerde yetiştirilmektedir. Çoğunlukla yaylada üretim sistemi hakimdir (Çam ve ark., 2012). Türkiye koyun varlığının yaklaşık % 3'lük kısmını oluşturan bir ırkımızdır. İnce kuyruklu koyun ırklarından olan Karayaka koyunlarının vücutları beyaz, baş, kulak ve bacaklarda siyah lekeler görülebilir. Karayaka koyunu, öncelikle et daha sonra süt ve yapağısı için yetiştirilir (Kaymakçı ve Sönmez, 1996). Vücutları küçük yapıdadır (cidago yüksekliği 60-62 cm). Anaç koyunlarda canlı ağırlık 35-40 kg kadar, kirli yapağı verimi 2.0-2. 5 kg, lüle uzunluğu 20-30 cm,süt verimi 30-45 kg, laktasyon süresi 100-140 gündür (Akçapınar, 2000). Karayaka koyununda et (karkas ağırlığı) verimi 20-22 kg, döl verimi ise 1.18 civarındadır (Ulutaş ve ark., 2008).

Diğer hayvancılık kolların da olduğu gibi koyunculukta da önemli olan döl yani kuzu verimidir. Et, süt, yapağı gibi ekonomik olarak önemi olan hayvansal ürünler verimlilik açısından büyük ölçüde döl verimine bağlıdır (Altınel ve Hacıismailoğlu, 1993). Döl verimine; ırk, yaş, damızlıkta kullanım yaşı, bakım besleme, iklim gibi çevresel faktörler gibi bir çok etmen etkilidir (Esen ve Bozkurt 2001; Esen ve Özbey 2002).

Koyun yetiştiriciliği çok farklı verimlere sahip bir hayvancılık koludur. Günümüz koşullarında ise en önemli verimi et üretimi yani kuzu üretimi oluşturmaktadır. Bu nedenle ekonomik olarak daha fazla kazanç sağlanması için, döl verimi ve canlı ağırlık artış hızının iyileştirilmesi gerekmektedir.

Bu çalışmada proje kapsamında elde edilen verilerin değerlendirilmesi sonucunda canlı ağırlık ve döl verimi ile ilgili ortalamaların belirlenmesi amaçlanmıştır.

2.MATERYAL VE METOT

Araştırma materyalini, "Halk Elinde Hayvan Islahı Ülkesel Projesi" kapsamında Tokat ilinde 2020-2024 yılları arası sürdürülen "Tokat İlinde Karayaka Koyununun Halk Elinde Islahı" projesi kapsamında yer alan 28360 baş Karayaka ırkı koyun ile bu koyunlardan doğan 26797 baş kuzuya ait veriler oluşturmuştur.

Meraların açık olduğu dönemde anaç hayvanlar tamamen meralardan faydalandırılmışlardır. Mera dışı dönemde ise kapalı barınaklarda tutulmuşlardır. Kapalı ağıllarda barındırıldıkları dönemlerde hayvanların ihtiyaçlarına göre buğday ya da arpa samanı, yonca, arpa ve buğday danesi ile birlikte kesif yem kullanılmıştır.

Sürülerde koç katım işlemi, Temmuz-Eylül ayları arasında serbest koç katım usulüne göre yapılmıştır. 20-25 baş anaç koyun için 1 baş koç olacak şekilde planlama yapılmıştır.

Doğumu takiben kuzulara ilk 24 saat içerisinde kulak küpesi takılarak 30 kg'lık el baskülü ile tartılmış ve kayıt altına alınmıştır. Ayrıca kuzulara ait ana numarası, doğum tarihi, doğum ağılığı, cinsiyet ve doğum şekli gibi bilgilerde tutulmuştur. Kuzular doğumu takiben 7 gün

süreyle 24 saat olacak şekilde anneleri ile birlikte tutularak ağız sütünü almaları sağlanmıştır. 7. günden sonra ise kuzular annelerinden ayrılarak günde 2 ya da 3 defa olacak şekilde annelerini emmelerine izin verilmiştir. Kuzular 90 günlük yaşta sütten kesilmişlerdir.

Kuzular ortalama 90 günlük yaşta olacak şekilde bir tarih belirlenerek 50 gr hassasiyetindeki bir baskül ile tartılmış ve sütten kesim ağırlıkları tespit edilmiştir.

Kuzulama oranı (doğum oranı), tekiz doğum oranı, ikiz doğum oranı, kısırlık oranı, koç altı koyun başına doğan kuzu sayısı (KAKBDKS) ve doğuran koyun başına doğan kuzu sayısı (DKBDKS) ile 3 aylık yaştaki yaşama gücü Kaymakçı ve Sönmez (1996)'in bildirdiği şekilde hesaplanmıştır. Hesaplamalar aşağıdaki formüllere göre yapılmıştır.

$$\text{Kuzulama oranı (Doğum oranı)} = \frac{\text{Doğuran Koyun Sayısı}}{\text{Koç Altı Koyun Sayısı}} X100$$

$$\text{Tekiz Doğum Oranı} = \frac{\text{Tekiz Doğuran Koyun Sayısı}}{\text{Doğuran Koyun Sayısı}} X100$$

$$\text{İkiz Doğum Oranı} = \frac{\text{İkiz Doğuran Koyun Sayısı}}{\text{Doğuran Koyun Sayısı}} X100$$

$$\text{Kısırlık Oranı} = \frac{\text{Kısır Koyun Sayısı}}{\text{Koç Altı Koyun Sayısı}} X100$$

$$\text{KAKBDKS} = \frac{\text{Doğan Kuzu Sayısı}}{\text{Koç Altı Koyun Sayısı}} X100$$

$$\text{DKBDKS} = \frac{\text{Doğan Kuzu Sayısı}}{\text{Doğuran Koyun Sayısı}} X100$$

$$\text{Yaşama Gücü} = \frac{\text{3 Aylık Yaşa Ulaşan Kuzu Sayısı}}{\text{Doğan Kuzu Sayısı}} X100$$

Bu çalışmada elde edilen sütten kesim ağırlığı ile ilgili veriler yaşa göre düzeltilmiştir. Bu verilen düzeltilmesinde aşağıdaki formülden yararlanılmıştır.

$$DA=CA-(b\times(TY-90))$$

DA: Düzeltilmiş ağırlık

CA: Canlı ağılık

TY: Tartım tarihindeki yaş

b:Tartım yapılan dönemdeki kuzu yaşı ile canlı ağırlıkları arasındaki regresyon katsayısı

Ayrıca bu çalışmada kuzuların doğum ve sütten kesim ağırlıkları üzerine etki eden çevresel faktörlerin (yıl, cinsiyet ve doğum şekli) etkisi MINITAB 13.0 programında en küçük kareler metoduna göre istatistiksel analize tabi tutulmuştur. Ortalamaların karşılaştırılmasında ise Tukey çoklu karşılaştırma testi kullanılmıştır.

3. BULGULAR ve TARTIŞMA

Karayaka kuzularının yıl, cinsiyet, ana yaşı ve doğum şekillerine göre doğum ağırlık ortalamaları Tablo 1'de verilmiştir. Buna göre istatistiksel olarak en yüksek doğum ağırlığına 2021 ve 2023 yıllarında ulaşılmıştır ($P<0.01$). Ana yaşı bakımından en yüksek doğum ağırlığına sahip kuzular 5 yaşındaki analardan elde edilmiştir ($P<0.01$). Buna göre 5 yaşındaki analardan elde edilen kuzuların doğum ağırlığı ortalaması 3.95 kg olarak gerçekleşmiştir. Doğum ağırlığı bakımından tekizler ikizlere göre, erkeklerde dişilere göre daha yüksek doğum ağırlığına sahiptirler ($P<0.01$). Olfaz ve Saylam, (1996) tarafından yapılan çalışmada sonbahar ve ilkbaharda doğan Karayaka kuzularında doğum ağırlıkları sırası ile 3.20 kg ve 3.84 kg olarak tespit edilmiştir. Çalışmamızda ise ortalama doğum 3.92 kg olarak tespit edilmiş ve tespit edilen bu doğum ağırlığı Olfaz ve Saylam, (1996) tarafından yapılan çalışmada elde edilen doğum ağırlığı ortalamasından yüksek bulunmuştur. Ünal ve ark., (2003) ve Çam ve ark., (2012) tarafından yapılan çalışmalarda sırası ile doğum ağırlığı 3.10 ve 3.30 kg olarak tespit edilmiştir. Bu doğum ağırlığı ortalamaları da çalışmamızdaki doğum ağırlığı ortalamasından düşük olduğu görülmektedir. Bu sonuçlar yıllar itibariyle yürütülen ıslah çalışması ile birlikte doğum ağırlığının Karayaka kuzularında arttığını göstermiştir. Doğum ağırlığının artması kuzularda yaşama gücünün de artırarak doğan kuzuların hayatta kalmalarına katkıda bulunmaktadır. Aynı zamanda doğum ağırlığı yüksek olan kuzuların beside daha iyi performans verdikleri de bilinmektedir.

Tablo 1. Yıl, ana yaşı, doğum şekli ve cinsiyete göre doğum ağırlığı ortalamaları (kg)

	n	Ort.	SH
Genel Ortalama	26797	3,91	± 0,06
Yıl			
2020	5576	3,90	± 0,06[a]
2021	5225	3,98	± 0,06[b]
2022	4655	3,86	± 0,07[a]
2023	5560	3,91	± 0,05[b]
2024	5781	3,86	± 0,06[a]
Ana Yaşı			
2	6158	3,67	± 0,04[a]
3	7072	3,86	± 0,06[b]
4	6690	3,89	± 0,07b
5	6379	3,95	± 0,06[c]
6	3498	3,86	± 0,06[b]
Doğum Şekli			
Tek	24504	3,92	± 0,06[a]
İkiz	2293	3,81	± 0,07[b]
Cinsiyet			
Erkek	13871	3,96	± 0,05[a]
Dişi	12926	3,84	± 0,07[b]

*Aynı sütün da farklı harfler ile gösterilen ortalamalar arasındaki farklılıklar çok önemli bulunmuştur (P<0.01).

Karayaka kuzularının yıl, cinsiyet, ana yaşı ve doğum şekillerine göre 60. ve 90. gün yaşa göre düzeltilmiş ağırlık ortalamaları Tablo 2'de verilmiştir. En yüksek 60.gün ağırlığına 2024 yılında, 90.gün ağırlığı bakımından ise 2021 yılında ulaşılmıştır (P<0.01). 4 yaşındaki analardan elde edilen kuzularda en yüksek 60.gün ve 90. gün ağırlığına ulaşılmıştır (P<0.01). Hem 60. gün hem de 90. gün ağırlıkları bakımından tekizler ikizlere göre, erkekler ise dişilere göre daha yüksek ağırlıklara ulaşmışlardır (P<0.01). Yapılan bir çalışmada Karayaka ve Bafra kuzuları 90. Günde sütten kesilmişler ve sırasıyla sütten kesim ağırlıkları 19.5 ve 22.5 kg olarak tespit edilmiştir (Ünal ve ark., 2003). Bu çalışmada Karayaka kuzuları için tespit edilen 90 günlük yaştaki sütten kesim ağırlığı çalışmamızda tespit edilen sütten kesim ağırlığından hatta 60. gün ağırlık ortalamasından bile daha düşük olduğunu göstermektedir. Çalışmamızdaki 60. gün ve 90. gün (sütten kesim) ağırlıklarının daha yüksek olmasının sebebi sürülerde uzun

yıllardır yürütülen ıslah çalışmalarında sütten kesim ağırlığının (90.gün) damızlık seçiminde bir kriter olarak baz alınmasından kaynaklandığı söylenebilir. Bu duruma bağlı olarak yıllar itibariyle sütten kesim ağırlığı Karayaka kuzularında artmıştır. Sütten kesim ağırlığının artmasındaki diğer etkili bir faktör ise doğum ağırlığındaki artışı da söylenebilir. Doğum ağırlığı yüksek olan kuzularda sütten kesim ağırlıklarının da yüksek olduğu bilinmektedir.

Karayaka kuzularında sütten kesim yaşına (90.gün) kadar ki günlük canlı ağırlık kazançları yıl, ana yaşı, cinsiyet ve doğum şekline göre Tablo 3'de verilmiştir. En yüksek günlük canlı ağırlık artışına 2021 yılında ulaşılmış ve bu yıldaki günlük canlı ağırlık kazancı 276.20 kg olarak gerçekleşmiştir ($P<0.01$). Ayrıca 4 ve 5 yaşlı annelerden elde edilen kuzularda günlük canlı ağırlık kazançlarının daha yüksek olduğu görülmüştür ($P<0.01$). Tekiz doğan kuzular ikizlerden, erkek kuzularda dişilerden daha yüksek canlı ağırlık artışına sahiptirler ($P<0.01$). Aksoy (2008)'in yaptığı çalışmada Karayaka kuzularında 8 ve 20 haftalık yaşa kadar olan günlük canlı ağırlık artışlarının sırasıyla 180 ve 150 gr olduğunu bildirmiştir. Çalışmamızda elde edilen Karayaka kuzularında 90 günlük yaşa kadar olan canlı ağırlık kazançlarının ortalama 262.07 gr olduğu tespit edilmiş ve bu günlük canlı ağırlık kazancının Aksoy (2008) tarafından yapılan çalışmada elde edilen ortalamadan çok daha yüksek olduğu belirlenmiştir. Bu farkın hem doğum ağırlığı artışından hem de yürütülen ıslah çalışmalarından kaynaklandığı söylenebilir.

Tablo 2. Yıl, ana yaşı, doğum şekli ve cinsiyete göre 60. ve 90. gün (sütten kesim) ağırlık ortalamaları (kg)

	60. Gün Ağırlığı (kg)			90. Gün Ağırlığı (kg)		
	n	Ort.	SH	n	Ort.	SH
Genel Ortalama	24725	22,34	± 0,6	24725	26,92	± 0,5
Yıl						
2020	5135	23,20	± 0,5^{a}	5135	27,71	± 0,5^{a}
2021	4881	22,92	± 0,4^{b}	4881	28,95	± 0,6^{b}
2022	4352	22,68	± 0,8^{b}	4352	24,46	± 0,7^{c}
2023	5123	23,02	± 0,5^{a}	5123	26,95	± 0,4^{a}
2024	5234	23,78	± 0,7^{c}	5234	26,91	± 0,6^{a}
Ana Yaşı						
2	4802	19,21	± 0,5^{a}	4802	26,79	± 0,5^{a}
3	5935	19,56	± 0,5^{a}	5935	28,86	± 0,6^{b}
4	6401	24,93	± 0,6^{b}	6401	29,41	± 0,6^{b}
5	4031	23,51	± 0,5^{c}	4031	27,88	± 0,7^{a}
6	3556	23,30	± 0,5^{c}	3556	27,70	± 0,5^{a}
Doğum Tipi						
Tek	13722	23,86	± 0,6^{a}	13722	28,26	± 0,6^{a}
İkiz	11003	22,85	± 0,5^{b}	11003	27,24	± 0,5^{b}
Cinsiyet						
Erkek	12908	24,77	± 0,8^{a}	12908	30,01	± 0,6^{a}
Dişi	11820	22,89	± 0,5^{b}	11820	26,68	± 0,5^{b}

*Aynı sütün da farklı harfler ile gösterilen ortalamalar arasındaki farklılıklar çok önemli bulunmuştur (P<0.01).

Karayaka kuzularında sütten kesim yaşına (90.gün) kadar ki yaşama gücü oranları yıl, ana yaşı, cinsiyet ve doğum şekline göre Tablo 4'de verilmiştir. Karayaka kuzularında en yüksek yaşama gücü oranlarına 2023 ve 2024 yıllarında (% 95) ulaşılmıştır (P<0.01). En yüksek yaşama gücü oranı 4 yaşındaki analardan (% 95) elde edilen kuzularda elde edilmiştir (P<0.01). Yaşama gücü oranı tekiz kuzularda ikiz kuzulara göre, erkek kuzularda dişi kuzulara göre daha yüksek olduğu tespit edilmiştir (P<0.01). Belgüzar (2011) tarafından yapılan çalışmada Karayaka kuzularında 56. ve 140. günlerdeki yaşama gücü sırasıyla % 89.39 ve % 93.77 olarak tespit edilmiştir. Çalışmamızdaki 90. Gün yaşama gücü oranı Belgüzar (2011) tarafından yapılan çalışmada elde

edilen bulgular ile benzerlik göstermektedir. Ayrıca çalışmamızda elde edilen yaşama gücü ekonomik bir hayvancılık için kabul edilen sınırlar içerisinde olduğu da söylenebilir.

Tablo 3. Yıl, ana yaşı, doğum şekli ve cinsiyete göre 90. gün (sütten kesim) yaştaki günlük canlı ağırlık artış ortalamaları (gr)

	n	Ort.	SH
Genel Ortalama	24725	262,07	± 3,25
Yıl			
2020	5135	242,10	± 4,65[a]
2021	4881	276,20	± 3,39[b]
2022	4352	271,60	± 5,75[c]
2023	5123	268,54	± 4,05[c]
2024	5234	261,60	± 4,87[d]
Ana Yaşı			
2	4802	257,35	± 4,54[a]
3	5935	261,20	± 2,95[b]
4	6401	268,05	± 4,62[c]
5	4031	267,90	± 3,55[c]
6	3556	262,20	± 4,40[b]
Doğum Tipi			
Tek	13722	266,45	± 3,58[a]
İkiz	11003	258.55	± 4,77[b]
Cinsiyet			
Erkek	12908	269,05	± 4,98[a]
Dişi	11820	257,95	± 3,75[b]

*Aynı sütün da farklı harfler ile gösterilen ortalamalar arasındaki farklılıklar çok önemli bulunmuştur (P<0.01).

Karayaka koyunlarında yıllara göre bazı döl verim ölçütleri Tablo 5'de verilmiştir. En yüksek doğum oranına 2023 yılında ulaşılmıştır. En yüksek ikiz doğum oranı 2020 yılında % 13 olarak gerçekleşmiştir. Tamer ve Şirin (2021) tarafından yapılan çalışmadaki ikiz doğum oranı %8 olarak tespit etmişlerdir. Çalışmamızda elde edilen ikizlik oranının daha yüksek olduğu tespit edilmiştir. Bu durum yıllardır sürülerde yapılan ıslah çalışmasında damızlık olarak ikiz doğmuş kuzuların daha fazla damızlık olarak kullanılmasından kaynaklandığı söylenebilir. En düşük

kısırlık oranı ise % 7 ile 2023 yılında gerçekleşmiştir. Yine Tamer ve Şirin (2021) tarafından yapılan çalışmada elde edilen kısırlık oranı % 13.8 olarak tespit edilmiştir. Çalışmamızda ise kısırlık oranı çok daha düşük tespit edilmiştir. Koç altı koyun başına kuzu sayısı en yüksek olarak 2020 yılında 1.10 şeklinde gerçekleşirken, doğuran koyun başına düşen kuzu sayısı yine 2020 yılında en yüksek 1.19 olarak gerçekleşmiştir. Olfaz ve Saylam (1996) yılında yapılan çalışmada KAKBDKS ve DKBDKS sırası ile 1.0 ve 1.15 olarak gerçekleşmiştir. Çalışmamızda elde edilen değerler ile benzerlik gösterdiği söylenebilir.

Tablo 4. Yıl, ana yaşı, doğum şekli ve cinsiyete göre 90. gün (sütten kesim) yaştaki yaşama gücü ortalamaları (%)

	n	Ort.	SH
Genel Ortalama	24725	93	± 0,07
Yıl			
2020	5135	92	± 0,06[a]
2021	4881	93	± 0,02[b]
2022	4352	92	± 0,06[a]
2023	5123	95	± 0,05[c]
2024	5234	95	± 0,04[c]
Ana Yaşı			
2	4802	92	± 0,06[a]
3	5935	93	± 0,07[b]
4	6401	95	± 0,05[c]
5	4031	93	± 0,07[b]
6	3556	93	± 0,06[b]
Doğum Tipi			
Tek	13722	95	± 0,06[a]
İkiz	11003	91	± 0,06[b]
Cinsiyet			
Erkek	12908	96	± 0,05[a]
Dişi	11820	91	± 0,05[b]

*Aynı sütün da farklı harfler ile gösterilen ortalamalar arasındaki farklılıklar çok önemli bulunmuştur (P<0.01).

Tablo 5. Yıllara Göre Karayaka koyunlarında bazı döl verim ölçütleri

Yıllar	DO (%)	TDO (%)	İDO (%)	KO (%)	KAKBDKS	DKBDKS
2020	92	87	13	8	1.10	1.19
2021	92	96	4	8	1.02	1.11
2022	89	92	8	11	1.05	1.18
2023	93	94	6	7	1.04	1.12
2024	92	91	9	8	1.06	1.15

DO: Kuzulama Oranı, TDO: Tekiz Doğum Oranı, İDO: İkiz Doğum Oranı, KO: Kısırlık Oranı, KAKBDKS: Koç Altı koyun Başına Doğan Kuzu Sayıs, DKBDKS: Doğran Koyun Başına Düşen Kuzu Sayısı

4. SONUÇLAR

Sonuç olarak yıllar itibariyle doğum ağırlığında dalgalanmaların olduğu görülmektedir. Bunun nedeni ise çevre koşullarından kaynaklanmaktadır. Koyunculuğun ülkemizde meraya dayalı bir hayvancılık faaliyeti olması nedeniyle o dönemki mera koşulları ve mera koşullarına ilave yapılan ek yemlemeler doğum ağırlığı üzerinde ciddi değişimlere yol açmaktadır. Çalışmamızda yıllar itibariyle doğum ağırlıklarındaki artış ve azalışların nedeni de bu duruma bağlı olarak gerçekleşmiş olabilir. Doğum ağırlığı bakımından Karayaka kuzuları için kabul edilebilir değerler olmakla birlikte sürülerde yürütülen ıslah çalışmalarının sonucu olarak bu ırk için daha önceki literatürler de belirlenen doğum ağırlıklarının üzerinde olduğu da görülmektedir. Bununla birlikte sütten kesim ağırlığı da yıllar itibariyle yükselmiştir. Sütten kesim ağırlığında ki iyileşmeler damızlık seçiminde bu ağırlığın referans olarak kabul edilmesine bağlı olduğu söylenebilir. Ayrıca kuzuların yaşama gücünde de iyileşmeler olmuştur. Bu durum kuzuların bakım ve beslenmesi noktasında yeniliklerin sürülerde uygulanması ile sağlanmıştır. Döl verim ölçütlerinde ise bu ırk için belirlenen ortalamaların genellikle üzerinde olduğu, özetle döl veriminin iyileştiği de söylenebilir. Ayrıca kısırlık oranlarının azaldığı tespit edilmiştir.

Sonuç olarak, yıllar itibariyle yürütülen ıslah çalışmasına bağlı olarak Karayaka ırkında canlı ağırlık ve döl veriminde ciddi iyileşmelerin olduğu tespit edilmiştir.

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GENETIC BASIS OF VOLATILE COMPOUND PRODUCTION IN STRAWBERRIES: INSIGHTS FROM QTL MAPPING AND GWAS

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ABSTRACT

The total of volatile compounds determines strawberry (Fragaria × ananassa) odor and taste alike while directly creating consumer preferences and commercial potential. This article delves into strawberry volatile compound genetic determinants using Quantitative Trait Loci (QTL) mapping wherein researchers apply Genome-Wide Association Studies (GWAS). The identification of volatile compound synthesis responsible genes and genomic regions becomes possible due to these genetic techniques , including esters along with aldehydes and terpenes. these Genetic tools integration provides beneficial knowledge to develop better strawberry flavors through breeding programs. The study of genetic volatile compound regulation helps breeders produce marketable varieties with better consumer appeal and enhanced market value.

Keywords: Strawberry, aroma, volatile compounds, QTL, GWAS

ÇİLEKLERDE UÇUCU BİLEŞİK ÜRETİMİNİN GENETİK TEMELİ: QTL HARİTALAMA VE GWAS'TAN ELDE EDİLEN BİLGİLER

ÖZET

Aroma ve tad temel çilek (Fragaria × ananassa) uçucu bileşiklerinin toplamı belirlerken doğrudan da sanı ve bunun niteliği de ticaret üstlendi. Yeni makale, araştırmacıların araştırma konusu olan genom çapında bağlantı çalışmaları (GWAS) araçlarını uygulama Niceliksel Karakter Bölgesi Biçimleri (QTL) haritalama yaparak çilek uçucu bileşiklerinin genetik galer◌ิเศษlerini anlamaya çalışıyor. Bu genetik teknolojiler ile esterler, aldehitler, terpenler dahil olmak üzere aromatik bileşik sentezinden sorumlu genlerin ve genomik alanların tanımlanması mümkün olur. Bu genetik araçların kullanımı on yıllar içinde gen kat hizmetleri sayesinde daha iyi çilek aromaları_AVAILABLE. Genetik uçucu bileşik/configürasyonunun incelenmesi ıslahçıların daha tüketici çekiciliği ve daha yüksek market değeri ile pazarlanabilir çeşitler üreterek yardımcı olur.

Anahtar Kelimeler: Çilek, aroma, uçucu bileşikler, QTL, GWA

INTRODUCTION

Strawberry is among the most consumed berries in the world. During the last decades, Strawberry programs have been mainly characterized by fruit quality and disease. resistance. However, consumers call for improved fruits' taste (Folta and Klee, 2016). and for this reason, quality traits such as volatiles and polyphenolic content has gained importance in breeding programs. Various volatile compounds that are enhanced in the fruit materials ripening, is seen to be part of a healthy nutrient label (Goff and Klee, 2006).

Of volatile organic compounds (VOCs) in strawberries 979 were identified. (Ulrich et al., 2018).but humans only detect a handful of them making up the strawberry aroma y aroma (Schieberle and Hofmann, 1997; Urrutia et al., 2017)The large variability genetics can explain strawberry volatile compound in strawberry. maturity stage and post harvest factors (Schwieterman et al. 2014). The synthesis of volatile compounds such as esters, aldehydes, alcohols and terpenes is of importance to the characteristic aroma of the strawberry. These compounds are of great importance in the determination of the sensory experience of the fruit and consumer preference (Urrutia et al., 2017). The complex taste profile of strawberries is a result of the balance shared between these volatile compounds, which differ according to the cultivar and the growing environment and the level of ripeness of the fruit (Fan et al., 2022). The biosynthesis of volatile compounds is controlled by a set of genetic and environmental factors. The recent advances in genomics especially through Quantitative Trait Loci (QTL) mapping and Genome-Wide Association Studies (GWAS) have revealed new opinions that pertain to the genetic causation of volatile production in strawberries (Zorrilla-Fontanesi et al. 2020). These were molecular tools and helped to identify areas of the genome were responsible for specific genes and genomic areas that compound volatile compounds and utilize these to develop strategies of breeding to enhance the flavor and aroma of the strawberry fruits. The identification of molecular determinants of aroma formation in strawberry is of great importance for breeding efforts of improved fruit quality. Combining genomic information with the biochemical pathways of VOC synthesis provides opportunities for VD targeted breeding via marker-assisted selection or genomic prediction. This paper summarizes recent findings for the genetic dissection of volatile compound biosynthesis in strawberry with emphasis given to QTL and GWAS analyses and their implications for genetic improvement of strawberry flavor using molecular breeding.

GENETIC BACKGROUND OF VOLATILE COMPOUND PRODUCTION.

The biosynthetic pathways of volatile compounds are numerous and for each class of compounds a different biosynthetic pathway exists. For instance, esters that make a considerable contribution to the delicious aroma fruit of strawberries are mainly produced by alcohol acyltransferases (Aharoni et al., 2004). Analogously, terpenes that add green, floral accents to strawberries are synthesized by terpene synthases (Fan et al., 2022). The regulation of these pathways is under genetic control by many genes, several of which map to environmental variables such as temperature, light, and soil components (Urrutia et al., 2017). The genetic mechanism underlying production of volatile compounds in strawberries, as well as in many other crops, is complicated by the existence of many alleles located on different loci.

QTL mapping is a strong tool for localization of genome regions that govern the traits such as production of volatile compounds. By intercrossing genetically different parental lines with opposite volatile profiles, QTL mapping of cv11 and cv12 will allow the identification of genomic regions correlated with the production of certain volatile compounds (Zorrilla-Fontanesi et al., 2020).

QTL MAPPING IN STRAWBERRIES

QTL mapping in strawberries has proven to be an effective way to identify the genetic basis of volatile compound production. In a typical QTL mapping study, a cross is made between two parental lines that exhibit differences in a particular trait, such as the levels of specific volatile compounds. The F1 population resulting from the cross is then phenotypically evaluated, and genetic markers are used to associate the observed variation in volatile compounds with specific regions of the genome (Zorrilla-Fontanesi et al., 2022).

Recently, a QTL mapping study across strawberries has identified several genomic sites that are directly tied to ester and terpene synthesis, and genes responsible for their synthesis are identified as key candidates (Zorrilla-Fontanesi et al., 2020). The information about these genetic regions has allowed researchers to choose specific markers to direct breeding strategies for strawberries bearing better aroma and flavour.

GWAS IN STRAWBERRY FLAVOR IMPROVEMENT

Genome-Wide Association Studies act as dissection of the genetic basis of building volatile compounds. GWAS treats the advantage of natural variation present in an existing population where quantile-quantile methods study the results from controlled crosses. When specialists use genetic markers in searching for relationships with measurable properties, they can find genome regions associated with the levels of strawberry volatile compounds (Fan et al., 2022).

Most recently, researchers who have employed GWAS in the strawberries have identified several genomic regions involved with the build-up of key volatile substances, including esters and terpenes key for floral fragrance (Zorrilla-Fontanesi et al., 2022). The results will prove of great use to the breeders of strawberries who will succeed in boosting flavor in general across the fruit. GWAS allows for accurate identification of the genes responsible for volatile compound synthesis, which is emphasized by this study, that can help in designing better genome-assisted breeding strategies.

INTEGRATION OF QTL AND GWAS FOR STRAWBERRY BREEDING.

Putting together results of the QTL mapping and GWAS provides a deeper understanding of the genetic organization controlling volatile compound synthesis in strawberries. Combining advantages of QTL mapping and GWAS allows researchers to identify candidate genes and regulatory network(s) that will control flavoration. Such insights are needed to design breeding

regimes, which address improving strawberry flavor of the fruit – a vital necessity in light of the rises of competition in the fruit market (Zorrilla-Fontanesi et al., 2022).

Both flavor quality as well as improvement of crucial characters like yield, disease tolerance and shelf life in the breeding of strawberries will gain from the use of genomic tools like QTL mapping and GWAS. Because there is increasing demand for superior-tasting strawberries, discovery of the genomic basis for the flavor substances is critical to meeting this demand.

CONCLUSION

Strawberry volatile compound synthesis is controlled by intricate genetic arrangements influenced by environmental conditions. QTL mapping and GWAS have proved their usefulness in identification of the genes and chromosomal regions responsible for the formation of significant volatile compounds. By combining these methods, researchers are in a position to increase the flavour characteristics of strawberries therefore honouring the interest of both farmers and the product consumers. As breeders try to make the taste of strawberries better, it is eventually going to be fundamental that the genetic loci controlling the production of volatile compounds be identified for creating flavorful, premium quality varieties.

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THE EFFECTIVENESS OF MICROBIAL INOCULANTS IN IMPROVING SILAGE QUALITY: MILLET (*Panicum miliaceum L.*)

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ABSTRACT

Silage is a basic feed source in animal husbandry, and quality silage production is of critical importance in terms of reducing animal feeding costs and increasing environmental sustainability. This study was carried out to determine the effects of five different commercial inoculants added to millet (Panicum miliaceum L.) on silage quality, microorganism growth, and aerobic stability. The study was conducted by vacuuming a control group (Control-M) and five different inoculant groups—MSILD, MSILAP, MLAC, MSILAL, MMIC—in 2 kg packages with eight replications. The prepared silage samples were left to ferment under laboratory conditions, and physical, chemical, microbiological, and aerobic stability analyses were performed after 90 days. As a result of chemical analyses, inoculant addition provided a significant decrease in the pH levels of the silages ($P<0.01$), with the lowest pH value (4.39±0.00) determined in the MMIC group. The highest crude protein (13.07±0.03%) was determined in the MSILAL group, and the highest water-soluble carbohydrate (WSC) value (13.40°Brix) was determined in the MLAC group. Although no statistically significant difference was observed between the groups in terms of color parameters, inoculant applications showed positive effects on color stability in ΔE* and hue (h) values ($P>0.05$). In microbiological analyses, the highest lactic acid bacteria density (36.33 log5 cfu/g) was determined in the MMIC group, and yeast-mold development was detected at the lowest level. This supports the aerobic stability-enhancing effects of inoculants. In terms of nutritional value parameters, the highest digestible dry matter (69.45%), total digestible nutrient (69.45%), metabolic energy (2.26 Mcal/kg), and net energy for milk yield (NEL: 1.41 Mcal/kg) values

were obtained in the MSILAL group. As a result, inoculant applications significantly improved silage quality, increased fermentation efficiency, decreased pH levels, suppressed yeast and mold formation, and improved aerobic stability. The MSILAL and MMIC groups showed superior performance compared to other groups, especially in terms of chemical composition, energy value, and microbiological quality.

Keywords: Millet Crop, Silage Quality, Microbial Inoculant, Fermentation, Aerobic Stability, Lactic Acid Bacteria, Color Stability, Energy Value, Feed Quality

THE EFFECTIVENESS OF MICROBIAL INOCULANTS IN IMPROVING SILAGE QUALITY: MILLET (*Panicum miliaceum L.*)

ÖZET

Silaj, hayvancılıkta temel bir yem kaynağı olup, kaliteli silaj üretimi, hayvan besleme maliyetlerinin azaltılması ve çevresel sürdürülebilirliğin artırılması açısından kritik öneme sahiptir. Bu çalışma, darıya (Panicum miliaceum L.) ilave edilen beş farklı ticari inokulantın silaj kalitesi, mikroorganizma gelişimi ve aerobik stabilite üzerine etkilerini belirlemek amacıyla yapılmıştır. Çalışma, bir kontrol grubu (Kontrol-M) ve beş farklı inokulant grubu - MSILD, MSILAP, MLAC, MSILAL, MMIC- 2 kg'lık paketler halinde vakumlanarak sekiz tekrarlamalı olarak yürütülmüştür. Hazırlanan silaj örnekleri laboratuvar koşullarında fermente edilmeye bırakılmış ve 90 gün sonra fiziksel, kimyasal, mikrobiyolojik ve aerobik stabilite analizleri yapılmıştır. Kimyasal analizler sonucunda, inokulant ilavesi silajların pH seviyelerinde önemli bir düşüş sağlamış ($P<0,01$), en düşük pH değeri (4,39±0,00) MMIC grubunda belirlenmiştir. En yüksek ham protein (%13,07±0,03) MSILAL grubunda, en yüksek suda çözünür karbonhidrat (WSC) değeri (13,40°Brix) ise MLAC grubunda belirlendi. Renk parametreleri açısından gruplar arasında istatistiksel olarak anlamlı bir fark gözlenmezken, inokulant uygulamalarının ΔE* ve renk tonu (h) değerlerinde renk stabilitesi üzerinde olumlu etkileri olduğu görüldü ($P>0,05$). Mikrobiyolojik analizlerde ise en yüksek laktik asit bakteri yoğunluğu (36,33 log5 cfu/g) MMIC grubunda belirlenirken, maya-küf gelişimi en düşük seviyede tespit edilmiştir. Bu durum inokulantların aerobik stabiliteyi artırıcı etkilerini desteklemektedir. Besin değeri parametreleri açısından en yüksek sindirilebilir kuru madde (%69,45), toplam sindirilebilir besin maddesi (%69,45), metabolik enerji (2,26 Mcal/kg) ve süt verimi için net enerji (NEL: 1,41 Mcal/kg) değerleri MSILAL grubunda elde edilmiştir. Sonuç olarak, aşılama uygulamaları silaj kalitesini önemli ölçüde iyileştirmiş, fermantasyon verimliliğini artırmış, pH seviyelerini düşürmüş, maya ve küf oluşumunu baskılamış ve aerobik stabiliteyi iyileştirmiştir. MSILAL ve MMIC grupları özellikle kimyasal bileşim, enerji değeri ve mikrobiyolojik kalite açısından diğer gruplara kıyasla üstün performans göstermiştir.

Anahtar Kelimeler: Darı Mahsulü, Silaj Kalitesi, Mikrobiyal Aşılayıcı, Fermantasyon, Aerobik Stabilite, Laktik Asit Bakterileri, Renk Stabilitesi, Enerji Değeri, Yem Kalitesi

INTRODUCTION

Silage is an effective preservation method that allows forage crops to be stored for extended periods through fermentation under anaerobic conditions and is used as a fundamental feed source in animal husbandry. High-quality silage production increases agricultural efficiency by reducing animal feeding costs and contributes to environmental sustainability (McDonald et al., 1991).

Millet (Panicum miliaceum L.) stands out as an alternative silage crop due to its drought resistance, rapid growth cycle, and high biomass production (Baltensperger, 1996). However, the low soluble carbohydrate content of millet can complicate the natural fermentation process, necessitating the use of microbial inoculants such as lactic acid bacteria (LAB) (Weinberg & Muck, 1996).

LAB produce lactic acid by utilizing easily fermentable carbohydrates in plant material, lowering the silage pH, reducing nutrient losses, and inhibiting the growth of undesirable microorganisms (e.g., molds and yeasts) (Kung et al., 2003). Homofermentative bacteria (e.g., Lactobacillus plantarum, Pediococcus acidilactici) enhance aerobic stability through rapid acid production, while heterofermentative bacteria (e.g., Lactobacillus buchneri) are effective in preventing aerobic spoilage (Filya, 2004; Muck, 2010).

Enzyme-containing inoculants (e.g., cellulase, xylanase) break down plant cell walls, providing more fermentable substrates for LAB and increasing silage digestibility (Özdüven et al., 2017). Inoculants combining LAB and enzymes have been reported to reduce NDF and ADF contents and improve organic matter digestibility (Özdüven et al., 2017). Similarly, Özdüven et al. (2009) reported that LAB inoculants improved fermentation parameters and aerobic stability in corn silage. This study aims to investigate the effects of different microbial inoculants (MSILD, MSILAP, MLAC, MSILAL, MMIC) on the physical, chemical, microbiological, and aerobic stability properties of millet silage, optimizing silage quality and nutritional value. The study seeks to contribute to the more effective use of alternative crops like millet in sustainable livestock systems.

MATERIALS AND METHODS

In this study, millet (Panicum miliaceum L.) harvested from the research field of Kırşehir Ahi Evran University's Department of Field Crops (Latitude: 39.1286°N, Longitude: 34.1078°E) was used as the primary silage material. The millet was harvested at the dough stage, chopped to approximately 2.0 cm using a silage machine, and 1000 g of plant material was placed into 2 kg plastic bags. A control group (Control-M) and five inoculant groups Millet+*Lactobacillus plantarum, Enterococcus faecium* bacteria and cellulase, pentosanase, amylase enzymes (SILAID, Global Nutritech Biotechnology LLC, USA), Millet+*L. plantarum, Pediococcus acidilactici, P. pentosaceus, Propionibacteria acidipropionici* and xylanase, β-glucanase enzymes (SILAP Timac Agro, USA), Millet+*Lactobacillus plantarum* only (LAC, Centro Sperimentale Del Latte, Italy), Millet+*L. plantarum, P. acidilactici, P. pentosaceus, P. acidipropionici* and Xylanase, β-glucanase, cellulase, amylase enzymes (SILAL, Alltech, UK), Millet+*Lactobacillus brevis, Enterococcus faecium, Bacillus subtilis, Pediococcus acidilactici*

and alpha–amylase (*A. oryzae*), cellulase, hemicellulase (*A. niger*) enzymes (MIC, Cuprem®, USA) were treated with inoculants at a concentration of 1×10^5 cfu/g, sprayed homogeneously onto the fresh material. After inoculation, the air inside the bags was vacuumed using a vacuum device (Packtech PT-VKM-CPRO). Following vacuum sealing, a total of 30 silage samples (six replicates per group) were incubated in laboratory conditions at 18.5±2°C in a dark environment for 90 days. At the end of the fermentation process, six parallel samples from each group were taken, and physical, chemical, microbiological, and statistical analyses were conducted. Dry matter (DM), crude protein (CP), and ash contents of silage samples were analyzed according to AOAC (1998) methods. Organic matter (OM) content was calculated using the formula [%OM = 100 - %ash]. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses were performed following the methods described by Van Soest et al. (1991), using amylase and sodium sulfite, with results expressed including residual ash. Additionally, NDF and ADF contents were corrected for residual ash and reported as NDFom and ADFom, respectively. Hemicellulose content was calculated as [Hemicellulose = NDF - ADF] as defined by Van Soest et al. (1991). Ether extract (EE) content was determined using the ANKOM XT15 Extraction System based on AOCS (2005) protocols. The pH values of silages were measured following Chen et al. (1994), and total soluble solids (TSM) contents were measured according to Singh et al. (2020). Total digestible nutrients (TDN), digestible crude protein (DCP), and metabolizable energy values were calculated using formulas reported by Filik (2020). Color measurements of silages were conducted using a Konica-Minolta CR-410 colorimeter after opening the silage packages, recording L*, a*, and b* values from three different regions of each sample. Chroma (C*, saturation index) and hue angle (h°) were calculated from a* and b* values following AMSA (2012) methods. Lactic acid bacteria, yeast, and mold counts in silage samples were determined using the method described by Seale et al. (1990). Carbon dioxide (CO_2) and pH values on the fifth day after opening the silage packages were measured according to the procedure reported by Ashbell et al. (1991). Relative feed value (RFV) and relative forage quality (RFQ) of silages were calculated using formulas reported by Kılıç and Abdiwali (2016) and Filik (2020). These analyses were conducted at the Animal Biotechnology Laboratory and the Enzyme and Microbial Biotechnology Laboratory of Kırşehir Ahi Evran University's Faculty of Agriculture, Department of Agricultural Biotechnology. Statistical analyses were performed using the SAS (2001) statistical package program. The General Linear Model (PROC GLM) procedure was applied based on a randomized complete block design, and linear relationships between experimental groups were evaluated using orthogonal polynomial contrast analysis. Differences between groups were determined using Duncan's Multiple Comparison Test (Genç & Soysal, 2018).

RESULTS AND DISCUSSION

The chemical analysis of millet silages revealed significant improvements in nutrient preservation with microbial inoculants (Table 1). The MSILD group recorded the highest dry matter (DM) content (928.35 g/kg), surpassing the control (926.55 g/kg; $P<0.01$), suggesting enhanced moisture retention compared to untreated silage. This aligns with Özdüven et al. (2009), who reported that Lactobacillus plantarum-based inoculants in corn silage improved DM retention by accelerating fermentation and reducing losses, a benefit extended to millet in

this study. However, the MLAC group's lower DM (924.90 g/kg) contrasts with Chen et al. (1994), who found that single-strain L. plantarum inoculants typically stabilize DM, indicating potential variability in millet's fermentation dynamics. Crude protein (CP) was highest in the MSILAL group (13.07%), significantly outperforming the MMIC group (12.25%; P<0.01). This protein preservation exceeds findings by Filya (2004), who observed modest CP increases in maize silage with homofermentative LAB, suggesting that MSILAL's enzyme-enhanced formulation (L. plantarum, Pediococcus acidilactici, cellulase) offers superior protein protection in millet. The control group's lower CP (12.50%) mirrors McDonald et al. (1991), who noted protein degradation in uninoculated silages due to slower acidification. Fiber fractions, acid detergent fiber (ADF) and neutral detergent fiber (NDF), were lowest in MSILAL (ADF: 24.98%; NDF: 44.11%), indicating improved digestibility. This corroborates Özdüven et al. (2017), who found that enzyme-containing inoculants reduced ADF and NDF in sunflower silage, enhancing nutrient availability. In contrast, the control group's higher ADF (29.22%) and NDF (51.25%) align with Weinberg and Muck (1996), who reported elevated fiber content in untreated silages due to limited cell wall degradation. The MSILAL group's low NDFom (36.22%) further distinguishes it from Özdüven et al.'s (2017) results, where NDFom reductions were less pronounced, highlighting millet's responsiveness to specific inoculants.

Table 1. Nutrient Content of Millet Silages

Parameters[5]		DM[1-4]	OM[2]	Ash[2]	CP[2]	EE[2]	CF[2]	ADF[2]	ADFom[3]	NDF[2]	NDFom[3]
Control		926.55^{C} ±0.35	91.93^{D} ±0.03	8.07^{A} ±0.03	12.50c ±0.09	5.02^{D} ±0.03	23.62^{A} ±0.06	29.22^{A} ±0.08	21.15^{A} ±0.11	51.25^{A} ±0.16	43.18^{A} ±0.13
MSILD		928.35^{A} ±0.25	92.80^{A} ±0.02	7.20^{D} ±0.02	12.40^{dc} ±0.02	5.36^{C} ±0.00	21.91^{C} ±0.01	26.77^{C} ±0.09	19.57^{B} ±0.11	47.80^{CB} ±0.28	40.60^{BC} ±0.26
MSILAP		927.55^{B} ±0.15	92.56^{B} ±0.01	7.45^{C} ±0.02	12.42^{dc} ±0.02	5.40^{cb} ±0.02	22.40^{B} ±0.05	27.45^{B} ±0.09	36.88^{B} ±0.02	49.30^{B} ±0.00	41.85^{BA} ±0.02
MLAC		924.90^{D} ±0.10	92.47^{B} ±0.01	7.53^{C} ±0.01	12.72^{b} ±0.02	5.80^{A} ±0.06	22.62^{B} ±0.04	27.27^{B} ±0.11	34.48^{B} ±0.36	47.20^{C} ±0.38	39.67^{C} ±0.37
MSILAL		925.10^{D} ±0.20	92.11^{C} ±0.04	7.89^{B} ±0.04	13.07^{a} ±0.03	5.51^{B} ±0.04	20.50^{D} ±0.02	24.98^{D} ±0.03	31.04^{D} ±0.22	44.11^{D} ±0.19	36.22^{D} ±0.23
MMIC		927.05^{CB} ±0.15	92.49^{B} ±0.09	7.52^{C} ±0.10	12.25^{d} ±0.10	5.30^{C} ±0.04	21.94^{C} ±0.17	26.49^{C} ±0.12	36.49^{C} ±0.08	48.74^{B} ±0.89	41.22^{BC} ±0.99
SED		0.0881	0.0184	0.0184	0.0241	0.0148	0.0311	0.0366	0.0510	0.1740	0.1870
P value		0.0002	<0.0001	<0.0001	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	0.0005
Effects ¥	L	0.0010	0.0005	0.0421	<0.0001	0.0003	<0.0001	0.0005	0.0014	0.0040	0.0010
	Q	<0.0001	<0.0001	0.0147	0.4792	<0.0001	<0.0001	0.0019	0.1658	0.6853	<0.0001
	C	0.4670	0.0007	0.5668	0.0070	0.0003	<0.0001	0.0027	0.0042	0.0122	0.4670

DM: Dry Matter (g/kg); OM: Organic Matter (%); Ash (%); CP: Crude Protein (%); EE:Ether Extract (%); CF: Crude Fiber (%); ADF: Acid Detergent Fiber (%); NDF: Neutral Detergent Fiber (%). ADFom = ADF - ash; NDFom = NDF - ash. Means within the same column with no common superscript differ significantly (P<0.01). SED: Standard erir of the difference between two means. L: Linear; Q: Quadratic; C: Cubic effects.

Energy parameters underscored the nutritional superiority of inoculated silages (Table 2). The MSILAL group achieved the highest digestible energy (DE: 2.76 Mcal/kg), metabolizable energy (ME: 2.26 Mcal/kg), and net energy for lactation (NEL: 1.41 Mcal/kg), outperforming the control (DE: 2.73 Mcal/kg; NEL: 1.40 Mcal/kg). These values surpass those reported by Marbun et al. (2020) for LAB-treated maize and rice straw silages (DE ≈ 2.70 Mcal/kg), suggesting that MSILAL's multi-strain and enzyme formulation optimizes energy retention in millet, a crop with inherently lower fermentable sugars (Baltensperger, 1996). The control group's lower energy content aligns with Aydın and Denek (2023), who noted nutrient losses in uninoculated corn silage due to inefficient fermentation. Non-fiber carbohydrates (NFC) were highest in MSILAL (29.43%), compared to the control's 23.17%. This exceeds Özdüven et al.'s (2017) findings in sunflower silage, where NFC increases were moderate, indicating that MSILAL's enzymatic activity (e.g., xylanase, cellulase) enhances carbohydrate availability more effectively in millet. The MMIC group's NFC (26.21%) was comparable to MLAC (26.76%), but both trailed MSILAL, suggesting that specific microbial combinations are critical for maximizing NFC, as noted by Chen et al. (1994).

Table 2. Energy Values of Millet Silages

Parameters[1, 2, 3]		NFE	NFC[1]	TC[1]	DE	ME	NE_L	NE_M	NE_G
Control		50.79^{D}	23.17^{D}	74.41	2.73^{C}	2.24^{CB}	1.40^{CB}	1.37	0.79^{C}
		±0.09	±0.13	±0.03	±0.00	±0.01	±0.01	^{C}±0.01	±0.00
MSILD		53.13^{A}	27.25B	75.05^{A}	2.72^{C}	2.23^{CB}	1.39^{C}	1.37^{CB}	0.79^{C}
		±0.01	±0.29	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00
MSILAP		52.34^{B}	25.44^{C}	74.74^{B}	2.72^{C}	2.23^{CB}	1.39^{C}	1.37^{CB}±	0.79^{C}
		±0.11	±0.05	±0.05	±0.00	±0.00	±0.00	0.00	±0.00
MLAC		51.34^{C}	26.76^{CB}	73.95^{D}	2.74^{B}	2.24^{B}	1.40^{B}	1.38^{B}	0.80^{B}
		±0.13	±0.47	±0.09	±0.00	±0.00	±0.00	±0.00	±0.00
MSILAL		53.04^{A}	29.43^{A}	73.54^{E}	2.76^{A}	2.26^{A}	1.41^{A}	1.40^{A}	0.81^{A}
		±0.05	±0.15	±0.03	±0.00	±0.00	±0.00	±0.01	±0.00
MMIC		53.01^{A}	26.21^{CB}	74.95^{BA}	2.72^{C}	2.23^{C}	1.39^{C}	1.37^{C}	0.79^{C}
		±0.00	±0.74	±0.16	±0.01	±0.00	±0.00	±0.01	±0.01
	SED	0.0322	0.1569	0.0335	0.0011	0.0011	0.0008	0.0014	0.0014
	P value	<.0001	0.0004	<.0001	0.0002	0.0013	0.0023	0.0059	0.0011
Effects [¥]	**L**	0.0548	0.0020	0.0037	0.0131	0.2894	0.1515	0.0293	0.0167
	Q	<.0001	0.0115	0.0001	0.0049	0.0408	0.0104	0.5060	0.0498
	C	0.0002	0.0019	0.2481	0.2894	0.7119	0.6036	0.3794	0.3153

NFE: Nitrogen-Free Extract (g/kg); NFC: Non-Fiber Carbohydrates (g/kg); TC: Total Carbohydrates (g/kg); DE: Digestible Energy; ME: Metabolizable Energy; NEL: Net Energy-Lactation; NEM: Net Energy-Maintenance; NEG: Net Energy-Gain. Means within the same column without common superscript are significantly different (P<0.01). SED: Standard error of the difference between two means. L: Linear; Q: Quadratic; C: Cubic effects.

Feed quality metrics highlighted the advantages of inoculated silages (Table 3). The MSILAL group recorded the highest relative feed value (RFV: 146.46) and relative forage quality (RFQ: 138.41), driven by superior digestible dry matter (DDM: 69.45%) and dry matter intake (DMI: 2.72%). These values outperform Okuyucu and Özdüven's (2018) results for alfalfa silage (RFV ≈ 130), underscoring MSILAL's efficacy in enhancing millet silage quality. The control group's lower RFV (120.06) and RFQ (117.57) are consistent with Kılıç and Abdiwali (2016), who reported reduced feed quality in untreated forages due to high fiber and poor digestibility. The MMIC group's RFV (130.36) and RFQ (123.39) were notable but lower than MSILAL's, aligning with Muck's (2010) observation that diverse inoculants (e.g., Bacillus subtilis in MMIC) improve fermentation stability but may not match multi-strain LAB formulations in nutritional enhancement. The MLAC group's strong performance (RFV: 133.38; RFQ: 128.29) contrasts with Chen et al. (1994), who found single-strain L. plantarum inoculants less effective, suggesting that millet's unique composition benefits from tailored inoculant strategies.

Table 3. Forage Quality of Millet Silages

Parameters[1, 2, 3]		DDM	DMI	TDN	RFV	RFQ
Control		66.14^{D} ±0.07	2.34^{D} ±0.01	66.14^{D} ±0.07	120.06^{D} ±0.27	117.57^{D} ±0.27
MSILD		68.06^{B} ±0.07	2.52^{B} ±0.01	68.06^{B} ±0.07	132.44^{B} ±0.62	126.08^{cb} ±0.62
MSILAP		67.52^{C} ±0.07	2.43^{C} ±0.00	67.52^{C} ±0.07	127.41^{C} ±01.4	122.22^{C} ±01.4
MLAC		67.66^{C} ±0.08	2.54^{B} ±0.02	67.66^{C} ±0.08	133.38^{B} ±1.25	128.29^{B} ±1.25
MSILAL		69.45^{A} ±0.01	2.72^{A} ±0.01	69.45^{A} ±0.01	146.46^{A} ±0.67	138.41^{A} ±0.67
MMIC		68.27^{B} ±0.09	2.47^{CB} ±0.04	68.27^{B} ±0.09	130.36^{CB} ±2.57	123.39^{C} ±2.57
SED		0.0286	0.0088	0.0263	0.5020	0.4902
P value		<.0001	0.0002	0.0004	<.0001	0.0002
Effects [¥]	**L**	<.0001	0.0019	0.0217	0.0007	0.0019
	Q	<.0001	0.1865	0.0734	0.0402	0.3489
	C	<.0001	0.0034	0.2970	0.0021	0.0060

DDM: Digestible Dry Matter (%); DMI: Dry Matter Intake (Live Weight: LW, %); TDN: Total Digestible Nutrients (%); RFV: Relative Feed Value; RFQ: Relative Forage Quality. Means within the same column without common superscript are significantly different (P<0.01). SED: Standard error of the difference between two means. L: Linear; Q: Quadratic; C: Cubic effects.

Physical quality parameters varied significantly across treatments (Table 4). The MMIC group exhibited the lowest pH (4.39), indicating robust acidification, which surpasses the pH reduction reported by Kung et al. (2003) in LAB-treated maize silage (pH ≈ 4.5). The MSILAL group's higher pH (4.67) remained within quality thresholds, consistent with Weinberg and Muck (1996), who noted that effective silages can maintain stability at slightly higher pH levels. The MLAC group's high water-soluble carbohydrate (WSC) content (13.40 °Brix) exceeds findings by Özdüven et al. (2009) for corn silage, highlighting millet's potential for sugar preservation with specific inoculants. Color parameters showed the control group with the highest lightness (L*: 62.98) and total color difference (ΔE*: 67.09), suggesting minimal pigment alteration, as per AMSA (2012). In contrast, the MLAC group's lower L* (39.64) and ΔE* (41.58) indicate some color degradation, differing from Kung et al. (2003), who reported stable color in LAB-treated silages. The lack of significant hue angle (h) differences (P>0.05) aligns with AMSA (2012), suggesting that inoculants maintain visual consistency despite microbial activity.

Table 4. Quality and Color of Millet Silage

Parameters[1]	°C±SEM	pH_1	WSC (°Brix)	*L**	*a**	*b**	*ΔE**	*h*	*C**
Control	19.70^{bac} ±0.15	4.43^{CD} ±0.00	12.55^{ba} ±0.25	62.98^{A} ±2.92	4.25^{A} ±0.19	22.73^{A} ±0.95	67.09^{A} ±3.05	79.41 ±0.15	23.12^{A} ±0.97
MSILD	19.28^{bc} ±0.34	4.46^{CB} ±0.04	12.85^{a} ±0.26	56.80^{BA} ±3.63	3.95^{BA} ±0.82	21.15^{A} ±1.24	60.75^{BA} ±3.86	79.60 ±1.87	21.55^{BA} ±1.32
MSILAP	19.17^{c} ±0.13	4.64^{A} ±0.00	12.58^{ba} ±0.19	42.67^{DC} ±2.39	2.59^{BC} ±0.32	15.89^{BC} ±1.02	45.61^{DC} ±2.60	80.81 ±0.69	16.10^{DC} ±1.06
MLAC	19.93^{a} ±0.15	4.51^{B} ±0.03	13.40^{a} ±0.57	39.64^{D} ±2.56	1.62^{C} ±0.24	12.43^{C} ±1.12	41.58^{D} ±2.78	82.60 ±0.70	12.54^{D} ±1.13
MSILAL	19.90^{a} ±0.19	4.67^{A} ±0.00	11.23^{b} ±0.08	51.51^{BC} ±0.79	2.72^{BC} ±0.38	19.07^{BA} ±0.35	55.00^{BC} ±0.86	81.88 ±1.12	19.27^{BC} ±0.35
MMIC	19.85^{ba} ±0.12	4.39^{D} ±0.00	11.45^{b} ±0.76	46.08^{DC} ±4.14	2.80^{BC} ±0.23	17.15^{B} ±1.91	49.25^{DC} ±4.55	80.59 ±0.58	17.38^{C} ±1.92
SED	0.0786	0.0079	0.1732	1.1988	0.1730	0.4866	1.2912	0.4109	0.4969
P Value	0.0411	<.0001	0.0142	0.0002	0.0042	0.0001	0.0002	0.2276	0.0001
Effects ¥ **L**	0.5130	0.0003	0.2462	<.0001	0.0001	<.0001	<.0001	0.0280	<.0001
Q	0.0069	0.0007	0.5439	0.5989	0.4413	0.4418	0.7192	0.4378	0.4256
C	0.5499	<.0001	0.3891	0.1643	0.4596	0.3172	0.1764	0.9219	0.3041

°C: Celsius degree; WSC: Water Soluble Carbohydrate value (Brix degree 0–25°); L: Lightness; a*: Redness; b*: Yellowness; ΔE*: Total Color Difference; h: Hue Angle; C*: Chroma or Saturation. Means within the same column without common superscript are significantly different (P<0.01). SED: Standard error of the difference between two means. L: Linear; Q: Quadratic; C: Cubic effects.*

Microbiological analysis at silage opening revealed significant LAB dominance in the MMIC group (36.33 $\log10^5$ cfu/g), far exceeding the control (9.00 $\log10^5$ cfu/g; P<0.01), with no yeast

or mold detected (Table 5). This out performs Özdüven et al.'s (2009) results for corn silage (LAB ≈ 20 log10^5 cfu/g), indicating that MMIC's diverse inoculant (Lactobacillus brevis, Bacillus subtilis) is particularly effective in millet. The absence of aerobic LAB in MSILD, MSILAP, MLAC, and MSILAL groups contrasts with Weinberg and Muck (1996), who noted persistent LAB in inoculated silages, suggesting a shift to anaerobic fermentation in these treatments. The control group's lower LAB count aligns with Baltensperger (1996), who highlighted millet's low sugar content as a fermentation constraint. Kung et al. (2003) emphasized that inoculants overcome such limitations by enhancing LAB proliferation, a benefit clearly demonstrated by MMIC's high LAB density and low pH (4.39; Table 4). Post-aerobic stability testing showed the MMIC group with the lowest pH (4.26) and CO_2 production (1.83), indicating superior stability compared to the control (pH: 4.39; CO_2: 5.60; P<0.01; Table 5). These results surpass Özdüven et al.'s (2009) findings for corn silage, where LAB inoculants reduced CO_2 but maintained higher pH (≈4.4). The MSILAP group's higher pH (4.51) aligns with Ashbell et al. (1991), who noted that less effective inoculants permit slight pH increases upon air exposure. The control group's elevated CO_2 suggests aerobic spoilage, consistent with Weinberg and Muck (1996), while MMIC and MSILAL's low CO_2 (2.26) reflects robust aerobic stability, as seen in Kung et al. (2003). Dry matter (DM) retention was highest in MLAC (41.31%), exceeding Chen et al.'s (1994) results for corn silage, while MSILAL's lower DM (37.19%) contrasts with its high nutritional quality (Table 3), suggesting trade-offs in aerobic exposure. The absence of yeast, anaerobic LAB, and mold across all groups highlights the ensiling process's efficacy, particularly with MMIC, as supported by Muck (2010).

Table 5. Effects of Microbial Inoculants on Millet Silages

Parameters[5]	DM after Aerobic Stability	pH	CO_2	Yeast After Aerobic Stability (Log 10^5 Cfu/g)	Lactic Acid Bacteria Before Aerobic Stability (Log10^5 cfu/g)	Lactic Acid Bacteria (Anaerobic) (Log10^5 cfu/g)	Molt After Aerobic Stability
Control	38.17^D ±0.01	4.39^{DC} ±0.03	5.60^a ±1.07	-	9.00^B ±2.52	-	-
MSILD	39.02^C ±0.01	4.43^{BC} ±0.02	2.58^b ±0.32	-	-	-	-
MSILAP	38.83^B ±0.00	4.51^A ±0.03	2.96^b ±0.19	-	-	-	-
MLAC	41.31^A ±0.01	4.48^{BA} ±0.02	2.89b ±0.38	-	-	-	-
MSILAL	37.19^F ±0.01	4.34^D ±0.02	2.26^b ±0.00	-	-	-	-
MMIC	37.25^E ±0.00	4.26^E ±0.01	1.83^b ±0.06	-	36.33^A ±4.67	-	-

CO_2: Amount of Carbon Dioxide; pH: After Aerobic Stability pH. Means within the same column without common superscript are significantly different (P<0.01). SED: Standard error of the difference between two means. L: Linear; Q: Quadratic; C: Cubic effects.

CONCLUSION

This study demonstrated that the use of microbial inoculants in millet silage significantly improved silage quality, nutritional value, and aerobic stability. In particular, the MSILAL and MMIC inoculants stood out with high crude protein content (13.07%), low pH (4.26), high energy content (DE: 2.76 Mcal/kg), and superior feed quality parameters (RFV: 146.46, RFQ: 138.41). The MSILAL group provided an advantage in digestibility due to low fiber content (ADF, NDF), while the MMIC group enhanced microbiological stability through effective fermentation. These inoculants reduced nutrient losses, resulting in more nutritious, durable, and energy-rich feed, offering the potential to lower feed costs and improve animal performance. The findings suggest that widespread use of microbial inoculants in silage production of alternative forage crops like millet can provide economic and environmental benefits for sustainable livestock systems. The study proved that high-quality silage production is possible with inoculants despite millet's low sugar content, encouraging the use of alternative feed sources in regional agricultural systems. Future research should focus on optimizing inoculant combinations, different plant species, and regional climate conditions. Additionally, more comprehensive studies on the long-term effects and economic feasibility of inoculants could support the widespread adoption of this technology at a commercial scale. Such studies will contribute to developing innovative and environmentally friendly solutions in global feed production.

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THE EFFECT OF MICROBIAL INOCULANTS ON THE SILAGE QUALITY AND STABILITY OF UNSHREDDED ITALIAN RYEGRASS (*Lolium multiflorum*)

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ABSTRACT

This study was conducted to assess the effects of different commercial microbial inoculants applied to unshredded silages obtained from Italian ryegrass (Lolium multiflorum) on silage quality, fermentation characteristics, aerobic stability, and microbial population dynamics. The Italian ryegrass was harvested from the research and application fields of the Department of Field Crops, Faculty of Agriculture, Kırşehir Ahi Evran University. Four different inoculants from Alltech were used in this study, and the experimental design was organized in a completely randomized block design with five treatment groups (Control-KHAY, HSILD, HLAC, HSILAL, HMIC) and eight replications. The prepared silage samples were fermented in a laboratory environment at a temperature of 18.5±2 °C for 90 days. Chemical analyses revealed that inoculant applications significantly reduced the pH levels of the silages ($p<0.01$), with the lowest pH değeri (5.08±0.01) observed in the HSILAL group. The HLAC group exhibited the highest crude protein content (19.15±0.06%) and water-soluble carbohydrate content (20.25 oBrix). Although no significant statistical differences were observed among the groups regarding color parameters, inoculant applications positively influenced color stability, as indicated by changes in ΔE* and hue (h) değeris. Microbiological analyses showed that the HSILD group had the highest lactic acid bacteria count (96.33 log10 cfu/g), while the HMIC group exhibited the lowest yeast and mold growth. These findings support the hypothesis that inoculants enhance aerobic stability. Additionally, CO_2 production and total bacterial load değeris decreased in the inoculated groups compared to the control group. In terms of nutritional değeri, the HLAC group showed the highest digestible dry matter (68.03%), total digestible nutrients (68.88%), metabolizable energy (2.49 Mcal/kg), and net energy for lactation (NEL: 1.57 Mcal/kg). Furthermore, the HLAC group stood out with the highest relative feed değeri (NYD: 167.55) and relative forage quality (NYK: 177.91).

In conclusion, the application of microbial inoculants significantly improved silage quality by enhancing fermentation efficiency, lowering pH levels, suppressing yeast and mold development, and improving aerobic stability. The HLAC and HSILAL groups demonstrated superior performance in terms of chemical composition, energy değeri, and microbiological quality compared to the other groups.

Keywords: Unshredded Italian ryegrass, silage quality, microbial inoculant, fermentation, lactic acid bacteria.

MİKROBİYAL İNOKÜLANTLARIN DOĞRANMAMIŞ İTALYAN ÇİMİ (*Lolium multiflorum*) SİLAJ KALİTESİ VE STABİLİTESİ ÜZERİNDEKİ ETKİSİ

ÖZET

Bu çalışma, İtalyan çimi (Lolium multiflorum) hasılından elde edilen doğranmamış silajlara uygulanan farklı ticari mikrobiyal inokülantların, silaj kalitesi, fermantasyon özellikleri, aerobik stabilite ve mikrobiyal populasyon dinamikleri üzerindeki etkilerini incelemek amacıyla gerçekleştirilmiştir. İtalyan çimi, Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü'nün araştırma ve uygulama arazisinde yetiştirilmiştir. Araştırma kapsamında, Alltech firmasına ait dört farklı inokülant kullanılmış ve deneysel tasarım, beş muamele grubu (Kontrol-KHAY, HSILD, HLAC, HSILAL, HMIC) ve sekiz tekerrür ile tamamen rastgele parseller düzeninde planlanmıştır. Hazırlanan silaj örnekleri, 90 gün süreyle laboratuvar ortamında 18.5±2 °C sıcaklık koşullarında fermentasyona bırakılmıştır. Kimyasal analizler, inokülant uygulamalarının silajların pH seviyelerinde anlamlı düşüşler sağladığını ($p<0.01$) ve özellikle HSILAL grubunda en düşük pH değerinin (5.08±0.01) tespit edildiğini göstermiştir. HLAC grubunda ise en yüksek ham protein içeriği (%19.15±0.06) ve suda çözünür karbonhidrat içeriği (20.25 oBrix) belirlenmiştir. Renk parametreleri açısından gruplar arasında istatistiksel bir farklılık gözlenmemekle birlikte, ΔE* ve hue (h) değerlerinde inokülant uygulamaları renk stabilitesi üzerinde olumlu etkiler göstermiştir. Mikrobiyolojik analizlerde, HSILD grubunda en yüksek laktik asit bakteri yoğunluğu (96.33 log10 cfu/g) belirlenirken, HMIC grubunda maya ve küf gelişimi en düşük düzeyde gözlemlenmiştir. Bu bulgular, inokülantların aerobik stabiliteyi artırıcı etkilerini desteklemektedir. Ayrıca, CO_2 üretim miktarları ve toplam bakteri yükü değerleri, inokülant uygulamaları ile birlikte kontrol grubuna kıyasla azalma göstermiştir. Besin değeri parametreleri açısından, HLAC grubunda en yüksek sindirilebilir kuru madde (%68.03), toplam sindirilebilir besin maddesi (%68.88), metabolik enerji (2.49 Mcal/kg) ve süt verimi için net enerji (NEL: 1.57 Mcal/kg) değerleri elde edilmiştir. HLAC grubu, aynı zamanda en yüksek yem değeri (NYD: 167.55) ve göreli kaba yem kalitesi (NYK: 177.91) ile öne çıkmıştır.

Sonuç olarak, inokülant uygulamaları silaj kalitesini önemli ölçüde iyileştirmiş, fermantasyon etkinliğini artırarak pH seviyesini düşürmüş, maya ve küf oluşumunu baskılamış ve aerobik stabiliteyi geliştirmiştir. HLAC ve HSILAL grupları, özellikle kimyasal kompozisyon, enerji değeri ve mikrobiyolojik kalite açısından diğer gruplara kıyasla üstün performans sergilemiştir.
Anahtar Kelimeler: Doğranmamış İtalyan çimi, silaj kalitesi, mikrobiyal inokülant, fermantasyon, laktik asit bakterisi.

1. GİRİŞ

İyi kaliteli silaj üretimi, özellikle ruminant hayvanların beslenmesinde önemli bir rol oynamaktadır. Silaj, hayvanların yıl boyunca beslenmesinde temel bir yem kaynağı olarak kullanılmakta olup, özellikle hasat edilen yeşil bitkilerin fermente edilerek saklanmasıyla elde edilmektedir. Silajın kalitesi, fermantasyon süreci ve mikrobiyal aktiviteler tarafından belirlenirken, bu süreçlerde kullanılan mikrobiyal inokülantlar, silajın besin değerini, aerobik stabilitesini ve genel kalitesini etkilemektedir (Özdemir ve Okumuş, 2022).

Kaliteli kaba yem olarak bilinen ve üretimi giderek yaygınlaşan İtalyan çimi (*Lolium multiflorum* Lam.) silaj üretiminde sıklıkla tercih edilmektedir (Fu ve ark., 2022).

İtalyan çimi, yüksek sindirilebilirlik ve zengin besin içeriği ile dikkat çeken tek yıllık bir yem bitkisidir. Bu bitki türü, yüksek kuru madde oranı sayesinde süt verimi ve canlı ağırlık artışı üzerinde olumlu etkiler sağlamaktadır. Ayrıca, uygun ekolojik koşullar altında son derece hızlı bir büyüme göstererek, yaklaşık 20 günlük aralıklarla biçim yapılmasına olanak tanımaktadır (Gürsoy ve ark., 2022).

Bununla birlikte, İtalyan çimi silajlarının kalitesini artırmak ve fermantasyon sürecini iyileştirmek amacıyla farklı mikrobiyal inokülantların kullanımı, son yıllarda önemli bir araştırma konusu olmuştur. Mikrobiyal inokülantlar, özellikle laktik asit bakterileri (LAB), fermantasyon sürecini hızlandırarak, pH seviyesini düşürüp istenmeyen mikroorganizmaların gelişimini engellemeye yardımcı olmaktadır (Başkavak ve ark., 2008).

Ancak, farklı mikrobiyal inokülantların silaj kalitesi ve fermantasyon dinamikleri üzerindeki etkileri, kullanılan bitki materyaline, çevresel koşullara ve inokülantın türüne bağlı olarak değişkenlik gösterebilmektedir (Türedi ve Çetingül, 2023).

Bu çalışma, İtalyan çimi hasılından elde edilen doğranmamış silajlara uygulanan farklı ticari mikrobiyal inokülantların, silaj kalitesi, fermantasyon özellikleri, aerobik stabilite ve mikrobiyal populasyon dinamikleri üzerindeki etkilerini incelemeyi amaçlamaktadır. Ayrıca, silaj üretiminde kullanılan mikrobiyal inokülantların besin değeri parametreleri ve genel silaj kalitesine katkılarını belirlemeyi hedeflemektedir. Çalışmanın sonucunda elde edilecek bulgular, ruminant hayvan beslemesinde kullanılacak kaliteli silajların üretimine yönelik önemli bilgiler sağlayacaktır.

2. MATERYAL VE METOD

Araştırmada silaj materyali olarak *Lolium multiflorum Lam.* (İtalyan çimi) bitkisi kullanılmıştır. Bitkisel materyal, Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü deneme alanında yetiştirilmiş ve hamur olum döneminde hasat edilmiştir. Hasat edilen bitkiler doğranmadan, 1000 g'lık örnekler hâlinde 2 kg kapasiteli vakumlanabilir polietilen torbalara sıkıştırılarak yerleştirilmiştir. Çalışmada kontrol ve beş farklı inokülant uygulamasından oluşmaktadır, her muamele sekiz tekerrürle yürütülmüştür. Uygulanan muamele grupları; inokülant uygulanmamış kontrol grubu (KHAY), *Lactobacillus plantarum* ve *Enterococcus faecium* ile birlikte selülaz, pentozanaz ve amilaz enzimleri içeren HSILD (Global Nutritech Biotechnology LLC, ABD), *L. plantarum, Pediococcus acidilactici, P. pentosaceus,*

Propionibacterium acidipropionici ile ksilanaz ve β-glukanaz enzimleri içeren HSILAP (Timac Agro, ABD), yalnızca *L. plantarum* içeren HLAC (Centro Sperimentale Del Latte, İtalya), *L. plantarum, P. acidilactici, P. pentosaceus, P. acidipropionici* ile ksilanaz, β-glukanaz, selülaz ve amilaz enzimleri içeren HSILAL (Alltech, Birleşik Krallık) ve *Lactobacillus brevis, Enterococcus faecium, Bacillus subtilis, Pediococcus acidilactici* ile α-amilaz (*Aspergillus oryzae*), selülaz ve hemiselülaz (*A. niger*) enzimleri içeren HMIC (Cuprem®, ABD) olarak belirlenmiştir. İnokülantlar, her bir muamele grubuna ait taze materyalin üzerine 1×10^5 kob/g (cfu/g) düzeyinde eşit ve homojen bir şekilde püskürtülerek uygulanmıştır. İnokülasyon işleminin ardından torbalardaki hava, vakum cihazı (Packtech PT-VKM-CPRO) kullanılarak uzaklaştırılmıştır. İşlem sonrasında materyaller, laboratuvar koşullarında (18.5 ± 2 °C) 90 gün süreyle fermentasyona bırakılmıştır.

Fermentasyon süresi sonunda silaj örnekleri açılarak fiziksel, kimyasal, mikrobiyolojik ve istatistiksel analizlere tabi tutulmuştur. Örneklerin sıcaklık, renk ve pH değerleri belirlenmiştir. Silaj örneklerinin renk özellikleri; açıldıktan sonra L*, a* ve b* renk parametreleri Konica-Minolta CR-410 renk ölçer cihazı ile üç farklı noktadan ölçülmüş, Chroma (C*) ve renk açısı (h°) değerleri AMSA (2012) yönergelerine göre hesaplanmıştır. pH ölçümleri Chen ve ark. (1994) tarafından tanımlanan yönteme uygun olarak yapılmış, toplam sindirilebilir madde (TSM) içerikleri ise Singh ve ark. (2020) yöntemine göre saptanmıştır. Kimyasal analizlerde kuru madde (KM), ham protein (HP), ham kül (HK), ham yağ (EE), ham selüloz (HS), asit deterjan fiber (ADF), nötr deterjan fiber (NDF) ve suda çözünür karbonhidrat (SÇK) içerikleri tayin edilmiştir. KM, HP ve HK analizleri AOAC (1998) prosedürlerine uygun olarak gerçekleştirilmiştir. Ham yağ içeriği, AOCS (2005) protokolü doğrultusunda ANKOM XT15 Ekstraksiyon Sistemi kullanılarak analiz edilmiştir. Ham selüloz, ADF ve NDF analizleri ise Van Soest ve ark. (1991) yöntemi esas alınarak ANKOM 200 Fiber Analyzer cihazı ile belirlenmiştir. Hemiselüloz içeriği, NDF ve ADF farkına dayalı olarak hesaplanmıştır. Mikrobiyolojik analizlerde laktik asit bakterisi, maya ve küf sayımları Seale ve ark. (1990) tarafından bildirilen yöntem esas alınarak belirlenmiştir. Silajlar açıldıktan sonraki beşinci günde CO_2 ve pH ölçümleri Ashbell ve ark. (1991) metodolojisine uygun gerçekleştirilmiştir. Silajların metabolize edilebilir enerji ve protein içerikleri, hemiselüloz, azot içermeyen ekstrakt (NFE) ve azot içermeyen karbonhidrat (NFC) değerlerine dayalı olarak Filik (2020) tarafından önerilen yöntemler kullanılarak hesaplanmıştır. Ayrıca, silajların bağıl yem değeri (RFV) ve bağıl yem kalitesi (RFQ) ise Kılıç ve Abdiwali (2016) ile Filik (2020) çalışmalarında belirtilen hesaplama yöntemlerine göre belirlenmiştir. Elde edilen veriler, SAS (2001) paket programı kullanılarak analiz edilmiştir ve ortalamanın Standart hatası'nı (SEM) için kullanılmıştır. Deneme grupları arasındaki doğrusal ilişkiler General Linear Model (PROC GLM) prosedürü ile belirlenmiş; grup ortalamaları arasındaki farklar ise Duncan Çoklu Karşılaştırma Testi kullanılarak değerlendirilmiştir (Genç ve Soysal, 2018). Silaj işlemlerinden kaynaklanan doğrusal, ikinci dereceden ve kübik etkileri test etmek için tek serbestlik dereceli polinom kontrastları kullanılmıştır (Steel & Torrie, 1980).

Tüm analizler, Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Tarımsal Biyoteknoloji Bölümü bünyesindeki Hayvansal Biyoteknoloji Laboratuvarı ile Enzim ve Mikrobiyal Biyoteknoloji Laboratuvarı'nda yürütülmüştür.

3. BULGULAR VE TARTIŞMA

Çalışmada değerlendirilen silaj örneklerinin kimyasal bileşimi yönünden karşılaştırmalı analizleri Tablo 1'de verilmiştir. Kuru madde (KM), organik madde (OM), ham kül (HK), ham protein (HP), ham yağ (HY), ham selüloz (HS), asit deterjan fiber (ADF, ADFom) ve nötr deterjan fiber (NDF, NDFom) içerikleri bakımından denemeye alınan gruplar arasında istatistiksel olarak anlamlı farklılıklar saptanmıştır ($P<0.05$).

Özellikle KM ve OM parametrelerinde kontrol grubu (KHAY), sırasıyla %91.08 ve %90.48 değerleriyle en yüksek ortalamalara sahip olurken, HLAC grubu %90.03 KM ve %88.69 OM değerleriyle en düşük ortalamaları göstermiştir. Bu farklılıkların istatistiksel olarak çok yüksek düzeyde anlamlı olduğu belirlenmiştir ($P<0.001$). Aynı şekilde, bu parametrelerde lineer (L), kuadratik (Q) ve kübik (C) etkiler de son derece anlamlı bulunmuştur (her üç etki için de $P<0.001$). Bu bulgular, inokülant uygulamasının KM ve OM içerikleri üzerinde istatistiksel olarak hem doğrusal hem de eğrisel etkiler yarattığını göstermektedir.

Ham protein (HP) içeriği bakımından HLAC grubu %19.15 ile en yüksek değeri sunarken, HSILD grubu %16.60 ile en düşük değeri göstermiştir. Gruplar arasındaki farklılıklar HP parametresinde de yüksek düzeyde anlamlı bulunmuş ($P<0.001$), lineer ($P<0.001$), kuadratik ($P<0.001$) ve kübik ($P<0.001$) etkilerin tamamı önemli çıkmıştır. Bu, inokülant seviyesindeki artışın protein içeriği üzerindeki etkisinin hem artan dozla birlikte belirginleştiğini hem de optimum noktanın eğrisel davranış gösterdiğini düşündürmektedir. Benzer şekilde HY parametresinde HLAC (%8.18) ve KHAY (%8.24) grupları birbirine yakın yüksek değerler gösterirken, HSILD grubu %8.07 ile en düşük değeri sunmuştur. HY değişkeni için $P<0.05$ düzeyinde anlamlılık tespit edilmiş; kuadratik etki ($P=0.0624$) sınırda önemli, kübik etki ($P=0.0134$) ise anlamlıdır. Bu durum, HY içeriğinde doğrusal olmayan bir varyasyonun varlığına işaret etmektedir.

Ham selüloz (HS), ADF ve NDF içerikleri yönünden ise KHAY grubu sırasıyla %22.84, %28.76 ve %40.22 değerleri ile en yüksek lif oranlarına sahip olmuş, HLAC grubu ise %26.80 ADF, %37.77 NDF ve %15.48 ADFom ile en düşük lif içeriğini göstermiştir. Bu farklılıkların tamamı istatistiksel olarak anlamlıdır ($P<0.001$). Özellikle ADF içeriği için lineer ($P=0.0046$), kuadratik ($P=0.0003$) ve kübik ($P=0.4894$) etkilerden anlamlı çıkmış, bu da ADF içeriğinde doğrusal ve eğrisel azalışın olduğunu ancak üçüncü dereceden varyasyonun belirgin olmadığını göstermektedir. Benzer şekilde NDF içeriği için lineer ($P=0.0002$), kuadratik ($P=0.0001$) ve kübik ($P=0.0007$) etkilerin tamamı istatistiksel olarak anlamlıdır ve bu parametrede inokülant uygulamasının güçlü bir yapısal etkiye sahip olduğu görülmektedir.

ADFom ve NDFom içerikleri için de gruplar arası farklılıkların yüksek düzeyde anlamlı olduğu (ADFom için $P=0.0002$; NDFom için $P=0.0011$) ve tüm etki bileşenlerinin (L, Q, C) istatistiksel olarak anlamlı düzeylerde olduğu belirlenmiştir. Özellikle HLAC silajının ADFom (%15.48) ve NDFom (%26.46) içerikleri ile diğer gruplardan anlamlı biçimde ayrışması, bu grubun yem sindirilebilirliği açısından avantajlı olduğunu göstermektedir.

Elde edilen bu sonuçlar, literatürde bildirilen İtalyan çimi silajlarına ait değerlerle karşılaştırıldığında olumlu yönde bir farklılık göstermektedir. Sarıkaya ve ark. (2024), Sivas ekolojik koşullarında üretilen İtalyan çimi silajlarında KM içeriklerini %21.27-29.90, HP

içeriklerini %9.76-12.34, ADF'yi %31.09-36.74 ve NDF'yi %52.56-61.75 aralığında bildirmiştir. Gürsoy ve ark. (2022) ise benzer parametreleri sırasıyla %24.90-27.10 (KM), %10.70-13.80 (HP), %30.80-36.60 (ADF) ve %53.30-58.60 (NDF) olarak raporlamıştır. Liu ve ark. (2021), inokülant uygulanan İtalyan çimi silajlarında KM: %21.10-31.90, HP: %8.50-13.90, ADF: %27.40-34.70 ve NDF: %47.50-55.80 oranları bildirmiştir. Son olarak, Li ve ark. (2024), farklı solma süreleriyle hazırlanan İtalyan çimi silajlarında HP içeriğini %11.20-14.60, ADF'yi %28.90-33.10 ve NDF'yi %50.20-57.00 arasında belirtmiştir. Bu çalışmada tespit edilen KM (%90.30-91.18), HP (%16.60-19.15) ve düşük ADF (%26.80-28.76) ile NDF (%37.77-40.22) içerikleri, literatürle karşılaştırıldığında dikkat çekici şekilde yüksek kalite göstergeleri sunmaktadır. Bu sonuçlar, inokülant uygulamasının fermantasyon kalitesini iyileştirdiği ve lif içeriğini azaltarak sindirilebilirliği artırdığı yönündeki önceki çalışmalarla örtüşmektedir (Liu et al., 2021; Li et al., 2024).

İstatistiksel analizler, inokülant uygulamasının İtalyan çimi silajlarının kimyasal bileşimini anlamlı şekilde etkilediğini ortaya koymuştur. Özellikle HP artışı ve ADF/NDF azalışı, yem kalitesinin iyileştirilmesi açısından önemli kazanımlar sunmaktadır. Bu bulgular doğrultusunda, inokülant kullanımı ile hazırlanan İtalyan çimi silajları, hem ruminant beslemede verimliliği artırmak hem de daha dengeli rasyonlar oluşturmak açısından stratejik öneme sahiptir.

Tablo 1. Doğranmamış İtalyan çimi silajlarının besin madde içeriği

Parametre[5]		KM[1-4]	OM[2]	HK[2]	HP[2]	HY[2]	HS[2]	ADF[2]	ADFom[3]	NDF[2]	NDFom[3]
KHAY		91.08^{A}±0.25	90.48^{B}±0.01	9.52^{D}±0.01	16.97^{C}±0.04	8.24^{a}±0.00	22.84^{A}±0.07	28.76^{A}±0.23	19.24^{A}±0.22	40.22^{a}±0.03	30.70^{A}±0.02
HSILD		91.18^{A}±0.20	90.86^{A}±0.02	9.15^{E}±0.03	16.60^{D}±0.03	8.07^{c}±0.03	21.99^{C}±0.05	26.97^{C}±0.04	17.83^{B}±0.02	38.15^{b}±0.50	29.00^{B}±048
HLAC		90.03^{C}±0.40	88.69^{E}±0.05	11.32^{A}±0.05	19.15^{A}±0.06	8.18^{ab}±0.04	20.71^{D}±0.08	26.80^{C}±0.08	15.48^{C}±0.14	37.77^{b}±0.19	26.46^{C}±0.25
HSILAL		90.91^{B}±0.20	89.93^{D}±0.04	10.07^{B}±0.04	17.55^{B}±0.01	8.13^{bc}±0.01	22.03^{C}±0.07	27.74^{B}±0.22	17.67^{B}±0.26	38.28^{b}±0.07	28.21^{B}±0.03
HMIC		91.04^{AB}±0.70	90.35^{C}±0.00	9.66^{C}±0.00	17.01^{C}±0.02	8.23^{a}±0.03	22.49^{B}±0.00	27.03^{C}±0.01	17.37^{B}±0.00	38.58^{b}±0.53	28.92^{B}±0.52
SED		0.1780	0.015	0.015	0.016	0.035	0.028	0.066	0.074	0.151	0.149
P değeri		<.0001	<.0001	<.0001	<.0001	0.0229	<.0001	0.0011	0.0002	0.0216	0.0025
Etki ¥	L	0.0002	<.0001	<.0001	<.0001	0.1203	<.0001	0.0046	0.0002	0.0093	0.0011
	Q	0.0002	<.0001	<.0001	<.0001	0.0624	<.0001	0.0003	0.0001	0.0124	0.0036
	C	<.0001	<.0001	<.0001	<.0001	0.0134	0.0001	0.4894	0.0007	0.6110	0.0187

[1] g/kg doğal materyal.[2] Kuru madde (%).[3] ADFom = ADF külü çıkarılmış; NDFom = NDF külü çıkarılmış.[4] KM: Havadaki Kuru Madde (g/kg); OM: Organik Madde (%); Ham Kül (%); HP: Ham Protein (%); HY: Ham Yağ (%); HS: Ham Selüloz (%); ADF: Asit Deterjan Fiber (%); NDF: Nötr Deterjan Fiber (%).[5] Veriler, her uygulamanın sekiz tekrarı için ortalamaları ifade etmektedir. Aynı sütun içinde ortak üst simgeye (harfe) sahip olmayan ortalamalar arasındaki farklar istatistiksel olarak anlamlıdır (P < 0.01). ¥ L: Lineer etki; Q: Kuadratik etki; C: Kübik etki. SED: İki ortalama arasındaki farkın standart hatası.

Tablo 2'de, doğranmamış İtalyan çimi silajlarının enerji içeriklerine ilişkin veriler sunulmaktadır. Enerji parametreleri arasında yer alan Sindirilebilir Enerji (DE), Metabolize Edilebilir Enerji (ME), Net Enerji Laktasyon (NEL), Net Enerji Bakım (NEM) ve Net Enerji Kilo Artışı (NEG) değerleri incelendiğinde, HLAC grubunun tüm parametrelerde istatistiksel olarak anlamlı şekilde (P<0.001) en yüksek değerleri gösterdiği belirlenmiştir. HLAC grubu sırasıyla 3.04 Mcal/kg DE, 2.49 Mcal/kg ME, 1.57 Mcal/kg NEL, 1.60 Mcal/kg NEM ve 1.00

Mcal/kg NEG değerleriyle öne çıkmıştır. Bu sonuçlar, HLAC silajının yüksek enerji gereksinimi olan hayvanlar için besinsel açıdan önemli bir alternatif olabileceğini göstermektedir.

Diğer gruplar ile karşılaştırıldığında, KHAY, HSILD ve HMIC gruplarının DE değerleri arasında fark gözlenmemiş (2.92–2.93 Mcal/kg aralığında), ancak bu gruplar HLAC'a kıyasla anlamlı derecede daha düşük enerji değerleri sergilemiştir ($P<0.001$). Bu durum, HLAC silajının enerji yoğunluğunun diğer gruplara göre istatistiksel olarak üstün olduğunu ortaya koymaktadır.

HSILAL grubu ise, HLAC'tan sonra en yüksek enerji içeriklerine sahip silaj olarak dikkat çekmiştir (DE: 2.96 Mcal/kg; ME: 2.43 Mcal/kg; NEL: 1.52 Mcal/kg; NEM: 1.54 Mcal/kg; NEG: 0.95 Mcal/kg). Bu grubun enerji parametrelerinde elde edilen değerler, KHAY, HMIC ve HSILD gruplarına göre istatistiksel olarak daha yüksek bulunmuştur ($P < 0.001$). HSILAL grubunun HLAC'a göre daha düşük olmasına karşın, diğer gruplardan anlamlı şekilde ayrışması, inokülant uygulamasının enerji içerikleri üzerinde olumlu bir etki yarattığını düşündürmektedir.

Ayrıca, varyans analizinde etki tipleri açısından bakıldığında hem lineer (L), hem kuadratik (Q) hem de kübik (C) etkilerin enerji parametreleri üzerinde çoğunlukla anlamlı olduğu görülmektedir ($P<0.001$). Özellikle DE, ME, NEL, NEM ve NEG için her üç etki de anlamlı bulunmuştur; bu da farklı inokülant düzeylerinin silaj enerji içeriği üzerindeki karmaşık etkilerine işaret etmektedir.

Bu bulgular literatürdeki mevcut çalışmalarla da uyumludur. Örneğin, Xia ve ark. (2023), Lactobacillus rhamnosus gibi homofermentatif LAB türleriyle yapılan inokülant uygulamalarının yüksek nemli İtalyan çimi silajlarında fermantasyon kalitesini iyileştirdiğini ve biyofonksiyonel metabolitlerin artışına katkı sağladığını belirtmişlerdir. Benzer şekilde, Liu ve ark. (2021), inokülant kullanımının kuru madde içeriğini ve sindirilebilirliği artırarak enerji parametreleri üzerinde olumlu etkiler oluşturduğunu rapor etmiştir. Bu bulgular, çalışmamızda elde edilen sonuçlarla uyumludur ve inokülant uygulamalarının silajların enerji içeriği üzerinde olumlu etkiler oluşturabileceğini desteklemektedir.

Tablo 2. Doğranmamış İtalyan çimi Silajlarının Enerji Değerleri

Parametre[1, 2, 3]		NFE	NFC[1]	TK[1]	DE	ME	NE_L	NE_M	NE_G
KHAY		42.44^{BC}±0.05	25.06^{C}±0.00	65.28^{B}±0.02	2.93^{C}±0.00	2.40^{C}±0.00	1.51^{C}±0.00	1.52^{C}±0.00	0.93^{C}±0.00
HSILD		44.21^{A}±0.09	28.05^{A}±0.47	66.19^{A}±0.03	2.92^{D}±0.00	2.39^{D}±0.00	1.50^{D}±0.00	1.51^{D}±0.00	0.92^{D}±0.00
HLAC		40.66^{D}±0.11	23.60^{D}±0.15	61.37^{E}±0.04	3.04^{A}±0.01	2.49^{A}±0.00	1.57^{A}±0.00	1.60^{A}±0.00	1.00^{A}±0.01
HSILAL		42.23^{C}±0.02	25.99^{BC}±0.12	64.26^{D}±0.05	2.96^{B}±0.00	2.43^{C}±0.00	1.52^{B}±0.00	1.54^{B}±0.00	0.95^{B}±0.00
HMIC		42.61^{B}±0.05	26.53^{B}±0.58	65.10^{C}±0.05	2.93^{C}±0.00	2.41^{C}±0.01	1.51^{C}±0.00	1.52^{C}±0.00	0.93^{C}±0.00
SED		0.04	0.16	0.01	0.01	0.01	0.00	0.00	0.01
P Değeri		<.0001	0.0020	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Etki ¥	L	<.0001	0.3327	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	Q	0.2201	0.4258	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005
	C	<.0001	0.0003	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

[1]Kuru madde oranı (%). [2]Veriler, her bir muameleye ait sekiz tekrarın ortalamasını temsil etmektedir. [3]NFE: Azotsuz öz maddeler (g/kg); NFC: Lifsiz karbonhidratlar (g/kg); TK: Toplam karbonhidratlar (g/kg); DE: Sindirilebilir enerji (Mcal/kg); ME: Metabolize olabilir enerji (Mcal/kg); NEL: Net enerji – laktasyon (Mcal/kg); NEM: Net enerji – bakım (Mcal/kg); NEG: Net enerji – canlı ağırlık artışı (Mcal/kg). a,b,c Aynı sütunda ortak üst simgeye sahip olmayan ortalamalar arasındaki farklar istatistiksel olarak anlamlıdır (P<0.01). ¥ L: Lineer; Q: Kuadratik; C: Kübik etkiler. SED: İki ortalama arasındaki farkın standart hatası.

Tablo 3, silajların sindirilebilirlik, tüketim potansiyeli ve kaba yem kalitesi parametrelerine ilişkin istatistiksel verileri içermektedir. HLAC grubu, Sindirilebilir Kuru Madde (SKM: %68.03±0.07), Toplam Sindirilebilir Besin Maddeleri (TMS: %68.88±0.06), Net Kaba Yem Değeri (NYD: 167.55±0.99) ve Net Kaba Yem Kalitesi (NYK: 177.91±0.72) açısından istatistiksel olarak anlamlı şekilde en yüksek değerlere ulaşmıştır (P<0.05). Bu parametreler HLAC grubunun yüksek düzeyde sindirilebilirliğe ve üstün kaba yem kalitesine sahip olduğunu kanıtlamaktadır.

HSILD ve HSILAL grupları da yüksek KKM ve NYK değerleriyle dikkat çekmektedir (KKM: sırasıyla %67.89 ve %67.29; NYK: 169.20 ve 171.08). Bu farklar istatistiksel olarak anlamlı olup (P<0.05), inokülant uygulamasının kaba yem kalitesine katkı sağladığını desteklemektedir. HMIC grubu da NYK bakımından %168.32 gibi kabul edilebilir bir değere sahiptir. Bu değer, Gürsoy ve ark. (2022) tarafından bildirilen 164.00–271.78 aralığıyla tutarlılık göstermektedir.

KHAY grubu ise istatistiksel olarak anlamlı şekilde en düşük TMS (%66.46±0.05) ve NYK (161.22±0.25) değerlerine sahiptir (P<0.01). Bu durum, KHAY silajının inokülant uygulaması yapılmış diğer gruplara göre daha düşük yem kalitesi sunduğunu ortaya koymaktadır.

Etki kaynakları analiz edildiğinde, TMS, NYD ve NYK değerlerinde doğrusal (L) ve kuadratik (Q) etkilerin P<0.001 düzeyinde anlamlı olduğu; buna karşın kübik (C) etkinin genellikle istatistiksel olarak anlamsız olduğu görülmüştür. Bu durum, inokülant uygulamalarının etkilerinin genellikle doğrusal ve kuadratik modellerle açıklanabileceğini göstermektedir.

HLAC grubunun en yüksek enerji ve yem kalitesi parametrelerine ulaşması ve bu farkların istatistiksel olarak yüksek düzeyde anlamlı bulunması, inokülant uygulamalarının İtalyan çimi

silajlarının besin değeri üzerindeki etkisini açıkça ortaya koymaktadır. İlgili literatürle (Xia ve ark., 2023; Liu ve ark., 2021; Gürsoy ve ark., 2022) tutarlı olan bu bulgular, inokülant kullanımının ruminant beslemede daha verimli ve kaliteli kaba yem üretimi için etkili bir strateji olabileceğini göstermektedir.

Tablo 3. Doğranmamış İtalyan Çimi Silajlarının Kaba Yem Kalitesi

Parametre[1, 2, 3]		SKM	KMT	TMS	NYD	NYK
KHAY		66.50^{C}±0.18	2.99^{b}±0.01	66.46^{C}±0.05	153.80^{B}±0.54	161.22^{C}±0.25
HSILD		67.89^{A}±0.03	3.15^{a}±0.04	66.14^{D}±0.02	165.60^{A}±2.27	169.20^{B}±2.31
HLAC		68.03^{A}±0.07	3.18^{a}±0.01	68.88^{A}±0.06	167.55^{A}±0.99	177.91^{A}±0.72
HSILAL		67.29^{B}±0.17	3.14^{a}±0.01	67.12^{B}±0.01	163.55^{A}±0.12	171.08^{B}±0.31
HMIC		67.85^{A}±0.00	3.11^{a}±0.04	66.53^{C}±0.02	163.66^{A}±2.24	168.32^{B}±2.23
	SED	0.05	0.01	0.02	0.67	0.66
	P Değeri	0.0010	0.0283	<.0001	0.0090	0.0050
Etki ¥	**L**	0.0043	0.0121	<.0001	0.0058	0.0022
	Q	0.0002	0.0159	<.0001	0.0034	0.0041
	C	0.4778	0.6512	<.0001	0.5877	0.0575

[1] Kuru madde (%). [2] Veriler, her bir muameleye ait sekiz tekrarlı uygulamanın ortalamasını temsil etmektedir. [3] SKM: Sindirilebilir kuru madde (%); KMT: Kuru madde tüketimi (canlı ağırlık: CA, %); TMS: Toplam sindirilebilir besin maddeleri (%); NYD: Göreli yem değeri ve NYK: Göreli kaba yem kalitesi. [a,b,c] Aynı sütunda farklı üst simgeler taşımayan ortalamalar arasındaki farklar istatistiksel olarak anlamlıdır (P<0.01). ¥ L: Doğrusal; Q: Kuadratik; C: Kübik etkiler. SED: İki ortalama arasındaki farkın standart hatası.

Silajlarda farklı inokülant uygulamalarının fermantasyon kalitesi ve renk özellikleri üzerine etkileri incelenmiş ve elde edilen bulgular Tablo 4'te sunulmuştur. Kontrol grubu (KHAY), 5.86 ± 0,10 ile en yüksek pH değerine sahip olup, bu durum fermentasyonun yeterince etkili gerçekleşmediğini göstermektedir. Buna karşın, yüksek doz inokülant uygulanan HSILAL grubu, 5.08 ± 0,07 ile en düşük pH değerini göstermiştir. Bu fark istatistiksel olarak oldukça anlamlı bulunmuş (P<0.001) ve inokülant uygulamasının fermantasyon sürecini iyileştirme potansiyelini açıkça ortaya koymuştur. Ayrıca, pH değerindeki değişimlerin hem lineer (P<0.001) hem de kuadratik (P=0.0093) etkilerle anlamlı düzeyde ilişki gösterdiği belirlenmiştir.

Suda çözünür karbonhidrat (WSC) içeriği bakımından en yüksek değer 21.00 ± 0.84 °Brix ile HSILAL grubunda tespit edilmiştir. Bu grubu HLAC (20.25 ± 0.42 °Brix) ve HSILD (16.16 ± 0.71 °Brix) takip etmiş, en düşük WSC içeriği ise HMIC grubunda 15.88 ± 0.54 °Brix olarak ölçülmüştür. WSC değerleri arasındaki farklılıklar da istatistiksel olarak anlamlı bulunmuş (P<0.001), lineer (P=0.0206) ve kuadratik etkiler (P=0.0393) açısından da anlamlılık gözlemlenmiştir. Bu sonuçlar, inokülantların şeker kaybını azaltarak fermantasyon kalitesini artırabileceğini göstermektedir. Bulgular, Xia ve ark. (2023) ile Liu ve ark. (2021) tarafından yapılan çalışmalardaki sonuçlarla örtüşmektedir. Söz konusu çalışmalarda, *Lactobacillus*

rhamnosus gibi inokülantların silajın pH'ını düşürerek fermantasyon kalitesini iyileştirdiği ve şeker kaybını sınırladığı belirtilmiştir.

Renk parametreleri açısından değerlendirildiğinde, KHAY grubu 28.38 ± 0.79 ile en yüksek L* değerine sahip olmuş, bu da silajın en açık renge sahip olduğunu göstermektedir. Aynı zamanda bu grup, 29.96 ± 0.64 ile en yüksek renk farkı (ΔE*) değerini de göstermiştir. L* parametresi açısından gruplar arası farklar istatistiksel olarak anlamlı bulunmuş (P<0.001), lineer etkiler de anlamlı çıkmıştır (P=0.0365). HLAC ve HSILAL grupları, daha yüksek a* (sırasıyla 1.85±0.05 ve 2.03±0.25) ve b* (sırasıyla 8.74±0.21ve 9.72±0.74) değerleri ile daha doygun kırmızı ve sarı tonlar sergilemiştir. Bu durum, bu gruplarda renk pigmentlerinin ve bitkisel bileşiklerin daha iyi korunduğunu düşündürmektedir. Ancak, a* ve b* parametreleri bakımından gruplar arası fark istatistiksel olarak anlamlı bulunmamıştır (P=0.0992 ve P=0.4187). ΔE* parametresi için de fark anlamlı olmamakla birlikte (P=0.5855), inokülant uygulamalarının renk farklılıklarını azalttığı ve görsel kaliteyi artırdığı söylenebilir.

Renk tonu (h) değeri en yüksek 81.81 ± 0.76 ile HSILD grubunda, en düşük ise 78.02 ± 0.30 ile HLAC grubunda ölçülmüştür. KHAY grubu da 80.14 ± 0.55 ile benzer şekilde yüksek bir h açısı göstermiştir. Renk yoğunluğu (C*) bakımından en yüksek değer 9.94 ± 0.76 ile HSILAL grubunda saptanmış, ancak gruplar arası farklılıklar h (P=0.0366) ve C* (P=0.4073) değerleri açısından istatistiksel olarak anlamlı bulunmamıştır. Bu bulgular, inokülant uygulamalarının renk parametreleri üzerinde sınırlı, ancak pozitif etkiler oluşturduğunu göstermektedir. İnce ve Vurarak (2019) tarafından yapılan çalışmada da renk parametreleri ile kaba yem kalitesi arasında anlamlı korelasyonlar tespit edilmiş, özellikle L*, a* ve b* değerlerinin pH ve protein içeriği gibi kalite parametreleriyle ilişkili olduğu rapor edilmiştir.

İnokülant uygulamaları İtalyan çimi silajlarında fermantasyon kalitesini belirgin şekilde artırmakta ve renk parametrelerini olumlu yönde etkilemektedir. pH düşüşü ve WSC'nin korunması, mikrobiyal aktivitenin etkinliğini ve silajın besin değerini artırmaktadır. Renk parametrelerindeki iyileşmeler ise yemlerin görsel kalitesini yükselterek hayvan tüketimini artırabilecek potansiyele sahiptir. Bu veriler, inokülant kullanımının yem kalitesi açısından önemli bir yönetim stratejisi olabileceğini göstermektedir.

Tablo 4. Doğranmamış İtalyan çimi silajının kalite ve renk özellikleri

Parametre[1]		°C±SEM	pH	WSC (°Brix)	*L**	*a**	*b**	*ΔE**	*h*	*C**
KHAY		19.13^{B}±0.06	5.86^{A}±0.10	16.33^{B}±0.17	28.38±0.79	1.64±0.08	9.46±0.29	29.96±0.84	80.14^{ab}±0.55	9.60±0.29
HSILD		19.43^{A}±0.11	5.43^{B}±0.01	16.15^{B}±0.71	26.81±0.30	1.28±0.13	8.85±0.22	28.26±0.34	81.81^{a}±0.76	8.94±0.23
HLAC		19.13^{B}±0.05	5.37^{B}±0.01	20.25^{A}±0.32	27.19±0.21	1.85±0.05	8.74±0.21	28.62±0.21	78.02^{b}±0.30	8.94±0.21
HSILAL		17.28^{C}±0.14	5.08^{C}±0.01	21.00^{A}±1.11	27.86±2.02	2.03±0.25	9.72±0.74	29.61±2.04	78.26^{b}±0.93	9.94±0.76
HMIC		17.53^{C}±0.08	5.39^{B}±0.01	15.68^{B}±0.54	28.77±0.40	1.86±0.30	9.33±0.33	1.37±0.02	78.89^{b}±1.34	9.52±0.38
SED		0.0415	0.0205	0.2946	0.4469	0.0841	0.1821	0.4589	0.3807	0.1898
P Değeri		<.0001	<.0001	<.0001	0.6295	0.0992	0.4187	0.5855	0.0366	0.4073
Etki ¥	L	<.0001	<.0001	<.0001	0.7983	0.0562	0.7131	0.8829	0.0258	0.6042
	Q	<.0001	0.1293	0.4934	0.2795	0.1715	0.695	0.2108	0.4150	0.0694
	C	0.0371	0.0093	0.0206	0.7192	0.1305	0.7454	0.7624	0.0248	0.8521

[1] °C: Santigrat derece; WSC: Suda çözünür karbonhidrat değeri (Brix derecesi 0–25°); L: Açıklık (parlaklık); a*: Kırmızılık; b*: Sarılılık; ΔE*: Toplam renk farkı; h: Renk tonu açısı; C*: Doygunluk (kroma). a,b,c Aynı sütunda farklı üst simgeler taşımayan ortalamalar arasındaki farklar istatistiksel olarak anlamlıdır (P<0.01). ¥ L: Doğrusal; Q: Kuadratik; C: Kübik etkiler. SED: İki ortalama arasındaki farkın standart hatası.*

Tablo 5 verilerine göre, farklı inokülant uygulamalarının İtalyan çimi silajlarının aerobik stabilitesi üzerindeki etkileri mikrobiyolojik ve kimyasal parametreler bakımından ayrıntılı olarak değerlendirilmiştir. HLAC uygulaması, aerobik stabilite sonrası %35.95 ± 0.01 ile en yüksek kuru madde (KM) içeriğine ulaşmıştır. Bu oran, KHAY (%34.03 ± 0.01), HSILD (%32.35 ± 0.01), HMIC (%32.67 ± 0.01) ve özellikle HSILAL (%29.77 ± 0.01) gruplarına kıyasla anlamlı derecede yüksektir (P<0.001). Söz konusu sonuçlar, yüksek kuru madde içeriğinin silajın aerobik stabilitesini artırıcı etkisini vurgulayan Srisesharam ve ark. (2018) tarafından bildirilen bulgularla örtüşmektedir.

pH değerleri açısından en yüksek ortalama, KHAY grubunda 5.57 ± 0.03 olarak tespit edilmiştir. Buna karşın, en düşük pH değeri 5.15 ± 0.08 ile HSILAL grubunda gözlemlenmiş ve bu fark istatistiksel olarak oldukça anlamlı bulunmuştur (P<0.001). pH değerleri bakımından elde edilen bu sonuçlar, inokülant uygulamalarının homofermentatif laktik asit bakterileri (LAB), özellikle Lactobacillus rhamnosus gibi türler aracılığıyla ortamın asitleşmesini hızlandırarak silajın aerobik stabilitesini iyileştirebileceğini ortaya koymaktadır (Xia ve ark., 2023).

Aerobik stabilite sonrasında CO_2 üretim miktarları gruplar arasında değişiklik göstermiştir. En yüksek CO_2 üretimi KHAY grubunda 3.65 ± 0.25 g/kg olarak kaydedilmiş, en düşük üretim ise 2.46 ± 0.32 g/kg ile HMIC grubunda gerçekleşmiştir. Ancak bu farklılık istatistiksel olarak anlamlı bulunmamıştır (P=0.2849). Bununla birlikte, varyans analizinde lineer etki (L) istatistiksel olarak anlamlı olmasa da (P=0.2976), kuadratik etki (Q) açısından CO_2 üretiminde eğilimsel bir fark gözlemlenmiştir (P=0.1458). Bu bulgular, inokülant uygulamalarının mikrobiyal bozulmayı sınırlandırarak CO_2 üretimini azaltabileceğini öne süren Uğurlu ve ark. (2022) tarafından bildirilen sonuçlarla paralellik göstermektedir.

Aerobik stabilite sonrası maya sayısı değerlendirmeye uygun düzeyde tespit edilememiştir. Küf varlığına hiçbir grupta rastlanmamış olması, inokülant uygulamalarının ve uygun fermentasyon koşullarının mantar gelişimini önleyici etkilerini göstermektedir. Bu durum, Li ve Nishino (2013)'nun silaj ortamında uygun asidifikasyonun maya ve küf gelişimini sınırlandırabileceğini belirttiği çalışmalarıyla tutarlıdır.

Laktik asit bakterisi (LAB) popülasyonu açısından, aerobik koşullar altında HSILD grubu 96.33 ± 8.19 log CFU/g ile en yüksek LAB yoğunluğuna ulaşmıştır ve bu fark istatistiksel olarak oldukça anlamlıdır (P<0.001). HLAC (%31.67 ± 2.91), HSILAL (%17.33 ± 1.76), HMIC (%63.67 ± 5.04) ve KHAY (%13.67 ± 3.84) grupları arasında da anlamlı farklılıklar gözlemlenmiştir. Anaerobik koşullarda LAB sayısı HLAC ve KHAY gruplarında 3.00 ± 0.00 log CFU/g iken, HMIC grubunda 1.00 ± 0.00 log CFU/g olarak belirlenmiştir (P=0.2055; istatistiksel olarak anlamsız). LAB düzeyindeki farklılıklar özellikle lineer (P=0.0336) ve kuadratik (P<0.0001) etkiler açısından anlamlı bulunmuştur. Bu durum, inokülantların silaj içerisindeki LAB popülasyonunu artırarak fermantasyon kalitesini geliştirme potansiyelini göstermektedir (Srisesharam ve ark., 2018).

Genel olarak değerlendirildiğinde, inokülant uygulamalarının hem kimyasal hem de mikrobiyolojik parametrelerde önemli farklılıklara neden olduğu görülmektedir. Yüksek kuru madde oranı, düşük pH, yüksek LAB popülasyonu ve düşük maya varlığı, aerobik stabiliteyi artıran temel unsurlar olarak öne çıkmaktadır. Bu bulgular, silaj kalitesinin artırılmasında inokülantların etkin kullanımının önemli bir yönetim aracı olabileceğini göstermektedir.

Tablo 5. İnokülantların doğranmamış İtalyan çimi silajları üzerindeki etkileri

Parametre[5]		KM Aerobik stabilite sonrası	pH Aerobik stabilite sonrası	CO_2	Maya Aerobik stabilite sonrası (Log 10^5 Cfu/g)	LAB (Aerobik) (Log10^5 Cfu/g)	LAB (Anaerobik) (Log10^5 Cfu/g)	Küf Aerobik stabilite sonrası
KHAY		34.03^{B}±0.01	5.57^{A}±0.03	3.65±0.25	-	13.67^{D}±3.84	3.00±0.00	-
HSILD		32.35^{D}±0.01	5.25^{BC}±0.00	2.96±0.06	-	96.33^{A}±8.19	4.67±0.88	-
HLAC		35.95^{A}±0.01	5.36^{B}±0.02	2.58±0.32	-	31.67^{C}±2.91	3.00±0.00	-
HSILAL		29.77^{E}±0.01	5.15^{C}±0.08	3.14±0.63	-	$17.33C^{D}$±1.76	2.50±0.50	-
HMIC		32.67^{C}±0.01	5.23^{C}±0.01	2.46±0.32	-	63.67^{B}±5.04	1.00±0.00	-
	SED	0.01	0.02	0.16	-	2.18	0.37	-
	P Değeri	<.0001	<.0001	0.2849	-	<.0001	0.2055	-
Etki ¥	**L**	<.0001	<.0001	0.2976	-	0.0336	0.4094	-
	Q	<.0001	0.1946	0.1458	-	<.0001	0.2041	-
	C	<.0001	0.0080	0.7130	-	<.0001	0.2151	-

KM: Aerobik stabilite sonrası kuru madde oranı (%), pH: Aerobik stabilite sonrası pH değeri, CO_2 miktarı (g/kg), Maya ve Laktik Asit Bakterisi (LAB) sayıları (log10^5 CFU/g) aerobik ve anaerobik koşullarda belirlenmiştir. Küf hiçbir grupta tespit edilmemiştir. Aynı sütunda farklı üst simgelerle belirtilen ortalamalar arasında p<0.01 düzeyinde anlamlı fark vardır. ¥ L: Lineer etki; Q: Kuadratik etki; C: Kübik etki. SED: İki ortalama arasındaki standart hata.

4. SONUÇ

Bu çalışmada elde edilen bulgular, inokülant uygulamalarının silaj kalitesini artırıcı etkilerini açıkça ortaya koymuştur. Kimyasal bileşim açısından, HLAC grubu silajı, yüksek ham protein (%19.15) ve kül (%11.32) içerikleriyle dikkat çekmiş ve en düşük ADFom (%15,48) değeriyle sindirilebilirlik potansiyelini göstermiştir. Ayrıca, HLAC silajı en yüksek enerji değerlerine (ME: 2.49 Mcal/kg) ulaşarak, yüksek enerji ihtiyacı olan ruminantlar için uygun bir yem alternatifi olabileceğini göstermiştir. Yem kalitesi parametreleri açısından HLAC silajı, KKM (%68.03), TMS (%68.88), NYD (167.55) ve NYK (177.91) değerleriyle üstün performans sergilemiştir. İnokülant uygulamaları (HSILD ve HSILAL) da benzer şekilde yem tüketimi (KMT) ve yem kalitesi (NYK) üzerinde olumlu etkiler sağlamıştır. Fermantasyon kalitesi ve görsel renk parametreleri yönünden HSILAL grubu, düşük pH (5.08) ve yüksek suda çözünür karbonhidrat (WSC) içeriği 21.00 °Brix ile güçlü fermentasyon ve iyi şeker korunumu sağlamıştır. Ayrıca HLAC ve HSILAL gruplarında daha zengin a* ve b* renk değerleri, daha iyi yem tazeliği ve görsel kaliteyi göstermiştir. Aerobik stabilite sonrası değerlendirmelerinde, HLAC uygulaması en yüksek kuru madde oranı (%35.95) ve HSILAL grubu ise en düşük pH (5.15) değerleriyle stabiliteyi desteklemiştir. HSILD grubu, aerobik koşullarda en yüksek LAB popülasyonuna (96.33 log CFU/g) ulaşarak fermentasyon kapasitesini koruduğunu göstermiştir. CO_2 üretimi ve küf/maya varlığı bulguları, inokülant uygulamalarının mikrobiyal bozulmayı sınırladığını ve aerobik stabiliteyi artırdığını kanıtlamaktadır.

Sonuç olarak, laktik asit bakteri bazlı inokülant uygulamalarının, İtalyan çimi silajlarının hem besin değerini hem de fermantasyon ve aerobik stabilite kalitesini anlamlı düzeyde iyileştirdiği belirlenmiştir. Özellikle HLAC ve HSILAL grupları, hem besleyici değer hem de koruma stabilitesi açısından öne çıkmıştır. Bu nedenle, yüksek kaliteli İtalyan çimi silaj üretiminde bakteriyel inokülant kullanımı, ruminant beslenmesinde verimlilik artışı sağlamak amacıyla önerilmektedir. İlerleyen çalışmalarda, bu silajların hayvan performansı ve süt/et verimi üzerine etkilerinin uzun dönemli değerlendirilmesi faydalı olacaktır.

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AGRICULTURAL WATER MANAGEMENT PLANNING: THE CASE OF BILECIK PROVINCE

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ABSTRACT

Water, the source of life and living things, is a resource that cannot be replaced. Water is an indispensable element of life and the basic input of agriculture. Global warming and climate change have a significant impact on rainfall regimes. This effect causes serious consequences such as drought and flood. In this study, the effects of flood-drought-water pollution on the main agricultural products produced in Bilecik Districts were examined. In the study, Arap stream and Delikbağ stream in Gölpazarı; Gümüşdere in Pazaryeri; Çöte stream basins in Yenipazar were used. The characteristics of the watershed (such as area, length, slope, curve number) and climate data (such as precipitation, temperature and evapotranspiration) were prepared and used in the WinTR-55 and DrinC model. As a result, the R^2 value between the RDI drought index result and hop yield reached the highest value among the compared districts with a value of 0.50 in Pazaryeri. The R^2 value between the RDI drought index result and wheat yield reached the highest value among the compared districts with a value of 0.80 in Söğüt. Besides, a significant decrease was observed in drought index values in Bilecik in 2017. The years when drought was most apparent in Bozüyük were 2006 and 2007. In Pazaryeri, 2007 was seen as the year when the effect of drought was felt most intensely. When the peak flow values of the 100-year return period were compared with the WinTR-55 model, Gölpazarı-Arap Stream was the area with the highest risk with 66.59 m^3/s. This was followed by Gölpazarı-Gümüşdere with 47.06 m^3/s, Gölpazarı-Delikbağ Stream with 47.00 m^3/s and Yenipazar-Çöte with 26.27 m^3/s, respectively.

Keywords: Climate change, Drought, Flood, WinTR-55

TARIMSAL SU YÖNETİMİ PLANLAMASI: BİLECİK İLİ ÖRNEĞİ

ÖZET

Yaşamın ve canlıların kaynağı olan su, yerine konulamayan bir kaynaktır. Su, yaşamın vazgeçilmez bir unsuru ve tarımın temel girdisidir. Küresel ısınma ve iklim değişikliği yağış rejimleri üzerinde önemli etkilere sahiptir. Bu etki kuraklık ve sel gibi ciddi sonuçlara neden olmaktadır. Bu çalışmada, Bilecik İlçelerinde üretilen başlıca tarım ürünlerine sel-kuraklık-su kirliliğinin etkileri incelenmiştir. Çalışmada Gölpazarı'nda Arap deresi ve Delikbağ deresi; Pazaryeri'nde Gümüşdere; Yenipazar'da Çöte Dere havzaları kullanılmıştır. Havza özellikleri (alan, uzunluk, eğim, eğri numarası gibi) ve iklim verileri (yağış, sıcaklık ve evapotranspirasyon gibi) hazırlanarak WinTR-55 ve DrinC modelinde kullanılmıştır. Sonuç olarak, RDI kuraklık indeksi sonucu ile şerbetçiotu verimi arasındaki R^2 değeri, karşılaştırılan ilçeler arasında en yüksek değere 0,50 değeri ile Pazaryeri'nde ulaşmıştır. RDI kuraklık indeksi sonucu ile buğday verimi arasındaki R2 değeri ise karşılaştırılan ilçeler arasında en yüksek değere 0,80 değeri ile Söğüt'te ulaşmıştır. Ayrıca, Bilecik'te 2017 yılında kuraklık indeksi değerlerinde önemli bir düşüş gözlenmiştir. Bozüyük'te kuraklığın en belirgin olduğu yıllar 2006 ve 2007 olmuştur. Pazaryeri'nde kuraklığın etkisinin en yoğun hissedildiği yıl 2007 yılı olarak görülmüştür. 100 yıllık tekerrür periyoduna ait pik debi değerleri WinTR-55 modeli ile karşılaştırıldığında, Gölpazarı-Arap Deresi 66,59 m^3/s ile en yüksek riske sahip alan olmuştur. Bunu sırasıyla 47,06 m^3/s ile Gölpazarı-Gümüşdere, 47,00 m^3/s ile Gölpazarı-Delikbağ Deresi ve 26,27 m^3/s ile Yenipazar-Çöte izlemiştir.

Anahtar Kelimeler: İklim değişikliği, kuraklık, sel, WinTR-55

1. INTRODUCTION

Water is the source of life and living things. Therefore, water resources need to be protected and need to used sustainably. Protection of water resources refers to the measures taken to prevent pollution and depletion of water resources. Sustainable usage of water resources refers to ensure their protection for future generations [1]. Water is an indispensable element of life and it is the basic input of agriculture. Irrigation enhances agricultural production. On the other hand, it can be harmful for environment and endamages the natural balance if it applies excessively. The agricultural sector is in danger in terms of two major problems. They are the increasing population and climate change. As water resources are consumed unconsciously, the agricultural sector will have more difficulty accessing water and world food security will be in danger [2]. Reasons such as population growth, urbanization, industrialization and increased agricultural activities enhance the need for water. This situation leads to excessive consumption and pollution of water resources [3]. In the globalizing system of the 21st century, the population of humanity has increased rapidly and has exceeded 8 billion [4]. According to United Nations (UN) reports, the world population will reach 10 billion in 2050. Therefore, cities might be uninhabitable and the water might be undrinkable [5].

At the 1972 Stockholm Conference, the United Nations emphasized that environmental protection requires "protection of water, soil, air and natural ecosystems for future generations through planning or management." The aims of the UN Conference on Environment and Development organized in Rio de Janeiro (Brazil) in June 1992 were strengthening relationships between different water-related programs and developing approaches to ensure coordination across sectors [6].

Turkey's total water potential is estimated as 501 billion m^3/year. 166 billion m^3/year of this amount passes directly into the flow. 67% of the remaining water is lost through percolation, evaporation and transpiration. The total flow rate of our rivers is on average 186.1 billion m^3/year with the contribution of water leaking underground. The amount of water stored in dams and ponds is approximately 91.1 billion m^3/year. A total of 111 billion m^3/year of water (consisting of rivers, lakes and groundwater) is accepted as usable water potential [7]. When we look at the sectoral distribution of water usage, it is seen that on average 74% is for agricultural irrigation, 13% is for industry, and 13% is for domestic usage [8].

The atmosphere consists of different gases. Gases such as CO_2, CH_4, N_2O, O_3, CFC (chlorofluorocarbon) in the atmosphere insulate some of the heat coming from the sun to the earth and they allow the earth to remain at a certain temperature [9]. The increase in earth temperature is called global warming. The warming affects the whole world and living things and it causes important environmental changes [10]. The temperature on the earth's surface can be determined with the help of factors such as the amount of sunlight received and reflected by the earth, the retention of heat by the atmosphere, the evaporation and condensation of water vapor [11].

As a result of global warming, direct and indirect problems in water resources will cause a decrease in agricultural and forest products, energy shortage and population movement from coastal areas to inland areas [12].

Climate is the average of weather conditions observed in any place on earth over many years. The limits of this average are determined by the highest and lowest values. Climate change is the alteration in the average state or change of the climate over decades or longer [13]. Climate change lead to dense droughts and floods [14].

Reduction of poverty and protection of ecosystems are necessary to ensure food security. Much more food can be produced per unit of water in an agricultural system. For sustainable water management, a major policy shift is required in irrigated and rain-fed agriculture. Remarkable developments occurred in water resources and agriculture in the last 50 years. Major developments in hydraulic infrastructure have made available water for people. As the world population has increased from 2.5 billion in 1950 to 6.5 billion for today, irrigated area has doubled and water usage has tripled. Water management plans should be made for each city. Water quantity and quality of the cities are at risk. They might be negatively affected by water-related disasters such as drought and flood [15].

Global warming and climate change have a significant impact on rainfall regimes. This effect causes serious results such as drought and flood. It is predicted that the problem might increase further in arid areas. On the other hand, much more rain might fall in rainy cities [16]. Long-term trends in drought occurrence, heat stress, and floods highlight geographic variation in the impact of climate change on agriculture [17]. The most important cause of global warming is the greenhouse gas effect. Greenhouse gases accumulated in the atmosphere prevent the sun's rays, which have turned into infrared radiation from leaving the atmosphere. This causes global warming. As a result, global warming leads to climate change. This changes the physical and human geography of our planet [18].

Studies on the impact of climate change on water resources were summarized below. Alkan (2021) investigated the effect of climate change on drought and wheat yield in the Porsuk Stream basin and he determined that the basin was in an arid region. It was determined that hydrological and agricultural droughts were common and a meteorologically normal climate prevailed for the past period. The researcher states that the Porsuk Stream watershed will become arid meteorologically, but a normal climate will prevail hydrologically in the future [19]. Sırdaş and Şen (2003) determined the spatial distribution of monthly precipitation data of 60 large stations in Turkey between 1930 and 1990. They also state that our country is in a semi-arid region and they stated that drought is a constant threat for Turkey [20].

Richter and Semenov (2005) investigated the effects of drought risks on wheat yield by modeling for future climate changes in the United Kingdom. They determined that the warming will increase in the region between 2020 and 2050, which will have a positive impact on agricultural production. Another result is that the average wheat production will increase by 1.5-2 tons per hectare [21].

Türkeş (2012) found that the significant decrease in frost and snowy days especially in the 1900s in the Eastern Mediterranean and Turkey. The researcher also found that climate parameters such as the number of warm days and nights and the air temperatures (average, lowest at night and highest during the day) have increased [22].

Kapluhan (2013) examined the impact of drought on agriculture in Turkey. The study emphasized that the effects of drought was generally firstly seen in agriculture and gradually spread to other sectors. The researcher stated that Turkey is among the high-risk group countries in terms of the negative effects of the warming. Especially, the Mediterranean and Central Anatolia regions will be more affected by climate change in the future. Besides, it was determined that reducing the negative effects of agricultural drought might be possible by taking precautions before the drought begins. [23].

Studies on agricultural water quality were summarized below. Öktüren Asri et al. (2013) conducted a study to determine the quality of well water used for irrigation purposes in greenhouse cultivation in Osmaneli district of Bilecik province. They took water samples from 46 well waters and determined the values of pH, EC, Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, HCO_3^{-}, Cl^{-}, SO_4^{-2} and B. Besides, they determined quality classes by calculating SAR and Na% values. In addition, it was determined that 41.30% of the samples were in the C_2 salinity class and 47.82% were in the C_3 salinity class. All irrigation water samples were classified as 1st class water in terms of sodium adsorption rate (SAR) [24].

Alkan and Meral (2024) comprehensively investigated agricultural water quality in Bilecik Karasu River. According to the results, in Bozüyük county, in 2023, SAR in June is 0.1 (A1), SAR is 0.45 (A1) in September. SAR in June 2023 is 0.83 (A1) in Bilecik, SAR in September is 0.93 (A1). As a result, no problems were observed in terms of agricultural water quality in Bilecik and Bozüyük [25].

Drought indices are usually calculated by manually applying the relevant equations or using tools designed for this purpose. Some of the calculation tools of drought index are [26] SPI_SL_6, SPATSIM, SPEI package program and CDI. The software package called DrinC was developed at the Center for Assessment of Natural Disasters and Proactive Planning and the Laboratory of Land Reclamation and Water Resources Management at the National Technical University of Athens. DrinC can be used to calculate drought indices suitable for drought characterization, drought monitoring, spatial analysis of drought risks and exploration of climate scenarios [27].

The main goal in the design of the DrinC software is to provide the widest applicability for different drought types and various locations such as meteorological, hydrological and agricultural drought. Based on these criteria, DrinC consists of Reconnaissance Drought Index (RDI), Streamflow Drought Index (SDI), Standardized Precipitation Index (SPI) and Precipitation Deciles (PD).

Studies on agricultural drought were summarized below. Menteşe and Akbulut (2023) investigated the drought situation of Bilecik station (1964–2021) and Bozüyük stations (1964–2021) with the help of Standardized Precipitation Index (SPI). Researchers determined that the dry, normal and humid period rates of the two districts are similar to each other. Arıkan Uysal (2022) applied trend analysis methods for Bursa's rainfall and temperature values between 1990 and 2019. As a result, she found no statistically significant trend in precipitation data and She observed increasing trends in temperature data. According to SPI and SPEI indices, “normal” drought class prevailed [28]. Bacanlı and Kargı (2018) conducted drought analysis in Bursa with the Standard Precipitation Index (SPI). While normal or mild droughts were more common

in short-term periods (3-6 months), severe and very severe droughts were observed in long-term periods (12-24-48 months) [29]. Karaer and Gültaş (2018) determined that drought was generally seen in the summer months for Bilecik province using the SPI method [30].

Studies on agricultural floods were summarized below. Bayazıt (2021) examined the effects of urbanization on flood risk in Bilecik province. It was determined that Bozüyük district is under constant flood risk. It is also found that agricultural lands have a higher flood risk than forest areas in the study [31]. Dursun (2022) examined the flood risk in Osmaneli district of Bilecik using a geographical information system. In the study, the weight values of the flooding parameters were calculated using the Analytical Hierarchy Process (AHP) Method. Besides, the areas with flood risk were determined. As a result, very high risk with 11.94%, high risk with 35.98%, risky with 28.72%, low risk with 20.61% and no risk with 2.75% areas were determined. It was also determined that the risk of flood occurrence is generally higher in areas close to river basins [32].

Alkan (2016) estimated flood flow values in Bursa Province using the WinTR-55 model, Mockus, Rational and DSI synthetic methods. As a result, it was found that the WinTR-55 model predicted higher flood flow compared to other methods in fifteen of the seventeen basins [33].

In this study, the sensitivity of the main agricultural products in Bilecik Province was analyzed in terms of flood, drought and water pollution. For this purpose, agricultural product data in Bilecik was accessed from Turkish Statistic Institution. Climatic data was accessed from Bilecik Meteorology Directorate. Firstly, studies on the subject was compiled and evaluated. Later, a comprehensive result that would be beneficial for the stakeholders in the city was reached through this study.

2. MATERIAL AND METHODS

2.1. Materials

2.1.1. The research area

Bilecik is located in the southeast corner of the Marmara Region. The region intersect to the Marmara, Black Sea, Central Anatolia and Aegean regions. It is located between 39° and 40° 31' north latitudes and 29° 43' and 30° 41' east longitudes. It is adjacent to the provinces of Bolu and Eskişehir in the east, it is adjacent to Kütahya in the south, the region is adjacent to Bursa in the west and Sakarya in the north (Figure 1). The ranking of surface area (4321 km^2) of Bilecik is 65th in Turkey. Bilecik's land structure varies from hilly areas to eroded plains divided by steep and deep valleys. The borders of Bilecik contain the Northern Anatolian Mountains, the Central Anatolian Plateaus and fluvial plains of the Marmara Region. Bilecik's average altitude above sea level is 500 meters. As you go towards Karasu Valley, the altitude decreases and goes down to sea level in Istasyon District.

Figure 1. Map of Bilecik [31]

Bilecik is a province located in the southeast of the Marmara Region. Being adjacent to different geographical regions and topographic diversity also affects the climate of the province. For this reason, there are three different climate types in Bilecik. They are below.

• Marmara Region Climate: It is dominant in the Central, Gölpazarı, Osmaneli and Söğüt districts. In these regions, winters are warm and rainy. Besides, summers are hot and dry.

• Central Anatolia Region Climate: It is seen in Bozüyük, Pazaryeri and Yenipazar districts. In these regions, winters are cold and snowy. Besides, summers are hot and dry.

• Micro-climate Climate: It is seen along the Sakarya River coastline of Gölpazarı, Osmaneli and Söğüt districts. A milder climate prevails in these regions due to the influence of the river.

The average annual rainfall in Bilecik is 450 kg/m². Precipitation is generally concentrated in January and May. In terms of cloudiness, 92 days of the year are clear, 96 days are muggy and 177 days are cloudy. The data used in the WinTR-55 model were shown in Tables 1 and 2.

Table 1. Physical characteristics of the basins in Bilecik for the WinTR-55 model

Name of the watershed	Area of the watershed (km^2)	Length of the watershed (km)	Harmonic slope of the watershed	T_c (Time of concentration, hour)	CN (Curve number)
Gölpazarı-Arap stream	3.4	3.3	0.094	0.005	75
Gölpazarı- Delikbağ stream	2.4	2.7	0.04	0.007	75
Pazaryeri-Gümüşdere	4.91	5.82	0.038	0.014	74
Yenipazar-Çöte	3.87	4.9	0.028	0.014	74

Table 2. 24-hour rainfall amount of the watersheds (mm)

Name of the watershed	Return period (year)	24-hour rainfall amount (mm)
Gölpazarı-Arap stream	2	29.42
	5	44.12
	10	56.02
	25	73.88
	50	89.39
	100	107
Gölpazarı- Delikbağ stream	2	29.42
	5	44.12
	10	56.02
	25	73.88
	50	89.39
	100	107
Pazaryeri-Gümüşdere	2	32.07
	5	42.57
	10	50.13
	25	60.37
	50	68.54
	100	77.17
Yenipazar-Çöte	2	31.64
	5	41.08
	10	47.32
	25	55.21
	50	61.06
	100	66.87

2.1.2. Determination of the study data

For drought analysis, average temperature and precipitation data for the period 1990-2021 for Bilecik-Central (Station No: 17120), for the period 2005-2022 for Pazaryeri (Station No: 17701), for the period 1990-2020 for Bozüyük were used. For this purpose, rainfall data measured in the periods of the relevant years were obtained from the General Directorate of Meteorology.

2.2. Methods

In this study, DrinC and WinTR-55 programs were used. The method equations used by the programs were explained below.

2.2.1. DrinC program

In the study, monthly maximum and minimum temperature, monthly average temperature and precipitation data of the Meteorology Station were processed in the format requested by the DrinC program. Indexes used in the DrinC model are Reconnaissance Drought Index (RDI), Streamflow Drought Index (SDI), Standardized Precipitation Index (SPI) and Precipitation Deciles (PD).

The Reconnaissance Drought Index (RDI) was developed to more accurately refer water deficit as a balance between input and output in a water system [35]. It is based on both cumulative precipitation (P) and potential evapotranspiration (PET). The initial value of RDI (α_k) is calculated in the k (month) time period for the i. year and is given in Equation (1).

$$\alpha_k = \frac{\sum_{j=1}^{k} p_{ij}}{\sum_{j=1}^{k} PET_{ij}}, i = 1(1)N \quad (1)$$

Where:

P_{ij}: Precipitation for month j for year i

PET_{ij}: Potential evapotranspiration for month j for year i

N: Total year

k: Month

Assuming that the lognormal distribution is valid, the calculation of RDIst is given in Equation (2).

$$RDI_{st}^{(i)} = \frac{y^{(i)} - \bar{y}}{\bar{\sigma}_y} \quad (2)$$

Where:

$y^{(i)}$: Logarithm of the αk value of year i

$\bar{y}$: Arithmetic mean of all αk values

$\bar{\sigma}_y$: Standard deviation of logarithms of αk values

2.2.2. WinTR-55 program

WinTR-55 model is based on the NRCS-TR 55 method in calculating the rate of peak surface flow. The NRCS-TR 55 method can be used safely in small, rural and urban basins if the area of the basin is less than 900 ha and the average slope is greater than 0.5%. The WinTR-55 model can be used safely in basins with a maximum of 10 sub-basins, where the curve number (CN) is greater than 40, where Tc is between 0.1 and 10 hours, and whose area is up to 6500 hectares. The method equation used in the model is also given in Equation (3).

$$q_p = q_u A\ Q\ F_p \quad (3)$$

Where:

q_p: Peak runoff discharge (m^3/s)

q_u: Unit peak runoff discharge (km^2/cm)

A: Watershed area (km^2)

Q: Surface runoff depth (mm) resulting from 24-hour rainfall in the desired return period

F_p: Correction factor determined according to the ratio of lakes and swamps in the basin fp value is shown in table 3.

Table 3. Correction factor, Fp (Huffman et al. 2013)

Percentage of lakes and swamps in the basin	*Fp*
0	1
0.2	0.97
1	0.87
3	0.75
5	0.72

After calculating *T*c by using Equation (4), unit peak runoff amount (*q*u) can be determined by using *T*c and la/p parameters from Figure 2 [33]. Figure 2 should be use for Type II Storm (A kind of precipitation distrubition).

$$T_c = L^{0.8} \left[\frac{\left(\frac{1000}{CN} - 9\right)^{0.7}}{4407\ (s_g)^{0.5}} \right] \quad (4)$$

where:

T_c: Concentration time (hours), L: Longest waterway length, which is from the farthest point of the basin to outlet (meters), CN: Runoff curve number, S_g: Average basin slope (m/m)

Precipitation distribution in the United States of America (USA) is divided into four different categories. They are Type I, Type IA, Type II, and Type III (Figure 3) [33]. The Type II precipitation distribution dominates most part of the USA. We have entered the distribution type II into the WinTR-55 model for the pond basins in Bilecik because this type represents an average distribution.

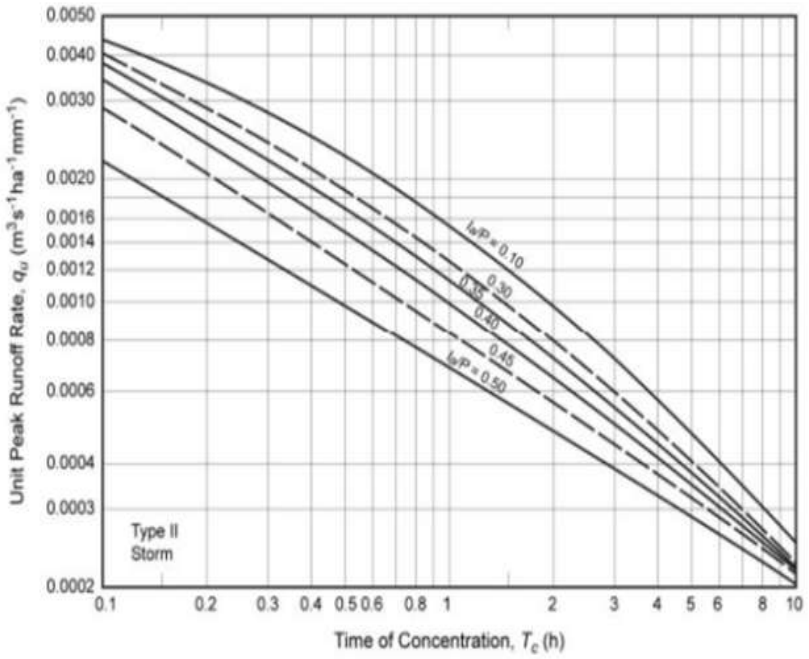

Figure 2. Unit peak runoff for NRCS Type II precipitation distribution

Figure 3. Precipitation distribution in the USA

In addition to calculating CN and Tc values, the WinTR-55 model also has the ability to calculate surface flow volume and peak flow rate. Basin characteristics such as size, shape, slope, soil type, land use, geological structure, vegetation and climate of the basin are among the factors. Besides, they affect the T_C value. There are different formulas developed to calculate the T_C value. Some of these formulas divide flow into categories such as channel flow and sheet flow. On the other hand, the others calculate Tc by using a single equation. In order to calculate the required CN value in the WinTR-55 model, the class of the soil group is shown in Table 4.

Table 4. The groups of soil class

Soil class	Description	The limit value that the infiltration capacity will reach as rainfall progresses, fc (mm/h)
A	Lowest runoff potential	8-12
B	Slightly low runoff potential	4-8
C	Slightly high runoff potential	1-4
D	Maximum runoff potential	0-1

The NRCS graphical (CN) method is shown below with its formula Equation (5) [33].

$$Q = \frac{(l-0.2S)^2}{l+0.8S} \quad (5)$$

Where:

Q : Runoff amount (mm) l: Storm rainfall amount (mm) S: Maximum potential difference between Runoff and Precipitation (Water holding capacity) (mm)

$$S = \left(\frac{25400}{CN}\right) - 254 \quad (6)$$

Where:

CN: Unoff Curve Number

l_a: 0.2S

l_a: The factors such as delay losses, surface deposits, infiltration etc

3. RESULTS AND DISCUSSION

In the study area, the effect of drought on crop production was analyzed spatially and temporally as follows.

3.1. Spatial variation of agricultural drought

In order to analyze the effect of drought on agricultural production, Durum wheat (Triticum Durum) and Hops (Humulus lupulus) plants were selected in this study and an analysis was made on their R^2 values (Determination coefficient between RDI and yield). The analysis results showed that the R^2 values for Durum wheat were 0.80 in Söğüt, 0.18 in Bilecik city center, 0.43 in Bozüyük and 0.0095 in Pazaryeri (Table 5). It can be seen that the region where Durum wheat is directly affected by drought is Söğüt with an R^2 value of 0.80, and Pazaryeri is the region where drought affects wheat yield the least with an R^2 value of 0.0095. As a result of the analysis, the R^2 value for hops was found to be 0.50 in Pazaryeri and 0.01 in Bilecik city center (Table 6). Agricultural drought affected Durum wheat and hop production in different ways. For Durum wheat yield, Bilecik was much more affected by drought compared to Pazaryeri. For Hop yield, Pazaryeri was much more affected by the drought compared to Bilecik. In order to examine the effects of drought on plant physiology and yield in more detail, the plant varieties used in studies can be increased.

Table 5. R^2 Determination coefficient results for Durum wheat (correlation with RDI)

R^2 results for Durum wheat	
Bilecik/City center	0.18
Bozüyük	0.043
Pazaryeri	0.0095
Söğüt	0.8

Table 6. R^2 Determination coefficient results for Hop (correlation with RDI)

R^2 results for Hop	
Bilecik/City center	0.01
Pazaryeri	0.5

Uzun (2024) found the high density of drought susceptibility in the area surrounding the Yenişehir Plain. In particular, this study reached the similar result in terms of results of Bilecik City center which was closed to Yenişehir Plain [36].

Taylan (2024) found that Bozuyuk reached positive SPI values. This study reached the similar result with the increasing trend of SPI too [37].

3.2. Temporal variation of agricultural drought

In this research, it was analyzed how the drought values of Bilecik, Bozüyük and Pazaryeri changed over the years. A significant decrease in drought index values was observed in Bilecik in 2017 and a significant increase in the index value was observed in 2011 (Figure 4).

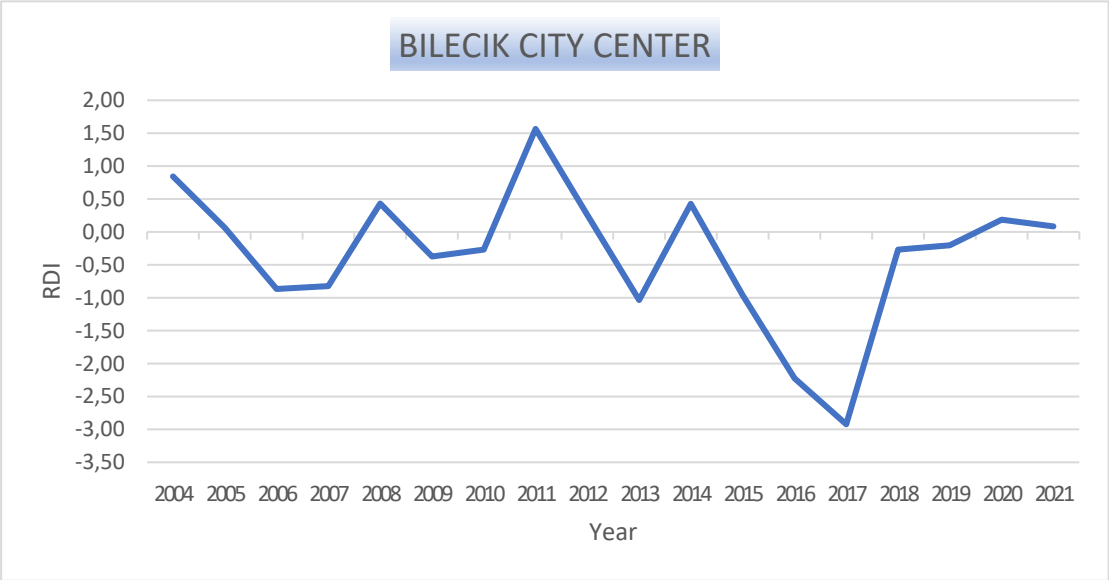

Figure 4. Temporal drought change of Bilecik

2006 and 2007 were most severe drought in Bozüyük. In 2004, there was an increase in the index value (Figure 5). In Pazaryeri, the drought was felt most intensely in 2007. In 2011 and 2015, an increase in drought index values was observed (Figure 6).

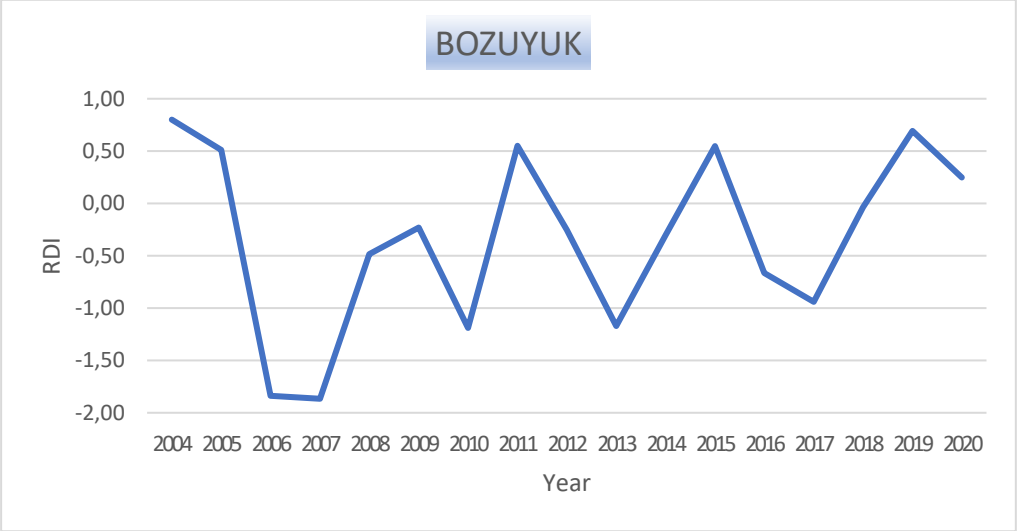

Figure 5. Temporal drought change of Bozüyük

Figure 6. Temporal drought change of Pazaryeri

3.3. The results related to reconnaissance drought index (RDI)

To compare with water quality results in the literature, the RDI values of Bilecik and Bozüyük in June and September in 2023 were taken and the correlation between them and the SAR water quality index was discussed in the conclusion section. RDI results were calculated with the help of DrinC model. RDI values were prepared based on the months of June and September in Bilecik and Bozüyük. While RDI was 1.18 in Bozüyük in June, it dropped to 0.17 in September and became more drier condition. In Bilecik province, the RDI value, which was 0.8 in June, decreased to 0.37 in September and started to trend towards drought (Figure 7)

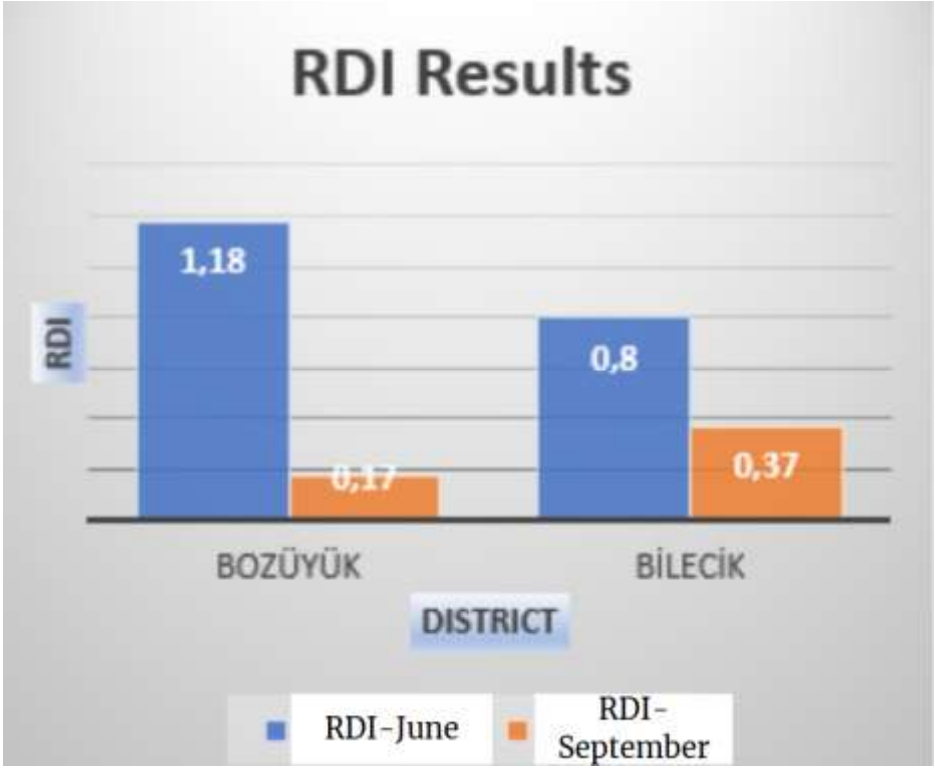

Figure 7. RDI change on a spatial and temporal basis

Kartal (2024) used RDI to determine the drought periods for between 1979 and 2022 years in Elazığ. He revealed that Ağın and Baskil County were drought regions [39]. Başakın et al. (2024) investigated determine of the correlation SPEI and scPDSI index [40].

As in these examples, there are widespread publications in the literature on the determination of the correlation between the drought indices and spatial distribution of drought. However, as in our study, there is very little research on the determination of the relationship between drought and crop yield. The results of our study are also very valuable in this respect.

3.4. Results related to agricultural flood

A comparative analysis of the flood risk was made by determining the peak flow values (m^3/s) of each research area at different return periods with the help of WinTR-55 model. For this purpose, peak flow values for 2, 5, 10, 25, 50 and 100 year return periods were calculated Table 7.

Table 7. Possible peak flow value for different return period

Watershed name	Return period (year)	Peak flow (m^3/s)
Gölpazarı-Arap stream	2	0.75
	5	7.82
	10	15.74
	25	31.54
	50	47.28
	100	66.59
Gölpazarı- Delikbağ stream	2	0.53
	5	5.52
	10	11.1
	25	22.26
	50	33.38
	100	47
Pazaryeri-Gümüşdere	2	1.65
	5	8.64
	10	15.16
	25	25.38
	50	35.46
	100	47.06
Yenipazar-Çöte	2	1.13
	5	5.9
	10	9.94
	25	15.79
	50	20.65
	100	26.27

The flood risk of each research area was compared based on the peak flow values of the 100-year return period. Gölpazarı-Arap Stream is the area with the highest risk with 66.59 m³/s. This is followed by Gölpazarı-Gümüşdere with 47.06 m³/s, Gölpazarı-Delikbağ Stream with 47.00 m³/s and Yenipazar-Çöte with 26.27 m³/s, respectively (Figure 8).

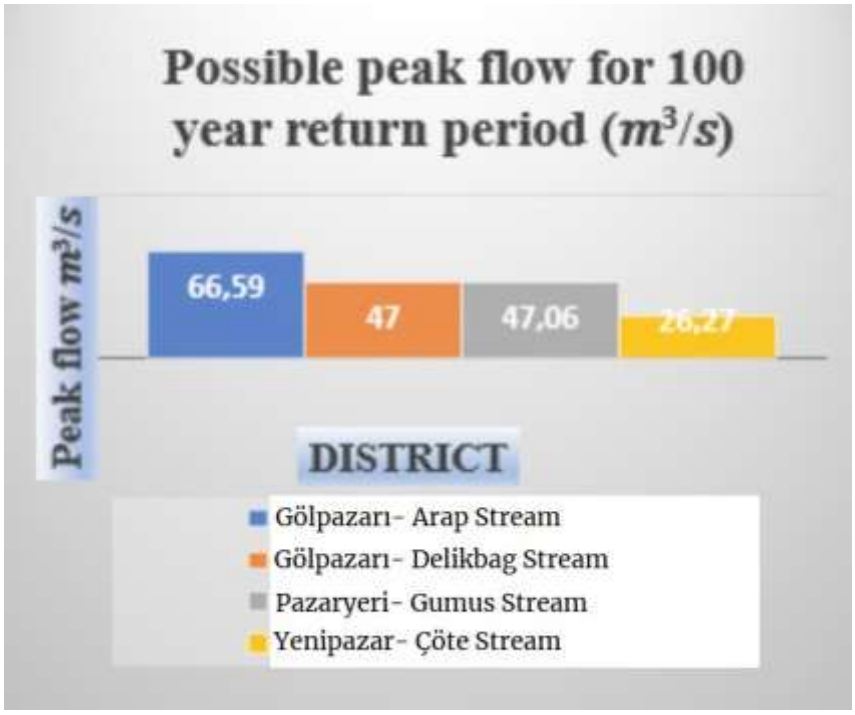

Figure 8. Possible peak flow for 100 year return period

Tarate et al. (2024) said that hydrologic models are so valuable in ungauged watersheds. The models are crucial for accurate runoff estimation. Besides, the NRCS-CN method is fertile and superior. WinTR-55 hydrologic model (NRCS-CN method inside of it), which are populer methods in the literature was used in this study [38].

Aktaş and Uncu (2024) stated that hollow areas carry flood risk. They especially draw attention to the fact that Gölpazarı district is quite mountainous and hollow [41]. The result of our study also coincides with this information in the literature. It is expected that very high peak flow rates will be observed in our Arap and Delikbağ basins in Gölpazarı.

Bathis and Ahmed (2016) used the HEC-HMS model in Doddahalla watershed [42]. The model is very similar to WinTR-55 medel. Both of these models are very valuable in ungauged watersheds and water-scarce regions where limited monitored data exist.

4. CONCLUSION

Menteşe and Akbulut (2023) found that the dry, normal and humid period rates of Bilecik and Bozüyük were similar to each other. They also noted that both weather stations are not facing a serious drought yet. Our study shows that the drought relationship between Bilecik and Bozüyük districts is similar and supports the study of Menteşe and Akbulut (2023). However,

when the R^2 values of Durum wheat are compared, the values of 0.043 in Bozüyük and 0.18 in Bilecik show that Durum wheat is much more affected by drought in terms of yield in Bozüyük compared to Bilecik City center. It is also important to consider that different plant varieties may have different levels of tolerance to drought. Therefore plant yield values and drought severity will not always correlate strongly. Future research should focus on examining the tolerance levels of different plant varieties to drought and adaptation strategies of crop against the drought.

Menteşe and Akbulut (2023) said that 2017 was a "very dry" year for Bilecik. In addition, Uysal (2022) examined 2017 for Bursa with the SPEI method and found that it was a less drier year than the estimation of SPI method. Our research evaluates Bilecik in terms of agricultural drought, which is similar to the results of Uysal (2022) conducted in Bursa. This shows that the drought assessment method used has a significant impact on the results. While the SPI method tries to evaluate drought severity using only precipitation data, the SPEI method offers a more comprehensive evaluation by consider other factors such as evapotranspiration and precipitation. Therefore, the SPEI method is expected to give more accurate results than the SPI method in different climatic regions and seasons. When compared to the results in these researches, the drought results of Menteşe and Akbulut (2023) and Uysal (2022) for 2017 show that the SPEI method is much more reliable than the SPI method. Therefore, it would be more appropriate to use the SPEI method in drought analyses. Drought indices are only indicators. To fully evaluate the effects of drought, other factors (soil moisture, plant stress, etc.) should also be considered.

Alkan (2016) found that for the Osmangazi Güneybayır basin, the peak flow rate, which may occur once in 100 years, reached 156.96 m^3/s. This value is quite above the peak flow rate values of the 4 regions selected as research areas in our research. Therefore, it is thought that this is due to the fact that the construction in the Osmangazi region of Bursa is more dense compared to the 4 regions in our research. On the other hand, the researcher found a peak flow rate of 41.13 m^3/s in the Bayramdere region of Karacabey Kocadere Village, and a peak flow rate of 47.06 m^3/s in the Pazaryeri-Gümüşdere region and 47 m^3/s in the Gölpazarı-Delikbağ stream in our Bilecik study. Since these basins are regionally close to Bursa and have similar hydrological characteristics, it can be said that their peak flow rates are similar.

Among these 4 regions investigated in the research, the fact that the peak flow values that may occur in 100 years in the Gölpazarı-Arap stream, Gölpazarı-Delikbağ stream and Pazaryeri-Gümüşdere region are higher than the Yenipazar-Çöte region. It shows that all 3 regions are higher in terms of construction and slope than Yenipazar-Çöte. Other factors that may affect peak flow values should also be considered. For example, factors such as land use, rainfall amount, concentration time and climate change may also play an important role.

Gölpazarı-Arap Stream has a higher flood risk than other research areas. This area should be considered as a priority to manage flood risk and take preventive precautions. Detailed flood risk maps should be created for each research area. Awareness and education activities should be carried out against flood risk. Necessary steps should be taken for the protection and sustainable management of water basins.

Alkan and Meral (2024) said that the sodium absorption rate in Bozüyük increased (350%) from 0.1 in September to 0.45 in June, and this caused the water quality to deteriorate. Similarly, in Bilecik province, it was observed that the sodium absorption rate increased by 12% from 0.83 to 0.93 and the water quality deteriorated. When the researcher's results are compared with the changes in the RDI values found in our research, it is seen that the deterioration of water quality rises and drought rises are directly proportional. The RDI value in Bozüyük, which was 1.18 in June, decreased to 0.17 (by 594%) in September, and the RDI value in Bilecik, which was 0.8 in June, decreased to 0.37 (by 116%) in September. The 594% decrease in the RDI value and the 350% increase in the SAR value in Bozüyük reveal a significant decrease in the availability of irrigation water. In Bilecik, the RDI value decreased by 116% and the SAR value increased by only 12%. The results indicate that Bilecik has a better water resource than Bozüyük and the quality of this water resource is less affected by drought. In Bilecik, the deterioration in water quality is also less because the drought effect is less.

As a result, factors such as floods, drought and water pollution can lead to yield losses in agricultural production and can lead to degradation of agricultural lands. Therefore, regional disaster risk maps should be created and irrigation planning should be made according to these maps.

As a result of this study, the sensitivity of the main agricultural products in Bilecik against the drought was determined. Besides, the amount of flood water likely to occur in Bilecik was determined. This study will contribute to the literature by examining major disasters such as drought and flood in Bilecik all together. This study has made a difference especially in terms of examining the relationship between drought index result and crop yield with the coefficient of determination.

It is recommended that the results obtained using different drought indices and hydrological models for the region in the future should be compared with the results of this study.

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EVALUATION OF REDUCED TILLAGE PRACTICES IN TERMS OF CONSERVATION TILLAGE TECHNIQUE

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ABSTRACT

Due to the developing environmental awareness, economic production demands and the necessity of saving in energy use, radical changes in soil cultivation have started to be made in the world and in Turkey in recent years. Accordingly, conservation tillage, which is an alternative to conventional tillage, especially direct sowing method is rapidly becoming widespread. Within the framework of this idea, it is important to protect natural resources, which cannot be renewed or take a long time to be renewed in the production process, and to reduce environmental pollution.

Although it is possible to make the soil suitable for the growth of cultivated plants by tillage, the destruction of nature caused by unconscious and excessive tillage is extremely important. Intensive tillage and clearing the upper surface of the soil from plant residues cause soil compaction and erosion. The increase in field traffic, especially in the period when the soil is moist, will rapidly compact the soil.

For sustainable and economical plant cultivation in the agricultural areas of our country, it is necessary to implement the most accurate cultivation techniques that have been put forward by experts in the period from soil preparation to harvest. In order for the soil treatments to be applied in field agriculture to be successful, optimum seed bed preparation that accumulates moisture in the soil profile is required. Suitable seed bed preparation is possible by taking into consideration the climate of the region, soil type, land slope, crop rotation, available agricultural tools and recommended technical information.

Reduced tillage techniques are an increasingly widespread agricultural practice that aims to ensure environmental sustainability by preserving soil structure. These methods aim to treat the soil surface with minimum intervention and thus help to prevent soil erosion, increase water holding capacity and protect biodiversity. Conservation tillage is recognised as a strategy to increase productivity without disturbing the natural functions of the soil. In this context, reduced tillage plays an important role in reducing environmental impacts by contributing to

the preservation of soil physical and chemical properties. However, the success of these practices may vary depending on local climatic conditions, soil types and agricultural production methods. In this study, how reduced tillage methods can be evaluated in line with the conservation tillage concept was analysed and the environmental impacts of the practices, their long-term consequences on soil health and their relationship with productivity were discussed. In addition, the findings of recent research on the potential benefits and limitations of these methods are also included.

Keywords: Tillage, Reduced Tillage, Conservation Tillage, Direct Seeding

AZALTILMIŞ TOPRAK İŞLEME UYGULAMALARININ KORUYUCU TOPRAK İŞLEME TEKNİĞİ AÇISINDAN DEĞERLENDİRİLMESİ

ÖZET

Gelişen çevre bilinci, ekonomik üretim talepleri ve enerji kullanımında tasarrufa gitme zorunluluğu nedeniyle son yıllarda, dünyada ve Türkiye'de toprak işlemede köklü değişiklikler yapılmaya başlanmıştır. Buna bağlı olarak geleneksel toprak işlemeye alternatif olan koruyucu toprak işleme, özellikle doğrudan ekim yöntemi hızlı bir şekilde yaygınlaşmaktadır. Bu düşünce çerçevesinde, üretim sürecinde özellikle yenilenemeyen veya yenilenmesi uzun zaman alan doğal kaynakları korumak ve çevre kirliliğini azaltmak önem kazanmaktadır.

Toprak işleme ile toprağın kültür bitkilerinin yetişmesi için uygun hale getirilmesi mümkün olmakla beraber, özellikle bilinçsiz ve aşırı toprak işleme ile meydana gelen doğadaki tahribat son derece önemlidir. Yoğun toprak işleme ve toprak üst yüzeyinin bitki artıklarından arındırılması toprağın sıkışmasına ve erozyona neden olur. Toprağın özellikle nemli olduğu dönemde tarla trafiğindeki artış toprağı hızla sıkıştıracaktır.

Ülkemizdeki tarım alanlarında sürdürülebilir, ekonomik bitki yetiştiriciliği için uzmanlarca, toprak hazırlığından hasada kadar olan dönemde araştırmalarla ortaya konulmuş en doğru yetiştirme tekniklerinin uygulamaya geçirilmesi gerekmektedir. Tarla tarımında uygulanacak toprak işlemlerinin başarılı olabilmesi için toprak profilinde nem biriktiren optimum tohum yatağı hazırlığına ihtiyaç vardır. Uygun tohum yatağı hazırlığı bölgenin iklimi, toprak tipi, arazi eğimi, ekim nöbeti, eldeki tarım aletleri ve tavsiye edilen teknik bilgilerin mutlaka göz önünde bulundurulması ile mümkündür.

Azaltılmış toprak işleme teknikleri, toprağın yapısını koruyarak çevresel sürdürülebilirliği sağlamayı amaçlayan, giderek yaygınlaşan tarım uygulamalarındandır. Bu yöntemler, toprak yüzeyinin minimum müdahale ile işlenmesini hedefler ve bu sayede toprak erozyonunu engellemeye, su tutma kapasitesini artırmaya ve biyolojik çeşitliliği korumaya yardımcı olur. Koruyucu toprak işleme, toprağın doğal işlevlerini bozmadan, verimliliği artırmaya yönelik bir strateji olarak kabul edilmektedir. Azaltılmış toprak işleme, bu bağlamda, toprağın fiziksel ve kimyasal özelliklerinin korunmasına katkı sağlayarak çevresel etkilerin azaltılmasında önemli bir rol oynamaktadır. Ancak, bu uygulamaların başarısı, yerel iklim koşulları, toprak tipleri ve tarımsal üretim yöntemlerine bağlı olarak değişiklik gösterebilmektedir. Bu çalışmada, azaltılmış toprak işleme yöntemlerinin koruyucu toprak işleme anlayışı doğrultusunda nasıl değerlendirilebileceği incelenmiş olup, uygulamaların çevresel etkileri, toprak sağlığı üzerindeki uzun dönemli sonuçları ve verimlilikle ilişkileri ele alınmıştır. Bununla beraber, söz konusu yöntemlerin potansiyel faydaları ve sınırlamaları üzerine yapılan güncel araştırmaların bulgularına da yer verilmiştir.

Anahtar Kelimeler: Toprak İşleme, Azaltılmış Toprak İşleme, Koruyucu Toprak İşleme, Doğrudan Ekim

1. GİRİŞ

Gelişen çevre bilinci, ekonomik üretim talepleri ve enerji kullanımında tasarrufa gitme zorunluluğu nedeniyle son yıllarda, dünyada ve Türkiye'de toprak işlemede köklü değişiklikler yapılmaya başlanmıştır. Bu değişikliklere bağlı olarak geleneksel toprak işlemeye alternatif olan koruyucu toprak işleme, özellikle doğrudan ekim yöntemi hızlı bir şekilde yaygınlaşmaktadır. Bu düşünce çerçevesinde, üretim sürecinde özellikle yenilenemeyen veya yenilenmesi uzun zaman alan doğal kaynakları korumak ve çevre kirliliğini azaltmak önem kazanmaktadır.

Toprak işleme ile toprağın kültür bitkilerinin yetişmesi için uygun hale getirilmesi mümkün olmakla beraber, özellikle bilinçsiz ve aşırı toprak işleme ile meydana gelen doğadaki tahribat son derece önemlidir. Yoğun toprak işleme ve toprak üst yüzeyinin bitki artıklarından arındırılması toprağın sıkışmasına ve erozyona neden olur. Toprağın özellikle nemli olduğu dönemde tarla trafiğindeki artış toprağı hızla sıkıştıracaktır.

2. TOPRAK İŞLEME

Tarla tarımında başarılı olabilmek için, tohumun ekimine uygun, iyi bir tohum yatağı hazırlamak gerekmektedir. İyi tohum yatağı hazırlığı da toprak bünyesine uygun tarım alet ve makineleri kullanarak zamanında, tekniğine uygun bilinçli bir toprak işleme ile mümkündür.
Toprak işlemeyi, tohumların ekilebilmesi, bitkilerin yetişebilmesi için, toprağın uygun duruma getirilmesi ve bu durumun korunması için herhangi bir araçla gevşetilmesi, ufalanması ve karıştırılması olarak tanımlayabiliriz.
Toprak işleme yöntemleri, toprak tipine, toprak işleme zamanına, ekim nöbetine, ekilen bitkinin cinsine, iklim şartlarına ve eldeki mekanizasyon seviyesine göre değişmektedir.
Toprak işlemenin amaçları:

- Tohum yatağını hazırlamak,
- Yabancı ot kontrolünü yapmak,
- Toprak yüzeyindeki bitki artıkları, anız ve ahır gübresinin gömülmesini sağlamak,
- Su ve rüzgâr erozyonunu kontrol etmektir.

3. TOPRAK İŞLEME SİSTEMLERİ

Toprak işlemenin amacı toprak verimliliğini korumak, erozyonu azaltmak, toprak sıkışıklığını önlemek, topraktaki flora ve faunanın korunmasını ve çeşitliliğin muhafazasını sağlamaktır(Önal,1995; Aykas ve Önal, 1999).
Çeşitli etkiye sahip toprak işleme aletlerinin kullanımına dayalı olarak farklı toprak işleme sistemleri ortaya çıkmıştır. Bu sistemleri iki ana grupta toplamak mümkündür.

- Geleneksel toprak işleme
- Koruyucu toprak işleme

Şekil 1. Toprak işleme sistemleri

3.1.GELENEKSEL TOPRAK İŞLEME

Geleneksel toprak işleme de toprağın üst yüzeyi isleme derinliğinde kabartılır. Bu toprak isleme yönteminde toprağın pullukla devrilmesi esastır. Geleneksel toprak işleme, özellikle ülkemizde yoğun ve aşırı toprak işlemeyi beraberinde getirmekte, toprak sıkışmasını ve erozyonu teşvik etmektedir. Türkiye topraklarının % 34,4'ünün erozyonu körükleyen yüksek eğimli alanlardan (%15-40) oluşması bu tehlikeyi daha da artırmaktadır(Korucu ve ark., 1998).

Şekil 2. Pullukla Toprak İşleme

3.2.KORUYUCU TOPRAK İŞLEME

Koruyucu toprak işleme sisteminde toprağı devirerek işleyen pulluk ve benzeri aletler kullanılmaz. Toprak sıkışıklığının sorun olduğu yerlerde toprağı belli bir derinlikte yırtarak işleyen çizel vb. aletler kullanılır. Bu sistemde ön bitki veya ürün artıkları tarla yüzeyinde bırakılır. Erozyon kontrolünde koruyucu toprak işleme ve doğrudan ekimin olumlu etkileri ortaya konulmuştur.

Genel kural olarak koruyucu toprak işleme sisteminde tarla yüzeyinin en az %30 oranında bitki artığı ile kaplı halde bulunması amaçlanır (Köller, 2003). Yüzeyde çok az miktarda bitki örtüsü bulunmasının bile erozyonu büyük ölçüde önlediği yapılan araştırmalar ile saptanmıştır.

Koruyucu toprak işleme; yabancı ot kontrolü ve tohum yatağı hazırlığı için yapılan ve geleneksel toprak işlemeye göre tarlada geçiş sayısını önemli ölçüde azaltan bir sistemdir. Bu sistem, prensip olarak toprağı devirmeden işlemeye yönelik uygulamaları içerir. Koruyucu toprak işlemede geleneksel toprak işlemede olduğu gibi temel toprak işleme, tohum yatağı hazırlama ve ekim işlemleri ayrı ayrı veya birleştirilerek yapılabilir. Koruyucu toprak işleme sisteminde iki temel düşüncenin gerçekleşmesi hedeflenir.

- Ön bitki veya ikinci ürün artıklarının tarla yüzeyine veya yüzeye yakın katmanlara yerleştirilmesi,
- Toprak işleme yoğunluğunun azaltılması (Önal, 1995).

Korumalı toprak işleme sistemi olarak uygulamada değişik alt sistemlere rastlamak mümkündür. Bunlardan bazıları aşağıda belirtilmektedir.

- Şerit Halinde Toprak İşleme
- Ekim Sırasında Toprak İşleme
- Malçlı Toprak İşleme
- Sırta Ekime Yönelik Toprak İşleme
- Doğrudan Ekim

3.2.1. ŞERİT HALİNDE TOPRAK İŞLEME

Tohum yatağı hazırlığı için ekim öncesi tarla yüzeyinin 1/3 ünün islenmesine izin veren koruyucu toprak işleme uygulamasıdır. Bu uygulamada toprak işleme genellikle ekimle beraber yapılır ve ekim sıralarının geleceği bölgelerde 5 ila 30 cm genişliğinde toprak işleme yapılarak bunun dışında kalan bölgeler anızla kaplı bırakılır (Godwin, 1990). Bu uygulamanın yanında sırta ekim için toprak işleme de yalnız sırtların yapılacağı şeritlerde toprak diskli ve benzeri aletlerle işlenir.

Şekil 3. Şerit halinde toprak işleme

3.2.2. EKİM SIRASINDA TOPRAK İŞLEME

Toprak frezesi, rotatiller veya PTO tahrikli tırmık ile ekim makinası birleştirilerek yapılan uygulamadır. Bu uygulamada, tarlanın tamamında toprak işlemesi yapılabileceği gibi, şerit halinde toprak işlemeye benzer şekilde sadece ekimin yapılacağı sıralarda toprak işlemesi yapılabilir.

Şekil 4. Ekim sırasında toprak işleme

3.2.3. MALÇLI TOPRAK İŞLEME

Malçlı toprak işlemenin temel felsefesi tüm yıl boyunca toprak yüzeyini bitki artıkları veya bitkiyle kaplı tutarak kaymak tabakası oluşumunu önlemek, filiz çıkış sorunlarını ve erozyonu azaltmaktır. Bu amaçla çizel, kültivatör, diskaro gibi aletler kullanılır.

Tohumun malçlı tohum yatağına ekiminde başarıya, ekim makinesinin performansının yanında, ekimden sonra tohum yatağı bölgesinde oluşan fiziksel ve kimyasal değişmelerde etki etmektedir.

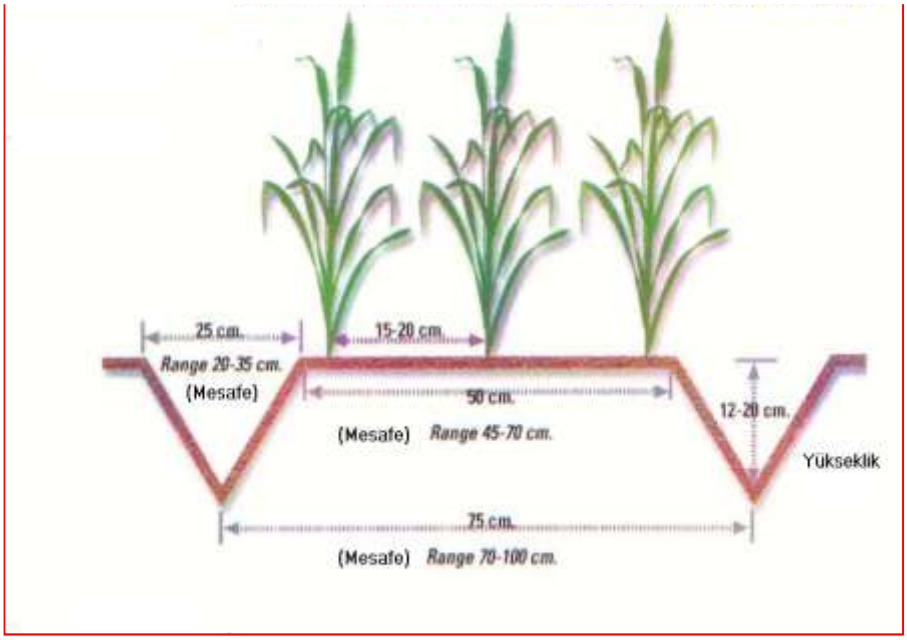
Şekil 5. Malçlı toprak işleme(Anonim)

3.2.4. SIRTA EKİME YÖNELİK TOPRAK İŞLEME

Bitki üzerine ekileceği ve bakım işlemleri sırasında veya hasat sonrasında sırt oluşturulması ve bunların her yıl aynı yerde korunmasını sağlayan sistemdir.

Sırta ekime yönelik toprak işlemede; toprak genellikle gübre uygulamaları dışında ekime kadar işlenmeden bırakılır. Bitkiler önceki yetiştirme döneminde yapılmış sırtlara ekilir veya dikilir Genellikle kazayağı, diskli sıra temizleyicileri, gömücü üniteler veya yatay diskleri bulunan ekim makineleri kullanılmaktadır.

Şekil 6. Sırta ekime yönelik toprak işleme



Şekil 7. Sırta ekime yönelik toprak işleme

3.2.5. DOĞRUDAN EKİM

Doğrudan ekim, koruyucu toprak işleme gibi toprağın yapısını iyileştirmekte, toprak neminin korunmasını sağlamaktadır. Doğrudan ekim yapılan alanlarda sonbahar toprak işlemesine belirli ölçüde izin verilebilir.

Tarlada anız artıklarının parçalanmasından sonra sonbaharda toprağı devirmeden işleyen aletlerle toprak işlenir. Bu durumda toprak yüzeyinde anız artıklarının en az % 50 sinin kalması gerekmektedir. Toprak yüzeyinde bulunan bitki artıkları toprağın korunması yönünden büyük önem taşımaktadır.

Doğrudan ekimin başarısı, iklim ve toprak koşullarına, ekim makinasının performansına ve yabancı ot mücadelesine bağlıdır. Ot mücadelesi genel olarak herbisitle yapılır. Doğrudan ekim yapılan tarlalarda ciddi yabancı ot sorunu varsa 4-5 yılda bir ekim öncesi azaltılmış toprak işleme uygulanabilir.

Şekil 8. Hasat edilmiş buğday tarlasına ekilmiş soya fasulyesi

Çizelge 1. Dünya genelinde toprak işlemesiz tarım alanlarının ülkelere ve kıtalara göre dağılımı (FAO)(Tekin, 2017)

Ülkeler	**Tarım Alanı (ha)**
Amerika	35 613 000
Brezilya	31 811 000
Arjantin	29 181 000
Kanada	18 313 000
Paraguay	3 000 000
Uruguay	1 072 000
Bolivya	706 000
Venezüella	300 000
Şili	180 000
Kolombiya	127 000
Meksika	41 000
Amerika	**120 344 000**

Çizelge 1. Dünya genelinde toprak işlemesiz tarım alanlarının ülkelere ve kıtalara göre dağılımı (FAO)(Devamı)(Tekin, 2017)

Ülkeler	**Tarım Alanı(ha)**
Rusya	4 500 000
Ukrayna	700 000
İspanya	672 000
İtalya	380 000
Fransa	200 000
Almanya	200 000
Finlandiya	200 000
İngiltere	150 000
Slovakya	35 000
Portekiz	32 000
İsviçre	17 000
Macaristan	5 000
Hollanda	500
Belçika	268
Avrupa	**7 091 768**

Çizelge 1. Dünya genelinde toprak işlemesiz tarım alanlarının ülkelere ve kıtalara göre dağılımı (FAO)(Devamı)(Tekin, 2017)

Ülkeler	**Tarım Alanı(ha)**
Çin	6 670 000
Kazakistan	2 000 000
Hindistan	1 500 000
Kuzey Kore	23 000
Asya	**10 193 000**

Çizelge 1. Dünya genelinde toprak işlemesiz tarım alanlarının ülkelere ve kıtalara göre dağılımı (FAO)(Devamı)(Tekin, 2017)

Ülkeler	**Tarım Alanı(ha)**
Türkiye	45 000
Suriye	30 000
Tunus	8 000
Fas	4 000
Lübnan	1 200
Batı Asya ve Kuzey Afrika	**88 200**

Çizelge 1. Dünya genelinde toprak işlemesiz tarım alanlarının ülkelere ve kıtalara göre dağılımı (FAO)(Devamı)(Tekin, 2017)

Ülkeler	**Tarım Alanı(ha)**
Güney Afrika	368 000
Zimbabve	332 000
Zambiya	200 000
Mozambik	152 000
Malavi	65 000
Kenya	33 100
Gana	30 000
Tanzanya	25 000
Sudan	10 000
Madagaskar	6 000
Lesotho	2 000
Namibya	340
Güney ve Orta Afrika	**1 223 440**

Çizelge 1. Dünya genelinde toprak işlemesiz tarım alanlarının ülkelere ve kıtalara göre dağılımı (FAO)(Devamı)(Tekin, 2017)

Ülkeler	**Tarım Alanı(ha)**
Avustralya	17 695 000
Yeni Zelanda	162 000
Avustralya ve Yeni Zelanda	**17 857 000**

4. TOPRAK İŞLEMESİZ- DOĞRUDAN EKİM YÖNTEMİNİN DEZAVANTAJLARI

- Üst üste tahıl ekilişlerinde kök çürüklüğü hastalıklarında artış olabilir.
- Üst üste tahıl ekilişlerinde nematodlarda yoğunlaşma meydana gelebilir.
- Mevcut mibzerler dönüş yapmak zorunluluğu vardır.
- Toprak yüzeyinde bitki atıkları varlığını sürdürdüğü ve ortam yaşamaları için daha iyi bir ortam sağlandığından, fazla böcek ve hastalık problemleri ortaya çıkabilir.
- Ürün artıkları ile ertesi döneme hastalık veya zararlılar taşınabilir.

- İyi bir tohum-toprak teması sağlayarak tohumu nemli toprağa yerleştirebilen ve bunu yüzeydeki artıklarla tıkanmadan gerçekleştirebilen özel makinelere veya mevcut ekim makinelerin da değişikliklere ihtiyaç duyulur.

5. TOPRAK İŞLEMESİZ -DOĞRUDAN EKİM YÖNTEMİNİN AVANTAJLARI

- Toprak işleme doğrudan ekim riskini azaltır.
- Yağmurun toprağa İnfiltrasyonunu artırır ve buharlaşmayı azaltarak rutubetin toprakta tutulmasını sağlar.
- Zaman tasarrufu sağlar.
- Atmosfere sera gazı (CO_2) salınımını azaltır.
- Bitki çıkışını güçleştiren ve yüzey akışın neden olan kaymak tabakası oluşumunu engeller.

Çizelge 2. Toprak İşleme ve Ekim sistemlerinin Karşılaştırılması

Sistem	Tarla Uygulaması	Üstünlükleri	Eksiklikleri
Kulaklı Pulluk	Son bahar ve ilkbaharda sürüm	Drenajı zayıf topraklar için uygunluğu	Erozyon kontrolündeki düşüklüğü
Çizel Pulluğu	Sonbaharda çizel ile sürüm	Yüzeyi tamamıyla temiz bırakan toprak işleme sistemine göre daha az erozyon oluşumu	Toprak nem kaybının yüksek oluşu
Disk	İlkbahar veya sonbaharda diskli aletlerle işleme	Toprak karıştırabilme kabiliyetinin yüksekliği	Erozyon kontrolünün düşüklüğü
Sırta Ekime Yönelik Toprak İşleme	Sapların parçalanması, sırta ekim, yabancı ot kontrolü için bakım ve tekrar sırt oluşturma	Değişik toprak tipleri için uygunluk	Makinelerde değişikliğe gereksinim duyulması
Toprak İşlemesiz	İlaçlama ve bozulmamış yüzeye ekim	Minimum yakıt ve iş gücü gideri	Aşırı herbisit bağımlılığı

6. KORUYUCU TOPRAK İŞLEMENİN YARARLARI VE SAKINCALARI

Korumalı toprak işleme de, toprağın en az işlenmesi söz konusudur. Toprağı işleme düzeyi ve sıklığı azaltıldığında, anız veya bitki atıkları toprağa tamamen karıştırılmaz ve toprağın üzerinde bırakılır. Tohum; bu anız veya işlenmiş topraktaki küçük şeritlere ekilmektedir. Burada bu işlemler yapılırken bazı avantajlar ve dezavantajlar söz konusu olmaktadır.

Avantajları

- Yerleştirilen ürünler , suyu daha etkin bir şekilde kullanır.
- Toprağın su tutabilme kapasitesi artar.
- Yağışlardan dolayı su kayıpları ve buharlaşma azalır.
- Ekim tahininde hava koşullarına bağımlılık azalır.
- Ekim öncesi toprak işleme çalışmaları azalır, böylece iş gücü ve yakıttan tasarruf sağlanır.
- Ekim için daha az işlem yapılması, gerek traktör gerekse toprak işleme ve ekim makinelerinin daha az aşınması. Bu ise tamir ve bakım masrafları azaltır.
- Toprak yüzeyine bırakılan bitki atıkları su ve toprak erozyonunu azaltır.
- Bitki çıkışını güçleştiren ve yüzey akışa neden olan kaymak tabakası oluşumunu engeller.

Dezavantajları

Pahalı ve değişik özellikleri olan üretim ekipmanları başlangıçta yüksek yatırım maliyeti gerektirir.

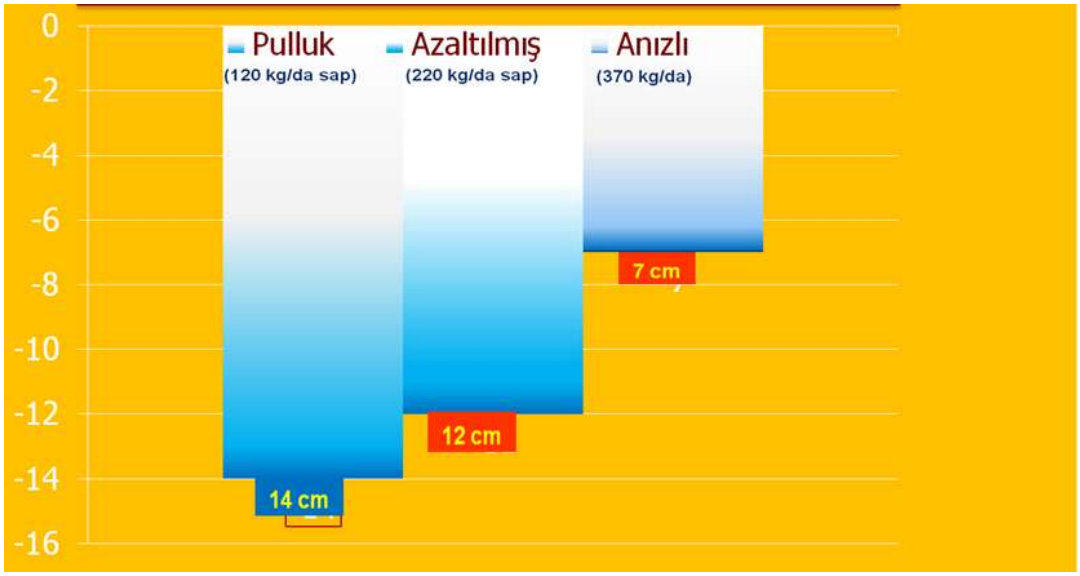
- Anız artıklarının tohumla teması toksik etki oluşturabileceğinden özel ekim makinelerinin kullanılması zorunlu olmaktadır.
- Toprak az veya hiç işlenmeyeceğinden ortaya çıkacak olan yabancı otlarla mücadele şarttır.
- Üreticilerin eğitimini gerektirir, çünkü tamamıyla yeni bir dinamiğe sahip koruyucu tarım sistemleri yüksek derecede yönetim kabiliyetine ihtiyaç duymaktadır.

7. KORUYUCU TOPRAK İŞLEMENİN ÇEVREYE SAĞLADIĞI YARARLAR

Geleneksel tarım; ürün artıklarının yakılması, yabancı ot kontrolü için derin toprak işleme gibi uygulamaları içerdiğinden, genel olarak çevre için zararlıdır. Bu teknikler toprakta sıkışıklığı arttırarak deformasyona ve erozyona neden olurken, aşırı gübre ve ilaç kullanımı sonucunda oluşan kalıntılar ile yeraltı sularının kirletilmesine de yol açarlar. Geleneksel yöntemde yer alan pulluk kullanımı ile toprağa yağmur damlalarının bombardımanı olmakta, sulama suyunun agregatlaşmamış toprak zerreciklerini sürüklemesi ile düşey erozyonla beraber taban taşı oluşumu da hızlanmaktadır.

Çizelge 3. Tarla Yüzeyinde Bulunan Bitki Artığı – Toprak Kaybı ilişkisi(Korucu ve ark.2001)

Bitki Artığı (Ton/ ha)	Yüzey Alanı (%)	İnfiltrasyon (%)	Toprak Kaybı (Ton/ ha)
0.00	45.0	54	13.00
0.63	40.0	60	7.50
1.25	25.0	74	2.50
2.50	0.5	99	0.75
5.00	0.1	99	0.00
10.00	0.0	100	0.00

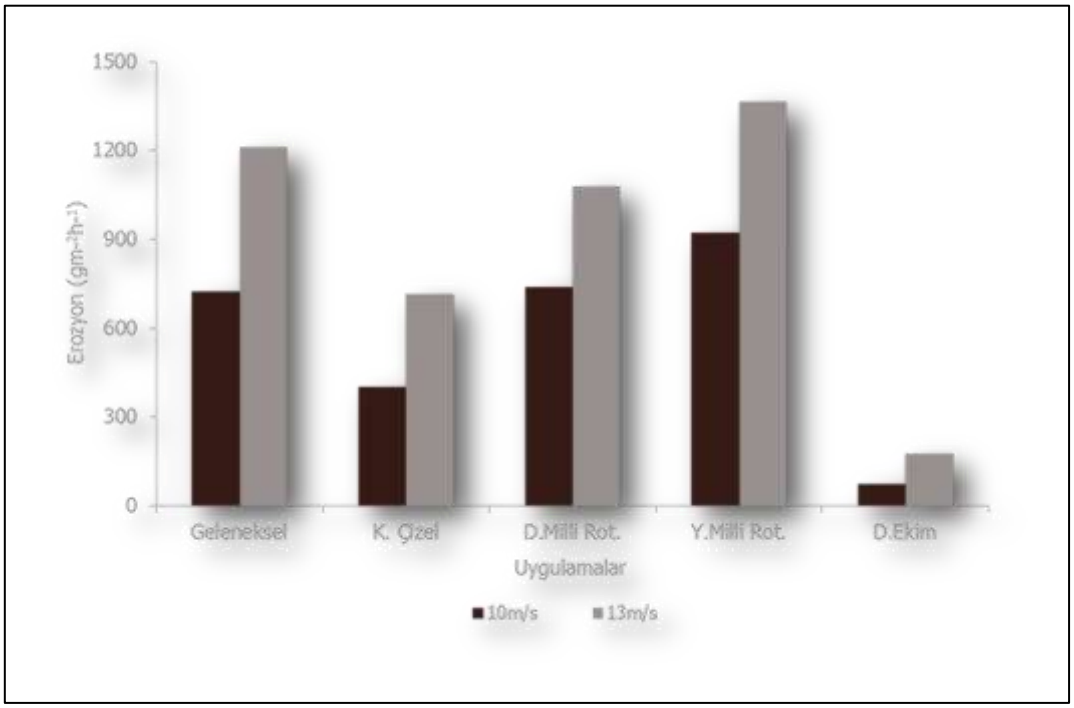


Şekil 10. Farklı toprak işleme sistemlerinde, ekim döneminde buğday tohumlarının çimlenmesi için yeterli nem seviyesinin bulunduğu toprak derinliği (Marakoğlu,T.,2010)

Her yıl erozyon nedeniyle Dünyada 75 milyar ton toprak kaybolmaktadır. Buda 9 milyon hektarlık bir tarımsal alanın kaybolması demektir. Türkiye topraklarının yaklaşık % 48 'nin ciddi erozyon tehdidi altında olduğu söylenebilir. Yanlış ve bilinçsiz toprak işlemeden kaynaklanan erozyon nedeniyle yılda 150 ton/ha' lık bir toprak kaybının meydana geldiği ortaya konmuştur. Doğrudan ekim, toprak erozyonunda %60-90 oranında azalmaya neden olmaktadır

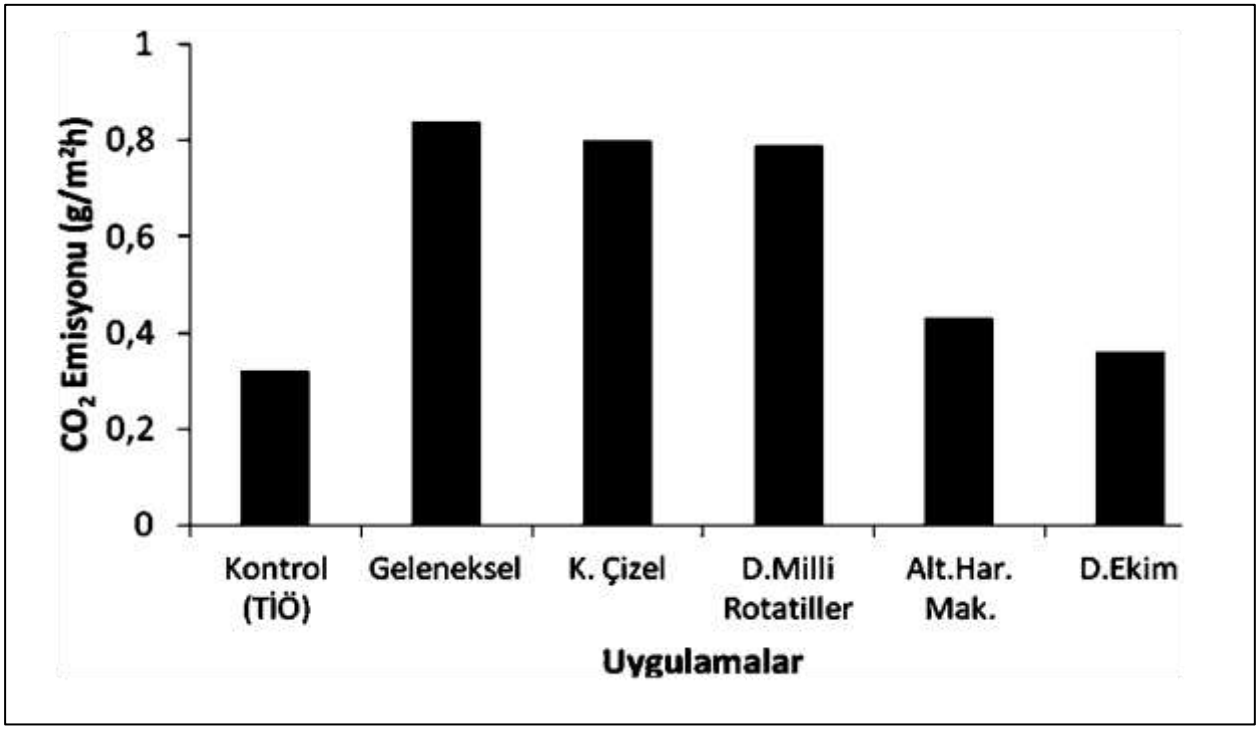
Yapılan denemeler yüzeyde çok az miktarda bitki artığının bulunmasının bile erozyonu büyük ölçüde önlediğini göstermiştir. Yüzeyde bulunan yaklaşık 500 kg/ha'lık bitki örtüsü yüzey akısını % 0.1 düzeyine indirirken, İnfiltrasyonu % 99 düzeyine çıkarmıştır. Yaklaşık 4 da

alanda 25.4 mm yağmur düşmesi ile bu alana uygulanan kinetik enerji 275,600 kpm dir. Yüzeyde bitki artığı bulunmayan tarlalarda bu enerji toprak zerrelerinin kopmasına, parçalanmasına dolayısıyla su ve rüzgar erozyonuna hassas hale gelmesine neden olur. Yüzeyde bulunan bitki artıkları bu enerjiyi absorbe ederek toprağın zarar görmesini engeller (Önal, 1995).

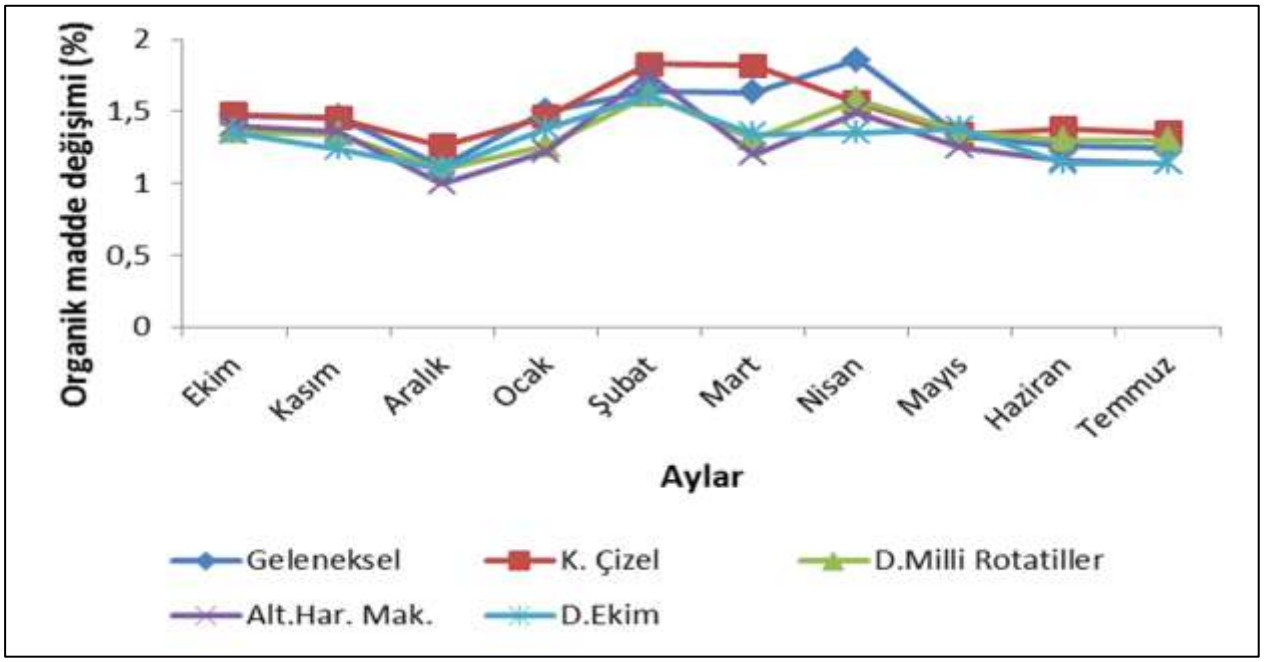


Şekil 11. Uygulamaların erozyon üzerindeki etkileri(Marakoğlu,T.,2012)

Geleneksel toprak işleme teknikleri, CO_2'in atmosfere emisyonunu arttırarak global ısınmaya neden olur. Tarımın sürdürülebilirliğini çevreye verdiği olumsuz etkiler nedeniyle azaltır.



Şekil 12. Toprak işleme tekniklerinin CO_2 emisyonu üzerinde etkisi (Talantimur,V.,2014)



Şekil 13. Toprak işleme tekniklerinin – organik madde değişimi eğrileri (Talantimur,V.,2014)

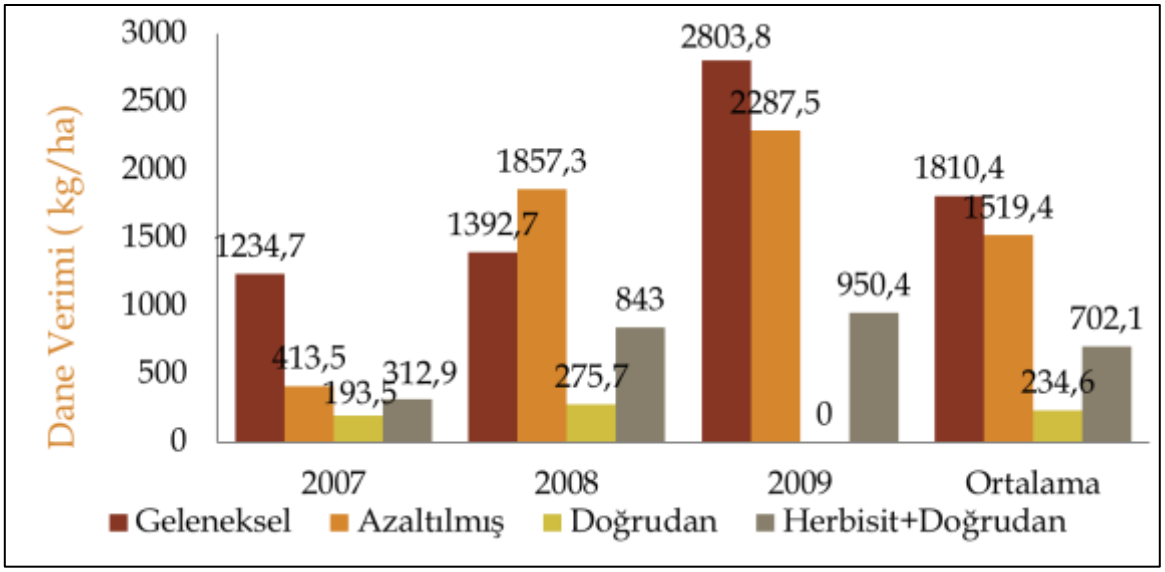
8. KORUYUCU TOPRAK İŞLEMENİN EKONOMİK AVANTAJLARI

Geleneksel toprak işleme, koruyucu toprak işlemeye özellikle sıfır toprak işlemeye göre makine yatırımı, bakım-onarımı, iş gücü bakımından daha yüksek girdilere ihtiyaç duymaktadır.

Doğrudan ekim yönteminde, tarlada sadece ekim için bir kez geçiş yapılırken, geleneksel yöntemde bu sayı en az iki veya daha fazladır. Daha az sayıda geçiş, daha az makine yıpranması ve bakım maliyeti demektir.

Özellikle çapa bitkileri ve tahıl üretimindeki koruyucu toprak işlemenin sağlamış olduğu aşağıdaki ekonomik faydalarını göz önünde bulundurmak gerekir.

- Yakıt, zaman, makine yıpranması ve işçilik tasarruf
- Üretimde düzenlilik,
- Topraktaki besin maddelerinin korunması
- Kurak iklim bölgelerinde ürün yetiştirme kolaylığı
- Çiftçilik ve yer altı sularındaki kalitenin korunması
- Devlet kredisi desteği(özellikle yurtdışında uygulanmaktadır.)



Şekil 14. Farklı Uygulamalara Ait Dane Verimi (kg/ha) (Marakoğlu,T., 2010.)

		UYGULAMALAR			
		Geleneksel Uygulama	**Azaltılmış Toprak İşleme**	**Doğrudan Ekim**	**Doğrudan Ekim (Herbisit uyg.)**
GİRDİLER					
İşgücü		**9.20**	**6.44**	**3.10**	**3.39**
Traktör		**124.81**	**90.88**	**49.82**	**58.78**
Makine		**309.35**	**216.56**	**104.32**	**115.16**
Yakıt-yağ		**2647.57**	**1895.84**	**922.64**	**1144.45**
İlaç		**360**	**360**	**360**	**720**
Gübre	**N**	**4521.6**	**4521.6**	**4521.6**	**4521.6**
	P	**1083.3**	**1083.3**	**1083.3**	**1083.3**
Tohum		**3750**	**3750**	**3750**	**3750**
TOPLAM GİRDİ		**12805.83**	**11924.62**	**10794.78**	**11396.68**
ÇIKTI	**Verim**	**25725.78**	**21591.14**	**2222.45**	**9976.84**

Şekil 16. Nohut Üretiminde Azaltılmış Toprak İşleme ve Doğrudan Ekim Uygulamalarının Enerji Bilançosu (Mj/ha)

9. SONUÇ

Ülkemizdeki tarım alanlarında sürdürülebilir, ekonomik bitki yetiştiriciliği için uzmanlarca, toprak hazırlığından hasada kadar olan dönemde araştırmalarla ortaya konulmuş en doğru yetiştirme tekniklerinin uygulamaya geçirilmesi gerekmektedir. Tarla tarımında uygulanacak toprak işlemlerinin başarılı olabilmesi için toprak profilinde nem biriktiren optimum tohum yatağı hazırlığına ihtiyaç vardır. Uygun tohum yatağı hazırlığı bölgenin iklimi, toprak tipi, arazi eğimi, ekim nöbeti, eldeki tarım aletleri ve tavsiye edilen teknik bilgilerin mutlaka göz önünde bulundurulması ile mümkündür.

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TECHNICAL AND ECONOMIC COMPARISON OF SPRAYING WITH UNMANNED AERIAL VEHICLES (UAVs) AND FIELD SPRAYERS

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ABSTRACT

Pesticides are extensively used in agricultural pest control to manage harmful organisms and prevent crop losses, making these chemicals a fundamental component of modern agriculture. However, the selection of pesticide application methods is critically important for ensuring both economic efficiency and environmental sustainability. The implementation of proper spraying techniques prevents pesticide drift to non-target areas, thereby mitigating adverse effects on ecosystems and enhancing agricultural productivity. In this context, the evaluation of spraying methods used in the agricultural sector in terms of their technical and economic dimensions is of great necessity for the development of environmentally sustainable agricultural practices. This study aims to provide comprehensive insights into the selection of effective spraying methods in agriculture, contributing to the development of sustainable practices and guiding the formulation of future agricultural strategies. The aim of this study was to compare the technical and economic aspects of spraying methods between field sprayers and unmanned aerial vehicles (UAVs), which are widely used in chemical control. Technical aspects such as technological innovation, time efficiency, operational standards, and application precision are examined. Economic factors including cost-effectiveness, return on investment periods, operating expenses, and maintenance costs are also evaluated. Furthermore, the study analyzes the pesticide drift potential of both methods, along with their impacts on ecosystems and potential threats to biodiversity. The findings reveal that, despite the high initial investment costs of UAVs, they offer lower operating costs and faster return periods in the long term. Additionally, UAVs demonstrate significant advantages over field sprayers in terms of automation, data collection capabilities, application precision, and coverage speed. Their environmentally friendly characteristics further highlight their potential to enhance agricultural productivity and minimize costs, establishing UAVs as a superior alternative to conventional field sprayers for sustainable agricultural practices.

Keywords: Field sprayers, Unmanned aerial vehicles (UAVs), Pesticide drift, Sustainable agriculture

İNSANSIZ HAVA ARAÇLARI (İHA) VE TARLA PÜLVERİZATÖRLERİ İLE YAPILAN İLAÇLAMALARIN TEKNİK ve EKONOMİK YÖNDEN KARŞILAŞTIRMASI

ÖZET

Tarımsal mücadelede, zararlı organizmaların kontrol altına alınması ve ürün kayıplarının önlenmesi amacıyla pestisitler yoğun bir şekilde kullanılmakta olup, bu kimyasallar modern tarımın temel unsurlarından biri haline gelmiştir.Ancak, pestisit uygulamalarında ilaçlama yöntemlerinin seçimi, hem ekonomik verimlilik hem de çevresel sürdürülebilirlik açısından kritik bir öneme sahiptir. Doğru ilaçlama tekniklerinin uygulanması, pestisitlerin hedef dışı alanlara taşınmasını engelleyerek ekosistem üzerindeki olumsuz etkileri azaltmakta ve tarımsal üretkenliği artırmaktadır. Bu bağlamda, tarım sektöründe kullanılan ilaçlama yöntemlerinin teknik ve ekonomik boyutlarıyla değerlendirilmesi, çevresel sürdürülebilir tarım uygulamalarının geliştirilmesi açısından büyük bir gereklilik taşımaktadır. Bu çalışmada, tarım sektöründe etkin ilaçlama yönteminin seçilmesine dair kapsamlı bilgiler sunarak, sürdürülebilir tarım uygulamalarının geliştirilmesine katkıda bulunmayı amaçlamakta ve gelecekteki tarımsal stratejilerin belirlenmesine yön vermektedir. Bu araştırmada, kimyasal mücadelede yaygın olarak kullanılan tarla pülverizatörleri ile insansız hava araçları (İHA) arasındaki ilaçlama yöntemlerini teknik ve ekonomik boyutlarını karşılaştırmalı bir şekilde incelemiştir. Çalışmada, her iki ilaçlama yöntemi çevre koruma kriterleri çerçevesinde de değerlendirilmiştir. Teknik özellikler açısından, teknolojik yenilik, zaman tasarrufu, kullanım normları, ilaçlama hassasiyeti gibi kriterler ele alınırken; ekonomik özellikler bakımından, maliyet etkinliği, yatırım geri dönüş süreleri, işletme giderleri ve bakım masrafları gibi unsurlar inceleniştir. Ayrıca her iki yöntemin ilaç sürükleme potansiyelleri ve bunların ekosistem üzerindeki etkileri ve biyoçeşitlilik üzerindeki potansiyel tehditler gibi kriterler de analiz edilmiştir. Elde edilen bulgular, İHA'ların başlangıçta yüksek yatırım gereksinimlerine rağmen, uzun vadede daha düşük işletme maliyetleri ve daha hızlı geri dönüş süreleri sağladığını ortaya koymaktadır. Ayrıca, İHA'ların otomasyon ve veri toplama yetenekleri, uygulama hassasiyeti, kaplama hızı gibi avantajları ile çevre dostu olma durumu, tarımsal üretkenliği artırma ve maliyetleri minimize etme konularında tarla pülverizatörlerine kıyasla belirgin üstünlükler sağladığı tespit edilmiştir.

Anahtar Kelimeler: Tarla pülverizatörleri, İnsansız hava araçları (İHA), İlaç sürüklenmesi, Sürdürülebilir tarım

1.GİRİŞ

Artan dünya nüfusu ile birlikte ortaya çıkan gıda maddesi ihtiyacı mevcut tarım alanlarından maksimum verim alabilmek için zirai ilaçların (pestisit) kullanımını kaçınılmaz kılmıştır. Birleşmiş Milletler Gıda ve Tarım Örgütü verilerine göre 2019 yılı dünya pestisit kullanımı 4,16 milyon ton olarak gerçekleşmiştir. Pestisit grupları itibarıyla değerlendirildiğinde %53,3'ünü herbisitler, %23,2'sini fungisit ve bakterisitler ve %16,7'sini de insektisitler oluşturmaktadır. Pestisitlerin aşırı kullanımı, tarımda verimliliği artırmak amacıyla yaygın olarak başvurulan bir yöntem olmasına rağmen, çeşitli çevresel ve sağlık sorunlarına yol açabilir. Aşırı pestisit tüketimi, çevre kirliliği, biyoçeşitlilik kaybı, toprak kalitesinin bozulması, su kirliliği, insan sağlığı üzerindeki olumsuz etkiler ve zararlı organizmaların pestisitlere karşı direnç geliştirmesi gibi sorunlara neden olabilir (Aktar ve ark., 2009). Aşırı pestisit kullanımı, ile oluşan ilaç sürüklenmesi çevresel kirlilik, biyoçeşitlilik kaybı ve insan sağlığı üzerinde olumsuz etkiler yaratabilir (Pimentel & Levitan, 1986). Tarımda kullanılan geleneksel tarla pulverizatörleri, geniş alanları kapsayarak ilaçlama işlemlerini gerçekleştirmekte, ancak bu süreçte bazı olumsuzluklar ortaya çıkmaktadır. Pulverizatörlerin hassasiyet eksikliği, ilaç sürüklenmesi riskini artırarak çevresel kirliliğe yol açabilir. Ayrıca, gereğinden fazla pestisit kullanımı ekonomik kayıplara ve çevresel zararlara neden olurken, ağır makinelerin tarlada sık kullanılması toprak sıkışmasına sebep olarak bitki köklerinin gelişimini engelleyebilmektedir. Bu yöntemler ayrıca daha fazla zaman ve iş gücü gerektirmektedir, bu da verimliliği olumsuz etkileyebilir. Bu durum, pestisitlerin doğru miktarda ve uygun koşullarda uygulanması ve alternatif tarım yöntemlerinin araştırılmasını gerektirmektedir. Bu kapsamda tarımda pestisit uygulamalarında, verimliliği artırmak ve maliyetleri düşürmek amacıyla çeşitli teknolojik yenilikler benimsemektedir. İnsansız Hava Araçları (İHA) bu yeni nesil sistemler arasında önemli bir yer tutmaktadır. İHA (UAV/UAS (Unmanned Aerial Vehicle/Systems)), uluslararası mevzuatta pilotun (operatör) içinde insan ve silah olmayan uçağa uzaktan kumanda ile kontrol etmesine (Manual uçuş) veya pilot müdahalesi söz konusu olmayıp, tamamen uydu kontrollü (Otomatik uçuş) kullanıma sahip olan cihazlara denilmektedir (Kahveci ve Can, 2017). Bu ilaçlama sisteminin ilaçlama süreçlerinde avantajları ve dezavantajları bulunmaktadır. Bu bağlamda, ilaç kullanım normları, sürüklenme potansiyelleri, operatör becerisi ve dekar başına düşen ekonomik değerlendirmeler gibi faktörler kritik öneme sahiptir.

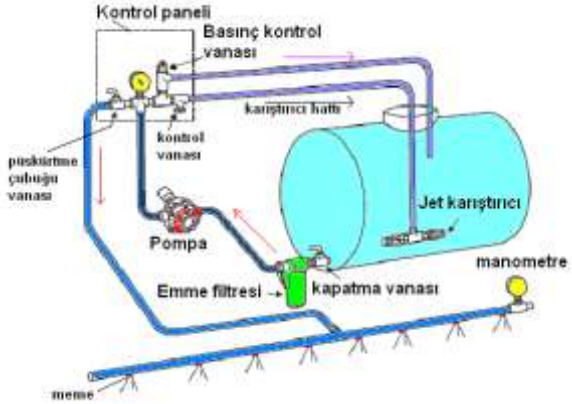
Bu araştırmada amaçlanan, kimyasal mücadelede yaygın olarak kullanılan tarla pülverizatörleri ile insansız hava araçları (İHA) arasındaki ilaçlama yöntemlerini teknik ve ekonomik olarak karşılaştırmaktır. Çalışmada, her iki ilaçlama yöntemi çevre koruma kriterleri çerçevesinde de değerlendirilmiştir.

2. MATERYAL VE YÖNTEM

Çalışmada tarla pülverizatörü ve İnsansız Hava Aracı yöntemleri değerlendirmeye alınmıştır. her iki yöntemin teknik özellikleri incelenmiş; uygulama hassasiyeti, alan kaplama hızı ve kullanıcı dostu olma gibi faktörler değerlendirilmiştir.

TARLA PÜLVERİZATÖRÜ İLE İLAÇLAMA TEKNİĞİ

Depodaki sıvı, bir pompanın sıvıya kazandırdığı basınç enerjisi ile memelere aktarılmakta ve damlalar halinde parçalanarak hedefe iletilmektedir (Şekil 1). Stardart tip mekanik bir tarla pülverizatörü depo,pompa, regülatör, manometre, dağıtım Vanaları, karıştırıcı ve memelerden oluşmaktadır.



Şekil 1. Tarla Pülverizatörü şematik görünümü

İNSANSIZ HAVA ARAÇLARI (İHA) İLE İLAÇLAMA TEKNİĞİ

Tarımda giderek popülerleşen bir yöntemdir. İHA'lar, hassas tarım uygulamaları için idealdir. Küçük ve orta ölçekli arazilerde, özellikle erişimi zor veya hassas bitkilerin olduğu alanlarda kullanılır. İHA (UAV/UAS uluslararası mevzuatta pilotun (operatörün) içinde olmadığı ve uydu kontrollü (otomatik uçuş) cihazlardır. İHA 'lar kontrol kartına bağlı sürücü ve pompa yardımıyla tankdaki sıvıyı basınçlı olarak memelere ulaştırarak püskürtme işlemi gerçekleştirmektedir (Şekil 2).

1-
2-
3- Şekil 2. İHA İlaçlama mekanizması diyagramı

İHA ilaçlama deposu, genellikle hafif ve dayanıklı malzemelerden üretilir ve taşıma kapasitesine uygun boyutlarda tasarlanır. Pompa sistemi, ilacın sabit bir basınçla püskürtülmesini sağlar ve pompanın akış hızı ve basıncı, ilaçlama verimliliğini doğrudan etkiler

ve bitki yüzeyine optimal miktarda ilacın ulaşmasını sağlar. İHA üzerinde 2 farklı tip püskürtme memeleri bulunmaktadır, bunlar Hidrolik memeli sistem ve Santrifüj (döner diskli) sistemlerdir.

Hidrolik Memeli Püskürtme Sistemi: Sıvı, pompa yardımıyla basınç altında memelere iletilir ve püskürtülür. Bu sistem daha düşük maliyetli ve düşük enerji tüketimine sahiptir ancak düşük akış hızı oluşur ve damlacık boyutunun ayarlanması zordur.

Santrifüj (Döner diskli) Püskürtme Sistemi: Sıvı, dönen bir disk veya çark üzerine dağıtılır ve santrifüj kuvveti ile püskürtülür. Yüksek Akış Hızı (12L/min), homojen damlacıklar üretir, ayrıca damlacık boyutu ayarlanabilir (50 – 500 mikron) ve düşük basınç ve enerji gereksinimi ile hassas uygulamalar için uygundur.

Her iki ilaçlama sistemi Teknik özellikler bakımından incelenerek bu özellikler bakımından karşılaştırmalar yapılmıştır (Tablo 1).

Tablo 1. Tarla pülverizatörü ve İHA İlaçlamanın Teknik Bakımından Karşılaştırması

Özellik	**Tarla Pülverizatörü**	**İnsansız Hava Aracı**
İlaç Kullanım Normları	200-400 litre/hektar	20-40 litre/hektar
Zaman Tasarrufu	5-10 hektar/saat	10-15 hektar/saat
Hassasiyet	Düşük	Yüksek
Sürüklenme Potansiyeli	%25	%15
Çevresel Etkiler	Yüksek ilaç israfı	Düşük ilaç israfı
Operatör Bilgi Gereksinimi	Orta	Yüksek
Biyolojik etkinlik	Orta	Yüksek

İlaç Kullanım Normları: İHA'lar, hektar başına 10-20 litre ilaç kullanarak daha az ilaç kaybı sağlar (Zhang ve ark., 2021). Tarla pülverizatörleri ise hektar başına 200-400 litre ilaç kullanmakta olup, bu durum daha fazla ilaç tüketimine ve dolayısıyla maliyet artışına yol açmaktadır (Lee ve Kim, 2021).

Zaman Tasarrufu : İHA'lar ile ilaçlamanın daha hızlı gerçekleştirilmesine olanak tanır (Zhang ve ark., 2021). Ortalama depo kapasitesinde bir İHA, saatte 10-15 hektar arazi ilaçlayabilir (Alkan ve Ertuğrul, 2022). Tarla pülverizatörleri ise saatte 5-10 hektar ilaçlama yapılabilmektedir (Garcia ve Chen, 2021).

Hassasiyet: İHA'lar, yüksek hassasiyetle ilaçlama yapabilmeleri sayesinde, hedef bitkilere daha az zarar verirken, ilaç kayıplarını da minimum seviyeye indirir (Chen ve ark., 2020). Tarla pülverizatörleri ise genellikle daha düşük hassasiyete sahiptir; bu da ilaçların hedef dışına taşınma riskini artırmaktadır (Hernandez ve ark., 2022).

Sürüklenme Potansiyeli: İHA'ların sürüklenme potansiyeli, rüzgar koşullarına bağlı olarak %15 olarak belirlenmiştir (Zhang ve ark., 2021). Rüzgar hızı arttıkça, ilaçların hedef dışına taşınma

oranı da artmaktadır. Tarla pülverizatörlerinde ise sürüklenme oranı %25 olarak belirlenmiştir (Hernandez ve ark., 2022). Bu durum, çevresel kirliliği arttırmakta ve hedef bitkilere zarar verebilmektedir.

Çevresel Etkiler: İHA'ların hassas uygulama yetenekleri, çevresel etkileri azaltma kapasitesine sahipken (Zhang ve ark., 2021), tarla pülverizatörleri daha yüksek ilaç israfı nedeniyle çevresel kirliliğe yol açmaktadır (Hernandez ve ark, 2022).

Operatör Beceri Gereksinimi: İHA kullanımı, teknik bilgi ve deneyim gerektirdiği için operatör becerisi yüksek olmalıdır (Martinez ve ark., 2022). Bu durum, bazı çiftçiler için engel teşkil edebilir. Tarla pülverizatörlerinde ise operatör becerisi orta seviyededir; deneyimli operatörler daha etkili bir şekilde ilaçlama yapabilir (Lee ve Kim, 2021).

Biyolojik Etkinlik Durumu: Yapılan bazı araştırmalarda , insansız hava araçlarının tarımda biyolojik etkinlik açısından geleneksel tarla pülverizatörlerine göre belirgin avantajlar sunduğunu göstermektedir. Örneğin Patil ve ark. (2024) pamuk bitkisinde İHA kullanımının, geleneksel pülverizatörlere göre %20 daha yüksek verimlilik gösterdiğini ve İHA'ların, pestisit uygulamalarında daha az ilaç kullanarak %30 daha az çevresel etki yarattığını belirtmiştir.

Her iki ilaçlama sistemi ekonomik özellikler bakımından incelenerek bu özellikler bakımından karşılaştırmalar yapılmıştır (Tablo 2).

Tablo 2. Tarla Pülverizatörü ve İHA İlaçlamanın Ekonomik Bakımından Karşılaştırması

Özellik	**Tarla Pülverizatörü**	**İnsansız Hava Aracı**
Başlangıç Maliyeti	Orta (1000-3000 USD)	Yüksek (5000-20.000 USD)
İşgücü Maliyetleri	Yüksek	Düşük
Bakım Maliyetleri	Düşük (50-600 USD)	Yüksek (500-1500 USD/Yıl)

Başlangıç Maliyeti: İHA'ların başlangıç maliyetleri standart tip tarla pülverizatörlerine göre daha yüksektir. Ancak sunduğu teknolojik avantajlar, uzun vadede daha yüksek verimlilik sağlayabilir (Garcia ve Chen, 2021).

İşgücü Maliyetleri: İHA kullanımı, genellikle daha az iş gücü gerektirmektedir. İHA'lar daha az iş gücü gerektirmesi nedeniyle çiftçilere önemli bir maliyet avantajı sunmaktadır. Bu avantaj, çiftçilerin toplam girdi maliyetlerini düşürmektedir (Kumar ve Singh, 2021).

Bakım Maliyeti: Bakım maliyetleri açısından, İHA'lar genellikle daha düşük maliyetler sunmaktadır. İHA'ların bakım maliyetleri, yıllık 500 ile 1.500 USD arasında değişirken, tarla pülverizatörlerin bakım maliyetleri yıllık satış fiyatlarının yaklaşık % 10 kadar olabilmektedir (Aiswarya ve ark., 2024).

3. SONUÇ VE ÖNERİLER

İHA'lar, tarla pülverizatörlerine göre daha az ilaç kullanımı, zaman tasarrufu ve yüksek hassasiyet sunarak çevresel ilaç sürüklenme riskini azaltma potansiyeline sahiptir. Bu durum, hem ekonomik hem de ekolojik açıdan önemli avantajlar sunmaktadır.

İHA uygulamaları için ise, şu önerilerin dikkate alınması faydalı olacaktır.

- Eğitim ve Bilinçlendirme: Çiftçilere İHA teknolojileri hakkında eğitim verilmesi, teknik bilgi ve deneyim kazanmaları için seminerler düzenlenmesi.
- Destekleyici Politikalar: Tarım Bakanlığı ve ilgili kurumlar, İHA kullanımını teşvik edici destek programları geliştirmesi ile İHA'ların yaygınlaşmasını sağlayabilir.
- Araştırma ve Geliştirme: İHA teknolojisi ile pülverizasyon teknikleri ve ilaç doz çalışmaları üzerine araştırma yapılmalıdır.
- Çevresel Etki Değerlendirmesi: İHA kullanımının çevresel etkileri ve ilaç sürüklenme potansiyelleri araştırılmalıdır.

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BİTKİ KORUMA TEKNOLOJİLERİNDE YAPAY ZEKA VE TARIM MAKİNELERİNİN ENTEGRASYONU

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ÖZET

Tarımda sürdürülebilirliğin sağlanması, artan küresel nüfusun beslenebilmesi ve çevresel etkilerin azaltılması açısından büyük önem taşımaktadır. Bitki koruma uygulamaları, bu hedeflerin gerçekleştirilmesinde önemli bir rol oynamaktadır. Geleneksel yöntemlerin yetersiz kaldığı günümüzde, yapay zeka (YZ) ve modern tarım makineleri, bitki koruma süreçlerinde devrim yaratmaktadır. Görüntü işleme, sensör teknolojileri, otonom sistemler ve karar destek yazılımları sayesinde hastalık, zararlı ve yabancı otların erken tespiti mümkün olmakta; hedefe yönelik, çevre dostu ve verimli mücadele yöntemleri geliştirilebilmektedir. Özellikle görüntüleme sistemleri, bitki dokularında oluşan anormallikleri yüksek doğruluk oranı ile analiz edebilmekte ve bu sayede müdahale sürecinin zamanında başlatılmasına olanak tanımaktadır. Bu teknolojilerin sağladığı en büyük avantajlardan biri, kaynak kullanımında önemli ölçüde tasarruf sağlamasıdır. Su, gübre ve pestisit gibi girdiler daha az miktarda kullanılmakta ve çevresel etkiler minimuma indirilmektedir.

Anahtar Kelimeler: Bitki Koruma, Yapay Zeka, Tarım Makineleri, Otonom Sistemler, Hassas Tarım

GİRİŞ,

Tarımda dijitalleşme, 21. yüzyılın en büyük dönüşüm süreçlerinden biri olarak değerlendirilmektedir. Nüfus artışı, iklim değişikliği, tarım arazilerinin azalması ve iş gücü yetersizliği gibi etkenler, geleneksel tarım yöntemlerinin artık yetersiz kaldığını göstermektedir. Bu bağlamda, özellikle bitki koruma alanında dijital teknolojilerin entegrasyonu, hem üretim verimliliğini hem de sürdürülebilirliği artırmak amacıyla büyük önem taşımaktadır.

Bitki koruma, tarımsal üretimin vazgeçilmez bir unsurudur. Bitkiler, üretim süreci boyunca birçok biyotik (hastalıklar, zararlılar, yabancı otlar) ve abiyotik (kuraklık, don, tuzluluk) stres faktörüne maruz kalmaktadır. Bu faktörlerle mücadele edebilmek için geliştirilen modern teknolojiler, artık yalnızca pestisit kullanımını değil, veriye dayalı, hedefe yönelik, zamana duyarlı müdahaleleri de kapsamaktadır.

Yapay zekâ (YZ), bu alandaki dönüşümün merkezinde yer almaktadır. Görüntü işleme, makine öğrenimi ve derin öğrenme algoritmaları sayesinde bitkilerin yaprak, sap, meyve gibi kısımlarında oluşan hastalık belirtileri çok erken safhalarda tespit edilebilmektedir. Örneğin; yaprakta meydana gelen renk değişimi, leke, deformasyon gibi belirtiler dronlar ya da sabit kameralar ile taranmakta, bu görüntüler analiz edilerek olası hastalık türleri belirlenmektedir. Geleneksel yöntemlerde gözle muayene ve manuel müdahale gerekirken, YZ destekli sistemlerde bu süreçler hem daha hızlı hem de daha hassas şekilde yönetilmektedir.

Makine öğrenimi algoritmaları, geçmişten gelen verilerle sürekli kendini güncelleyerek daha doğru tahminler yapabilmektedir. Bitki sağlığına dair veri kümeleri, hava durumu bilgileri, toprak özellikleri ve geçmiş hastalık kayıtları birleştirilerek, gelecekte oluşabilecek riskler önceden öngörülebilir. Bu da çiftçinin karar alma sürecini büyük ölçüde kolaylaştırmakta ve doğru zamanda doğru müdahalenin yapılmasını sağlamaktadır.

Nesnelerin interneti (IoT), bitki koruma teknolojilerinin bir diğer önemli bileşenidir. Tarım alanlarına yerleştirilen nem, sıcaklık, pH, yaprak ıslaklığı, toprak sıcaklığı gibi çeşitli sensörler, çevresel koşulları anlık olarak izleyebilir. Bu sensörlerden elde edilen veriler, bir merkezde toplanarak yapay zekâ sistemlerine aktarılır. Böylece, örneğin mantar hastalıklarının nemli ortamlarda daha hızlı yayıldığı bilgisiyle entegre şekilde çalışan sistem, kritik nem seviyelerine ulaşıldığında otomatik olarak ilaçlama yapılmasını önerebilir veya gerçekleştirebilir.

Otonom tarım makineleri, bu teknolojilerin sahaya yansıyan fiziksel araçlarıdır. GPS destekli traktörler, insansız hava araçları (dronlar), yer robotları ve otomatik ilaçlama makineleri, bitki koruma uygulamalarında devrim niteliğinde yenilikler sunmaktadır. Dronlar, geniş arazilerin hızlıca taranmasını ve haritalanmasını sağlar. Bu haritalar üzerinden riskli bölgeler belirlenerek yalnızca o alanlara müdahale edilir. Böylece hem pestisit kullanım miktarı azaltılır, hem de çevresel zararlar en aza indirilir.

Yapay zekâ ile donatılmış makineler, aynı zamanda hasat zamanını belirlemede, toprak analizlerinde ve ürün kalitesinin izlenmesinde de aktif rol oynamaktadır. Örneğin; meyve renginin olgunluk düzeyine göre analiz edilmesiyle en verimli hasat zamanı tespit edilebilir. Bu, hem kalite hem de raf ömrü açısından avantaj sağlar.

Tüm bu teknolojilerin entegre şekilde çalıştığı sistemlere "akıllı tarım" ya da "Tarım 4.0" adı verilmektedir. Tarım 4.0, tarımsal faaliyetlerde insan müdahalesinin en aza indirildiği, yapay zekâ ve otomasyonun temel rol oynadığı bir üretim modelini temsil etmektedir. Bitki koruma teknolojileri de bu modelin kilit noktalarından biridir. Günümüzde birçok ülkede, kamu destekli projelerle bu sistemlerin geliştirilmesi ve çiftçilere yaygınlaştırılması hedeflenmektedir.

Ancak bu süreç bazı zorlukları da beraberinde getirmektedir. Öncelikle, yapay zekâ destekli sistemlerin maliyeti hâlâ birçok küçük ölçekli üretici için yüksek seviyelerdedir. Ayrıca, bu teknolojilerin etkin şekilde kullanılabilmesi için tarım alanında çalışanların teknik bilgiye sahip olması gerekmektedir. Kırsal alanlarda internet altyapısının yetersizliği, sensör sistemlerinin düzgün çalışmasını engelleyebilmektedir. Tüm bu zorlukların aşılması için kapsamlı eğitim programlarına, altyapı yatırımlarına ve devlet destekli finansal teşviklere ihtiyaç duyulmaktadır.

Buna rağmen, uzun vadede bu teknolojilere yapılan yatırımın karşılığı oldukça büyüktür. Yapay zekâ ve dijital teknolojiler sayesinde tarımda verimlilik %20-40 oranında artabilmekte, pestisit kullanımı %30-50 oranında azaltılabilmektedir. Ayrıca bu teknolojiler sayesinde ürün kayıpları minimize edilmekte ve gıda güvenliği artırılmaktadır.

Bir diğer önemli konu da veri güvenliği ve etik kullanımdır. Tarımsal verilerin toplanması, işlenmesi ve paylaşılması sırasında çiftçilerin kişisel haklarının korunması önem arz etmektedir. Yapay zekâ sistemlerinin şeffaflığı, karar alma süreçlerinde kullanıcıya bilgi verme zorunluluğu, veri gizliliği gibi konulara dikkat edilmesi gerekmektedir.

Sonuç olarak, yapay zekâ, IoT ve otonom sistemlerin bitki koruma uygulamalarına entegrasyonu, sadece üretim miktarını artırmakla kalmamakta; aynı zamanda çevresel sürdürülebilirliği sağlamakta, kaynakları daha verimli kullanmakta ve tarımın geleceğini şekillendirmektedir. Bu dönüşüm süreci, bilgi teknolojileri ile tarımsal bilgi birikiminin birleştiği bir yapıyı zorunlu kılmaktadır. Bu sebeple, çiftçilere teknolojik okuryazarlık kazandırılması, üniversite-sanayi iş birliğinin artırılması ve tarım politikalarının bu yönde şekillendirilmesi büyük önem taşımaktadır.

GELİŞME

Tarım sektörü, dünya genelinde giderek artan nüfusun beslenme ihtiyaçlarını karşılamak, gıda güvenliğini sağlamak ve çevresel sürdürülebilirliği desteklemek gibi çok yönlü hedeflerle dönüşmektedir. Bu dönüşümde, teknolojik gelişmeler ve dijitalleşme süreci, üretimin her aşamasında büyük rol oynamaktadır. Özellikle bitki koruma alanında yapay zekâ destekli uygulamaların kullanımı, geleneksel yöntemlere göre çok daha verimli, ekonomik ve çevre dostu çözümler sunmaktadır.

Yapay zekâ (YZ), büyük veri analizinden görüntü işleme tekniklerine, otonom makinelerden karar destek sistemlerine kadar birçok bileşeni bir araya getirerek tarımda devrim yaratmaktadır. Bu sistemler sayesinde, tarım alanlarından toplanan büyük veriler (iklim bilgileri, toprak nemi, bitki sağlığı parametreleri, geçmiş zararlı ve hastalık verileri vb.) işlenerek hastalıkların ve zararlıların yayılma modelleri çıkartılabilmekte, olası tehditler öngörülebilmekte ve gerekli müdahaleler zamanında yapılabilmektedir.

Görüntü işleme teknolojileri, özellikle yapay sinir ağları ve derin öğrenme algoritmaları ile birleştiğinde, bitkilerde meydana gelen anormallikleri erken aşamada tespit edebilmekte ve yüksek doğrulukla sınıflandırabilmektedir. Örneğin, domates bitkisinde meydana gelen sararma, beneklenme, solma gibi hastalık belirtileri bu sistemler sayesinde insan gözünden çok daha hızlı ve doğru şekilde analiz edilebilmektedir. Bu teşhis verileri, otonom makinelerle entegre edilerek ilaçlamanın sadece gerekli alanlara yapılmasını sağlamakta, böylece pestisit kullanımını azaltarak çevre ve insan sağlığına olumlu katkı sağlamaktadır.

GPS ve drone teknolojileri ile desteklenen bu sistemler, tarım arazilerinde konum bazlı müdahale imkânı sunmaktadır. Bu sayede tarlanın sadece hastalık riski taşıyan alanları ilaçlanmakta, diğer alanlara gereksiz müdahale edilmemektedir. Aynı şekilde, su ve gübre kullanımı da optimize edilerek hem maliyet düşürülmekte hem de doğal kaynakların sürdürülebilir kullanımı sağlanmaktadır. Araştırmalar, bu teknolojilerin doğru entegrasyonu ile ilaç kullanımında %40'a varan azalma, ürün verimliliğinde ise %20'ye kadar artış sağlanabildiğini göstermektedir.

Yapay zekâ destekli karar destek sistemleri (DSS), geçmiş yıllara ait verileri analiz ederek çiftçilere proaktif stratejiler önermektedir. Bu sistemler, hava durumu verileriyle birlikte bitki gelişim takvimlerini analiz ederek hastalık riskinin yüksek olduğu dönemlerde uyarı verebilir. Bu sayede çiftçiler, müdahalelerini plansız şekilde değil, bilimsel temellere dayalı biçimde gerçekleştirebilir.

Sensör teknolojileri, tarımsal dijitalleşmenin temel taşlarından biridir. Toprak pH'ı, nem düzeyi, sıcaklık, yaprak ıslaklığı gibi birçok parametreyi gerçek zamanlı olarak ölçen sensörler sayesinde, tarım alanlarında anlık durum takibi yapılabilmekte ve bu bilgiler YZ sistemlerine beslenerek daha isabetli kararlar alınabilmektedir. Örneğin, bir bölgedeki nem oranı ideal seviyenin altına düştüğünde, otomatik sulama sistemleri devreye girebilmekte ya da düşük nem koşullarının bazı mantar hastalıkları için risk oluşturabileceği değerlendirilerek önleyici müdahale planları geliştirilebilmektedir.

Ancak bu gelişmelere rağmen, dijital tarım teknolojilerinin yaygınlaştırılmasında bazı yapısal sorunlar da bulunmaktadır. Öncelikle, bu teknolojilerin kurulumu ve bakımı ciddi bir maliyet gerektirmektedir. Özellikle küçük ölçekli üreticiler için bu tür yatırımlar çoğu zaman erişilebilir değildir. Ayrıca, sistemlerin etkin bir şekilde kullanılabilmesi için kullanıcıların belirli bir teknik bilgi seviyesine sahip olmaları gerekmektedir. Bu da çiftçiler için sürekli eğitim, teknik destek ve danışmanlık hizmetlerinin önemini artırmaktadır.

Devlet destekli programlar, üniversite-sanayi işbirlikleri ve AR-GE projeleri, dijital tarımın yaygınlaştırılmasında kritik rol oynamaktadır. Çiftçilerin bu teknolojilere erişimini kolaylaştırmak, altyapıyı güçlendirmek ve eğitim programlarını yaygınlaştırmak bu sürecin başarılı olması için gereklidir. Avrupa Birliği ve Amerika gibi bölgelerde dijital tarım uygulamaları kamu politikalarıyla desteklenmekte, çiftçilere hibe ve kredi kolaylıkları sağlanmaktadır. Türkiye'de de benzer şekilde Tarım ve Orman Bakanlığı tarafından yürütülen projelerle çiftçilere yönelik teknoloji destekleri artırılmaktadır.

Sonuç olarak, yapay zekâ, IoT, otonom sistemler ve sensör teknolojilerinin bitki koruma alanına entegrasyonu, yalnızca tarımsal verimliliği artırmakla kalmayıp aynı zamanda çevresel sürdürülebilirlik ve ekonomik kalkınma açısından da büyük fırsatlar sunmaktadır. Bu dönüşüm süreci, yalnızca teknoloji transferi değil, aynı zamanda kültürel ve yapısal değişimi de beraberinde getirmektedir. Tarımda dijitalleşmenin başarısı, bu teknolojilerin yerel koşullara uyarlanması, çiftçilere uygun hale getirilmesi ve uzun vadeli politikalarla desteklenmesi ile mümkün olacaktır.

SONUÇ

Tarımda dijitalleşme, son yıllarda dünya genelinde tarımsal üretimi dönüştüren önemli bir süreç haline gelmiştir. Artan nüfus, iklim değişikliği, doğal kaynakların tükenmesi ve gıda güvenliği gibi faktörler, tarım sektöründe daha verimli, sürdürülebilir ve teknolojik çözümlere olan ihtiyacı artırmıştır. Bu bağlamda, yapay zeka (YZ), nesnelerin interneti (IoT), büyük veri, sensör teknolojileri ve otonom tarım makineleri gibi dijital araçlar, bitki koruma uygulamalarının doğasını temelden değiştirme po...

Bitki koruma, tarımsal üretimin sürdürülebilirliği açısından stratejik bir alan olarak öne çıkmaktadır. Geleneksel bitki koruma yöntemleri, genellikle geniş alanlara homojen bir şekilde kimyasal ilaç uygulamasını içermekteydi. Bu yaklaşım, hem çevresel hem de ekonomik açıdan önemli sorunlara neden olmaktaydı. Gereksiz ilaç kullanımı, toprak ve su kaynaklarının kirlenmesine, yararlı organizmaların zarar görmesine ve pestlerin direnç geliştirmesine yol açmaktaydı. Dijital teknolojiler, bu problemlerle baş edebişlmek için önemli bir silah niteliğindedir

Yapay zeka destekli bitki koruma sistemleri, tarla verilerini analiz ederek hastalık ve zararlıların yayılma olasılığını tahmin edebilmektedir. Bu amaçla kullanılan algoritmalar, geçmiş yıllara ait iklim verileri, toprak nem düzeyleri, sıcaklık, rüzgar yönü ve güneşlenme gibi parametreleri değerlendirmektedir. Böylece, yalnızca mevcut durum değil, gelecekteki olası risk senaryoları da modellenebilir hale gelmektedir. Bu durum, bitki koruma önlemlerinin önceden planlanmasını ve zamanında uygulanmasını sağlar

Görüntü işleme teknolojileri de YZ sistemlerinin tarımda kullanımında büyük rol oynamaktadır. Özellikle yaprak, gövde ve meyve yüzeylerinde oluşan renk değişimleri, lekeler, deformasyonlar ve gelişim bozuklukları, YZ tabanlı görüntü analiz sistemleri tarafından yüksek doğrulukla tespit edilebilmektedir. Bu sistemler genellikle makine öğrenmesi ve derin öğrenme algoritmaları ile desteklenmekte, zaman içinde yeni verilerle kendini güncelleyebilmektedir. Bu teknolojiler sayesinde hastalık ve zararlı teşhisi kolaylıkla yapılabilmektedir

Ayrıca, bu tespitlerin ardından otonom ilaçlama sistemleri devreye girmektedir. Bu sistemler, tarla üzerinde konum bazlı çalışmakta ve sadece gerekli alanlara müdahale etmektedir. Örneğin, yapay zekâ destekli bir drone veya traktör, tarla üzerinde analiz edilen bölgeleri haritalandırmakta, zararlı bulunan alanlara hassas ilaçlama yaparken sağlıklı bölgelere hiçbir müdahalede bulunmamaktadır. Bu durum, hem ilaç kullanımında ciddi bir tasarruf sağlamakta hem de çevresel zararı minimuma indirmektedir.

Bu otonom sistemlerin etkinliği, yalnızca ilaçlama değil, aynı zamanda toprak işleme, gübreleme ve hasat gibi diğer tarımsal işlemlerde de giderek artmaktadır. YZ destekli robotlar, ekim sırasında optimum tohum yerleşimini sağlayabilmekte, gübre uygulamasında dozajı dinamik olarak ayarlayabilmekte ve hasat zamanının doğru tespitiyle ürün kalitesini artırabilmektedir. Bu tür uygulamalar, sadece üretim verimliliğini artırmakla kalmamakta, aynı zamanda çiftçilerin iş yükünü azaltarak kırsalda yaşam kalitesini artırır

Sensör teknolojileri, bu sistemlerin temelini oluşturmaktadır. Toprak sensörleri nem, sıcaklık, pH ve besin seviyeleri gibi kritik verileri anlık olarak ölçerken, bitki sensörleri ise yaprak sıcaklığı, yaprak nemi ve bitki büyüme hızı gibi parametreleri izlemektedir. Bu veriler, YZ sistemlerine gerçek zamanlı olarak aktarılmakta ve tüm bu parametreler üzerinden analizler yapılmaktadır. Örneğin, düşük toprak nemi ve yüksek sıcaklık tespit edildiğinde, bu koşulların bazı fungal hastalıklar için risk oluştur...

Drone teknolojisi ile birleşen bu sistemler, büyük arazilerde hızlı ve etkili bir veri toplama imkânı sunmaktadır. Yüksek çözünürlüklü kameralar ve termal sensörler ile donatılmış insansız hava araçları, tarlaların üzerinde uçuş yaparak, hem görüntü verilerini toplamakta hem de bitki sağlığı haritaları oluşturabilmektedir. Bu haritalar üzerinden analiz yapan YZ algoritmaları, riskli bölgeleri tespit ederek çiftçiye dijital rapor sunmakta ve önerilerde bulunmaktadır.

Karar destek sistemleri (Decision Support Systems – DSS), çiftçilere yalnızca mevcut durumu göstermekle kalmamakta, aynı zamanda olası riskleri öngörerek alınması gereken önlemleri önermektedir. Bu sistemler, geçmiş yılların verileriyle birlikte çalışarak, mevsimsel eğilimleri tespit edebilmekte ve ilaçlama-sulama programlarını optimize edebilmektedir. Yapay zekâ, bu noktada sistemin özelleştirilmesini ve kişisel tarla koşullarına göre ayarlanmasını mümkün kılmaktadır.

Bu teknolojilerin sahada kullanımına dair birçok başarılı örnek bulunmaktadır. Örneğin, Amerika Birleşik Devletleri'nde geliştirilen "See & Spray" adlı sistem, bitkiler üzerindeki zararlıları yapay görme ile tespit ederek, sadece o bölgelere pestisit püskürtülmesini sağlamaktadır. Bu uygulama, ilaç kullanımını ortalama %90 oranında azaltmakta ve aynı zamanda işçilik maliyetlerinde ciddi bir tasarruf sağlamaktadır.

Benzer şekilde, Avrupa'da yaygınlaşmaya başlayan robotik sistemler, bağcılık ve sebze üretimi gibi özel üretim alanlarında kullanılarak, hassas ilaçlama ve bitki bakımı işlemlerini gerçekleştirmektedir. Bu sistemler, gece gündüz çalışabilmekte ve insan gücüne duyulan ihtiyacı azaltarak kırsal bölgelerde tarımsal işgücü açığını kapatmaktadır.

Türkiye'de de son yıllarda dijital tarım uygulamalarına yönelik önemli adımlar atılmaktadır. Tarım ve Orman Bakanlığı'nın "Dijital Tarım Pazarı" (DİTAP) gibi projeleri, çiftçilerin dijital tarım teknolojilerine erişimini artırmayı hedeflemektedir. Bunun yanı sıra TÜBİTAK destekli Ar-Ge projeleri ve üniversite iş birlikleri ile yerli üretim tarım teknolojileri geliştirilmektedir. Ancak, bu gelişmelerin kırsal kesimde yaygınlaşabilmesi için altyapı yatırımları, teknik eğitim programları ve finansal desteklerin artması gerekmektedir

Bu dönüşüm süreci aynı zamanda bazı yapısal sorunları da beraberinde getirmektedir. Özellikle küçük ölçekli çiftçiler için teknolojiye erişim, yeterli bilgi ve beceri eksikliği önemli bir engel oluşturmaktadır. Yüksek maliyetli ekipmanların edinimi, bakım ve onarım ihtiyaçları, dijital

altyapı eksiklikleri gibi faktörler, bu sürecin önünde ciddi birer bariyer niteliğindedir. Bu nedenle devlet politikalarının ve destek mekanizmalarının, yalnızca büyük işletmeleri değil, küçük üreticileri de kapsayacaktır

Ayrıca, dijital tarımda veri güvenliği ve özel hayatın gizliliği gibi konular da göz ardı edilmemelidir. Çiftçilerin üretim süreçlerinden elde edilen verilerin kim tarafından, nasıl kullanılacağına dair yasal düzenlemeler yapılmalı ve etik kurallar belirlenmelidir. Teknoloji tedarikçileri ile çiftçiler arasındaki güven ilişkisinin sağlanabilmesi için şeffaflık, veri yönetimi ve kullanıcı dostu tasarım ön planda tutulmalıdır.

Uzun vadede YZ ve dijital tarım sistemlerinin daha yaygın hale gelmesiyle birlikte, bitki koruma yöntemlerinin de evrim geçirmesi beklenmektedir. Gelecekte, tohumdan hasada kadar tüm üretim sürecinin YZ tabanlı otomasyonla yürütüldüğü entegre sistemlerin daha fazla kullanılacağı öngörülmektedir. Bu sistemler sayesinde yalnızca ekonomik verimlilik değil, çevresel sürdürülebilirlik ve sosyal kalkınma da sağlanacaktır.

Sonuç olarak, yapay zeka ve tarım makinelerinin entegrasyonu, bitki koruma uygulamalarında çevreci, ekonomik ve etkili çözümler sunmaktadır. Bu teknolojiler sayesinde hastalık ve zararlılarla mücadele daha akılcı ve hedefe yönelik hale gelmiştir. Tarımda dijitalleşme süreci devam ettikçe, veri analitiği ve otomasyonun sağladığı avantajlar daha geniş alanlara yayılacak, üretim kalitesi artacaktır. Ancak bu dönüşüm sürecinin başarılı olabilmesi için çiftçilerin bu teknolojilere erişimi, eğitimi ve desteklenmeleri gerekmektedir

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MONITORING EARLY-STAGE CROP EMERGENCE IN OAT FIELDS USING MULTISPECTRAL UAV-BASED VEGETATION INDICES

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ABSTRACT

Monitoring early-stage crop development holds a significant role within precision agriculture practices. In particular, assessing crop emergence success and identifying irregular emergence patterns are critically important for timely and accurate planning of agronomic interventions such as reseeding or fertilization. In this context, unmanned aerial vehicles (UAVs) equipped with multispectral imaging technologies enable high-resolution data acquisition across agricultural fields. This study aims to evaluate the effectiveness of vegetation indices derived from multispectral unmanned aerial vehicle (UAV) images in determining early crop emergence in oats on a farm in Kırşehir.

Field observations were made 15 days after the oat sowing date using a DJI Phantom 4 Multispectral UAV flight at a flight altitude of 30 meters. As a result of the flight, multispectral images of 0.599 hectares of oat cultivation area were obtained. NDVI (Normalized Difference Vegetation Index) and GNDVI (Green Normalized Difference Vegetation Index) maps were produced to detect plant emergence from the images obtained. The average NDVI value of these maps was determined as 0.062, and the GNDVI value as 0.224. These index values indicate an early growth stage in which the vegetation cover is still sparse but spectrally distinguishable from bare soil. The spatial distribution of both indices proved effective in detecting emergence problems, particularly in low-lying areas and regions affected by soil compaction. GNDVI provided more precise differentiation of early emergence variations due to its higher spectral sensitivity to chlorophyll content than NDVI.

The research showed that, with multispectral UAV imaging technology, uniform emergence rates can be determined with high accuracy, even in the early stages of oat development Timely detection of irregular emergence or unsuccessful germination zones allows earlier and pinpoint

planning of interventions such as resowing, regional fertilization, or soil analysis in problem areas. The use of vegetation indices, such as NDVI and GNDVI, for these purposes increases the effectiveness of agricultural management decisions at the beginning of the production season and contributes to the improvement of agricultural productivity. Integrating early detection systems for crop emergence into agricultural management practices offers substantial advantages in minimizing economic losses and enhancing the effectiveness of precision agriculture applications.

Keywords: Oat, Crop emergence, Multispectral UAV, NDVI, GNDVI, Precision Agriculture

MULTİSPEKTRAL İHA TABANLI BİTKİ İNDEKSLERİ İLE YULAF TARLALARINDA ERKEN DÖNEM BİTKİ ÇIKIŞLARIN İZLENMESİ

ÖZET

Erken dönem bitki gelişiminin izlenmesi, hassas tarım uygulamaları içerisinde önemli bir yer tutmaktadır. Özellikle bitki çıkış başarısının değerlendirilmesi ve düzensiz çıkışların tespit edilmesi, yeniden ekim veya gübreleme gibi tarımsal müdahalelerin zamanında ve doğru şekilde planlanabilmesi açısından kritik öneme sahiptir. Bu doğrultuda multispektral görüntüleme teknolojileriyle donatılmış insansız hava araçları, tarım alanlarında yüksek çözünürlüklü veri elde edilmesini sağlamaktadır. Bu çalışma, Kırşehir'de yer alan bir tarım işletmesinde, multispektral insansız hava aracı (İHA) görüntülerinden türetilen bitki indekslerinin, yulafta erken dönem bitki çıkışlarının belirlenmesindeki etkinliğini değerlendirmeyi amaçlamaktadır.

Arazi gözlemleri, yulaf ekim tarihinden 15 gün sonra, 30 metre uçuş irtifasında gerçekleştirilen DJI Phantom 4 Multispectral İHA uçuşu ile yapılmıştır. Uçuş sonucunda, yulaf ekim alanına ait 0.599 hektar büyüklüğünde multispektral görüntüler elde edilmiştir. Elde edilen görüntülerden bitki çıkışlarını tespit etmek için NDVI (Normalized Difference Vegetation Index) ve GNDVI (Green Normalized Difference Vegetation Index) haritaları üretilmiştir. Bu haritalara ait ortalama NDVI değeri 0.062, GNDVI değeri ise 0.224 olarak belirlenmiştir. Elde edilen indeks değerleri, bitki örtüsünün henüz yoğunlaşmadığı, ancak bitki çıkışlarının spektral olarak algılanabildiği bir döneme işaret etmektedir. Her iki indeksin mekânsal dağılımı, özellikle düşük kotlu alanlar ve toprak sıkışmasının gözlendiği bölgelerdeki çıkış problemlerinin tespiti açısından etkili olmuştur. GNDVI, klorofile olan daha yüksek spektral duyarlılığı sayesinde, NDVI'ya kıyasla erken çıkış farklılıklarını daha net biçimde ortaya koymuştur.

Araştırma sonuçları multispektral İHA görüntüleme teknolojisiyle, yulaf gelişiminin erken dönemlerinde bile üniform çıkış oranlarının yüksek doğrulukla belirlenmesinin mümkün olduğunu göstermiştir. Düzensiz çıkış veya başarısız çimlenme bölgelerinin zamanında tespiti, sorunlu alanlarda yeniden ekim, bölgesel gübreleme veya toprak analizi gibi müdahalelerin daha erken ve kesin olarak planlanmasına olanak tanır. Bu amaçlar için NDVI ve GNDVI gibi bitki örtüsü endekslerinin kullanılması, üretim sezonunun başlangıcında tarımsal yönetim kararlarının etkinliğini artırır ve tarımsal üretkenliğin iyileştirilmesine katkıda bulunur. Bitki çıkışlarına yönelik erken algılama sistemlerinin tarımsal uygulamalara entegre edilmesi, hem ekonomik kayıpların en aza indirilmesine hem de hassas tarım uygulamalarının daha etkin biçimde uygulanmasına olanak tanımaktadır.

Anahtar Kelimeler: Yulaf, Bitki çıkışı, Multispektral İHA, NDVI, GNDVI, Hassas Tarım

1. GİRİŞ

Günümüzde tarımsal üretimde yalnızca verimliliğin artırılması değil aynı zamanda doğal kaynakların etkin kullanımı, girdi maliyetlerinin azaltılması ve karar destek sistemlerinin bilimsel verilere dayalı olarak yürütülmesi oldukça önemlidir (Gebbers & Adamchuk, 2010). Bu doğrultuda geliştirilen hassas tarım teknolojileri tarımsal alanlardaki çevresel ve yapısal değişkenliğin dikkate alındığı, arazi içi farklılıkların veriye dayalı olarak yönetildiği yeni bir uygulama mekanizmasını devreye sokmuştur (Mulla, 2013). Uzaktan algılama sistemleri hassas tarımın teknolojik altyapısında kritik bir rol üstlenir. Özellikle bu sistemin içerisinde bulunan ve gelişmiş kamera sensörlerle donatılmış insansız hava araçlarıyla (İHA), tarla düzeyinde yüksek mekânsal çözünürlükte ve zamansal hassasiyette veri elde edilmesini mümkün kılmaktadır (Tsouros et al., 2019; Zhang & Kovacs, 2012). Bu sayede tarımsal kararlar daha erken ve yerinde alınabilmektedir. Bu teknolojik altyapının temel bileşenlerinden biri uzaktan algılama sistemleridir. Özellikle multispektral sensörlerle donatılmış insansız hava araçları (İHA), tarla düzeyinde çok yüksek çözünürlükte ve zamansal hassasiyette veri toplamaya imkân tanımakta; bu da tarımsal kararların daha yerinde ve erken dönemde alınmasını sağlamaktadır (Hunt et al., 2010; Tripicchio et al., 2015).

Yulaf (*Avena sativa* L.) hem insan hem de hayvan beslenmesinde kullanılan önemli bir serin tahılıdır. Hayvan yemi ve insan gıdası olmasının yanında; ilaç ve kozmetik sanayisinde kullanım alanlarının artması sebebiyle özellikle son yıllarda oldukça önem kazanmıştır (Çeri & Acar, 2019; Karaman et al., 2020). Ülkemizde 142.740 hektarda tane ve 362.438 hektarda hasıl olmak üzere toplamda 505.178 hektarda yulaf tarımı yapılmaktadır (TÜİK, 2024).

Bu çalışmanın amacı yulaf tarımında multispektral İHA görüntülerinden elde edilen NDVI ve GNDVI indeksleri aracılığıyla, yulaf tarlalarında erken çıkış başarısının değerlendirilmesini sağlamak ve bu teknolojilerin uygulama potansiyelini ortaya koymaktır.

2. MATERYAL ve YÖNTEM

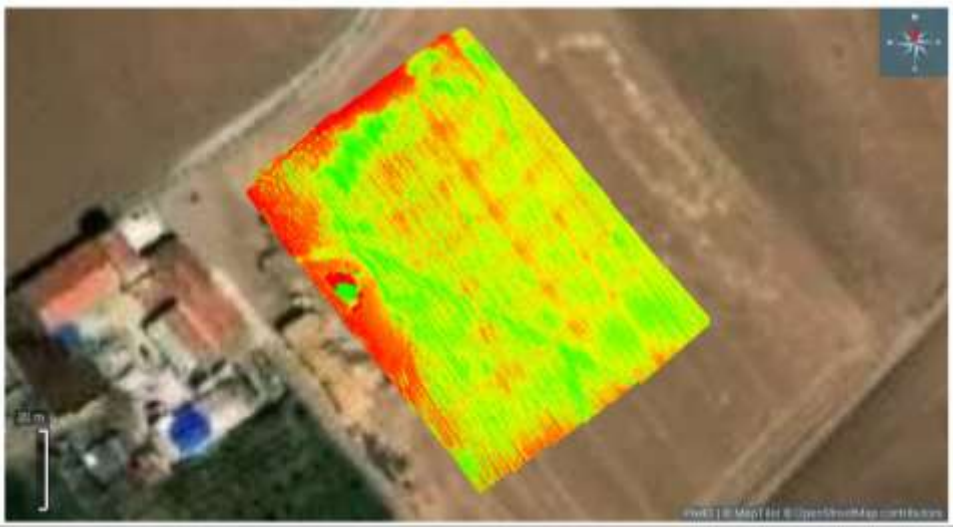
Bu çalışma, Türkiye'nin İç Anadolu Bölgesi'nde yer alan Kırşehir ilinde, 0.599 hektarlık yulaf (Avena sativa L.) ekili bir tarla üzerinde gerçekleştirilmiştir. Görüntüleme işlemi, ekimden 15 gün sonra, doğrudan güneş ışığı etkisini en aza indirmek amacıyla sabah saat 10:00 ile 11:00 arasında gerçekleştirilmiştir. Veriler, DJI Phantom 4 Multispectral insansız hava aracı (İHA) kullanılarak 30 metre irtifadan tek bir uçuşla toplanmıştır. Uçuş planlamasında, yanal örtüşme oranı %80 olarak ayarlanmış ve bu sayede görüntü mozaikleme doğruluğu artırılmıştır. Multispektral kamera sistemiyle elde edilen görüntüler, 1.545 cm/piksel Ground Sampling Distance (GSD) değerine sahiptir.

Elde edilen ham görüntüler, Pix4Dfields yazılımı kullanılarak işlenmiş ve bu süreçte görüntüler tek bir ortomozaik harita halinde birleştirilmiştir (Sekil 2.1). Daha sonra bu ortomozaik veri üzerinden bitki sağlığına ilişkin NDVI (Normalized Difference Vegetation Index) ve GNDVI (Green Normalized Difference Vegetation Index) değerleri hesaplanmıştır. NDVI ve GNDVI bitki indeksleri piksel bazlı olarak raster formatında analiz edilmiş, ve harita çıktıları üzerinden düşük yoğunluklu bitki örtüsüne sahip alanlar mekânsal olarak tanımlanmıştır.

Sekil 2.1. Araştırma sahasına ait ortomozaik harita

3. BULGULAR ve TARTIŞMA

Araştırma sonucunda ortalama NDVI bitki indeksi değeri 0.062, GNDVI değeri ise 0.224 olarak belirlenmiştir. Harita çıktıları üzerinden düşük yoğunluklu bitki örtüsüne sahip alanlar mekânsal olarak tanımlanmıştır. Elde edilen NDVI ve GNDVI haritaları, yulaf bitkisinin ekim sonrası erken çıkış dönemine ait gelişim durumunu yansıtmaktadır (Şekil 3.1 ve Şekil 3.2). Bu dönemde bitkiler henüz sık bir örtü oluşturmamış olup, spektral indeksler bitkisel örtü yoğunluğunun ve çıkış homojenliğinin değerlendirilmesine imkân tanımıştır.



Şekil 3.1. Araştırma alanına ait NDVI bitki indeksi haritası

Şekil 3.2. Araştırma alanına ait GNDVI bitki indeksi haritası

NDVI ve GNDVI değerleri incelendiğinde, GNDVI'nın klorofil ve azot duyarlılığı daha yüksek olduğundan, erken dönem çıkış farklılıklarını NDVI'ya kıyasla daha net biçimde ortaya koyduğu gözlemlenmiştir (Gitelson et al., 1996; Gnyp et al., 2014). Özellikle arazi üzerindeki düşük kotlu alanlar ile toprak sıkışmasının belirgin olduğu bölgelerde, her iki indeks üzerinden de çıkışın düzensiz olduğu alanlar mekânsal olarak belirlenmiştir. Bu farklılıkların, tarla içi değişkenliklerin erken dönemde haritalanmasına olanak tanıdığı daha önceki çalışmalarda da vurgulanmıştır (Bendig et al., 2014; Madec et al., 2017). Böylece, NDVI ve GNDVI'nin birlikte kullanımı, üreticilerin çıkış problemlerinin yoğunlaştığı bölgelere yönelik ve hedefe odaklı müdahaleler geliştirmesine ya da uygulamasına olanak sağlamaktadır.

Ayrıca bu indeksler aracılığıyla elde edilen mekânsal veri, geleneksel gözleme dayalı yöntemlere kıyasla daha hızlı, tekrarlanabilir ve nesnel analizler yapılmasına imkân tanımaktadır. GNDVI'nin yeşil bant üzerinden hesaplanması, erken dönemde klorofil miktarındaki küçük farklılıkları algılayabilme kapasitesini artırmış ve bu durum bitkiler henüz homojen bir yaprak alanı oluşturmadan çıkış sorunlarının tanımlanmasını mümkün kılmıştır. Çeşitli çalışmalar, yeşil bant temelli indekslerin özellikle azot yönetimi ve erken bitki gelişim dönemlerinde NDVI'ya kıyasla daha yüksek duyarlılık ve doğruluk sunduğunu ortaya koymuştur (Gitelson et al., 1996; Gnyp et al., 2014). Elde edilen bulgular, İHA tabanlı multispektral görüntülemenin yalnızca genel bitki sağlığının izlenmesinde değil, aynı zamanda erken dönem çıkış başarısının değerlendirilmesinde de etkili bir yöntem olarak kullanılabileceğini ortaya koymaktadır.

4. SONUÇ

NDVI ve GNDVI haritalarının birlikte kullanımıyla elde edilen erken fenolojik döneme ait uzamsal indeks çıktıları, sezon boyunca uygulanacak tarımsal yönetim stratejileri için önemli bir temel oluşturabilir. Özellikle İHA tabanlı multispektral görüntüleme teknolojisi, bitkilerin

çıkış dönemine ait mekânsal farklılıkları belirleyerek, üreticiye alan bazlı müdahale imkânı sunmaktadır. Bu sayede, tarla içi heterojenlik erken evrede tespit edilerek, verim kaybının engellenmesi ve kaynakların daha etkin kullanılması mümkün hale gelmektedir.

Araştırma sonuçları hassas tarım uygulamaları içinde önemli bir yeri olan İHA tabanlı multispektral görüntülemenin, erken bitki çıkışlarının izlenmesinde etkin bir araç olduğunu ortaya koymuştur. Spektral indekslerin mekânsal dağılımının çözümü, çıkış düzensizliklerini ve zeminle ilişkili çevresel faktörleri açığa çıkararak, müdahale stratejilerinin hem zamanlamasını hem de mekânsal hassasiyetini geliştirme potansiyeline sahiptir. Bu yöntemin tarımda yaygınlaşması, yalnızca ekonomik kayıpların azaltılmasına değil, aynı zamanda çevresel sürdürülebilirliğin güçlendirilmesine de önemli katkılar sunacaktır.

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AN INVESTIGATION OF NUTRITION STATUS IN OLIVE (*Olea europaea* L.) GARDENS IN ONIKİŞUBAT (KAHRAMANMARAŞ) COUNTY BASED ON SOIL AND LEAF ANALYSIS

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ABSTRACT

This study was conducted to determine the physical and chemical properties as well as the macro and micro nutrient element contents of soils from olive (Olea europaea) orchards. In the analyzed soil samples, sand, silt, and clay contents ranged between 30.51–73.40%, 12.00–40.42%, and 11.11–39.01%, respectively, and the soils were generally classified as sandy clay loam and sandy loam in terms of texture. Soil pH values ranged from 7.15 to 8.18, indicating that most of the soils were mildly alkaline. Organic matter contents varied between 0.98% and 3.52%, with approximately 60% of the soils found to be deficient. The EC (soluble salt) values of all samples fell within the non-saline class, while $CaCO_3$ contents ranged from 2.53% to 24.31%, indicating that the soils were rich in lime. Among the macro nutrients, phosphorus and potassium were mostly found at sufficient levels, calcium was high, whereas magnesium was generally below the threshold. Of the micro nutrients, iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) were generally present in adequate amounts; however, zinc deficiency was observed in some samples. Leaf analysis supported these findings and revealed nutritional deficiencies in some orchards, particularly in phosphorus, magnesium, and zinc. It was also evaluated that the high lime content could reduce the availability of phosphorus and certain microelements, negatively affecting plant nutrition. In conclusion, although the soils in these olive orchards generally possess favorable properties, deficiencies in organic matter and some essential nutrients pose potential constraints for sustainable productivity. Therefore, strategies aimed at increasing soil organic matter and implementing conscious fertilization practices based on regular soil and leaf analyses are recommended.

Keywords: olive, *Olea europaea*, soil properties, leaf analysis

ONİKİŞUBAT (KAHRAMANMARAŞ) İLÇESİNDEKİ ZEYTİN (*Olea europaea* L.) BAHÇELERİNDE TOPRAK VE YAPRAK ANALİZLERİNE DAYALI BESLENME DURUMUNUN İNCELENMESİ

ÖZET

Bu çalışma, zeytin (*Olea europaea*) yetiştirilen bahçelerdeki toprakların fiziksel ve kimyasal özelliklerinin yanı sıra makro ve mikro besin element içeriklerini belirlemek amacıyla yürütülmüştür. İncelenen toprak örneklerinde kum, silt ve kil oranları sırasıyla %30.51-73.40, %12.00-40.42 ve %11.11-39.01 arasında değişmiş; genel olarak kumlu killi tın ve kumlu tın tekstür sınıflarında yer almıştır. Toprakların pH değerleri 7.15–8.18 aralığında olup, çoğunluğu hafif alkali karakter göstermektedir. Organik madde içerikleri %0.98-3.52 arasında değişmiş ve toprakların yaklaşık %60'ının yetersiz düzeyde olduğu belirlenmiştir. EC (çözünebilir tuz) değerleri tüm örneklerde tuzsuz sınıfa girmekte; $CaCO_3$ içerikleri ise %2.53-24.31 aralığında seyrederek toprakların kireççe zengin olduğunu göstermektedir. Makro besin elementlerinden fosfor ve potasyum çoğunlukla yeterli düzeyde tespit edilmiş; kalsiyum içeriği yüksek, magnezyum ise sınır değerin altında bulunmuştur. Mikro besin elementlerinden demir (Fe), mangan (Mn), bakır (Cu) ve çinko (Zn) genellikle yeterli seviyelerde olmakla birlikte, Zn eksikliği bazı örneklerde gözlemlenmiştir. Yaprak analizleri de bu bulguları desteklemiş; özellikle fosfor, magnezyum ve çinko yönünden bazı bahçelerde beslenme yetersizlikleri tespit edilmiştir. Yüksek kireç içeriklerinin fosfor ve mikro elementlerin yarayışlılığını azaltabileceği ve bu durumun bitki beslenmesi üzerinde olumsuz etkiler oluşturabileceği değerlendirilmiştir. Sonuç olarak, zeytin yetiştirilen bu topraklar genel olarak uygun özellikler taşısa da, organik madde yetersizliği ve bazı besin element eksiklikleri, sürdürülebilir verim açısından potansiyel sorun oluşturmaktadır. Bu nedenle, düzenli toprak ve yaprak analizlerine dayalı bilinçli gübreleme uygulamaları ile toprak organik madde düzeyinin artırılmasına yönelik stratejiler geliştirilmelidir.

Anahtar kelimeler: zeytin, *Olea europaea*, toprak özellikleri, yaprak analizleri

1. GİRİŞ

Zeytin (*Olea europaea* L.), özellikle Akdeniz iklimi başta olmak üzere, dünya genelinde farklı iklim bölgelerinde yetiştirilebilen önemli bir tarım ürünüdür. Zeytin yetiştiriciliği, hem ekonomik hem de çevresel açıdan büyük bir öneme sahiptir, çünkü bu bitki, su kaynaklarının sınırlı olduğu bölgelerde bile verimli bir şekilde yetişebilme kapasitesine sahiptir (Makhlouf ve M'Hamdi, 2020). Zeytinyağı, içerdiği antioksidanlar ve tekli doymamış yağ asitleri sayesinde kardiyovasküler hastalıklar başta olmak üzere çeşitli kronik hastalıklara karşı koruyucu etkiler göstermektedir (Cicerale ve Keast, 2012). Ayrıca, zeytin ağacı çevresel açıdan büyük bir öneme sahiptir; zeytinlikler, toprak erozyonunun engellenmesine ve biyolojik çeşitliliğin korunmasına katkı sağlamaktadır (Gómez ve García, 2012).

Türkiye, zeytin üretiminde dünya sıralamasında üst sıralarda yer almakta olup, hem sofralık zeytin hem de zeytinyağı üretimi açısından önemli bir potansiyele sahiptir. Bu üretim potansiyeli içinde Kahramanmaraş, son yıllarda zeytin tarımının yaygınlaştığı önemli illerden biri olarak öne çıkmaktadır (Çolak ve Özkan, 2017). Akdeniz, Doğu Anadolu ve Güneydoğu Anadolu iklim kuşaklarının kesişim noktasında yer alan Kahramanmaraş, bu yönüyle farklı agroekolojik özellikler göstermekte ve bu durum zeytin tarımı açısından hem fırsatlar hem de bazı sınırlılıklar yaratmaktadır. Kahramanmaraş, zeytin yetiştiriciliği için uygun iklim ve toprak koşullarına sahip bir bölgedir. Akdeniz iklimi özellikleri gösteren bu bölgede, zeytin yetiştiriciliği, özellikle kış mevsimlerinin ılıman geçmesi ve yaz mevsimlerinde sıcaklıkların yüksek olmasının etkisiyle yaygındır.

Zeytin yetiştiriciliğinde optimum verim ve kaliteye ulaşmak, uygun toprak koşullarının sağlanmasına doğrudan bağlıdır. Zeytin bitkisi, iyi drene olmuş, hafif asidik veya nötr pH seviyesine sahip, organik maddece zengin ve mineral içeriği yüksek topraklarda sağlıklı gelişim göstermektedir (Yılmaz, 2015). Kahramanmaraş'ta zeytin yetiştirilen topraklar; iklimsel farklılıklar, topografik yapı ve jeolojik özelliklere bağlı olarak çeşitlilik göstermekte, bu da toprak özelliklerinin yerel düzeyde analiz edilmesini gerekli kılmaktadır. Özellikle toprak pH'ı, tuzluluk seviyesi, kireç içeriği, organik madde miktarı ve su tutma kapasitesi gibi faktörler, zeytin ağaçlarının gelişimi üzerinde belirleyici rol oynamaktadır (Tosun, 2014; Pekcan ve ark., 2021).

Kahramanmaraş, Türkiye'nin zeytin yetiştiriciliği yapılan illerinden biri olup, bu ilde zeytin yetiştiriciliği her geçen yıl artan bir ivme göstermektedir. Kahramanmaraş, Doğu Akdeniz Bölgesi'nde yer almasına rağmen, iklim özellikleri açısından Akdeniz, Doğu Anadolu ve Güneydoğu Anadolu bölgelerinin geçiş noktasında yer alır. Bu durum, zeytin yetiştiriciliği açısından hem avantajlar hem de zorluklar yaratmaktadır. Zeytin bitkisi, iyi havalanan, kum, silt ve kil oranlarının uygun olduğu topraklarda iyi gelişim gösterirken, toprak özellikleri, verim ve kalite üzerinde doğrudan etkili olmaktadır (Pekcan ve ark., 2021). Kahramanmaraş'ta zeytin yetiştirilen toprakların özellikleri, bölgenin iklim koşullarına ve topografyasına bağlı olarak farklılık gösterebilmektedir. Bu toprakların pH değeri, tuzluluk oranı, kireç içeriği ve organik madde miktarı, zeytin ağaçlarının gelişimi üzerinde doğrudan etkili olmaktadır. Bölgedeki toprakların genellikle kireçli ve kalkerli yapıda olması, zeytinin yetişmesine uygun bir ortam sağlasa da, bazı yerlerde toprağın asidik veya bazik özellikler taşıması, zeytin üretiminin

verimini etkileyebilmektedir (Tosun, 2014). Ayrıca, toprak derinliği ve su tutma kapasitesi gibi faktörler de, zeytin yetiştiriciliği açısından önemli parametrelerdir.

Zeytin üretiminde gübreleme stratejilerinin belirlenmesi, toprakta bulunan besin elementlerinin miktarı ve bunların bitki tarafından alım düzeyine göre planlanmalıdır. Zeytin bitkisinde görülen bazı fizyolojik bozukluklar, çoğunlukla besin elementi eksiklikleri veya bu elementler arasındaki dengesizliklerden kaynaklanmaktadır. Bu nedenle, sürdürülebilir ve kaliteli üretim için toprakların fiziksel ve kimyasal özelliklerinin detaylı biçimde incelenmesi büyük önem taşımaktadır (Keleş-Uzel ve Çimrin, 2020).

Bu çalışmanın amacı, Kahramanmaraş ilinde zeytin yetiştirilen alanlara ait toprakların fiziko-kimyasal özelliklerini belirleyerek beslenme durumlarını incelemektir. Çalışma, bölgedeki farklı zeytinlik alanlardan alınan toprak örnekleri üzerinde yapılan analizler ışığında, toprak özelliklerinin zeytin yetiştiriciliği ile ilişkisini ortaya koymayı hedeflemektedir.

2. MATERYAL ve YÖNTEM

Çalışma alanı olan Onikişubat İlçesi, Türkiye'nin Akdeniz Bölgesi'nde yer alan Kahramanmaraş ilinin merkez ilçelerinden biridir. Coğrafi açıdan Akdeniz, Doğu Anadolu ve Güneydoğu Anadolu bölgelerinin kesişim noktasında yer alması nedeniyle geçiş iklimi özellikleri gösterir. İlçenin arazisi dağlık ve engebeli olup, kuzey ve doğu kesimlerinde yüksek rakımlı alanlar bulunur. Onikişubat ilçesinin matematiksel (enlem ve boylam) konumu yaklaşık olarak 37°30' - 38°00' kuzey enlemleri ile 36°30' - 37°00' doğu boylamları arasında yer almaktadır. Bu konumu ile Onikişubat, Türkiye'nin güney kuşağında yer almakta olup, karasal ve yarı kurak iklim özelliklerinin görüldüğü bir yerleşim birimidir.

2.1.Toprak Örnekleme ve Analiz Yöntemleri

Bu çalışmada verimlilik analizlerinin sağlıklı bir şekilde yapılabilmesi amacıyla, hastalık ve zararlılarla bulaşık olmayan, kaliteli ve yüksek verim potansiyeline sahip, verim çağındaki tesadüfen belirlenen 11 adet bahçeden toprak örnekleri alınmıştır. Örnekleme, her bahçede iki farklı derinlikten (0–30 cm ve 30–60 cm) gerçekleştirilmiştir. Toprak örnekleri, her iki ağaç taç izdüşümünün ortasından zigzaglar çizilerek alınmış ve bahçeyi temsil edecek şekilde örnekleme yapılmıştır. Elde edilen topraklar, sahada plastik bir kovada homojen şekilde karıştırılmış; ardından her örnekten yaklaşık 1–1.5 kg alınarak etiketlenmiş naylon torbalara konulmuş ve laboratuvara taşınmıştır. Laboratuvara ulaştırılan örnekler, bekletilmeden gölgede hava ile kurutulmuştur.

Kuruyan toprak örnekleri tahta tokmaklarla dövülerek, 2 mm çapındaki elekten geçirilerek analizlere hazırlanmıştır. Analize hazır topraklarda; Toprak tekstürü, Bouyoucos hidrometre yöntemi ile belirlenmiştir (Bouyoucos, 1951). Toprak reaksiyonu (pH), 1:2.5 toprak-su süspansiyonunda pH metre ile ölçülmüştür (McLean, 1982). Organik madde içeriği Walkley-Black yöntemiyle (Ülgen ve Ateşalp, 1972), kireç içeriği ise Scheibler kalsimetresi ile tekrarlamalı olarak saptanmıştır (Hızalan ve Ünal, 1966). Toplam tuz miktarı Richards (1954) yöntemine göre analiz edilmiştir. Değişebilir potasyum (K), kalsiyum (Ca) ve magnezyum

(Mg) miktarları amonyum asetat ekstraksiyonu ile (Richards, 1954), alınabilir demir (Fe), çinko (Zn), bakır (Cu) ve mangan (Mn) ise DTPA ile ekstrakte edildikten sonra atomik absorpsiyon spektrofotometresi (AAS) cihazında ölçülmüştür (Lindsay ve Norvell, 1978). Topraklarda yarayışlı fosfor (P) içeriği ise 0.5 N sodyum bikarbonat ekstraksiyonu ve mavi renk oluşumuna dayanan kolorimetrik yöntemle belirlenmiştir (Olsen ve ark., 1954).

2.2.Yaprak Örnekleme ve Analiz Yöntemleri

Seçilen bahçelerde yaprak örnekleri, kış dinlenme döneminde (Kasım-Aralık) zeytin ağaçlarının her ağacın 4 yönünden ve yıllık sürgünlerin ortasından karşılıklı yaprak çifti alınmıştır (Canözer, 1978; Eryüce, 1979). Örnekleme sırasında, ağaçların bir yıllık sürgünlerinin ortasında yer alan, güneş ışığı alan dallardaki gelişimini yeni tamamlamış yaprak çiftleri tercih edilmiştir. Örnekler, her ağacın dört yönünden dengeli bir şekilde alınarak, bireyleri temsil edecek şekilde hazırlanmıştır.

Toplanan yaprak örnekleri aynı gün laboratuvara getirilmiş, önce çeşme suyu ardından saf su ile yıkanarak yüzey kirleticilerden arındırılmıştır. Daha sonra, kurutma kağıdı ile kurutulmuş ve etüvde 70 ºC'de 48 saat sabit ağırlığa gelinceye kadar kurutulmuş ve daha sonra porselen havanda öğütülerek analiz için hazırlanmıştır (Kacar, 2014). Öğütülen yaprak örnekleri, yaş yakma yöntemi (nitrik asit + perklorik asit karışımı) ile yakılmıştır. Analizlerde, yapraklardaki fosfor (P) içeriği Vanadomolibdofosforik sarı renk yöntemi ile belirlenmiştir (Kacar, 1984). Potasyum (K), kalsiyum (Ca), magnezyum (Mg), sodyum (Na), demir (Fe), çinko (Zn), bakır (Cu) ve mangan (Mn) elementlerinin konsantrasyonları ise Atomik Absorpsiyon Spektrofotometresi (AAS) ile tespit edilmiştir (Kacar ve İnal, 2008).

3.BULGULAR ve TARTIŞMA

Bu çalışmada analiz edilen zeytinlik topraklarının fiziksel yapıları, kimyasal özellikleri ve besin elementi içerikleri değerlendirilmiştir. Tekstür analizine göre toprakların kum, silt ve kil oranları sırasıyla %30.51–73.40, %12.00–40.42 ve %11.11–39.01 arasında değişmiştir. Bu oranlar doğrultusunda topraklar genel olarak "kumlu killi tın" ve "kumlu tın" sınıfına girmektedir. Benzer şekilde, Özsayar ve Çimrin (2022) tarafından yapılan bir araştırmada da zeytinlik topraklarının büyük kısmının kumlu killi tın, killi tın, killi ve kumlu tın bünyeye sahip olduğu bildirilmiştir. Zeytin bitkisi toprak bünyesi açısından yüksek seçicilik göstermemekle birlikte, killi ve tınlı topraklarda daha iyi gelişim sergilemektedir (Llamas, 1984).

Toprakların pH değerleri 7.15 ile 8.18 arasında olup, hafif alkali karakter göstermektedir. Ülgen ve Yurtsever (1995) tarafından yapılan sınıflamaya göre toprakların %45'i nötr, %55'i hafif alkali özelliktedir. Zeytin bitkisi geniş bir pH aralığına tolerans gösterebilen bir türdür (Hartmann ve Lilleland, 1966; Özbek, 1981; Llamas, 1984).

Organik madde içeriği %0.98 ile %3.52 arasında değişmekte, ortalama %2.25 seviyesindedir. Zeytinliklerin %60'ında organik madde içeriği yetersiz olarak değerlendirilmiştir. Bu bulgu, Özsayar ve Çimrin (2022) tarafından yapılan çalışmada da desteklenmiş ve bölgedeki toprakların büyük çoğunluğunun organik madde bakımından yetersiz olduğu ortaya konmuştur.

Toprakların tuz içeriği %0.011 ile %0.13 arasında değişmektedir. Tüzüner (1990) tarafından belirtilen sınıflandırmaya göre bu değerler tuzsuz sınıfa girmektedir. Zeytin bitkisi tuza karşı orta derecede tolerans gösteren bir tür olup (Özbek, 1981; Llamas, 1984), incelenen zeytinliklerde tuzluluktan kaynaklanan herhangi bir olumsuzluk gözlenmemiştir.

Toprakların kireç ($CaCO_3$) içerikleri %2.53 ile %24.31 arasında değişmekte olup, bu da toprakların kireççe zengin olduğunu göstermektedir. Zeytin bitkisi yüksek kireç içeriğine dayanıklı olmakla birlikte, optimal gelişimini %9–19 arasında kireç içeren topraklarda göstermektedir (Hartmann ve Lilleland, 1966; Mengel ve Kirkby, 1987). Özsayar ve Çimrin (2022), benzer şekilde zeytinlik topraklarının kireç içeriklerini %1.12 ile %18.40 arasında, ortalama %2.60 olarak rapor etmiştir.

Makro ve mikro besin elementlerine ilişkin analizlerde; fosfor (P) içeriği 2.51–33.21 mg kg^{-1} arasında değişmiş, ortalama 17.68 mg kg^{-1} olarak tespit edilmiştir. Sillanpää (1990) sınıflamasına göre örneklerin %33'ü yüksek, %40'ı yeterli, %27'si düşük düzeyde P içermektedir. Potasyum (K) içeriği 112–678 mg kg^{-1} arasında değişmiş, ortalama 268 mg kg^{-1} olarak bulunmuş ve örneklerin %45'i yüksek, %55'i yeterli düzeydedir. Kalsiyum (Ca) içeriği ise %63 oranında yüksek, %37 oranında yeterli seviyededir. Magnezyum (Mg) içeriği 102–328 mg kg^{-1} arasında değişmiş ve %48.2'si yetersiz, %51.8'i yeterli bulunmuştur.

Yarayışlı mikro elementlerden demir (Fe) içeriği 0.19–12.03 mg kg^{-1} aralığında olup, ortalama 6.11 mg kg^{-1} olarak belirlenmiş; örneklerin %50'sinde yüksek, %47'sinde orta ve %3'ünde düşük düzeyde bulunmuştur. Bakır (Cu) içeriği 0.55–6.34 mg kg^{-1} arasında değişmiş ve tamamı yeterli düzeydedir. Mangan (Mn) içerikleri 3.83–12.23 mg kg^{-1} arasında değişmiş ve tüm örneklerde yeterli düzeydedir. Çinko (Zn) içerikleri %87 oranında yeterli, %13 oranında düşük düzeydedir.

Yapılan bitki analizleri sonucunda zeytin yapraklarında P oranı %0.053–0.17 arasında belirlenmiş, örneklerin %18.18'i yetersiz, %81.82'si yeterli düzeydedir. Diğer makro elementlerden kalsiyum %0.65–1.51, potasyum %0.28–0.92, magnezyum %0.11–0.41 arasında değişmiştir. Yapraklardaki Fe, Mn, Cu ve Zn içerikleri sırasıyla 39.2–182.6, 18–134, 4.05–28.32 ve 6.24–32.15 mg kg^{-1} aralığında belirlenmiştir. Söylemez ve ark. (2017), Şanlıurfa yöresinde yürüttükleri çalışmada yapraklardaki P içeriğinin %82.5 oranında yetersiz olduğunu bildirmiş, bu durumu yüksek toprak kireci ile ilişkilendirmiştir. Özsayar ve Çimrin (2022) ise P (%13.33), K (%40), Ca (%73.33), Mg (%93.33), Cu (%53.33), Mn (%26.67) ve Zn (%13.33) bakımından yapraklarda eksiklikler saptamıştır. Doran ve ark. (2008) tarafından yapılan benzer bir çalışmada, yaprakların P, K, Ca, Mg, Fe ve Mn düzeylerinin yeterli, ancak N, Zn, Cu ve B düzeylerinin yetersiz olduğu belirtilmiş ve bu durumun zeytinliklerde önemli bir beslenme sorunu oluşturduğu vurgulanmıştır.

Bu veriler, zeytinlik topraklarının kimyasal yapısında bazı besin maddeleri açısından dengesizlikler bulunduğunu ve özellikle bilinçsiz gübreleme uygulamalarının bu dengesizlikleri artırabileceğini göstermektedir.

Zeytin (*Olea europaea*) türüne ait toprağın bazı fiziksel ve kimyasal özellikleri Çizelge 1 ve 2'de verilmiştir.

Çizelge 1. *Olea europaea* türüne ait toprağın bazı fiziksel ve kimyasal özellikleri.

Bitki Türü	Kum (%)	Silt (%)	Kil (%)	Bünye sınıfı	pH	Tuz (EC) ($dS.m^{-1}$)	Kireç ($CaCO_3$) (%)	Organik madde (OM) (%)
Olea europaea	52,05	26,21	25,18	SCL	7,77	0,07	13,42	2,25

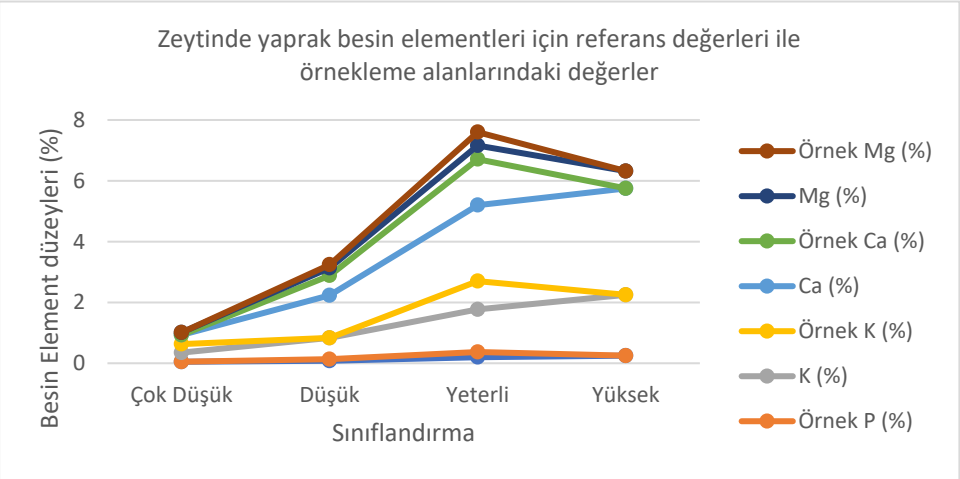
Çizelge 2. *Olea europaea* türüne ait toprağın bazı makro ve mikro besin elementleri özellikleri.

		Değişebilir katyonlar			Yarayışlı elementler			
Bitki Türü	Yarayışlı P ($mg\ kg^{-1}$)	K($mg\ kg^{-1}$)	Ca ($mg\ kg^{-1}$)	Mg ($mg\ kg^{-1}$)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)
Olea europaea	17.68	268	3350	215	6.11	8.03	3.45	2.37

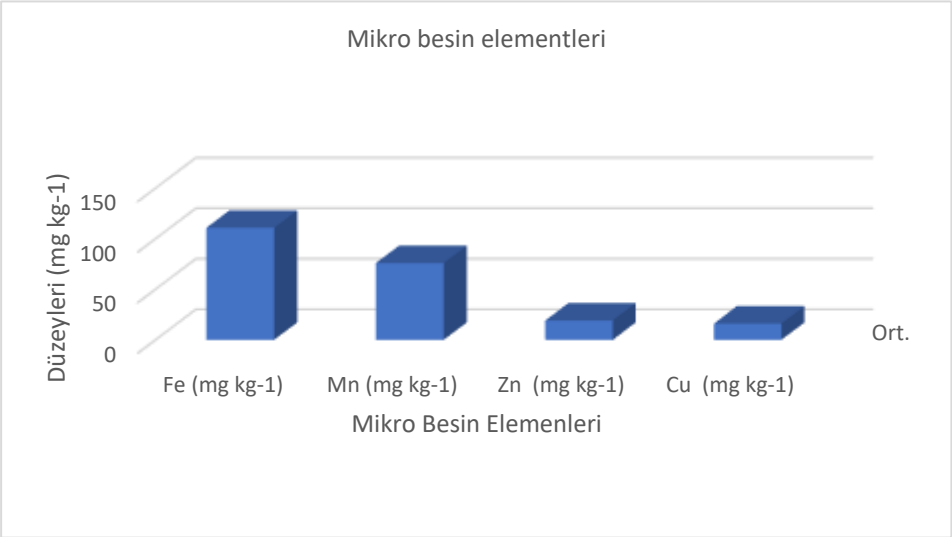
Olea europaea türü yapraklarının bazı makro ve mikro besin elementi içerikleri Çizelge 3'te verilmiştir. *Olea europaea* türüne ait yaprakların makro besin elementi konsantrasyonları sınır değerleri şekil 1'de, mikro besin elementi konsantrasyonları şekil 2'de verilmiştir.

Çizelge 3. *Olea europaea* türüne ait yaprağın makro ve mikro besin elementi içerikleri.

Bitki Türü	Aksam	P (%)	Ca (%)	K (%)	Mg (%)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)
Olea europaea	Yaprak	0.11	1.08	0.6	0.26	110.9	76.0	16.20	19.20



Şekil 1. *Olea europaea* türüne ait yaprakların makro besin elementi konsantrasyonları sınır değerleri



Şekil 2. *Olea europaea* türüne ait yaprakların mikro besin elementi konsantrasyonları sınır değerleri

4. SONUÇ

Bu çalışma kapsamında incelenen zeytin bahçesi topraklarının fiziksel ve kimyasal özellikleri ile besin element içerikleri değerlendirilmiştir. Toprak bünyesi bakımından örneklerin büyük çoğunluğunun kumlu killi tın ve kumlu tın sınıfında yer aldığı belirlenmiş, bu durum zeytin tarımı açısından elverişli bir yapı sunmakla birlikte, bazı örneklerde yüksek kil içeriği gözlenmiştir. Toprakların pH değerleri genellikle hafif alkali karakter göstermekte olup (%55), bu durum zeytin bitkisinin adaptasyon aralığı içinde yer almakta ve gelişimini olumsuz yönde etkilememektedir. Ancak, organik madde içeriklerinin ortalama %2.25 gibi düşük seviyelerde bulunması, uzun vadede toprak verimliliği ve besin elementi döngüsü açısından olumsuz sonuçlar doğurabilir.

Topraklarda tuz içeriği %0.011 - %0.13 arasında değişmekte olup, tüm örnekler tuzsuz sınıfında yer almakta ve bu açıdan zeytin yetiştiriciliği için herhangi bir tuzluluk sorunu bulunmamaktadır. Kireç içeriği ise oldukça geniş bir aralıkta (%2.53 - %24.31) dağılım göstermekte ve genel olarak kireççe zengin topraklar olarak sınıflandırılmaktadır. Yüksek kireç içerikleri, özellikle fosfor ve mikro elementlerin yarayışlılığı üzerinde olumsuz etki yapabileceğinden, bu durum dikkatle izlenmelidir. Makro besin elementlerinden fosfor (P) ve potasyum (K) düzeyleri genel olarak yeterli ya da yüksek bulunmuş, ancak bazı örneklerde P eksikliği gözlemlenmiştir. Kalsiyum (Ca) içeriği toprakların %63'ünde fazla, magnezyum (Mg) ise %48.2 oranında yetersiz seviyede bulunmuştur. Mikro elementler açısından Fe, Mn, Cu ve Zn içerikleri büyük oranda yeterli düzeyde saptanmakla birlikte, Zn eksikliği %13 oranında belirlenmiştir.

Yaprak analizlerine göre, zeytin bitkisinin makro ve mikro besin element içerikleri büyük ölçüde yeterli düzeyde olmakla birlikte, %18.18 oranında fosfor eksikliği, ayrıca bazı örneklerde potasyum, magnezyum ve çinko gibi elementlerde düşük seviyeler tespit edilmiştir. Bu eksikliklerin büyük ölçüde yüksek kireç içeriği ve düzensiz gübreleme uygulamalarından kaynaklandığı düşünülmektedir.

Sonuç olarak, çalışma alanındaki zeytin bahçesi toprakları genel olarak zeytin yetiştiriciliği için uygun özellikler göstermekte, ancak organik madde ve bazı mikro besin elementleri yönünden iyileştirmelere ihtiyaç duymaktadır. Bu bağlamda, dengeli gübreleme programlarının uygulanması, organik madde düzeyinin artırılmasına yönelik tedbirlerin alınması ve düzenli toprak-yaprak analizleriyle izleme çalışmalarının sürdürülmesi önerilmektedir.

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FROM ORGANIC WASTE TO FISH FEED: *Eisenia fetida* BIOMASS IN BIOGAS RESIDUE AND OLIVE MILL WASTEWATER BY VERMICOMPOSTING FOR AGRICULTURE AND AQUACULTURE NUTRIENT INTEGRATION

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ABSTRACT

This study presents the evaluation of the preliminary data from a comprehensive project. The umbrella project, titled "TR.AQUA: Innovative and Sustainable Practices in Aquaculture within the Framework of Food Supply Security", is supported by the TÜBİTAK-1004 program. Comprising 16 sub-projects, the initiative aims to generate high-level technology. Our research group contributes with the project titled "From Organic Waste to Fish Feed", which brings together various disciplines and is expected to yield valuable outcomes for sustainable food production while positively impacting fish and plant producers socioeconomically and technologically.

The project aims to integrate earthworm-based vermicompost production with fish and plant cultivation. The key topics include: utilization of organic waste, vermicompost production, biochemical composition (fatty acids, lipids, antioxidant defense system etc.). of composting worms, the use of obtained vermicompost in plant cultivation, and the incorporation of composting worms into fish feed rations. This particular study focuses on evaluating the vermicomposting process of organic wastes. The selected organic wastes were solid digestate from a biogas plant (BD) and liquid olive mill wastewater (OMWW). Cattle manure (CM), the natural habitat of composting worms, was used as the primary substrate. *Eisenia fetida* was selected as the vermicomposting species.

Biogas digestate and OMWW were studied as two separate waste types. To determine optimal mixing ratios for the vermicomposting process, cattle manure was mixed with these wastes at 0%, 25%, 50%, 75%, and 100% ratios. Due to its solid form, BD was mixed with manure following principles of solid blending, whereas OMWW was applied by replacing the water used for moistening the vermicomposting piles (consisting of 100% cow manure) with the liquid waste.

This study evaluated the reproductive performance of the worms to determine ideal mixing ratios, using parameters such as cocoon count, number of hatchlings, and worm biomass. The experiment lasted for 90 days, considering the reproductive cycle of the worms. All experimental bins were maintained at 70% field capacity moisture throughout the trial. At the end of the experiment, worm counts were conducted in each bin, and chemical analyses were performed on initial materials and mixtures.

Results indicated that 25% and 50% biogas digestate mixtures were optimal. However, OMWW, even at the lowest tested concentration (25%), had a toxic effect; although worms survived in this mixture, no reproduction occurred, and higher concentrations caused rapid mortality. These findings suggest that OMWW requires further investigation at significantly lower concentrations to be viable for vermicomposting.

Keywords: Vermicomposting, *Eisenia fetida*, Biogas residue, Olive mill wastewater, Agri-aquaculture integration

ORGANİK ATIKTAN BALIK YEMİNE: TARIM VE SU ÜRÜNLERI ENTEGRASYONU İÇİN BİYOGAZ ATIĞI VE ZEYTİN KARA SUYUNUN VERMİKOMPOSTLAMASINDA *Eisenia fetida* BİYOMASI

ÖZET

Çalışma geniş kapsamlı bir projenin bir bölümüne ait ilk verilerin değerlendirilmesini içermektedir. Bir çatı proje olan "TR.AQUA Gıda Arzı Güvenliği Çerçevesinde Su Ürünlerinde Yenilikçi ve Sürdürülebilir Uygulamaları" projesi TUBITAK-1004 programı tarafından desteklenmiştir. Çalışma, 16 adet projeden oluşmakta olup yüksek teknoloji üretmek hedeflenmiştir. Çalışma grubumuza ait proje, "Organik Atıktan Balık Yemine" başlıklı, farklı disiplinleri bir araya getiren, balık ve bitki üreticilerini sosyo-ekonomik ve teknolojik yönden olumlu şeklide etkileyecek, sürdürülebilir gıda üretimi açısından değerli sonuçlar ortaya koyabilecek bir çalışmadır.

Projenin hedefi, toprak solucanı ve nitelikli vermikompost üretimi ile balık ve bitki yetiştiriciliği entegrasyonunu sağlayabilmektir. Çalışma konuları; organik atıkların değerlendirilmesi, vermikompost üretimi, vermikompost solucanlarının biyokimyasal içeriği (yağlar, yağ asitleri, antioksidan içeriği gibi), elde edilen vermikompostun bitki yetiştiriciliğinde kullanımı ve son olarak elde edilen vermikompost solucanlarının balık yemi rasyonlarına katılabilmeleri şeklinde özetlenebilir. Bu çalışmada organik atıkların vermikopostlama sürecine ait veriler değerlendirilmektedir. Organik atık olarak, biyogaz tesisi katı atığı ve sıvı zeytin karasuyu belirlenmiştir. Ayrıca solucanların doğal yataklığı olan ahır gübresi ana materyal olarak kullanılmıştır. Vermikompostlama için *Eisenia fetida* türü solucanlar tercih edilmiştir.

Biyogaz atığı ve karasu iki ayrı konu olarak çalışılmıştır. Her iki organik atığın vermikompostlanma süreci için ahır gübresi ile ideal karışım oranlarının belirlenmesi amacıyla karışım dozları belirlenmiştir. Biyogaz atığı katı olduğundan ahır gübresi ile katıların homojen karışabilme ilkelerine bağlı kalarak karışımlar hazırlanmıştır. Karasuyun karıştırılmasında ise %100 ahır gübresinden oluşan, vermikopostlanacak yığınların nemlendirilmesinde kullanılacak saf su ile karasuyun karıştırılması şeklinde bir yol izlenmiştir. Her iki atık için de karışım oranları; %0, 25, 50, 75 ve 100 olarak belirlenmiştir. Bu çalışmada solucanlara ait üreme özelliklerine ait veriler ve buna bağlı olan ideal karışım oranlara ait veriler değerlendirilmektedir. İdeal karışım oranları belirlenirken kullanılan solucan biyolojisine ait parametrelerden ise kokon sayısı, yavru sayısı ve solucan biyoması seçilmiştir. Deneme süresi solucanların üreme kabiliyetleri de göz önüne alınarak 90 gün olarak belirlenmiştir. Denemedeki kovalar, karışımlar hazırlandıktan ve solucan ilaveleri yapıldıktan sonra her gün tarla kapasitesinin %70 seviyesinde nemlendirilmiştir. Deneme sonunda tüm kovalardan solucanlara ait sayımlar yapılmıştır. Bunu yanı sıra, denemede kullanılan başlangıç organik materyallere ve karışımlara ait kimyasal analizler yapılmıştır. Veriler değerlendirildiğinde, biyogaz atığı karışımları içerisinde ideal oranların %25 ve %50 olduğu, karasuyun ise vermikompostlamada bu konsantrasyonlarda kullanılamayacağı belirlenmiştir. Belirlenen konsantrasyonlarda karasu uygulamalarında %25'lik uygulamada solucanlar yaşamakta olsalar da hiç üremeyişler diğer konsantrasyonlarda ise hızlıca ölmüşlerdir. En düşük konsantrasyonun

bile solucanlara toksik etki yaptığı belirlenmiş olup çok daha düşük dozlarda çalışmanın yenilenmesi gerektiği ortaya çıkmıştır.

Anahtar Kelimeler: Vermikompostlama, Eisenia fetida, Biogas residue, Olive mill wastewater, Agri-aquaculture integration

1. GİRİŞ

The increasing global population and concomitant rise in food demand necessitate the development of sustainable solutions across both terrestrial and aquatic production systems. While traditional disposal of organic wastes exacerbates environmental burdens, valorizing these wastes within the value chain both enhances waste management and reduces production costs. In this context, mesophilic vermicomposting yields two principal products: a compost rich in microbial activity and beneficial-microorganism diversity (vermicompost/vermicast) and, secondly, earthworm biomass (Hepşen Türkay, 2023).

Vermicompost (vermicompost/vermicast) is a soil-like material with high levels of plant-available nutrients and enzymatic activity, produced through the combined action of earthworms (e.g., Eisenia fetida) and microorganisms on organic residues. Earthworm biomass, by contrast, is rich in protein, fatty acids, and antioxidants, offering a sustainable alternative to conventional fishmeal sources. These two products are integrated to increase crop yields and soil health in plant production, while simultaneously reducing feed costs and environmental impacts in aquaculture.

The world population is projected to reach approximately 10 billion by 2050, requiring a 60 % increase in food production over current levels. In addition to terrestrial agriculture, there is now an imperative to utilize aquatic resources more intensively to meet human nutritional needs (FAO). Indeed, aquaculture has long been the fastest-growing food-production sector globally and in Türkiye, underscoring its promise for meeting animal-protein requirements and supporting healthy diets. The share of farmed fish—including crustaceans and molluscs—in total fisheries production rose from 3.9 % in 1970 to 33 % in 2005 and reached 46 % in 2018 (FAO, 2020). Currently, aquaculture supplies 50 % of the fish consumed worldwide, a figure expected to climb to 62 % by 2030. In Türkiye, cage-culture production has mirrored this growth, reaching 420 000 t yr^{-1}: 144 000 t of rainbow trout (Oncorhynchus mykiss) and 149 000 t of European sea bass (Dicentrarchus labrax), together accounting for 70 % of national output (TÜİK, 2021).

This expansion in fish production brings a corresponding increase in feed demand. Reliance on fishmeal and fish oil (limited by natural stocks and high cost) has driven the search for alternative protein and lipid sources that maintain ecological balance (Gatlin et al., 2007). Potential plant- and animal-based alternatives must be evaluated for their effects on fish health, and by extension, on human health (Engin et al., 2024). Protein remains the principal determinant of both growth performance and feed cost in aquafeeds (Lovell, 1989). Numerous studies have demonstrated successful use of plant ingredients as alternative protein sources (Gomes et al., 1995; Gomez-Requeni et al., 2004; Kaushik et al., 2004), yet antinutritional factors and essential-amino-acid deficiencies remain challenges.

Recently, earthworm meal has emerged as a promising aquafeed ingredient. Its nutrient profile closely approximates that of fishmeal (Hasanuzzaman et al., 2010), and studies have shown superior growth in common carp (Cyprinus carpio) compared with fishmeal and soybean meal (Rawling et al., 2012). In African catfish (Clarias gariepinus), earthworm meal significantly enhanced growth, indicating its potential as a major protein source (Zakaria et al., 2012). A

study in Vietnam likewise highlighted earthworms as an important feed ingredient for local carp farming systems (Pucher et al., 2014).

Although Turkish vermicompost producers utilize earthworm biomass, its application as a protein source has not yet been explored. Therefore, integrating fish farms with vermiculture operations holds particular promise. The properties of vermicompost are determined by the composition of the worm feed, which also influences the worms' biochemical makeup. To maximize yields for both crops and live feed, it is essential to investigate different worm-feed substrates and identify formulations that optimize performance in both systems.

This paper presents preliminary results from a comprehensive project and introduces its overall framework. Under the 2021 TÜBİTAK 1004 Program, twelve high-technology platforms were supported; one of these—the "TR.AQUA Innovative and Sustainable Practices in Aquatic Products for Food Security" platform—comprises sixteen distinct projects. Our group's contribution, entitled "From Organic Waste to Fish Feed," brings together multiple disciplines to deliver socio-economic and technological benefits for plant and fish production, thereby advancing sustainable food systems.

The present study aims to determine the optimal mixture ratios of two common organic residues (BD and OMWW) in vermicomposting by E. fetida, maximizing both vermicompost yield and the nutritional quality of earthworm biomass. Substrate selection considered availability, valorization potential, environmental risks when unmanaged, contributions to vermicompost properties, and effects on worm composition. The findings will provide a novel, practicable model for sustainable soil-health management and diversification of live-feed resources.

2. MATERIAL METHOD

In this study, two types of organic residues were selected to evaluate the different compositional profiles that develop within earthworms. Biogas plant digestate and olive mill wastewater were chosen as the test substrates. Selection criteria included the volumes generated, potential for valorization, environmental hazards posed by open discharge, contributions to the quality of the vermicompost product, and effects on the biochemical composition of the earthworms.

In this study, 2 types of organic waste were preferred in order to evaluate the different compositions that will occur in the worm body. For this purpose, biogas plant waste and olive processing waste, olive mill waste, were determined as organic waste. While determining the organic wastes, the amounts released, the amounts to be evaluated, the environmental disadvantages created by the wastes remaining open, their contributions to the vermicompost product and their effects on the composition in the worm body were taken into consideration.

Since biogas digestate is a solid material, mixtures were prepared according to principles of homogeneous blending with CM. For the olive mill wastewater, the wastewater was mixed with deionized water—used to moisten the piles of %100 CM for vermicomposting—to achieve the desired moisture content. The earthworm species Eisenia fetida was used throughout.

Table 1. Life cycle and optimum ecological requirements of Eisenia fetida

Eisenia fetida	Biological cycle
Optimum temperature	25 °C
Optimum moisture content	70–90 %
Average adult weight	0.55 g (± 0.01 g)
Adult size	4–8 mm (diameter) × 50–100 mm (length)
Time to reach juvenile stage	21–28 days

Biogas digestate (BD) and olive mill wastewater (OMW) were treated as separate trials. To determine the optimal mixing ratios with CM for each residue, the proportions given in the table were established. CM and BD (both solid materials) were air-dried, passed through a 2 mm sieve, and then blended.

Table 2. Mixture Ratios of Organic Residues Used in the Experiment

Biogas digestate mixture ratios	**Olive mill wastewater mixture ratios**
100 % CM + 0 % BD	100 % CM + 0 % OMW (100 % DW + 0 % OMW)
75 % CM + 25 % BD	100 % CM + 25 % OMW (75 % DW + 25 % OMW)
50 % CM + 50 % BD	100 % CM + 50 % OMW (50 % DW + 50 % OMW)
25 % CM + 75 % BD	100 % CM + 75 % OMW (25 % DW + 75 % OMW)
0 % CM + 100 % BD	100 % CM + 100 % OMW (0 % DW + 100 % OMW)

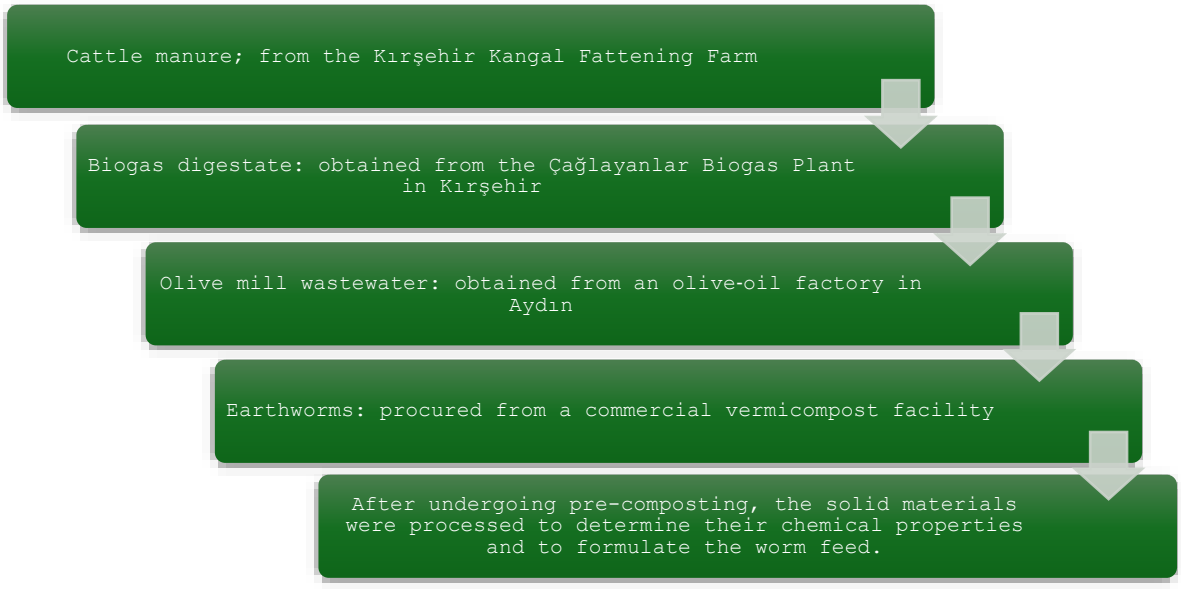

Table 3. Analyses and Methods Used to Determine the Chemical Composition of the Organic Wastes

Analysis	Method
pH	Potentiometric (1:10 organic material : deionized water), pH meter
Electrical conductivity (EC)	Potentiometric (1:10 organic material : deionized water), EC meter
Organic matter (%)	Dry combustion in a muffle furnace
Total nitrogen (N_total)	Distillation; Kjeldahl method
Analizler	Metot
pH	Potansiyometrik (1:10 organik materyal:saf su), Ph metre
EC	Potansiyometrik (1:10 organik materyal:saf su), EC metre
Organik madde, %	Kuru yakma ile, kül fırını
N total	Distilasyon ile, Kjeldahl metot

Figre1. Procurement of materials and preparation for testing

The experimental design was created in a randomized plot experimental design with 30 experimental buckets, including 2 organic wastes, 5 mixing ratios and 3 replications.

Table 4. Experimental design

Lab No.	Sample No.	Mixture	Lab No.	Sample No.	Mixture
1	1_1	100 % CM + 0 % BD	16	6_1	100 % CM + 0 % OMWW
2	1_2	100 % CM + 0 % BD	17	6_2	100 % CM + 0 % OMWW
3	1_3	100 % CM + 0 % BD	18	6_3	100 % CM + 0 % OMWW
4	2_1	75 % CM + 25 % BD	19	7_1	100 % CM + 25 % OMWW
5	2_2	75 % CM + 25 % BD	20	7_2	100 % CM + 25 % OMWW
6	2_3	75 % CM + 25 % BD	21	7_3	100 % CM + 25 % OMWW
7	3_1	50 % CM + 50 % BD	22	8_1	100 % CM + 50 % OMWW
8	3_2	50 % CM + 50 % BD	23	8_2	100 % CM + 50 % OMWW

9	3_3	50 % CM + 50 % BD	24	8_3	100 % CM + 50 % OMWW
10	4_1	25 % CM + 75 % BD	25	9_1	100 % CM + 75 % OMWW
11	4_2	25 % CM + 75 % BD	26	9_2	100 % CM + 75 % OMWW
12	4_3	25 % CM + 75 % BD	27	9_3	100 % CM + 75 % OMWW
13	5_1	0 % CM + 100 % BD	28	10_1	100 % CM + 100 % OMWW
14	5_2	0 % CM + 100 % BD	29	10_2	100 % CM + 100 % OMWW
15	5_3	0 % CM + 100 % BD	30	10_3	100 % CM + 100 % OMWW

Each mixture (20 kg per treatment) was placed into plastic buckets in accordance with homogeneous mixing protocols. Prior to adding worms, all buckets were moistened daily with deionized water for seven days to raise the moisture content to 70%. Moisture additions for each blend were calculated based on maximum water-holding-capacity analyses.

Figure 2. Preparation and Initiation of the Experiment

Subsequently, 1,000 individuals of E. fetida were introduced into each bucket. During the trial, any moisture lost from the surface was replenished daily to maintain constant humidity. The experiment was conducted in the Soil Science and Plant Nutrition Laboratory of the Faculty of Agriculture at KAEÜ for 30 days. Although originally planned for 90 days, the trial was terminated on day 30.

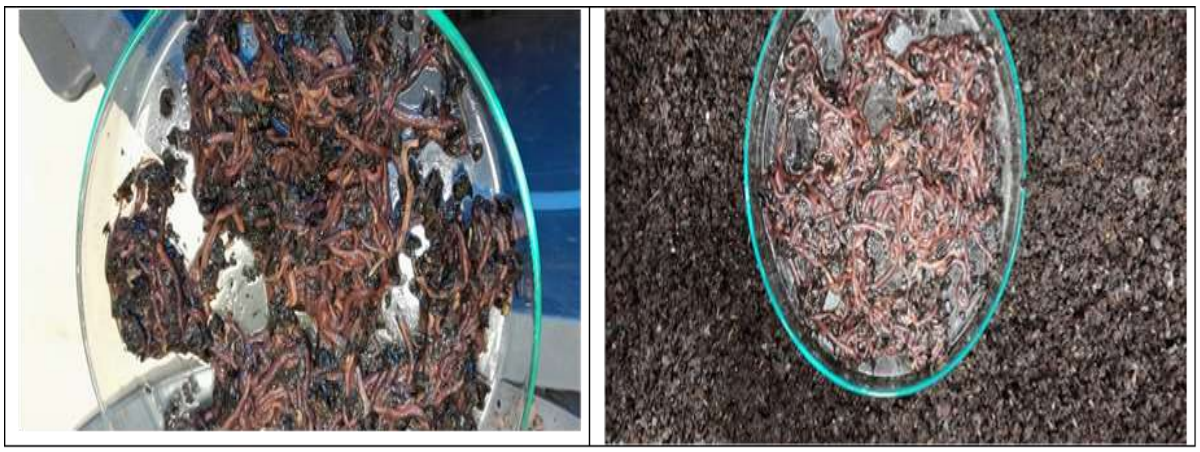

Figure 3. Initial worm enumeration and addition to the buckets

3. RESULTS

Chemical analyses of the organic residues were performed using the methods described above.

Table 5. Chemical Composition of the Organic Wastes Used in the Experiment

Analysis	**Cattle manure**	**Biogas digestate**	**Olive mill wastewater**
pH (1:10 w/v)	8.17	7.30	5.80
EC (dS m^{-1}, 1:10 w/v)	5.04	2.50	5.67
Organic matter (%)	32.29	78.00	36.50
Total nitrogen (%)	1.30	2.60	1.19
C/N ratio	18.03	21.72	22.20

Trial termination and worm harvest, although planned for 90 days, the trial was halted on day 30 because worm survival was negligible in most treatments. All worms, cocoons, and juveniles were carefully counted.

Figure 4. Worm images from olive mill wastewater and biogas waste applications

Table 6. Earthworm biomass and reproduction data. Mixtures (CM: cattle manure; BD: biogas digestate)

Mixture	Worm biomass increase (%)	Number of cocoons	Number of juveniles
100 % CM + 0 % BD	1.01	162	235
75 % CM + 25 % BD	0.68	63	97
50 % CM + 50 % BD	0.41	11	0
25 % CM + 75 % BD	0	0	0
0 % CM + 100 % BD	0	0	0

Table 7. Earthworm biomass and reproduction data. Mixtures (CM: cattle manure; OMWW: olive mill wastewater)

Mixture	Worm biomass increase (%)	Number of cocoons	Number of juveniles
100 % CM + 0 % OMW	1.94	157	274
100 % CM + 10 % OMW	0.12	3	0
100 % CM + 25 % OMW	0	0	0
100 % CM + 50 % OMW	0	0	0
100 % CM + 75 % OMW	0	0	0
100 % CM + 100 % OMW	0	0	0

At high application rates of both residues, worm biomass and reproductive output declined, and survival ceased altogether. In the OMW treatments, worms did not survive at any of the planned concentrations. At 75 % and 100 % OMW, all worms died on day 1; at 50 %, they died by day 3; and at 25 %, they perished one week later. Unexpectedly, a 10 % OMW treatment was added on day 3; although worms appeared lethargic and nearly immobile, some were still alive at harvest. The few cocoons observed likely resulted from gravid individuals introduced at the start.

In the BD trials, worms in the 75 % and 100 % treatments became immobile and died within the first week. In contrast, the 25 % and 50 % BD treatments supported worm survival and biomass increases. However, the highest biomass and reproductive counts were observed in the control (100 % CM) treatment, which received no additional residue.

4. DISCUSSION

Because the primary goal of vermicomposting is waste management, it is essential to identify the highest residue-application rates that still allow active worm metabolism. Although worms thrive naturally in pure CM, effective waste valorization requires determining how much alternative residue can be blended without compromising worm health. In this project, BD was retained at three application rates, whereas OMW was eliminated and replaced with olive pomace (the solid olive cake); the trial has since been reestablished and is ongoing.

Notably, the surviving worms in the 10 % OMW treatment indicate that even lower concentrations warrant investigation. The acute mortality observed in the OMW treatments may stem from the high phenolic content, as well as pH and salinity levels outside the worms' tolerance range. Nonetheless, earthworms generally tolerate slight deviations, and previous studies have shown that even toxic–rich sludges (e.g., certain sewage sludges) can support limited colonization at low blend ratios (Kızılkaya & Hepşen, 2014).

Losses at high BD rates likely reflect the physicochemical transformations undergone during anaerobic digestion. Overall, earthworms were negatively affected as the proportion of their natural bedding (CM) decreased across all alternative-residue treatments.

Acknowledgement:
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A SIGNIFICANT PROBLEM IN APPLE GROWING: PRE-HARVEST FRUIT DROPPING

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ABSTRACT

Apple, which is in the pome fruit group, is one of the most produced and consumed species in the world. Although Turkey is at the top in terms of production amount, due to the lack of standardization in terms of yield and quality, the rate in production amount is not reflected in apple exports. One of the factors that directly affects yield and quality is; pre-harvest fruit drop, which is the fruit falling from the tree before reaching ideal size and quality. It has been determined that pre-harvest fruit drop causes serious economic losses in many apple varieties, especially in commercial terms, in some years. It has been determined that the main factor causing fruit drop is the increase in the amount of ethylene in the plant, and pre-harvest drop can be reduced by using substances that inhibit ethylene biosynthesis. In order to reduce pre-harvest drop, many researchers use plant growth regulators such as SADH daminozide (Alar), 2.4 DP (dicloropene) 2.4.5-trichloropenoxypropionic acid (2.4.5-TP), especially AVG and NAA. In literature studies, the most commonly used one is AVG (aminoethoxyvinylycine). AVG is used commercially in apple orchards in many countries around the world to delay fruit ripening and improve harvest and storage quality by inhibiting ethylene biosynthesis in various plant tissues.

Keywords: Apple, pre-harvest drop, fruit drop

ELMA YETİŞTİRİCİLİĞİNDE ÖNEMLİ BİR SORUN: HASATÖNÜ MEYVE DÖKÜMLERİ

ÖZET

Yumuşak çekirdekli meyveler grubunda yer alan elma, dünya üzerinde en fazla üretimi ve tüketimi yapılan türlerden biridir. Türkiye üretim miktarı yönünden üst sıralarda yer almasına rağmen, verim ve kalite yönünden bir standardizasyon sağlanamaması nedeniyle, üretim miktarındaki oran, elma ihracatına yansımamaktadır. Verim ve kaliteyi doğrudan etkileyen faktörlerden biriside; meyvenin ideal büyüklük ve kaliteye ulaşmadan ağaç üzerinden düşmesi yani hasat önü meyve dökümüdür. Hasat önü meyve dökümlerinin bazı yıllarda özellikle ticari açıdan önemli olan birçok elma çeşidinde ciddi ekonomik kayıplara neden olduğu belirlenmiştir. Meyve dökümüne neden olan başlıca faktörün bitki bünyesindeki etilen miktarındaki artış olduğu, etilen biyosentezini engelleyen maddelerin kullanımı ile hasat önü dökümün azaltılabileceği belirlenmiştir. Birçok araştırıcı tarafından hasat önü dökümü azaltmak amacıyla; AVG ve NAA başta olmak üzere, SADH daminozide (Alar), 2,4 DP (dicloropen) 2,4,5-trikoropenoksipropionik asit (2,4,5-TP) gibi bitki büyüme düzenleyiciler kullanılmaktadır. Yapılan literatür çalışmalarında en çok AVG (aminoethoxyvinylycine)'nin kullanımına rastlanmıştır. AVG çeşitli bitki dokularında etilen biyosentezini inhibe ederek, meyve olgunlaşmasını geciktirmek, hasat ve depolama kalitesini iyileştirmek için dünyanın birçok ülkesinde elma bahçelerinde ticari olarak kullanılmaktadır.

Anahtar Kelimeler: Elma, hasatönü döküm, meyve dökümü

GİRİŞ

Yumuşak çekirdekli meyveler grubunda yer alan elma, dünya üzerinde en fazla üretimi yapılan türlerden biridir. Dünya gıda örgütüne göre, 2023 yılında dünyada yaklaşık 97.3 milyon ton elma üretilmiştir. Üretim sıralamasında Çin, 49.601.700 ton ile ilk sırada yer alırken, ABD 5.151.680 ton üretimi ile 2. sırada, Türkiye ise 4.602.517 ton ile 3. sırada yer almaktadır. (Anonymous, 2025). Ancak verim ve kalite yönünden bir standardizasyon sağlanamaması nedeniyle (Oğuz ve Karaçayır, 2009), üretim miktarındaki oran, elma ihracatına yansımamaktadır (Bashimov, 2016). Verim ve kaliteyi doğrudan etkileyen faktörlerden biriside; meyvenin ideal büyüklük ve kaliteye ulaşmadan ağaç üzerinden düşmesi yani hasat önü meyve dökümüdür (Wargo ve ark., 2004; Greene, 2006).

Elma yetiştiriciliğinde meyvenin renk ve irilik açısından istenen kaliteye ulaşmadan dökülmesi olayı hasat önü döküm olarak ifade edilmekte ve bu durum bazı yıllarda ve özellikle bazı çeşitlerde yüksek seviyelere ulaşarak ciddi ekonomik kayıplara neden olmaktadır (Greene ve ark., 1987). Yere düşen meyvelerin raf veya depo ömrü azalmaktadır. Hasat önü dökümü önlemek için bazı üreticiler meyveleri yeterli olgunluğa gelmeden toplamakta bu ise yine depolanma yeteneğini azaltmakta ve kalite kayıplarına neden olmaktadır. Elmada meyvenin ağaç üzerinde durduğu her hafta için ağırlığı % 5 ile 7 arasında artmaktadır (Byers ve Eno, 2002). Bu durumda elma yetiştiriciliğinde, kalite kayıplarını en aza indirerek, meyveyi ağaç üzerinde tutulabildiği kadar tutmak yetiştiricilere ciddi kazanç sağlayacaktır. Bu nedenle bahçede sulama, gübreleme, tarımsal mücadele, seyreltme gibi kültürel uygulamaları yerine getirmek bir zorunluluktur.

Sulama, gübreleme, seyreltme gibi kültürel önlemler yanında, ekoloji, kullanılan anaç ve çeşit, ağacın yaşı ve ürün yükü hasat önü dökümde etkili olan başlıca faktörlerdir (Wargo ve ark., 2004). Hasat önü dökümü azaltmak için öncelikle kültürel işlemlerin uygun şekilde ve zamanında yerine getirilmesi gereklidir. Ancak, ideal şartlarda yetiştirilse bile, her zaman hasat önü dökümün önüne geçilememektedir.

Hasat önü meyve dökümlerinin bazı yıllarda özellikle ticari açıdan önemli olan birçok elma çeşidinde ciddi ekonomik kayıplara neden olduğu belirlenmiştir (Yuan ve Carbaugh, 2007; Yuan and Li 2008). Meyve dökümüne neden olan başlıca faktörün bitki bünyesindeki etilen miktarındaki artış olduğu, etilen biyosentezini engelleyen maddelerin kullanımı ile hasat önü dökümün azaltılabileceği belirlenmiştir (Rath et al 2006). Birçok fizyolojik olayda olduğu gibi hasat önü dökümde de gelişme düzenleyicilerin belirleyici rolü olduğundan, ticari olarak farklı gelişme düzenleyiciler eskiden beri kullanılmaktadır. Bu amaçla, sentetik oksinlerden naftalin asetik asit (NAA) ve 2.4.5-TP, ile daminozid (Alar) meyveciliğin ileri olduğu ülkelerde, elma üreticileri tarafından kullanılmaktadır. Daminozidin kırmızı renk oluşumunu hızlandırdığı, meyve olgunlaşmasını yavaşlattığı ve dökümü geciktirdiği bildirilmiştir (Polland, 1974). Ancak, çevreye verdikleri bazı olumsuz etkilerden dolayı bugün daminozid ve 2,4,5-TP'nin hasat önü dökümde kullanımı birçok ülkede yasaklanmıştır. Bu ürünlerin yasaklanmasından sonra hasat önü dökümde kullanılacak gelişme düzenleyici olarak, NAA tek ürün olarak kalmıştır. NAA, genel olarak elmada meyve seyreltmesi ve hasat önü dökümü engellemek amacıyla kullanılmaktadır (Greene and Schupp, 2004). Bazı çalışmalarda NAA'nın bazı çeşitlerde hasat önü dökümü engellemede etkili olduğu ifade edilmiştir (Marini ve ark., 1993).

Ancak diğer taraftan NAA'nın meyve etinde yumuşamaya neden olduğu ve meyvenin hasattan sonra raf veya depo ömrünü azalttığı tespit edilmiştir (Yuan ve Carbaugh, 2007). Ayrıca gün geçtikçe yapılan çalışmalarda NAA'nın dökümü kontrol etmede yetersiz kaldığı, olgunluğu ilerlettiği ve meyve etinde yumuşaya neden olduğu belirlenmiştir (Greene, 2003; Yuan ve Carbaugh, 2007). Greene ve ark. (1987) ise dökümü kontrol etmede NAA kullanmanın her zaman iyi sonuç vermediğini ve bu kimyasaldan tutarlı sonuçlar alınmadığını vurgulamıştır.

1970'li yılların başında AVG, [{S}–trans–2-amino–4–(2–aminoetoksi)–3–butenoik asit hidroklorid], Hoffman LaRoche'daki bilim adamları tarafından keşfedilmiş rizobitoksin'nin etoksi anoloğudur (Boller ve ark., 1979). ilk olarak AVG'nin ticari üretimine, Maag Kimya şirketi tarafından başlanmıştır. Fakat yüksek maliyetinden dolayı üretimi devam etmemiştir. Daha sonraki aşamada Abbott Laboratuvarı tarafından araştırmalara yeniden hız verilmiştir (Clarke ve ark., 1996).

AVG, çeşitli bitki dokularında etilen biyosentezini inhibe ederek (Byers, 1997), meyve olgunlaşmasını geciktirmek, hasat ve depolama kalitesini iyileştirmek için dünyanın birçok ülkesinde elma bahçelerinde ticari olarak kullanılmaktadır (Phan-Thien et al 2004). AVG'nin hasat önü dökümün engellemesi ve olgunlaşmanın geciktirilmesindeki etkinliği yapılan çalışmalarla belgelenmiştir (Greene and Schupp, 2004; Schupp and Greene, 2004).

Son yıllarda yapılan pek çok çalışma sonucunda, doğal bir etilen engelleyici olarak görülen aminoethoksivinilglisin hidroklorid (AVG) hasat önü dökümü engelleme de NAA'ya alternatif olarak değerlendirilmiştir. Birçok araştırma sonucuna göre, AVG elmada etilen üretimini baskı altına alarak meyve olgunlaşmasını yavaşlatmakta ve dökümü geciktirmektedir (Schupp ve Greene, 2004; Greene, 2005; Yuan ve Carbaugh, 2007). Diğer taraftan AVG'nin bu etkisi kullanılan çeşide, uygulama zamanı ve dozuna bağlı olarak değişmektedir (Autio ve Bramlage, 1982). Schupp ve Greene (2004)'e göre uygulanan AVG konsantrasyonu arttıkça, döküm oranı azaldığını bildirmişlerdir. Ayrıca AVG'nin uygulama zamanının da önemli olduğu bildirilmekte, çeşit ve ekolojik koşullara bağlı olarak tahmini hasattan 4 veya 8 hafta önce uygulamanın iyi sonuç verdiği bildirilmektedir (Greene, 2002). AVG'nin döküm oranını kontrol etme yanında, NAA'nın aksine, meyve olgunlaşmasını da geciktirerek, et sertliğini muhafaza ettiği ve hasattan sonra raf ve depolama ömrünü artırdığı bildirilmektedir (Greene ve Schupp, 2004).

AVG ve amino oksi asetik asit (AOA) kofaktör olarak pridoksal fosfatı (PLP) kullanarak enzimleri engellemektedir (Taiz ve Zeiger, 2008). Autio ve Bramlage (1982) ise, bu mekanizma neticesinde meyvede olgunlaşmanın ve hasadın geciktirildiği, meyve eti sertliğinin arttırıldığı ve depo ömrünün uzatıldığını tespit etmiştir. Son yıllarda yapılan çalışmalarda, AVG'nin armut, vişne, kayısı, erik, nektarin ve şeftali gibi birçok meyve türünde, meyve eti sertliğinin muhafaza edilmesinde etkili olduğu; elmada ise bu etkisinin yanında, hasat önü dökümün azaltılmasında da başarılı sonuçlar verdiği bildirilmiştir (Williams, 1980; Amarante ve ark., 2002; Bregoli ve ark., 2002; Greene ve Schupp, 2004). Ayrıca AVG meyvelerde, meyve kopma direncini artırmakta, nişasta parçalanmasını ve çözünebilir şeker birikimini geciktirmekte, asitlik ve meyvelerin tatlanmasını sağlayan aromatik esterlerin oluşumunu azaltmaktadır (Autio ve Bramlage, 1982; Bregoli ve ark., 2002; Jobling ve ark., 2003; Silverman ve ark., 2004; Torrigiani ve ark., 2004).

AVG'nin etkisi meyve tür ve çeşidine, ağacın yaşına, anaca, uygulama zamanına, uygulama dozuna ve ekolojik koşullara bağlı olarak önemli değişiklikler göstermektedir (Greene ve Schupp, 2004). Bangerth (1978), AVG'nin elmada hasat önü döküm üzerine tam bir etki göstermesi için uygulamaların tek bir uygulama zamanında değil farklı uygulama rejimleri şeklinde yapılması gerektiğini bildirmektedir. Matoo ve ark. (1977)'ı AVG uygulamasını müteakiben meydana gelen yüksek sıcaklıkların, etilen salınımının engellenmesinde daha etkin rol oynadığını bildirmişlerdir.

AVG'nin etkisi çeşitlere göre değişmektedir. Chu (1998) AVG'nin nişasta parçalanmasını ve meyve eti sertliğinde meydana gelen kaybı geciktirdiğini, Greene (2000) yaptığı çalışmada meyve eti sertliğinin AVG uygulamasına ve çeşide bağlı olarak farklılık gösterdiğini tespit etmiştir. Lurie (2000) ise AVG uygulamaları ile meyve kabuğunda meydana gelen renk gelişiminin geciktirildiğini belirtmektedir.

Greene (2006), AVG'nin etkinliğinin artan uygulama dozlarına bağlı olarak doğrusal bir şekilde arttığını, AVG uygulamalarının ağacın her tarafını iyice kaplayacak şekilde yapılması gerektiğini, bunun için yayıcı yapıştırıcılar ile birlikte yapılan uygulamaların daha başarılı sonuçlar verdiğini bildirmiştir. Ayrıca uygulamaların rüzgarsız ve yağışsız bir zaman diliminde yapılması gerektiğini vurgulamıştır.

SONUÇ

Sonuç olarak meyve ağaçlarında üreticiler açısından önemli bir problem olan hasat önü dökümün azaltılmasına yönelik olarak yapılan birçok çalışmada, AVG'nin etkili bir madde olduğu ve hasat önü dökümden kaynaklanan kayıpları azaltmada önemli bir rol oynadığı, dozlarının, uygulama zamanının iyi belirlenerek kültürel önlemler ile birlikte kullanılabileceği görülmüştür. Ayrıca, AVG'nin diğer büyümeyi düzenleyici maddeler ile kombinasyonlar yapılması ile AVG'nin etkinliğinin ortaya çıkarılması sağlanacaktır.

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CARBON SEQUESTRATION OF FRUIT ORCHARDS AND THEIR ROLE IN SUSTAINABLE AGRICULTURE

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ABSTRACT

Tree plantations offer a significant advantage in carbon fixation within ecosystems due to their perennial structure, especially when compared to herbaceous plants. Although fruit orchards have a shorter lifespan than forest ecosystems, they possess a higher carbon sequestration potential than annual crops. This potential can be further enhanced through sustainable agricultural strategies. Carbon sequestration is defined as the process of absorbing and storing carbon dioxide from the atmosphere, and fruit trees play a crucial role in this process. Through photosynthesis, they absorb atmospheric CO_2 and convert it into structural components such as cellulose, thereby reducing the accumulation of carbon dioxide in the atmosphere. However, the destruction and removal of fruit trees can lead to the release of the carbon they have accumulated over time back into the atmosphere, thereby increasing greenhouse gas emissions. In recent years, climate change has become increasingly evident, exposing many regions to challenges such as floods, droughts, and unpredictable weather events, which in turn have posed serious threats to food security. Fruit trees are of great importance in mitigating the effects of climate change and ensuring food security. To accurately assess the carbon balance in agricultural production, various practices such as cultivation techniques, soil tillage, and fertilizer use must also be taken into account. Agriculture not only supports human and animal nutrition, but also provides essential ecosystem services such as improving soil quality, preventing erosion, and producing high levels of biomass, making it a vital component in the fight against climate change.

Walnut orchards, olive groves, cherry orchards, vineyards, and other perennial fruit species can contribute to the development of renewable energy strategies due to their carbon retention capacity. Moreover, pruning residues generate a substantial amount of biomass, and incorporating these materials into the soil enhances carbon accumulation, thereby contributing positively to the ecosystem's carbon cycle.This process not only enhances the productivity of agricultural land but also requires the evaluation of environmental impacts such as water use, pesticide application, and energy consumption.

This study evaluates the impacts of fruit orchards on carbon emissions in light of existing literature.

Keywords: Carbon Sequestration, Agricultural Sustainability, Fruit Orchards, Renewable Energy

MEYVE BAHÇELERİNİN KARBON SEKESTRASYONU VE SÜRDÜRÜLEBİLİR TARIMDAKİ ROLÜ

ÖZET

Ağaç plantasyonları, çok yıllık yapıları sayesinde otsu bitkilere kıyasla ekosistem içerisinde karbon fiksasyonu açısından önemli bir avantaj sunar. Meyve bahçeleri, orman ekosistemlerine kıyasla daha kısa bir ömre sahip olmalarına rağmen, otsu bitkilere oranla daha yüksek karbon fiksasyon potansiyeline sahiptir. Bu potansiyel, sürdürülebilir tarım stratejileriyle daha da artırılabilir. Karbon sekestrasyonu, atmosferdeki karbondioksitin emilerek biyokütlede veya toprakta depolaması süreci olarak tanımlanır. Meyve ağaçları, bu süreçte önemli bir oynar. Fotosentez yoluyla atmosferden CO_2'yi emerek bunu selüloz gibi yapısal bileşenlerine dönüştürürler. Bu durum atmosferdeki karbondioksit birikimini azaltır. Ancak meyve ağaçlarının tahribi ve kesilmesi, zamanla biriktirdikleri karbonun atmosfere geri salınmasına ve dolayısıyla sera gazı emisyonlarının artmasına neden olabilir. Son yıllarda giderek daha belirgin hale gelen iklim değişiklikleri; sel, kuraklık ve öngörülmeyen hava olayları gibi çevresel zorluklarla pek çok bölgeyi karşı karşıya bırakmış bu durum ise gıda güvenliğini ciddi şekilde tehdit etmiştir. Meyve ağaçları, iklim değişikliğinin etkilerinin azaltılmasında hem de gıda güvenliğinin sağlanmasında önemli bir rol üstlenmektedir. Tarımsal üretimde karbon dengesini doğru değerlendirilebilmesi için; yetiştirme teknikleri, toprak işleme ve gübre kullanımı gibi uygulamalar dikkate alınmalıdır. Tarım, yalnızca insan ve hayvan beslenmesini sağlamakla kalmaz; aynı zamanda toprak kalitesini iyileştirme, erozyonu önleme ve yüksek düzeyde biyokütle üretme gibi temel ekosistem hizmetlerini sunarak, iklim değişikliğiyle mücadelede hayati bir rol üstlenir. Ceviz bahçeleri, zeytinlikler, kiraz bahçeleri ve üzüm bağları gibi çok yıllık meyve türleri, karbonu tutma kapasitesi sayesinde yenilenebilir enerji stratejilerinin geliştirilmesine de katkı sunabilir. Ayrıca budama kalıntıları, önemli miktarda biyokütle üretir ve bu artıkların toprağa kazandırılması, toprakta karbon birikimini artırarak ekosistemin karbon döngüsüne olumlu katkı sağlar. Bu süreç, yalnızca tarımsal arazi verimliliğini yükseltmekle kalmaz; aynı zamanda su kaynaklarının kullanımı, pestisit uygulamaları ve enerji tüketimi gibi çevresel etkilerin de değerlendirilmesini gerektirir.

Bu çalışmada meyve bahçelerinin karbon emisyonları üzerine etkileri mevcut literatürler çerçevesinde değerlendirilmiştir.

Anahtar Kelimeler: Karbon Sekestrasyonu, Tarımsal Sürdürülebilirlik, Meyve Bahçeleri, Yenilenebilir Enerji

1. GİRİŞ

Karbon sekestrasyonu, atmosferdeki CO_2'nin bitkiler, bitki artıkları ve diğer organik bileşikler yoluyla toprağa aktarılması süreci olarak tanımlanır. Bu karbon, toprak organik maddesinin (humus) bir parçası olarak depolanır ve uzun süreli olarak tutulur. Toprakta karbon (C) sekestrasyonu, atmosferik CO_2'nin toprak örtüsü (pedosfer) tarafından tutularak depolanması ve uzun vadeli olarak güvenli biçimde muhafaza edilmesini ifade eder. Bu süreç, karbonun toprakta kalış süresini artırmayı ve yeniden atmosfere salınımını en aza indirmeyi hedeflemektedir. (Lal ve ark., 2015). Yaşam döngüsü değerlendirmesi (LCA), bir ürünün, süreç veya faaliyetin yaşam döngüsü boyunca enerji ve malzeme kullanımıyla ortaya çıkan atıklar ve emisyonların çevresel etkilerini nicel olarak analiz eden bir yöntemdir (ISO, 2006). Tarım sistemlerinde LCA uygulamaları, üretim süreçlerinin çevresel etkilerine yönelik artan farkındalıkla birlikte giderek yaygınlaşmaktadır. Bu etkiler arasında su tüketimi, biyolojik çeşitlilik kaybına yol açan arazi dönüşümleri, pestisit, herbisit ve fungisit kullanımı ile enerji tüketimi yer almaktadır. Karbon ayak izi, bir ürün ya da faaliyetin yaşam döngüsü boyunca neden olduğu sera gazı emisyonlarının hesaplanmasıdır ve çevresel sürdürülebilirliğin geliştirilmesinde önemli bir araçtır (EPLCA, 2007). Karbon ayak izi, LCA metodolojisi içerisinde önemli bir değerlendirme aracı olup, ürünlerin çevresel etkilerinin analizinde temel bileşenlerden biri olarak yer almaktadır. Birçok çalışma, bir ürünle doğrudan veya dolaylı ilişkili girdiler ve emisyonları analiz etmek amacıyla sistematik bir yaşam döngüsü değerlendirmesi (LCA) yaklaşımını benimsemiştir. Tarım ürünlerinin çevresel etkilerinin değerlendirilmesinde yaşam döngüsü değerlendirmesi (LCA) yönteminin uygulanması, çiftlik ölçeğinden yerel ve bölgesel düzeylere kadar uzanan önemli varyasyonlar nedeniyle karmaşık bir süreç olarak karşımıza çıkmaktadır. Bu bağlamda, özellikle doğal koşullar ve pazar dinamikleri açısından büyük çeşitlilik gösteren bölgelerde, farklı meyve üretim sistemlerinin çevresel performanslarının karşılaştırmalı olarak analiz edilmesi büyük önem taşımaktadır (Liu ve ark., 2010). Karbon ayak izi (CF) analizi bir ürünün yaşam döngüsü boyunca gerçekleşen doğrudan ve dolaylı sera gazı (GHG) emisyonlarını ölçmeye yönelik bir yöntemdir. Bu yöntem, ürünün tedarik süresince karşılaşılan çevresel açıdan kritik noktaların, sınırlamaların ve sorunların belirlenmesini sağlarken, karbon ayak izinin azaltılmasına yönelik stratejilerin geliştirilmesine imkân tanır (Wiedmann & Minx, 2007). Organik ürünlerin, geleneksel ürünlere kıyasla daha düşük fosil enerji kullanımı ve sera gazı (GHG) emisyonuna sahip olduğu, dolayısıyla ile küresel ısınmaya daha az katkı sağladığı kabul edilmektedir (Kaltsas ve ark., 2007). Organik ürünlerin daha düşük sera gazı emisyonu sağladığına dair bu görüş, farklı ürün türleri ve üretim koşullarında yapılan organik-konvansiyonel sistem karşılaştırmalarına dayanmaktadır. Ancak organik üretim standartlarının öngördüğü yöntemsel farklılıkların yanı sıra, topografya, çiftlik yönetimi, girdi temini, ürün verimliliği ve pazara erişim gibi etkenler de tarımsal üretim sistemlerinin çevresel performansını önemli ölçüde etkileyebilmektedir (Edwards-Jones ve ark., 2008). Bu çalışmanın amacı, meyve bahçelerinin karbon sekestrasyonuna olan katkılarını ortaya koymak ve bu sistemlerin iklim değişikliğiyle mücadele ile toprak kalitesinin artırılmasındaki potansiyelini mevcut literatür doğrultusunda değerlendirmektir.

2. MEYVE BAHÇELERİNİN KARBON SEKESTRASYONUNDAKİ ROLÜ

Meyve ağaçları, fotosentez yoluyla atmosferden CO_2'yi absorbe ederek hücresel yapılarında özellikle selülozda biriktirir. Bu şekilde atmosferdeki karbon birikiminin azaltılmasına önemli katkı sağlarlar. Ancak bu ağaçların kesilmesi veya yok edilmesi durumunda depolanan karbon yeniden atmosfere salınır ve bu durum sera gazı emisyonlarını artırabilir. Dünya genelinde sera gazı emisyonlarının yaklaşık %19–20'sinin, azot oksit kullanımı, yoğun toprak işleme ve arazi hazırlığı gibi tarımsal faaliyetlerden kaynaklanmaktadır. Bu nedenle, tarımsal uygulamaların çevresel etkileri büyük önem taşımaktadır (Rahman ve ark., 2021). Karbon sekestrasyonu, atmosferden CO_2 emilimini ile bu karbonun ağaçların gövde, dal, yaprak, kök ve topraktaki biyokütle bileşenlerinde depolanma sürecidir (Hurd ve ark., 2022). Bu süreç, ağacın yaşı, yaprak alanı ve fotosentez verimliliği gibi biyolojik özeliklerinin yanı sıra (Wang ve ark., 2023), ağaç türü, toprak tipi, iklim koşulları, arazi yapısı ve uygulanan tarımsal yönetim stratejilerine bağlı olarak değişkenlik gösterir (Vacek ve ark., 2023). Yapılan tahminlere göre, meyve ağaçları da dahil olmak üzere odunsu bitkiler yılda 0,42 ila 0,65 petagram karbonu atmosferden çekebilmektedir. Meyve ağaçlarının bu yönüyle atmosferik karbondioksit seviyelerinin düşürülmesine önemli ölçüde katkıda sağladığı bildirilmektedir (DiMatteo ve ark., 2023). Karbon depolama oranının, genellikle ağaçların gençlik dönemlerinde yüksek seviyededir ve ağaçlar maksimum büyüklüğe ulaştıkça bu oran azalma eğilimi gösterir (Harris & Betts, 2023). Bu nedenle tarımsal ormancılık uygulamaları, biyokütlede karbon tutulumunu destekleyici tüm meyve türlerini kapsamalıdır. Karbon sekestrasyonu ve iklim değişikliğiyle mücadele çabalarının yalnızca çevresel değil, politik ve ekonomik açılardan da sürdürülebilir olması; gıda ve beslenme güvenliğini sağlaması açısından ülkeleri çok yönlü meyve ağaçlarının kullanımına yönlendirmelidir (Gelaye & Getahun, 2024).

İran'da ceviz bahçelerinde yapılan bir çalışmada, enerji kullanım desenleri, enerji girdileri ve verim arasındaki ilişki analiz edilmiştir. Doğrudan ve yenilenebilir enerji girdilerinin üretim çıktıları üzerinde olumlu etkileri olduğu; özellikle ahır gübresi, insan iş gücü ve sulama suyunun verime katkı sağladığı belirlenmiştir. Bu bulgular, ceviz yetiştiriciliğinde organik girdilerin ve sürdürülebilir enerji kullanımının yaygınlaştırılmasıyla karbon ayak izinin azaltılabileceğini göstermektedir (Banaeian ve Zangeneh, 2011).

Zeytin yetiştiriciliğinde önerilen sürdürülebilir yönetim modeli, karbon sekestrasyonu açısından çevresel faydalar sağlamaktadır. Bu modelde kentsel atık suyun geri dönüştürülerek damla sulamada kullanılması, örtü bitkileri ile budama artıklarının geri dönüşümüne dayalı toprak yönetim uygulamaları benimsenmiştir. Güney İtalya'da sekiz yıl boyunca uygulanan bu yöntem hem toprakta hem de bitki biyokütlesinde karbon stoklarını arttırmış; geleneksel sistemlere kıyasla antropojenik sera gazı emisyonlarının azaltmıştır. Bu uygulamalar çevresel sürdürülebilirliğin yanında üreticilerin ekonomik gelirlerini artırarak tarımsal faaliyetlerin sürekliliğini desteklemiş ve arazi terkini azaltmıştır (Palese ve ark., 2013).

İspanya'da yapılan bir çalışmada, organik ve geleneksel tarım sistemlerinin sera gazı emisyon performansı yaşam döngüsü değerlendirmesi (LCA) ile karşılaştırmıştır. Alan bazında %56, ürün bazında %39 oranında sera gazı emisyonu azalması tespit edilmiştir. Bu azalmanın örtü bitkilerinin kullanımı ve budama artıklarının toprağa dâhil edilmesiyle sağlanan karbon

girdileri sayesinde toprakta gerçekleşen sekestrasyondan kaynaklandığını belirlenmiştir. (Aguilera ve ark., 2015).

İtalya'da yürütülen çalışmada zeytin yetiştiriciliği ve yağ üretim süreçlerinde karbon ayak izi yöntemi kullanılarak yaşam döngüsü analizi yapılmış, sera gazı emisyonları ayrıntılı şekilde değerlendirilmiştir. Emisyonlarının büyük ölçüde gübre ve pestisit uygulamalarından kaynaklandığını (3,34–7,74 kg CO_2-eq) ve ikinci en büyük katkının ise cam şişe kaynaklı ambalajlama sürecinden geldiğini (1,13–3,20 kg CO_2-eq) bildirmişlerdir (Pattara ve ark., 2016).

Russo ve ark. (2016), zeytin yetiştiriciliği için LCA ve Ürün Çevresel Ayak İzi (PEF) metodolojilerini kullanılarak yaptıkları çalışmada ülkeler arası önemli farklılıklar tespit etmişlerdir. Yunanistan'da, düşük dizel, elektrik ve su kullanımı çevresel etkiyi azaltırken düşük verim dezavantaj yaratmıştır. İtalya'da yüksek zeytin verimi birim ürün başına düşen sera gazı emisyonlarını azaltarak küresel ısınma etkisini hafifletmiş, ancak bu verim genellikle yüksek gübre kullanımıyla sağlandığı için çevresel etkileri artırmıştır. İspanya'da ise organo-fosforlu pestisitlerin yoğun kullanımı, özellikle ekotoksisite kategorisinde çevresel yükün artmasına neden olmuştur.

Yan ve ark. (2016), yaptıkları çalışmada, Çin'de beş farklı meyve türü (portakal, armut, elma, muz, şeftali) üzerinden meyve üretiminin karbon ayak izini değerlendirmiştir. Yaşam döngüsü analizine dayalı verililerle, hektar başına karbon ayak izi 2,9–12,8 t CO_2-eş/ha, ürün başına ise 0,07–0,7 kg CO_2-eş/kg olarak hesaplamıştır. Portakal ve armut ürün ve besin bazında en düşük karbon ayak izine sahipken, sentetik azot gübresinin tüm meyve türlerinde toplam sera gazı emisyonlarının %50'sinden fazlasına neden olduğunu bildirmişlerdir.

İtalya'da yürütülen bir araştırmada, altı farklı zeytinyağı üretim sisteminin çevresel etkileri LCA yöntemiyle incelenmiş ve 1 litre zeytinyağı üretiminin 0,22–3,39 kg CO_2 eşdeğeri emisyona neden olduğu belirlenmiştir. En düşük çevresel etki pestisit kullanılmayan organik üretim sistemlerinde gözlemlenmiş; toplam etkinin %60'ının ambalajdan kaynaklandığı saptanmıştır (Maffia ve ark., 2020).

İran'da, ceviz bahçelerinde yapılan başka bir analizde, enerji akışı ve emisyonlar değerlendirilmiş; enerjinin en büyük tüketicisinin %40 oranında benzin olduğu, gübre, sulama ve makine kullanımının da karbon ayak izini arttırdığı tespit edilmiştir. Toprak işleme ve pestisit uygulamalarının sera gazı emisyonlarına kayda değer katkı sağladığını belirtmişlerdir (Khanali ve ark., 2021).

İtalya'da konvansiyonel ve organik zeytin fidanlıklarının çevresel etkileri LCA yöntemi ile karşılaştırılmıştır. En büyük emisyon kaynaklarının plastik saksılar (%45-63) ve torf bazlı yetiştirme ortamı (%22-32) olduğu belirlenmiştir. Organik yönetim sistemi, toplam sera gazı emisyonlarını konvansiyonel sistemlere kıyasla %13 oranında azaltmış; karbon sekestrasyonu da dikkate alındığında bu azalma %15,7'ye ulaşmıştır. Ancak, organik sistemle yetiştirilen fidanların odunsu dokularında biriken karbon miktarının %6,7 oranında daha düşük olduğu gözlemlemişlerdir. Zeytin fidanlığı sektöründe organik üretime geçişin karbon ayak izini azaltma potansiyeline sahip olduğunu bildirmişlerdir (Lazzerini ve ark., 2022).

Certini ve ark. (2023), ceviz ağaçlarının düşük verimli alanlarda dahi yüksek karbon sekestrasyonu potansiyeline sahip olduğu ve bu potansiyelin, azot bağlayıcı türlerle birlikte

yetiştirildiğinde (*Alnus cordata*) daha da arttığını belirlenmiştir. Bu tür birlikteliklerin, cevizde erken büyümeyi teşvik ederek hem odun kalitesini hem de karbon depolama kapasitesini artırdığı ifade edilmiştir.

3. TOPRAK YÖNETİM UYGULAMALARI VE KARBON SEKESTRASYONU

Toprak organik maddesi (SOM), biyosferdeki en büyük karbon havuzlarından birini oluşturmaktadır. Küresel ölçekte yaklaşık 1400 petagram (Pg) olarak tahmin edilen bu miktar, atmosferdeki CO_2'nin yaklaşık iki katına karşılık gelmektedir. Toprak hem karbon hem de besin elementleri açısından önemli bir kaynak ve yutak olarak işlev görebilir. Tarımsal arazi kullanımında ve iklimde meydana gelen değişiklikler, toprakta depolanan karbon miktarında dalgalanmalara yol açarak, atmosfer ile toprak arasındaki CO_2 akışlarını etkileyebilir. Bununla birlikte, bazı tarımsal yönetim uygulamaları, toprakta net karbon sekestrasyonunu teşvik edebilir. (Falloone ve ark., 1998). Toprak organik karbon konsantrasyonu, toprak kalitesi, işlevselliği ve ekosistem hizmetlerinin belirlenmesinde kritik bir unsur olup, on yıllık ölçeklerde yenilenebilir bir kaynak niteliğindedir (Lal, 2021). Karbondioksit (CO2), küresel ısınmadan birincil olarak sorumludur ve atmosferik CO2 konsantrasyonundaki artış, nüfus artışı, endüstriyel genişleme ve ormansızlaşmanın birleşik etkisinden kaynaklanmaktadır (Ma ve ark., 2000). Maryo ve ark. (2023), son 250 yılda atmosferdeki CO_2 düzeyinin yaklaşık 280 ppm'den 412 ppm'nin üzerine çıktığını ve bunun küresel ısınmanın temel nedenlerinden biri olduğunu belirtmiştir. Bu bağlamda, iklim değişikliğiyle mücadele ve atmosferik karbonun azaltılması için toprak yönetimi stratejileri büyük önem taşımaktadır. Toprakta karbon tutulmasını artırmak amacıyla organik artıklar veya gübre yoluyla sağlanan karbon girdileri, toprağın dokusal özelliklerinden daha belirleyici bir rol oynamaktadır (Blanco-Canqui, 2013). Bu kapsamda öne çıkan yöntemlerden biri olan Koruyucu Tarım (CA), iklim değişikliğini hafifletmede önemli bir araç olarak öne çıkmaktadır ve iki temel mekanizma ile bu etkiyi sağlar. Topraktaki karbon dinamiklerini değiştirerek toprak karbon stoklarını artırmak ve toprağın mekanik olarak işlenmesini azaltarak karbon oksidasyon süreçlerini sınırlamak. Özellikle, İspanya'da, doğrudan ekim ve örtü bitkisi kombinasyonlarına dayalı koruyucu tarım sistemlerinin, önemli bir karbon yutağı potansiyeli taşıdığı bildirilmektedir. Ancak bu sistemlerin, iklim koşulları ve bitki desenine göre optimize edilmesi gereklidir. Nitekim karbon sekestrasyon oranlarının, monokültür yerine ürün rotasyonunun uygulandığı ve minimum toprak işleme uygulanan sistemlerde daha yüksek olduğu saptanmıştır (González-Sánchez ve ark., 2012). Toprak organik karbonunun 30–100 cm derinlikteki alt toprak katmanlarında birikimini sağlamak için kullanılan başlıca yöntemler, derin köklü bitki türlerinin yetiştirilmesi ve derinlere tünel açan toprak solucanlarının etkinliğinden yararlanılmasıdır. Toprak organik karbonu ile toprak agregasyon yeteneği, bitkilerin kullanabileceği su kapasitesi, besin maddelerinin tutulması, hacim ağırlığı ve porozite arasında pozitif bir ilişki bulunmaktadır. Bu nedenle, bozulmuş topraklardaki organik karbon stoklarının yeniden kazandırılması, küresel gıda güvenliğinin artırılması ve iklim değişikliğiyle mücadele açısından önemli bir stratejidir. Böylece çevresel sorunlara tarımsal temelli çözümler sunulması mümkün hale gelmektedir (Lal, 2021). Özellikle çok yıllık bitkilerin yer aldığı agroekosistemlerde, toprak ve bitki kaynaklı karbon tutulumuna özel önem verilmesi gerekmektedir. Akdeniz iklim koşullarında yapılan araştırmalar, organik tarım uygulamalarında kullanılan organik gübre kullanımının

daha düşük N_2O emisyonları ve daha yüksek toprak organik karbon (SOC) stokları ile ilişkili olduğunu göstermektedir (Aguilera ve ark., 2015). Diğer yandan, atmosferik karbonun azaltılması noktasında yalnızca toprak değil, bitki örtüsünün yapısı da önem arz etmektedir. Shiferaw ve ark. (2022), odunsu bitki türlerinin karbon stoğu ve biyokütle potansiyelinin, CO_2 emisyonları üzerindeki etkisine dikkat çekerek bu türlerin iklim değişikliği sürecindeki rollerinin kritik olduğunu vurgulamışlardır. Bu değerlendirme, odunsu bitkilerin atmosferik karbonu depolama kapasiteleri sayesinde sera gazı emisyonlarının azaltılmasına kayda değer katkılar sunduğunu göstermektedir.

4. SONUÇ

Dünya genelinde sera gazı emisyonlarının yaklaşık %19–20'si, azot oksit salınımı, yoğun toprak işleme ve arazi hazırlığı gibi tarımsal faaliyetlerden kaynaklanmaktadır. Bu çerçevede, konvansiyonel tarımdan organik tarıma geçiş, sera gazı (GHG) emisyonlarının ve enerji tüketiminin azaltılmasında etkili bir strateji olarak öne çıkmaktadır. Ayrıca, mekanik toprak işlemenin sınırlandırılması ile sulama suyu, pestisit ve gübre gibi tarımsal girdilerin daha verimli kullanımı, üretimin çevresel etkilerini azaltmada önemli katkılar sunmaktadır. Düşük karbonlu üretim ve tüketim politikalarının benimsenmesi ve uygun pazarlama mekanizmalarının geliştirilmesi; ürün besin değeri, üretici geliri ve iklim değişikliğiyle mücadele arasında denge kurulmasını sağlayarak meyve üretiminden kaynaklanan karbon emisyonlarının azaltılmasına katkıda bulunabilir. Meyve bahçelerinin, özellikle ceviz ve zeytin gibi çok yıllık türlerin hem biyokütlelerinde hem de toprakta önemli miktarda karbon depolama kapasitesine sahip olduğu gösterilmiştir. Organik üretim sistemleri ve sürdürülebilir bahçe yönetim modelleri (örneğin örtü bitkileri kullanımı, atıkların geri dönüşümü, damla sulama) bu kapasiteyi artırmakta ve net karbon sekestrasyonunu teşvik etmektedir. Nitekim İtalya, İspanya, İran ve Çin'de yapılan çeşitli yaşam döngüsü değerlendirmeleri; üretim sistemlerinin enerji girdisi, ambalajlama biçimi, pestisit ve gübre kullanımı gibi faktörlerle doğrudan ilişkili olarak karbon ayak izi üzerinde önemli etkilere sahip olduğunu ortaya koymuştur. Özellikle sentetik gübre kullanımı, meyve üretiminin birincil aşamasında oluşan toplam sera gazı emisyonlarının büyük bir kısmından sorumlu olduğundan, bu girdinin azaltılması sektördeki emisyonların düşürülmesi açısından kritik öneme sahiptir. Bitkisel üretime yönelik yaşam döngüsü değerlendirmesi (LCA), karbon ayak izi ve sera gazı emisyonlarının belirlenmesinde etkili bir analiz aracı olup, meyve üretiminin çevresel etkilerinin kapsamlı biçimde ortaya konulmasına olanak tanır. Bu yöntem aracılığıyla, bahçe yönetimi süreçlerinde alınacak kararlarla emisyon azaltımına yönelik sürdürülebilir iyileştirme stratejileri geliştirilebilir. Ayrıca ceviz gibi azot bağlayıcı türlerle birlikte yetiştirildiğinde karbon sekestrasyon kapasitesi daha da artırılabilmekte, böylece düşük verimli alanlarda bile iklim değişikliğiyle mücadeleye katkı sağlanabilmektedir. Tüm bu bulgular, meyve ağaçlarının sadece tarımsal üretim unsurları değil, aynı zamanda etkili birer karbon yutağı olarak da değerlendirilmesi gerektiğini ortaya koymaktadır.

5. KAYNAKLAR

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SOIL SUITABILITY MAP FOR WALNUT CULTIVATION IN KIRŞEHİR: EVALUATION USING THE AHP METHOD BASED ON SOILGRIDS DATA

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ABSTRACT

Walnut (*Juglans regia.L*) thrives best in deep, well-aerated and fertile soils. In walnut cultivation, factors such as soil pH, texture (sand,silt and clay ratios), organic matter content, and permeability significant affect growth and yield. Walnuts can grow within a wide pH range; while a Ph between 5,5 and 8,5 is considered suitable, the optimal range is between 6,2 and 7,5 When the humus content falls bellow 2%, it negatively impacts growth and fruit production. Walnut trees cannot develop in waterlogged soils, and even short-term flooding can cause severe damage to their roots. In general, deep, well-drained soils with high productivitiy are considered essential for walnut plantations.

Geographic Information Systems (GIS) have long been a key tool for identifying alternative uses of agricultural land, applying precision agriculture techniques, evaluating crop productivity, and creating land suitability maps. Lands suitability analysis stands out as one of the most beneficial applications of GIS in spatial planning and management processes. These analyses utilize various datasets, including climate, soil an vegetation information.

This study utilized soil data obtained from the SoilGrids platform to create a suitability map for walnut cultivation in Kırşehir province. The SoilGrids data for Kırşehir were integrated into the ArcGıs Pro software. These data include soil properties at depths of 15-30 cm, 30-60 cm and 60-100 cm, covering factors such as pH, soil texture,and organic matter content. Using these data,maps of soil pH, organic matter content, and soil texture parameters were generated to assess the suitability of soils for walnut cultivation. The Analytic Hierarchy Process (AHP), a weighted overlay analysis method, was used to determine the suitabilitiy of different soil properties for walnut cultivation. This approach enabled a comprehensive evaluation of potential walnut cultivation areas in Kırşehir based on fundamental soil characteristics and provided insights for sustainable agricultural practices.

Keywords: Kırşehir, Walnut Cultivation, Soil Properties, SoilGrids, Suitability Map, AHP

KIRŞEHİR'DE CEVİZ YETİŞTİRİCİLİĞİ İÇİN TOPRAK UYGUNLUK HARİTASI: SOİLGRİDS VERİLERİNE DAYALI AHP YÖNTEMİYLE DEĞERLENDİRME

ÖZET

Ceviz (*Juglans regia* L.) derin, iyi havalanmış ve verimli topraklarda en iyi şekilde gelişir. Ceviz yetiştiriciliğinde, toprağın pH değeri, tekstür (kum, silt, kil oranları), organik madde içeriği ve geçirgenliği gibi faktörler, büyüme ve verim üzerinde önemli bir etkiye sahiptir. Ceviz, geniş bir pH aralığında yetişebilir; pH değeri 5,5 ile 8,5 arasında uygun olup, optimum aralık 6,2 ile 7,5 arasında yer almaktadır. Humus içeriği %2'nin altına düştüğünde, büyüme ve meyve verme üzerinde olumsuz etkiler meydana gelir. Ceviz ağaçları, uzun süreli suya doygun topraklarda gelişemez ve kısa süreli su baskınları bile köklerine ciddi zarar verebilir. Genellikle yüksek verimliliğe sahip derin, iyi drenajlı topraklar ceviz plantasyonları için bir gereklilik olarak kabul edilir. Coğrafi Bilgi Sistemleri (CBS), uzun süredir tarım arazilerinin alternatif kullanım alanlarını belirleme, hassas tarım uygulamaları, ürün verimliliğini değerlendirilmesi ve arazi uygunluk haritalarını oluşturulmasında önemli bir araç olarak kullanılmaktadır. Arazi uygunluk analizi, CBS'nin mekânsal planlama ve yönetim süreçlerinde en faydalı uygulamalardan biri olarak öne çıkmaktadır. Bu analizlerde, iklim, toprak ve vejetasyon gibi çeşitli veri setlerinden yararlanılmaktadır.

Bu çalışma, Kırşehir ilindeki ceviz yetiştiriciliği için uygun toprak haritası oluşturmak amacıyla SoilGrids platformundan elde edilen toprak verilerini kullanmıştır. Çalışmada, Kırşehir iline ait SoilGrids verileri ArcGIS Pro programına entegre edilmiştir. SoilGrids verileri, 15-30 cm, 30-60 cm ve 60-100 cm derinliklerindeki toprak özelliklerine dair verileri içermektedir. Bu veriler arasında pH değeri, toprak tekstürü, organik madde içeriği faktörleri yer almaktadır. Bu veriler üzerinden, toprak pH'sı, organik madde içeriği ve toprak tekstürü parametreleri haritalanarak ceviz yetiştiriciliği için uygunluk haritası oluşturulmuştur. Ağırlıklı çakışma analizi yöntemi olan Analitik Hiyerarşi Süreci (AHP), farklı toprak özelliklerinin ceviz yetiştiriciliği için uygunluk derecesini belirlemek amacıyla kullanılmıştır. Bu yaklaşım, Kırşehir ilinde ceviz yetiştiriciliği için potansiyel alanlarının temel toprak özellikleri açısından kapsamlı bir şekilde değerlendirilmesini ve sürdürülebilir tarım uygulamaları için öngörüler sağlamıştır.

Anahtar Kelimeler: Kırşehir, Ceviz yetiştiriciliği, Toprak özellikleri, SoilGrids, Uygunluk haritası, AHP

1. GİRİŞ

Artan nüfusun gıda talebini karşılamak için tarımsal üretime duyulan ihtiyaç artarken, toprakların üretim potansiyeli giderek azalmaktadır. Araştırmalar, toprak erozyonu, aşırı toprak işleme ve kontrolsüz otlatma gibi etkenlerle dünya genelinde bitki örtüsüyle kaplı alanların %10'undan fazlasında ciddi verim kayıpları yaşandığını ortaya koymaktadır. Bu durum, sürdürülebilir toprak yönetimi uygulamalarının gerekliliğini ve toprak bozulmasının küresel gıda güvenliği üzerindeki olumsuz etkilerini açıkça göstermektedir (Lal, 1994; Teka ve Haftu, 2012). Arazinin en uygun şekilde kullanımı, bitki gereksinimleri ile toprak ve arazi özelliklerinin birlikte değerlendirilmesine bağlıdır. Bu nedenle, etkili arazi yönetimi uygulamalarının planlanmasında ayrıntılı mekânsal toprak verilerine ihtiyaç duyulmaktadır (Burrough, 1996; Teka ve Haftu, 2012).

Ceviz ağacı, yüksek verimli ve kaliteli toprak koşullarında ideal gelişimini gösterir. Bu nedenle, sağlıklı bir büyüme ve verimli üretim için ceviz bitkisinin besince zengin topraklara ihtiyacı vardır. Büyüme dönemi boyunca hem yeterli nem sağlayabilen hem de köklerin hava almasına olanak tanıyan toprak yapıları tercih edilmelidir. Köklerin etkili bir şekilde yayılabilmesi için toprak derinliğinin 90 ila 150 cm ya da daha fazla olması gerekir. Alt tabakada kum, çakıl, sıkışmış kil veya ana kaya gibi geçirimsiz katmanların bulunması kök gelişimini sınırlandırabilir. Fazla su tutan ve hava geçirmez topraklar, köklerin oksijen alımını engelleyerek hem kök büyümesini yavaşlatır hem de ağacın genel gelişimini olumsuz etkiler (Ponder, 2004). Ceviz, gelişmiş kök sistemi sayesinde toprak koruma projelerinde, erozyonla mücadelede ve tarımsal ormancılık faaliyetlerinde önemli bir rol oynar (Craioveanu, 2006). Toprak, sınıflandırma ve saha değerlendirmesinin ötesinde, oluşumu ve çevresel işlevleri açısından da kapsamlı bir şekilde ele alınmalı ve yorumlanmalıdır.

Topraklar, endüstriyel, kentsel ve tarımsal insan faaliyetleri sonucunda genellikle bozulmaya uğrar ve işlevlerinde azalma meydana gelir. Toprak bozulmasını önlemek ve bozulan toprakları rehabilite etmek için güvenilir toprak verileri, uygun arazi kullanım sistemleri ve etkili toprak yönetim uygulamaları kritik öneme sahiptir. Ayrıca, çevrenin daha iyi anlaşılması bu süreçlerin başarısı için temel bir gerekliliktir. Toprak tekstür sınıfları, birleşik parçacık boyutu dağılımlarını tanımlayan kategoriler olarak belirlenmiştir. Tekstür sınıflarına ek olarak, kil yüzdesine yönelik saha tahmini de sağlanmış olup, bu tahminler kil içeriğindeki değişimleri belirlemek ve analitik verilerle karşılaştırmak için kullanılmaktadır. Kil, silt ve kum yüzdeleri arasındaki temel ilişki dikkate alınarak, kum fraksiyonu; kumlar, tınlı kumlar ve kumlu tınlar olarak alt bölümlere ayrılmıştır. Bu sınıflandırma, çok iri, iri, orta, ince ve çok ince kum oranlarına göre yapılmaktadır (FAO, 2006).

Toprak tekstürü, toprak su tutma kapasitesini, suyun toprak içinde ve üzerinden hareket etme hızını ve köklerin topraktaki ilerleme kolaylığını etkiler. Toprak tekstürü, içerdiği kum, silt ve kil parçacıklarının oranına bağlıdır. Kumlu topraklar genellikle besin maddelerinden fakirdir ve aşırı drenajlıdır; ağır tekstürlü topraklar ise su hareketini ve kök gelişimini engelleyebilir. Tınlı topraklar, toprak parçacıkları arasındaki çeşitliliği sayesinde en iyi yapıya sahiptir; bu yapılar, suyun ve havanın geçişini kolaylaştıran büyük boşluklara sahip olur. Silt tınısına sahip ve alt tabakasında kil bulunan kireçli topraklar iyi dikim alanları olarak kabul edilebilir. Ancak, taşlı topraklar, tarım için uygun olmadığı için bu tür alanlardan kaçınılmalıdır. Siyah ceviz, besin

açısından talepkâr bir bitkidir ve toprak parçacıklarının boyutu, besin maddelerinin bulunabilirliğini etkiler. İnce dokulu topraklar, daha kaba topraklara kıyasla daha fazla besin sunar. Toprağın pH'ı, besin maddelerinin bulunabilirliğini düzenler. Toprağın üst 6 inçlik (yaklaşık 15 cm) katmanının pH'ı 6,5 ile 7,2 arasında olmalıdır.

Yüzey toprağının (A horizonu) yaklaşık %2,0- %3,5 organik madde içermesi ve yeterli besin maddesine sahip olması tavsiye edilir (Parker et al.,1992; USDA Forest Service, 2008). Toprak profili, kök sistemi gelişimini engelleyebilecek engellerden arınmış, en az 3 feet (yaklaşık 1 metre) derinlikte olmalıdır. Daha sığ topraklar, yeterli su tutma kapasitesine sahip olmayabilir ve bu durum tatmin edici ağaç büyümesini engeller. Aşırı drenajlı ya da kötü drenajlı topraklar, siyah ceviz yetiştiriciliği için uygun değildir. Bu tür topraklar, hava hareketini kısıtlar, kök büyümesini engeller ve ağaçların boyunu ve çapını sınırlar. Yüksek alanlardaki daha iyi ceviz yetiştirme alanları, genellikle kuzey ve doğuya bakan düşük eğimli yamaçlarda, vadilerde ve dar akarsular boyunca yer almaktadır. Güney yönüne bakan yamaçlar ve dar sırt tepeleri ise, toprakların genellikle kuru, sığ ve erozyona oldukça duyarlı olması nedeniyle ceviz yetiştirmek için uygun olmayan alanlardır. Potansiyel ceviz yetiştiricisi için, ceviz yetiştirmek amacıyla "iyi" ve "kötü" toprakların belirlenip harita üzerinde gösterilmesi büyük bir kolaylık sağlayacaktır. Illinois, güneydoğu Minnesota, Iowa ve Indiana gibi bölgelerde, topraklar siyah ceviz yetiştirmek için "uygun", "sınırlı" ve "uygunsuz" olarak sınıflandırılmıştır (Ponder et al., 1989; USDA Forest Service, 2008). İyi drene olabilen, derin ve üretken topraklar ceviz plantasyonları için temel gerekliliklerdendir. Toprak dokusu bakımından tınlı yapıda olması (kil <%35, silt %30-50, kum %30-50) uygundur. Ancak yağış miktarı arttıkça toprağın kil içeriğine olan tolerans azalır (Mohni ve ark., 2009). Toprak pH'ı konusunda geniş bir aralıkta gelişim gösterebilen ceviz, 5,5 ile 8,5 arası pH değerlerine uyum sağlayabilirken, ideal aralık 6,2 ile 7,5'tir. Toprak pH'ı alkali düzeylere çıktığında kalsiyum ve sodyum birikimi, asidik düzeylerde ise manganez artışı görülebilir. Topraktaki humus oranı %2'nin altına düştüğünde, ceviz ağaçlarında hem büyüme hem de verim üzerinde olumsuz etkiler ortaya çıkar (Strugstad ve Despotovski, 2012; Popa ve ark., 2023). Ayrıca, ceviz ağaçları çinko ve bor eksikliklerine duyarlıdır; bu nedenle dikim öncesi toprak analizleri yapılarak özellikle çinko düzeyleri kontrol edilmelidir. En uygun gelişim için, kireç bakımından zengin, humus içeriği yüksek, derin, gevşek yapılı tınlı veya killi-tınlı topraklar tercih edilmelidir. Köklerin 3 ila 4 metreye kadar ulaşabilmesi için, alt toprak tabakalarının geçirgen olması, yoğun kil, taşlı yapı veya su tutan katmanlar içermemesi önemlidir. Çünkü ceviz ağaçları uzun süreli toprak su doygunluğuna karşı duyarlıdır ve kısa süreli su baskınları bile kök sistemine zarar vererek ağacın gelişimini durdurabilir (Ahmad ve ark., 2018).

Coğrafi Bilgi Sistemleri (CBS) destekli Çok Kriterli Karar Analizi (ÇKKA), son dönemlerde özellikle arazi uygunluğunun değerlendirilmesi ve toprakların bozulmasının önüne geçilmesine yönelik tarımsal planlamalarda önemli bir araç olarak öne çıkmaktadır (Akpoti ve ark., 2019; Tashayo ve ark., 2020a). Bu yöntem, birden çok kriter ve amaca dayalı olarak karar olasılıklarını analiz eder. ÇKKA kapsamında kriterlere verilecek ağırlıkların belirlenmesinde çeşitli yöntemler kullanılabilmektedir. Bu yöntemler arasında Analitik Hiyerarşi Süreci (AHS), farklı ve çok sayıda faktörü aynı anda değerlendirebilme kapasitesi sayesinde oldukça etkili bir teknik olarak kabul görmektedir. AHS, karar verme sürecinde kriterlerin önem düzeylerini hiyerarşik bir yapı aracılığıyla belirler (Zhang ve ark., 2015; Mardani ve ark., 2016; Bilgilioğlu

ve ark., 2021). Bu yöntem, kriterler arasında ikili karşılaştırmalar yapılmasını sağlayarak süreci sadeleştirir ve değerlendirmelerin tutarlılığı, tutarlılık oranı (index) kullanılarak doğrulanır (Akıncı ve ark., 2013; Mondal ve ark., 2019).

SoilGrids, 250 metrelik mekânsal çözünürlüğe sahip hücre boyutlarıyla, makine öğrenme yöntemleri kullanarak dünya çapında toprak özelliklerine ait haritalar üretmektedir. Dünya genelinde yaklaşık 240.000 lokasyondan elde edilen toprak gözlemlerini; bitki örtüsü, arazi morfolojisi, iklim, jeoloji ve hidroloji gibi özellikleri tanımlayan 400'den fazla küresel çevresel yardımcı değişkenle birlikte analiz ederek toprak özelliklerini modellemektedir (Poggio ve ark.,2021). Çalışmamızda SoilGrids, verileri ve ArcGIS Pro 3.2 yazılımı ile Kırşehir ilinde ceviz yetiştiriciliği için toprak uygunluk haritalarının oluşturulması amaçlanmıştır.

2. MATERYAL ve YÖNTEM

Bu çalışmada, toprak özelliklerinin ceviz yetiştiriciliği açısından uygunluğunu belirlemek amacıyla Analitik Hiyerarşi Süreci (AHS/AHP) yöntemi kullanılmıştır. Değerlendirme kriterleri olarak organik madde, kum, silt, kil ve pH parametreleri seçilmiştir. Bu kriterler, toprakların fiziksel ve kimyasal özelliklerini temsil etmekte olup, her biri ceviz yetiştiriciliği üzerinde önemli etkiye sahiptir. AHP yöntemiyle kriterlerin göreceli önem derecelerini belirlemek amacıyla 1–9 ölçeğinde ikili karşılaştırma matrisi oluşturulmuştur. Oluşturulan 5×5 boyutundaki karşılaştırma matrisi, kriterlerin birbirlerine göre ne derece önemli olduğunu yansıtmaktadır.

Bu ağırlıklar, ArcGIS Pro 3.2 yazılımında toprak uygunluk haritalarının oluşturulmasında kullanılmıştır. Her toprak verisi katmanı (kil, silt, kum, pH ve organik madde), SoilGrids platformundan 15–30 cm, 30–60 cm ve 60–100 cm derinliklerden elde edilmiştir (ISRIC – World Soil Information, 2023). Katmanlar sınıflandırılmış ve uygunluk skorları belirlenmiştir. Ardından, bu katmanlar Weighted Overlay (Ağırlıklı Bindirme) analizine dahil edilerek birleşik toprak uygunluk haritası oluşturulmuştur.

Tablo 1. İkili Karşılaştırma Yönteminden Kullanılan 1-9 Skalası (Saaty, 2008)

1	Her iki faktör eşit öneme sahip
3	Biraz daha fazla önemli
5	Kuvvetli derecede önemli
7	Çok kuvvetli derecede önemli
9	Aşırı önemli
2,4,6,8,	Ara ortalama değer

Analitik Hiyerarşi Süreci (AHS) Yöntemi ve Uygulama Aşamaları

Analitik Hiyerarşi Süreci (AHS/AHP), belirsizlik ortamında karar verme süreçlerini sistematik hale getiren hem nitel hem de nicel verilerin birlikte değerlendirilebildiği çok kriterli karar

verme (ÇKDV) yöntemlerinden biridir. Saaty (1980), tarafından geliştirilen bu yöntem, karar vericilerin bilgi, deneyim ve sezgilerini karar sürecine entegre etmelerine olanak tanıması açısından önemlidir. AHS, karmaşık karar problemlerini daha sade ve anlaşılır bir yapıya kavuştururken, karar vericinin problem üzerindeki kontrolünü ve farkındalığını artırır. Yöntem, özellikle birden fazla kriterin ve alternatifin değerlendirilmesini gerektiren durumlarda hem bireysel hem de grup kararları için uygulanabilir ve güvenilir sonuçlar sunar. Analitik Hiyerarşi yöntemi temel olarak üç ana aşamadan oluşmaktadır (Wind & Saaty, 1980), İlk adımda, karar problemini oluşturan hedef, kriterler, alt kriterler ve alternatifler hiyerarşik bir yapıya dönüştürülür. Bu yapı, problemin temel unsurlarının sistematik bir şekilde modellenmesini sağlar. İkili Karşılaştırma Matrisi ve Ağırlıkların Belirlenmesi: İkinci aşamada, hiyerarşide yer alan kriterler ve alt kriterler kendi aralarında ikili olarak karşılaştırılır. Bu karşılaştırmalar, karar vericinin her bir unsurun göreli önemine ilişkin algısını yansıtır. Saaty'nin önerdiği ölçek kullanılarak oluşturulan karşılaştırma matrisi yardımıyla kriterlerin ağırlıkları hesaplanır. Son aşamada, ikili karşılaştırma matrisinden elde edilen verilerin tutarlılığı, tutarlılık oranı (Consistency Ratio- CR) hesaplanarak değerlendirilir.

CR değeri %10'un altındaysa tutarlılık kabul edilebilir düzeydedir. Bu koşul sağlandığında, alternatifler belirlenen kriter ağırlıklarına göre değerlendirilir ve en uygun alternatif, en yüksek öncelik değerine sahip olan olarak belirlenir. AHS'nin sunduğu sistematik yapı sayesinde, karmaşık karar verme süreçleri daha şeffaf ve rasyonel bir şekilde yönetilebilmekte, böylece karar vericilerin daha güvenilir sonuçlara ulaşmaları mümkün hale gelmektedir (Ömürbek ve Şimşek ,2014).

Çalışmamızda oluşturulan karşılaştırma matrisinin tutarlılığı değerlendirilmiştir. CR değerinin 0.10'dan küçük olması, karşılaştırma matrisinin tutarlı olduğunu göstermektedir. Bu amaçla tutarlılık oranı (CR) hesaplanmış ve 0 olarak bulunmuştur, matris tam tutarlıdır. Bu matris aşağıda sunulmuştur;

Tablo 1. AHP İkili Karşılaştırma Matrisi

Kriter	OM	PH	Kil	Kum	Silt
OM	1	9/8	9/4	9/3	9/2
PH	8/9	1	8/4	8/3	8/2
Kil	4/9	4/8	1	4/3	4/2
Kum	3/9	3/8	3/4	1	3/2
Silt	2/9	2/8	2/4	2/3	1

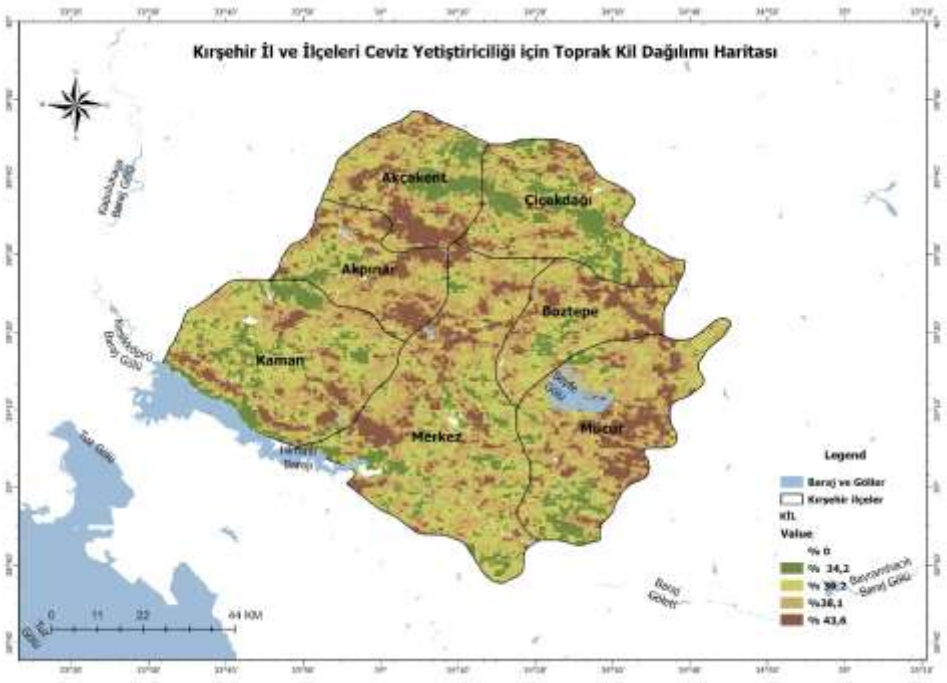
Matris normalleştirilerek her kriter için ağırlık vektörü hesaplanmıştır. Elde edilen ağırlıklar şu şekildedir;

Tablo 2. Toprak Değerlendirme Kriterleri ve AHP Karşılaştırma Matrisi

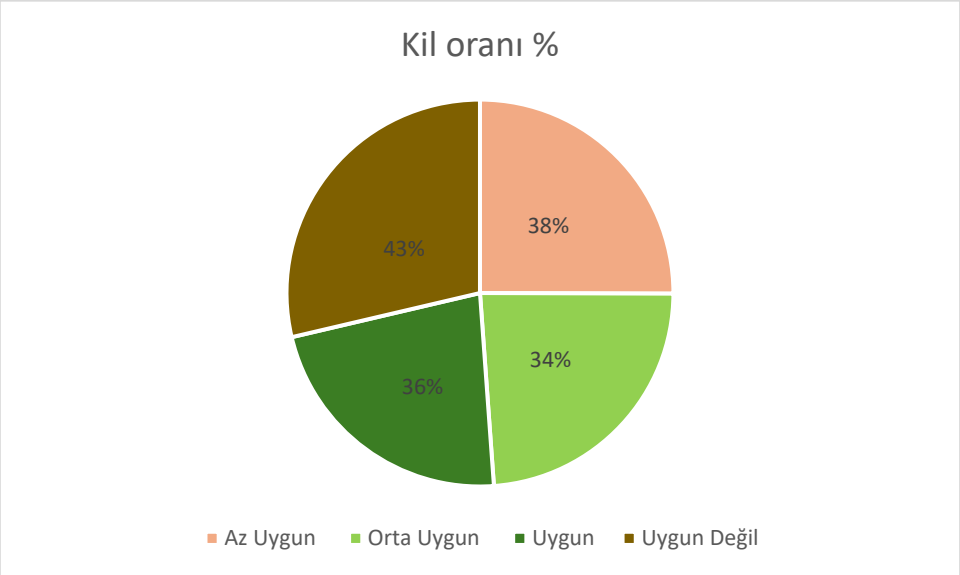
Toprak Değerlendirme Kriterleri	Kriter Ağırlıkları
Organik Madde (OM)	%34,6
PH	%30,8
Kil	%15,4
Silt	%11,5
Kum	%7,7

Tablo 3. Toprak Parametreleri Optimum aralık ve Riskli aralık

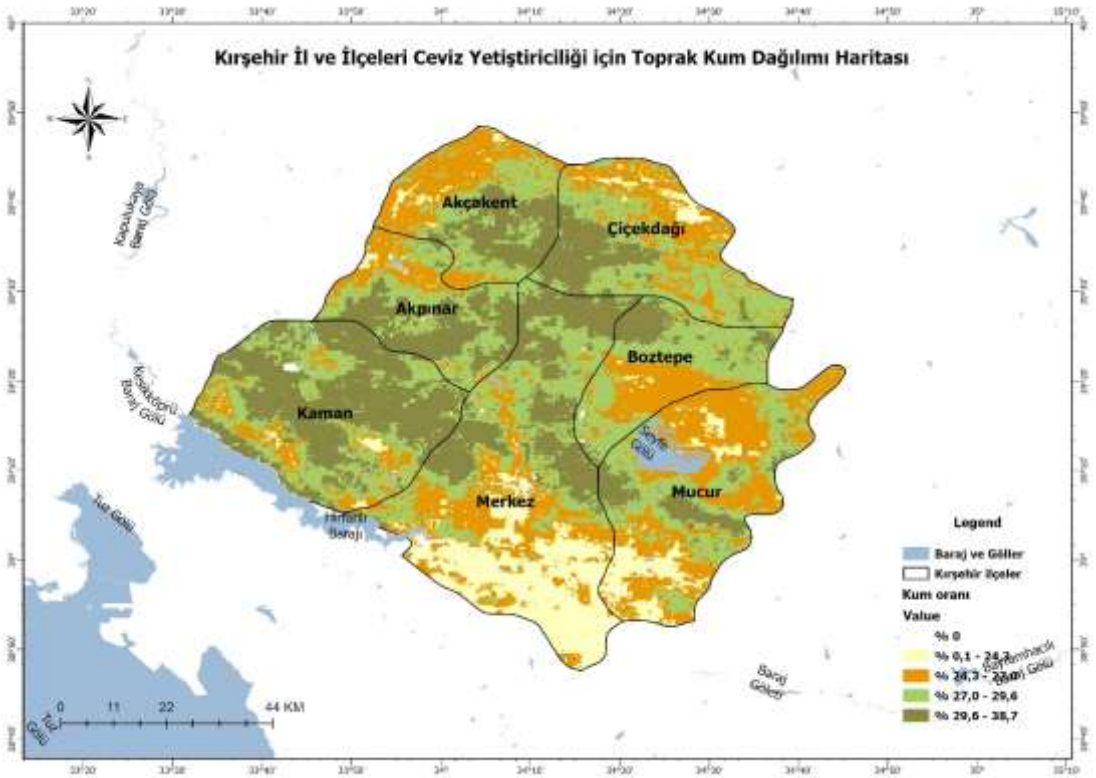
Parametre	Optimum Aralık	Riskli aralık
OM	%2-3,5	<1,5
PH	6,2-7,5	<5,0- >8,2
KUM	30-50 (%)	>50 (%) Aşırı geçirgen
KİL	<35 (%)	>35 (%) Kompakt
SİLT	30-50 (%)	>50 (%) Erozyon Riski



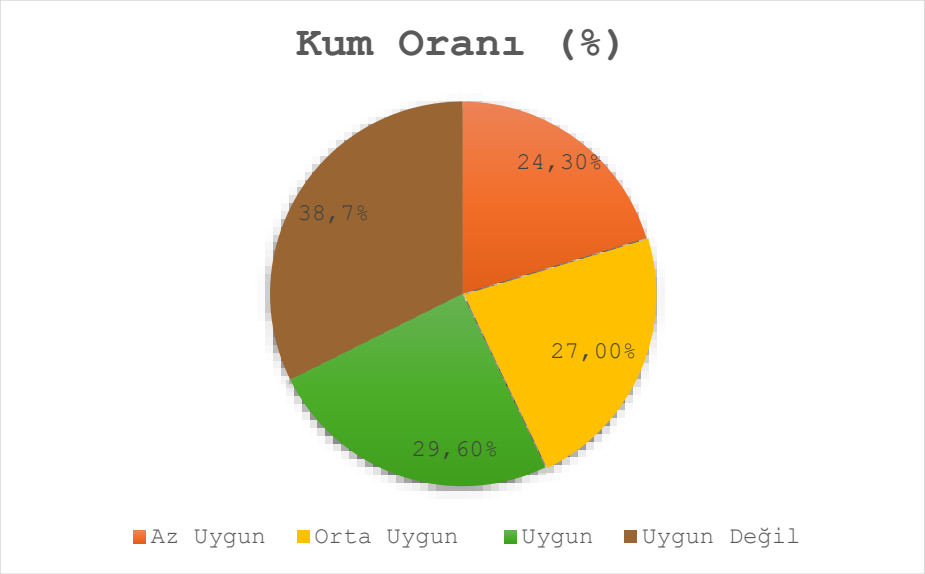
Şekil 1. Kırşehir ili Toprak Kil Dağılımı (%) Uygunluk Haritası



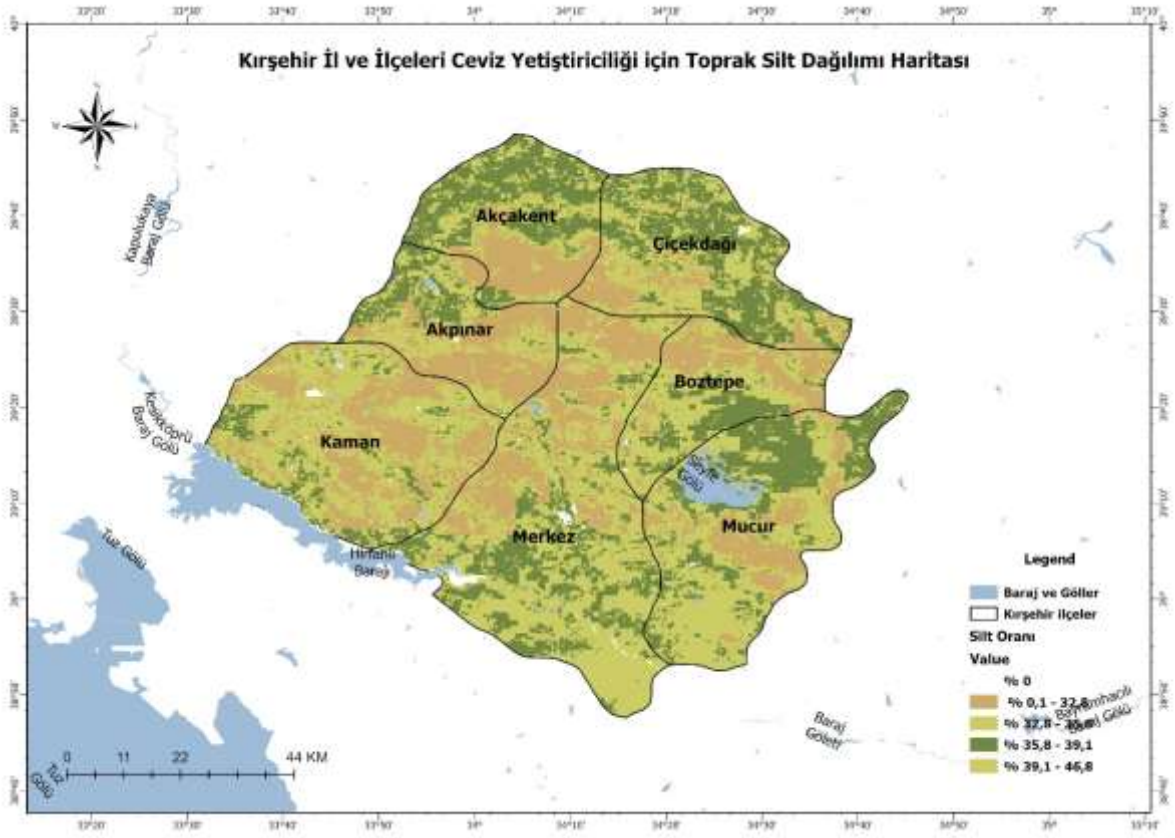
Şekil 2. Kil Oranına Göre Toprak Uygunluk Sınıflandırması



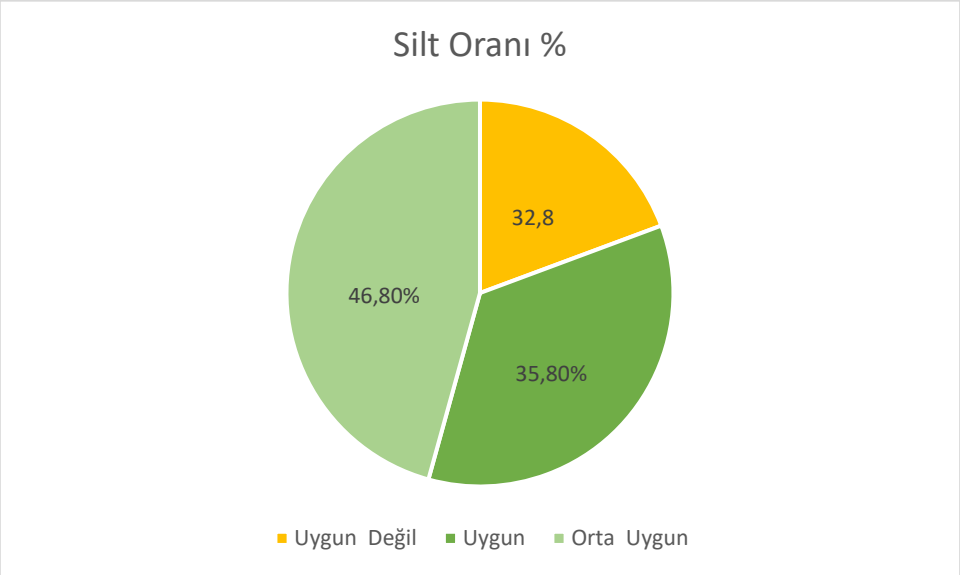
Şekil 3. Kırşehir İli Toprak Kum Oranı (%) Uygunluk Haritası



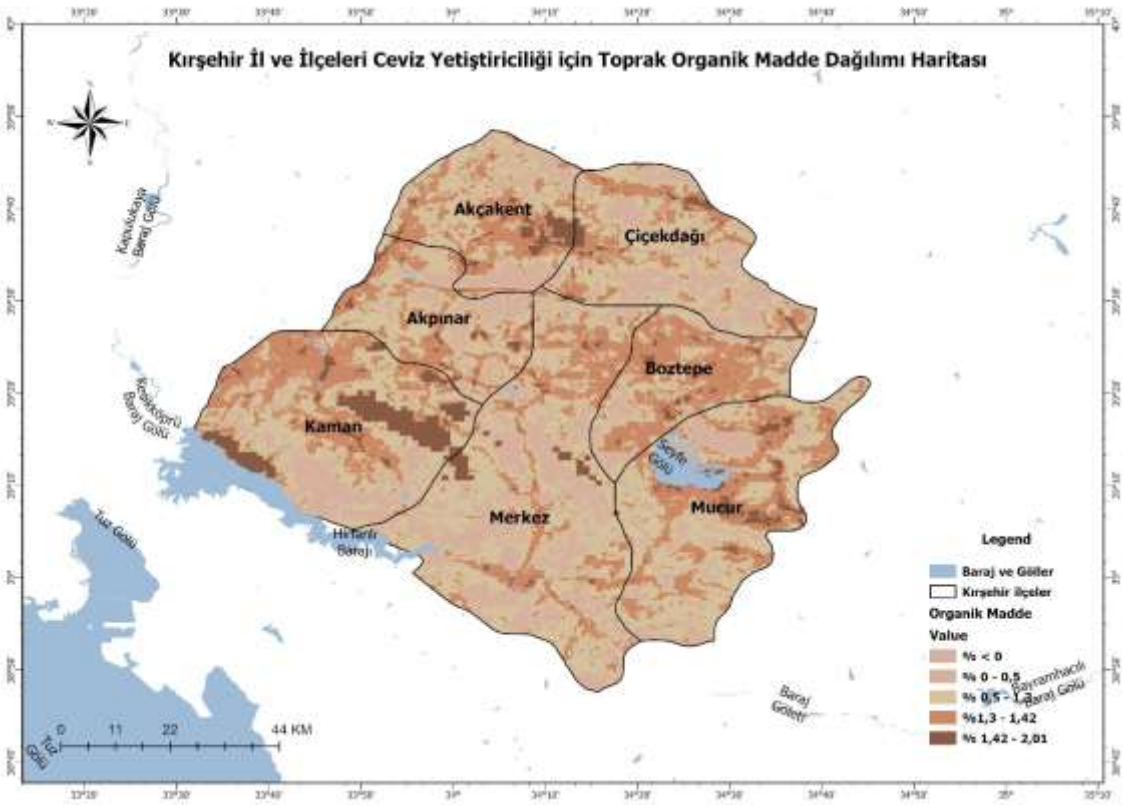
Şekil 4. Kum Oranına Göre Toprak Uygunluk Sınıflandırması



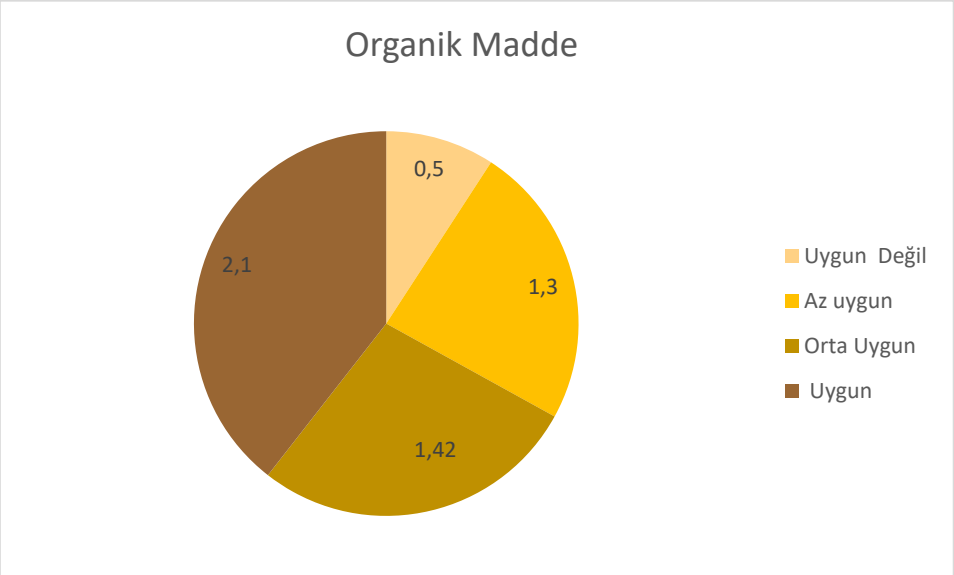
Şekil 5. Kırşehir İli Toprak Silt Oranı (%) Uygunluk Haritası



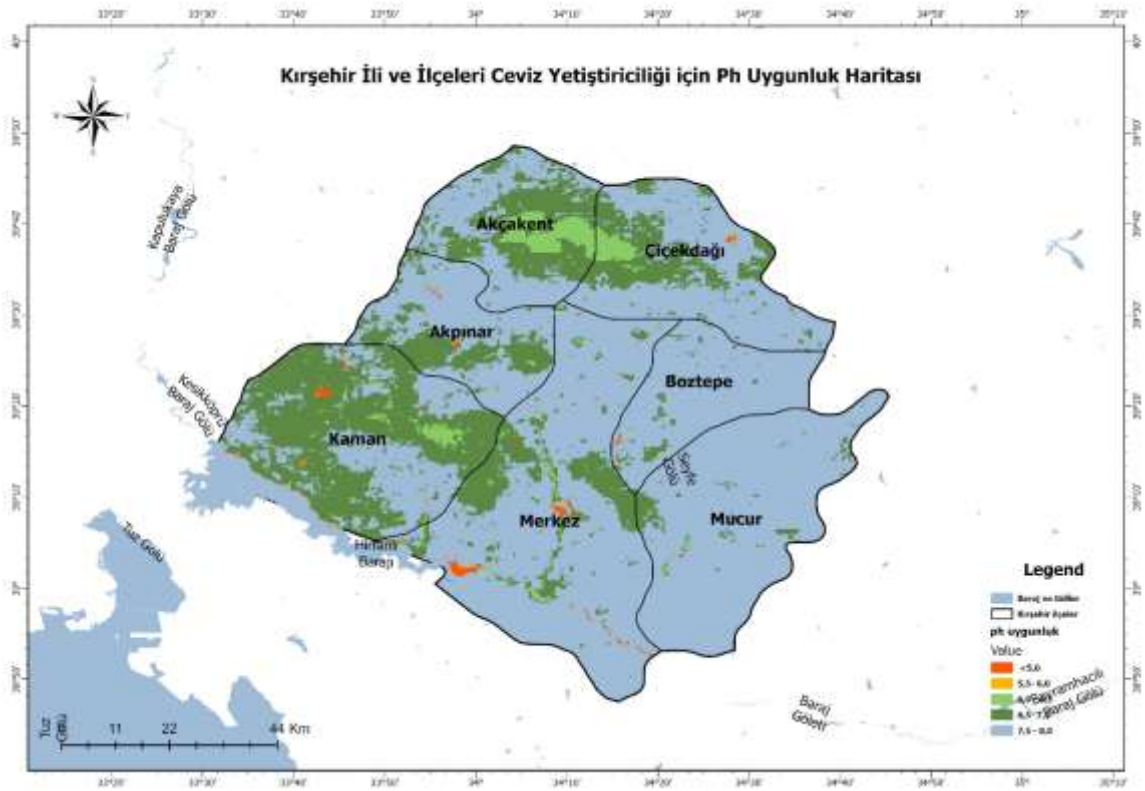
Şekil 6. Silt Oranına Göre Toprak Uygunluk Sınıflandırması



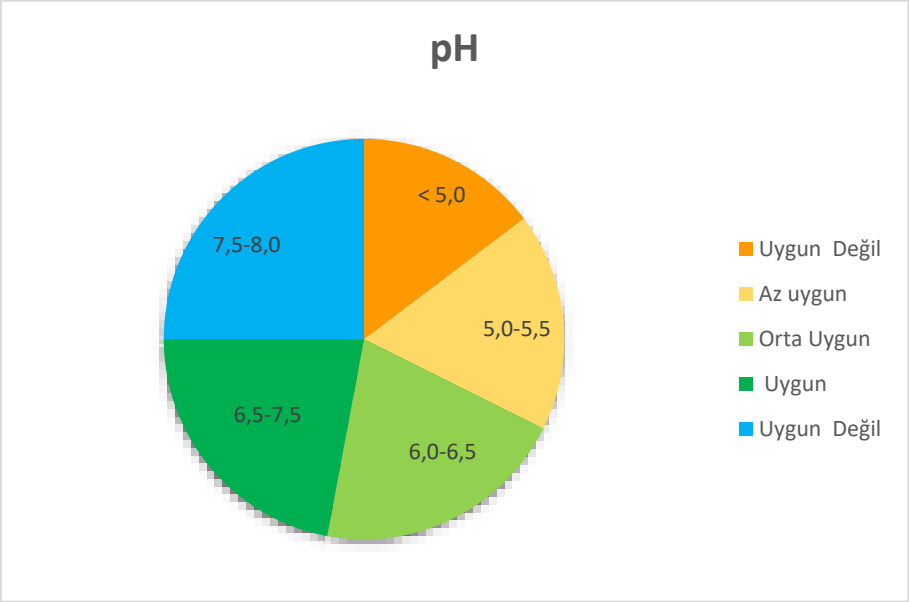
Şekil 7. Kırşehir İli Toprak Organik Madde (OM‰) Sınıflandırma Haritası



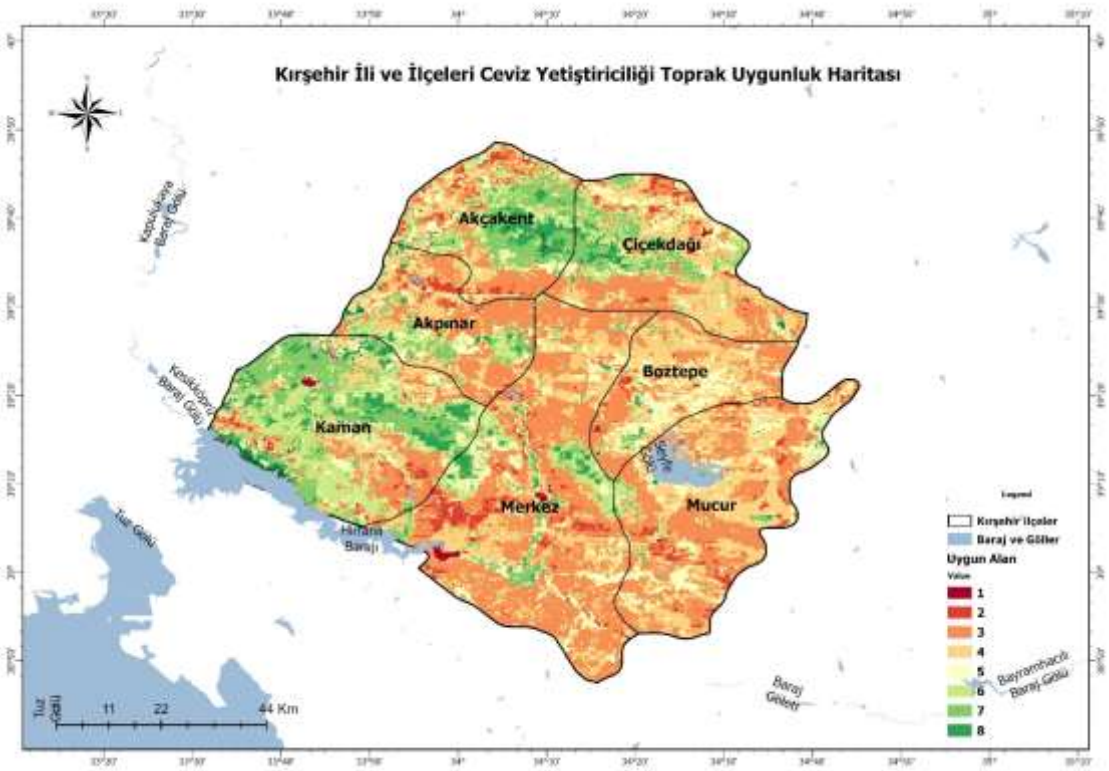
Şekil 8. Organik Madde Oranına Göre Toprak Uygunluk Sınıflandırması



Şekil 9. Kırşehir İli Toprak pH Uygunluk Haritası



Şekil 10. pH Oranına Göre Toprak Uygunluk Sınıflandırması



Şekil 11. Kırşehir İli Ceviz Yetiştiriciliği İçin Toprak Uygunluk Haritası

Bu harita, SoilGrids verilerine dayalı toprak parametrelerinin AHP yöntemiyle değerlendirilmesi sonucu oluşturulmuş toprak uygunluk haritasıdır. Renk skalası üzerinden ceviz yetiştiriciliği açısından toprakların uygunluk düzeyleri 1 (en düşük) ile 8 (en yüksek) arasında derecelendirilmiştir. Ceviz yetiştiriciliği açısından farklı toprak katmanlarında değerlendirilen fiziksel ve kimyasal özelliklerin bütüncül bir yaklaşımla mekânsal olarak yorumlanmasını sağlamıştır. Elde edilen sonuçlara göre, belirli bölgelerdeki toprakların ceviz yetiştiriciliği açısından yüksek düzeyde uygun olduğu görülmüştür. Bu alanlar, optimum pH aralığına, yeterli organik madde içeriğine ve uygun doku yapısına sahip toprakları içermektedir. Kaman ilçesi, en yüksek uygunluk değerlerine sahip alanların büyük bölümünü barındırmaktadır. Bu, bölgenin ceviz yetiştiriciliği açısından en elverişli yerlerden biri olduğunu ortaya koymaktadır. Seyfe Gölü çevresi hem su varlığı hem de toprak yapısı açısından bazı avantajlara sahip olmasına rağmen, uygunluk düzeyinin düşük olduğu (turuncu-kırmızı alanlar) görülmektedir. Bu da muhtemelen tuzluluk veya yüksek pH gibi sorunlara işaret etmektedir.

3. BULGULAR ve TARTIŞMA

Bu çalışmada, SoilGrids veri tabanından elde edilen toprak özellikleri değerlendirilerek, ceviz yetiştiriciliği açısından uygunluk aralıkları belirlenmiştir. SoilGrids, 250 metrelik mekânsal çözünürlüğe sahip hücre boyutlarıyla, makine öğrenme yöntemleri kullanarak dünya çapında toprak özelliklerine ait haritalar üretmektedir Belirlenen toprak parametreleri, Analitik Hiyerarşi Süreci (AHS/AHP) yöntemi kullanılarak ikili karşılaştırmalarla ağırlıklandırılmıştır. Her bir kriterin göreli önemi, uzman görüşleri ve literatür verileri doğrultusunda sayısal olarak ifade edilmiştir. Ağırlıklandırılmış kriterler, ArcGIS Pro 3.2 yazılımı aracılığıyla CBS (Coğrafi Bilgi Sistemleri) tabanlı "Weighted Overlay" analizi ile mekânsal olarak bütünleştirilmiş ve ceviz yetiştiriciliği açısından uygunluk düzeylerini gösteren tematik haritalar oluşturulmuştur. Bu analiz, farklı çevresel faktörlerin bir arada değerlendirilmesini sağlayarak potansiyel üretim alanlarının mekânsal dağılımını ortaya konulmuştur. Yön ve Sönmez'in (2021), Burdur bölgesinde gerçekleştirdikleri çalışmada, ceviz yetiştirilen toprakların pH değerlerinin 0–30 cm derinlikte 6,58–7,59; 30–60 cm derinlikte ise 6,84–7,64 arasında değiştiği belirlenmiştir. Araştırmada, toprak örneklerinin organik madde bakımından düşük humuslu, fosfor açısından yetersiz ve alınabilir demir (Fe) ile çinko (Zn) içerikleri yönünden de eksik olduğu ifade edilmiştir. Toprakların büyük çoğunluğunun (%80'den fazlası) yüksek oranda kireç içerdiği, bu nedenle özellikle demir, çinko ve kısmen de fosfor gibi besin maddelerinin yeterli düzeyde bulunmadığı vurgulanmıştır. Bruning ve ark. (2021), gerçekleştirdiği saha gözlemlerinde, bazı ceviz bahçelerinde ağaçların kuraklık belirtileri gösterdiği, bu durumun olası bir tuzluluk problemiyle ilişkili olup olmadığının araştırıldığı bildirilmiştir. Ölçümlerde, üst toprakta pH değeri 8,3; alt toprakta ise 8,5 olarak saptanmış, bu yüksek pH seviyelerinin bazı mikro besin elementlerinin alımını zorlaştırarak besin eksikliklerine neden olabileceği ifade edilmiştir. Çalışmamızda en uygun pH aralığı olan 6,2-7,5 parametresi belirlenmiş analizler bu parametreye göre yapılmıştır. Son olarak, Yan ve arkadaşları (2024), Tibet'in Gyaca bölgesinde gerçekleştirdikleri araştırmada farklı toprak ana materyalleri ve toprak tiplerinin ceviz verimi üzerindeki etkilerini incelemişlerdir. Özellikle 0–20 cm derinliğindeki üst toprak katmanında, organik madde içeriği, toplam azot miktarı, mikrobiyal biyokütle (MBC), fosfor ve diğer besin

elementlerinin seviyelerinin yüksek olduğu ve bu unsurların ceviz verimini doğrudan etkileyen önemli faktörler olduğu sonucuna varılmıştır. Ayrıca, bu besin elementlerinin ve mikrobiyal aktivitenin yüksekliğinin toprak yönetimi ve gübreleme stratejilerinin verimlilik üzerindeki önemini ortaya koyduğu belirtilmiştir. Çalışmada, ceviz bahçesi topraklarının pH seviyesinin 7,0'ın üzerinde olduğu ve bu durumun plato tipi ceviz çeşitleri için uygun olan hafif alkali bir ortam sağladığı sonucuna ulaşılmıştır. Çalışmamızda, SoilGrids veri tabanından elde edilen toprak özellikleri kullanılarak 15–30 cm, 30–60 cm ve 60–100 cm derinlik aralıklarında analizler gerçekleştirilmiştir. Bu derinlik katmanlarında toprak pH'ı, kil oranı, organik madde gibi önemli toprak parametreleri değerlendirilmiştir. Her bir parametre için ceviz yetiştiriciliğine uygunluk aralıkları tanımlanmış ve bu uygunluk düzeylerine göre mekânsal analizler yapılmıştır. Parametre bazlı uygunluk analizlerinin ardından, toprak verilerine dayalı genel bir toprak uygunluk haritası oluşturulmuştur.

4. SONUÇ

Ceviz yetiştiriciliği açısından farklı toprak katmanlarında değerlendirilen fiziksel ve kimyasal özelliklerin bütüncül bir yaklaşımla mekânsal olarak yorumlanmasını sağlamıştır. Elde edilen sonuçlara göre, belirli bölgelerdeki toprakların ceviz yetiştiriciliği açısından yüksek düzeyde uygun olduğu görülmüştür. Bu alanlar, optimum pH aralığına, yeterli organik madde içeriğine ve uygun doku yapısına sahip toprakları içermektedir. Kaman ilçesi, en yüksek uygunluk değerlerine sahip alanların büyük bölümünü barındırmaktadır. Bu, bölgenin ceviz yetiştiriciliği açısından en elverişli yerlerden biri olduğunu ortaya koymaktadır. Seyfe Gölü çevresi hem su varlığı hem de toprak yapısı açısından bazı avantajlara sahip olmasına rağmen, uygunluk düzeyinin düşük olduğu (turuncu-kırmızı alanlar) görülmektedir. Bu da muhtemelen tuzluluk veya yüksek pH gibi sorunlara işaret etmektedir. Elde edilen bu toprak uygunluk haritası, ceviz yetiştiriciliği için yatırım planlamasında, arazi kullanım kararlarında ve sürdürülebilir üretim alanlarının seçilmesinde rehber niteliği taşımaktadır. Sonuç olarak, çalışmada kullanılan CBS tabanlı analiz yöntemleri, bölgesel düzeyde ceviz yetiştiriciliği için uygun alanların belirlenmesine katkı sağlamış ve tarımsal planlamaya yönelik önemli bir zemin oluşturmuştur. Bu yöntem, sadece ceviz değil, diğer tarım ürünleri için de benzer şekilde uygulanabilirliği olan sürdürülebilir bir analiz yaklaşımı sunmaktadır.

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EVALUATIONS ON INVITRO MICROPROPAGATION OF WALNUT

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ABSTRACT

Walnut (*Junglans* sp.), which is valued for both its fruits and timber, is one of the most important hard-shelled fruit species that grows in many regions around the world and has also become widespread in Anatolia. It is widely produced in North and South America, Asia and to a limited extent in North Africa, Australia and New Zealand. Its fruits being rich in oil and protein are important features that are increasing its consumption in the world. Following the USA, China and Iran, Turkey is the country that produces more than half of the walnuts in the world.

Walnut, which is an allogamous plant, is a species that is very difficult or impossible to propagate by cutting or dipping. It is propagated by grafting classically. In terms of obtaining production material in walnut cultivation, this method creates obstacles both because it is time consuming and because of serious labor costs. In addition, the fact that plants grafted onto rootstocks propagated by seeds form large trees causes difficulties in terms of cultural practices. Also, micropropagation is the most important starting point in terms of the widespread use of clonal rootstock production. In order to overcome these problems, micropropagation in *in vitro* conditions is becoming increasingly important in walnut cultivation. Micropropagation in walnut was initially done to overcome the difficulties encountered in rooting methods in traditional production of these species. With this production method, it is possible to obtain many identical seedlings from a single bud. Grafting labor can be eliminated and time and labor can be saved. In addition, the use of clonal rootstocks, which should be widespread in nursery farming as soon as possible, will also increase. Micropropagation is quite valuable in terms of providing easy reproduction of rootstocks, providing pest-free plant material, and providing mass production opportunities and providing phenotypic and genotypic similarities in the produced plants. Although the success of micropropagation depends on many internal and external factors, adventitious root formation is the most important stage. Phytohormones and plant growth regulators have significant effects on adventitious root formation of plant species. The main problems in *in vitro studies*; problems such as microbial contamination, phenolic release and adaptation of explants to tissue culture conditions. These factors cause the loss of explants and thus prevent successful *in vitro* formation.

This evaluation study aimed to summarize the studies conducted in micropropagation of both varieties and rootstocks of walnut *in vitro* conditions and the current situation.

Keywords: *Juglans regia* L., Micropropogation, Explant, media

CEVİZİN *in vitro*'DA MİKRO ÇOĞALTILMASI İLE İLGİLİ DEĞERLENDİRMELER

ÖZET

Hem meyveleri hem de kerestesi için değerlendirilen ceviz (*Junglans* sp.) dünya üzerinde birçok bölgede yetişen, Anadolu coğrafyasında da yaygınlaşmış olan en önemli sert kabuklu meyve türlerinden birisidir. Dünyada yaygın bir şekilde Kuzey ve Güney Amerika, Asya'da sınırlı olarak ta Kuzey Afrika, Avustralya ve Yeni Zellanda'da üretimi yapılmaktadır. Meyvelerinin zengin yağ ve protein kaynağı olması dünyada tüketimini giderek artıran önemli özelliklerindendir. ABD, Çin ve İran'ın ardından Türkiye dünya üzerinde ceviz üretiminin yarıdan fazlasını gerçekleştiren ülkelerdir.

Allogam bir bitki olan ceviz, çelik veya daldırma ile çoğaltılması çok güç ya da imkânsız olan bir türdür. Klasik olarak aşı ile çoğaltılmaktadır. Ceviz yetiştiriciliğinde üretim materyalinin elde edilmesi açısından bu metot, hem zaman alması hem de ciddi işçilik maliyetleri nedeniyle engeller oluşturmaktadır. Ayrıca tohumla çoğaltılan anaçlar üzerine aşılanan bitkilerin büyük ağaçlar oluşturması, kültürel uygulamalar açısından zorluklara neden olmaktadır. Bunun yanında klonal anaç üretiminin de yaygınlaşması açısından mikroçoğaltım en önemli çıkış noktasıdır. Bu problemleri aşabilmek için ceviz yetiştiriciliğinde *in vitro* koşullarda mikro çoğaltım giderek daha fazla önem kazanmaktadır. Cevizde mikro üretim başlangıçta bu türlerde geleneksel üretimde köklendirme metotlarında karşı karşıya kalınan güçlükleri yenmek için yapılmıştır. Bu üretim şekli ile bir tomurcuktan çok sayıda birbirinin aynı, adına doğru fidan elde etmek mümkün olmaktadır. Aşı işçiliği ortadan kalkarak zamandan ve işçilikten tasarruf sağlanabilir. Ayrıca, bir an önce fidancılıkta yaygınlaşması gereken klonal anaçların bu sayede fidancılıkta kullanımı da artacaktır. Mikroçoğaltım, anaçların kolayca çoğaltılmasını sağlayan, zararlılardan ari bitkisel materyal sağlamakla birlikte kitlesel üretim imkânı sunması ve üretilen bitkilerde fenotipik ve genotipik benzerlikler sağlaması açısından oldukça değerlidir. Mikroçoğaltımın başarısı çok sayıda içsel ve dışsal faktörlere bağlı olsa da adventif kök oluşumu en önemli aşamadır. Fitohormonlar ve bitki büyüme düzenleyicileri, bitki türlerinin adventif kök oluşumu üzerinde önemli etkilere sahiptir. *In vitro* çalışmalarındaki başlıca sorunlar; mikrobiyal kontaminasyonlar, fenolik salınımı ve eksplantların doku kültürü koşullarına adaptasyonu gibi problemlerdir. Bu faktörler, eksplantların kaybedilmesine dolayısıyla başarılı bir *in vitro* oluşumunun engellenmesine neden olmaktadır.

Bu değerlendirme çalışması; *in vitro* koşullarda cevizin hem çeşit hem de anaçlarının mikroçoğaltımında yapılan çalışmaları ve mevcut durumu özetlemeyi amaçlamıştır.

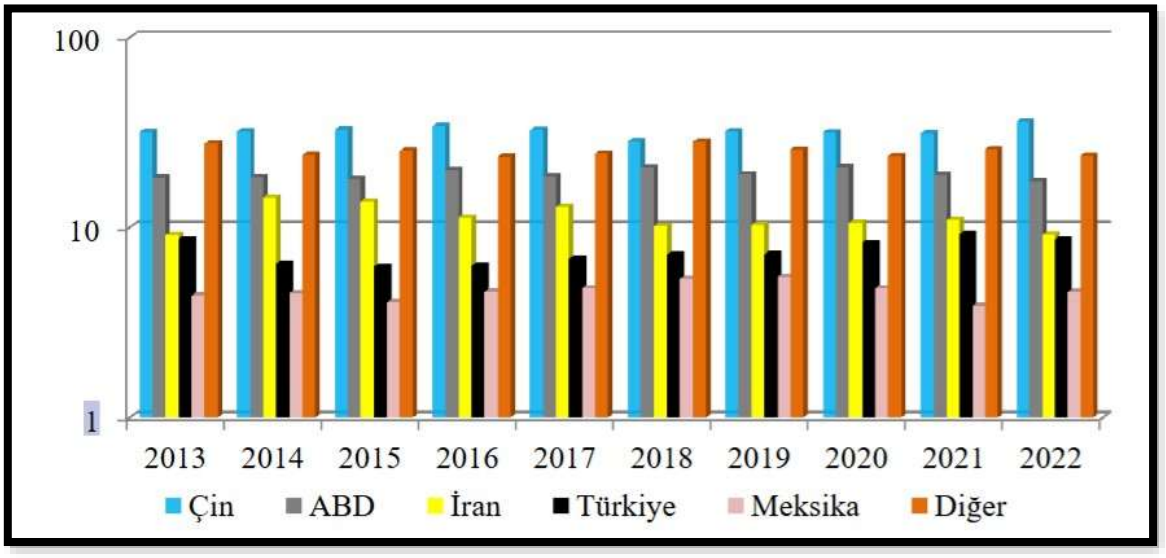
Anahtar Kelimeler: *Juglans regia* L., Mikroçoğaltım, Eksplant, Ortam

1.GİRİŞ

Ceviz Juglandales takımının, Juglandaceae familyasında *Juglans* cinsi içerisinde sert kabuklu meyvelerindendir (Şen, 2011). *Juglans* cinsine ait 22 tür olup, diploid yapılı *Juglans* türlerinin kromozom sayısı 2n=32' dir. Ceviz türleri arasında en çok yetiştirilen *Juglans regia* L.'dir (Akça,2014). Ceviz sert kabuklu meyve yapısına sahip olup, yeşil kabuk ve iç cevizden oluşmaktadır. İç ceviz ise embriyodan meydana gelir. Tohumda endosperm bulunmadığından yedek besin kotiledon içerisinde birikmektedir (Esen, 2013). Genç dal yapısı pürüzsüz, ilerleyen yıllarda gövdede çatlaklar meydana gelir ve kabuk rengi gri ya da siyahımsı renk alır. Ceviz ağacı için gerekli koşullar sağlandığında boyları 25m'ye kadar ulaşabilir. Büyük yuvarlak taç yapısının olmasının yanında taç özelliği çeşitlerine göre farklılık göstermektedir (Şen, 1986).

Ceviz, meyve ve çerezlik şeklinde yaygın olarak tüketilen ve besin içeriği bakımından zengin bir beslenme içeriği sunar. Vücudun günlük ihtiyacı olduğu birçok besin elementini barındırır. Yüksek oranda yağ (%65 civarında) ve protein (%15 civarında) içeriğine sahip oldukları bilinmektedir (Yiğit ve ark. 2005). Türkiye'de ve dünyada ceviz ihtiyacının artmasıyla yetiştiricilik, üretim miktarı ve niteliği de artmaktadır.

Tablo 1. Dünya ceviz üretim miktarında ülkelerin payı (%) (Tarım ve Orman Bakanlığı 2024)



Tablo 1 de Çin birinci sırada yer alırken hemen arkasından ABD gelmektedir.

Tablo 2. Türkiye'de ceviz üretim alanı ve üretim miktarı (TÜİK, 2024)

Yıllar	Üretim alanı (da)	Üretim (t)
2013	639.000	212.000
2014	694.000	181.000
2015	718.000	190.000
2016	869.000	195.000
2017	920.000	210.000
2018	1.118.000	215.000
2019	1.246.000	225.000
2020	1.418.000	287.000
2021	1.535.000	325.000
2022	1.665.000	335.000
2023	1.741.000	360.000

2013-2023 yılları göz önünde tutulduğunda; üretim alanındaki artış %172.45 iken, üretim miktarında ise %69.8'lik bir artış olduğu görünmektedir. Türkiye'de 2023 yılında bir önceki yıla göre ceviz üretimi %7.46'lık bir artışla 360 bin tona ulaşmıştır. Bu artışın zamanla yeni tesis edilen bahçelerin meyveye yatmasıyla daha da artacağı düşünülse de, üretim alanına bağlı olarak üretim miktarındaki artışın yetersiz olduğu söylenebilir.

Ceviz ağaçlarının çiçek yapısı monoiktir. Erkek ve dişi çiçeklerin olgunlaşma zamanının farklı olması nedeniyle, allogam bir yapı gösterir dolayısıyla heterozigoti belirgindir. Ülkemizde ceviz yetiştiriciliğinde aşı ile çoğaltılan fidanlar kullanılmakta, anaç olarak hemen tamamı tohumdan elde edilmiş çöğürler tercih edilmektedir. Ekonomik değeri yüksek olan ceviz fidanlarının yetiştirilmesi zaman alır. Bilindiği gibi birçok çalışma, anacın üzerine aşılanan çeşidin verimliliğine ve kalitesine etki ettiğini bildirmiştir. Özellikle diğer türlerde de tercih edilen klonal anaçların bu etkide stabil oldukları, adına doğru fidan üretimini büyük oranda sağlayabildikleri bilinmektedir. Ceviz ile ilgili araştırmaların büyük bir çoğunluğu çeşit geliştirme üzerindedir. Bunun yanında klonal anaçların çoğaltılmasına dönük bir ilgi de söz konusudur. Kaliforniya'da eskiden beri en yaygın kullanılan Paradox çöğürleri (*J. hinsii* tohumları ve *J. regia* melezi) anaç olarak kullanılmaktadır. Bu anaçların üretimi tohum anaçlarına göre daha maliyetli olmasının yanında da bulunabilirlik sorunları olduğundan fidan üreticileri hala tohum anaçlarıyla üretim gerçekleştirmektedirler (Özelçi, 2024). Ülkemizde ise *J.regia* tohumlarından elde edilen çöğürler anaç olarak kullanılmaktadır (Erdoğan 2006). Ceviz yetiştiriciliğinde kullanılan anaçların bazı problemlerinin olduğu, cevizde modern üretimi sağlayabilecek özelliklerde olmadığı bilinmektedir. (Sütyemez, 2011). Dolayısıyla standart ceviz anaç/lar eldesine yönelik ıslah çalışmalarına ve mevcut klon anaçlarının hızlı bir şekilde üretilerek devreye sokulmalarına ihtiyaç vardır.

2. BAZI CEVİZ ANAÇLARI

2.1. *Juglans hindisii:* Kaliforniya bölgesinde en yaygın kullanılır. Derin ve verimli topraklarda tercih edilir. Ağır ve yüksek kireçli topraklara karşı toleransı yoktur. *Phytophthora*, nematod ve siyah çizgi hastalığı olmayan topraklarda kullanımı önerilir.

2.2. *Juglans regia*: Tüm dünyada en yaygın olarak kullanılan Anadolu cevizi (*Juglans regia*) anacıdır. Bu anaç siyah çizgi hastalığına karşı dayanıklıdır. Ancak aşırı tuzlu topraklara, kök urlarına, nemotadlara, kök çürüklüğüne neden olan *Armillaria*, kök kanserine ve taç çürüklüğüne duyarlıdır. Bu nedenle, toprak koşulları ve hastalık risklerinin dikkate alınması önemlidir

2.3. Paradox (*J. hindsii* X *J. regia*): Bu anacın en önemli özelliği *Phytophthora* türlerine ve nematodlara karşı ebeveynlerine göre daha dayanıklı olmasıdır. Hızlı gelişim göstermesine rağmen, siyah çizgi hastalığına ve kök kanserine karşı duyarlıdır Paradox anacından son yıllarda geliştirilen klonal üç farklı anaç mevcuttur. Bunlar; Vlach, RX1 ve VX211'dir.

2.3.1. VX211: Bu anaç nemotodlara karşı diğer paradox klon anaçlarına kıyasla daha dayanıklı olduğu bilinmektedir.

2.3.2. RX1*:* *Phytophthora citricola* türüne karşı oldukça dayanıklı bir anaçtır.

2.3.3. Vlach: Güçlü yapısıyla bilinen ilk klonal paradoks anacıdır. Nematodlara karşı duyarlı olmasının yanında kök enfeksiyon hastalıklarına karşı dirençli olduğu bilinmektedir.

2.4. Royal (*J. nigra* X *J. hindsii*): Oldukça kuvvetli bir ceviz anacıdır ve çok hızlı büyür. Özellikle kereste yönünden değerli bir ağaç yapısına sahiptir. Ancak yaygın bir kullanıma ulaşamamıştır.

2.5. *Juglans major*: Yüksek pH içeren topraklara uygun bir ceviz anacıdır. Ancak diğer anaçlara kıyasla fazla bir üstünlüğe sahip olmaması nedeniyle kullanımı yaygın değildir (Şen 1986).

Cevizin zor çoğaltılan bir tür olması nedeniyle alternatif olarak son yıllarda mikroçoğaltma tekniği giderek önem kazanmaktadır. Özellikle ceviz yetiştiriciliğinde, *J. regia x J. hindsii* melezi olan Paradox tohum anacının klonları (Vlach, RX1 ve VX211) ve bazı ceviz çeşitleri (Chandler, Fernor, Fernette, Franquette, Hartley, Vina, Howard, Tulare, Lara ve Serr), ABD, İspanya, Fransa ve Yunanistan'da ekonomik olarak *in vitro* da çoğaltılmaktadır (Anonim

2025a). Ülkemizde ise Vlach anacı ve Chandler çeşidi, doku kültürü yoluyla üretilmeye başlanmıştır (Anonim 2025b).

Mikroçoğaltım, bir bitkiden alınan embriyo, sürgün, kök, kallus gibi dokuların yapay besin ortamlarında ve aseptik olarak yeni bitkiler elde edilmesini içerir (Babaoğlu ve ark. 2002). Bu yöntem, anaçların üremesini sağlayan, zararlılardan arındırılmış bitkisel materyal sağlamakla birlikte kitlesel üretim imkânı sunar. Aynı zamanda, üretilen bitkilerde fenotipik ve genotipik benzerlikler sağlar. Mikroçoğaltım diğer metotlarla karşılaştırıldığında daha kısa sürede sonuç verir ve zor üretilen türlerin üretimi gerçekleştirilebilir.

Ceviz mikroçoğaltımına ilişkin ilk başarılı raporlar 1980'li yıllara dayanmaktadır (Driver, McGranahan, Gruselle – Rodriguez). Genetik, eksplantların fizyolojik ve biyokimyasal durumu, çevre koşulları ve kültür ortamının kimyasal ve besinsel bileşimi en önemli faktörler arasındadır. Fitohormonlar ve bitki büyüme düzenleyicileri bitki türlerinin adventif kök oluşumu üzerinde önemli etkilere sahiptir.

3. *İn Vitro* OLUŞUMU VE ÇOĞALTMAYI ETKİLEYEN FAKTÖRLER

Ceviz mikroçoğaltımı, türün ticari ölçekte üretimi için önemli bir araç olmasına rağmen bu sürecin en öngörülemeyen aşaması olan *in vitro* oluşum, hala aşılması gereken çeşitli zorluklar ile karşı karşıyadır. *In vitro* oluşumunun karşılaştığı başlıca sorunlar; mikrobiyal kontaminasyonlar, fenolik salınımı ve eksplantların doku kültürü koşullarına adaptasyon gibi problemlerdir. Bu faktörler, eksplantların kaybedilmesine dolayısıyla başarılı bir *in vitro* oluşumun engellenmesine neden olmaktadır. Ayrıca, her bitkide karşılaştığımız gibi cevizde de genotipleri arasında da önemli farklılıklar gözlemlenmiştir. Bazı genotipler kültüre alınmaya daha yatkınken, diğerleri oldukça direnç göstermektedir. Genotip değiştirilemeyen bir faktör olarak bilinse de, gençlik derecesi ve kültür koşulları optimize edilerek bu faktörün olumsuz etkileri azaltılabilir. Örneğin, saha koşullarında yetişen ağaçlardan alınan eksplantların, *ex vitro* kontrollü koşullar altında tomurcukları filizlenmeye zorlanarak *in vitro* başlatmanın başarısı artırılabilir. Bu yaklaşım, Licea-Moreno ve ark. (2015) (ceviz melezleri için) ve Yegizbayeva ve ark. (2021) (*J. regia* için) tarafından başarıyla uygulanmıştır

Çoğalma oranı, ticari mikroçoğaltımın uygulanabilirliğini doğrudan etkiler. Yüksek çoğalma oranları, potansiyel üretim maliyetlerini düşürür. Ancak, genel mikroçoğaltım iyileştirmelerine dair çalışmalar bulunsa da, özellikle çoğalma oranlarının artırılmasına yönelik araştırmalar sınırlıdır. Bazı araştırmalar, DKW-C formülasyonunda yapılan değişikliklerin, örneğin floroglusinol takviyesi ve FeEDTA'nın FeEDDHA ile değiştirilmesi, ceviz hibritleri ve İran cevizi için büyümeyi ve *in vitro* materyallerin çoğalma oranlarını teşvik ettiğini göstermiştir. Paradox cevizleri, Amerikan siyah ceviz genotipleri ve bazı İran ceviz klonlarında da B5, Cheng, MS ve WPM yerine DKW ortamı kullanılarak önemli çoğalma oranı farklılıkları kaydedilmiştir (Yegizbayeva ve ark. 2021).

Sıvı ortamların kullanılması, ticari mikroçoğaltım da potansiyel bir atılım olarak görülmektedir. Ancak, bu konuda bugüne kadar çok az ve sınırlı sayıda çalışma yapılmıştır. Heile-Sudholt ve arkadaşları, Amerikan siyah cevizinden elde edilen sürgünleri sabit sıvı ortamlarda kültüre alsalar da, bu durum *in vitro* materyallerin kalitesi veya çoğalma oranları için katkı

yapmamıştır. Diğer yandan, Stevens ve Pijut (2018), çalkalamalı sıvı ortam kullanarak iki Amerikan siyah ceviz klonunun çoğalmasını sağlamışlardır. Fakat, kontrol olarak jelleşmiş ortam kullanılmadığından dolayı iklimlendirme sırasında köklü mikro sürgünlerin tamamen ölümünün, bu ortamdan mı kaynaklandığını belirlemek mümkün olmamıştır. Licea-Moreno ve ark., (2015), geçici daldırma biyoreaktörlerinde (TIB'ler) çeşitli ceviz hibrid klonlarının çoğalma oranlarının arttığını bildirmiştir. Daha sonra, Licea-Moreno ve ark., (2020) bu sistemlerde karşılaşılan bazı sorunları çözerek jelleşmiş ortamda kültüre edilenlere benzer yüksek kaliteli mikro sürgünler üretmeyi başarmışlardır. Bununla birlikte, cevizlerin ticari mikroçoğaltımında geçici daldırma sistemlerinin (TIS) kullanımı için daha fazla araştırmaya ihtiyaç duyulmaktadır.

Saeedi ve Vahdati (2023*) in vitro* daki ceviz eksplantlarını farklı ışık spektrumlarına sahip aydınlatma sistemlerine maruz bırakarak morfo-fizyolojik özellikler ve biyokütle birikimi üzerindeki etkilerini incelemiştir. Birleştirilmiş spektrumların, özellikle mavi-kırmızı ve kırmızı-uzak kırmızı kombinasyonlarının, diğer tek renkli ışık spektrumlarına kıyasla daha iyi biyokütle birikimine (toplam taze ve kuru ağırlık) yol açtığını göstermişlerdir. Işık-yayan diyot (LED) uygulamalarının, ceviz *in vitro* eksplantlarının morfo-fizyolojik özelliklerini önemli ölçüde etkilediği de gözlemlenmiştir. Beyaz ışık spektrumları spesifik yaprak alanını (SLA) artırırken, yeşil ışık spektrumları yaprak su içeriğini (LWC) yükseltmiştir. Uzak kırmızı ışığın uygulanması ise yaprak kütle alanını (LMA) ve birim yaprak alanı başına su içeriğini (LWCA) artırmıştır. Sonuç olarak belirli ışık spektrumları kullanılarak ceviz *in vitro* eksplantlarının morfolojik ve büyüme özelliklerinin iyileştirilebileceği belirlenmiştir. Dolayısıyla, ceviz *in vitro* yayılımında daha etkili protokoller geliştirmek için yeni stratejilerin optimizasyonu önemli bir potansiyele sahiptir.

Sonuç olarak, ceviz mikroçoğaltımında *in vitro* oluşum aşaması, üstesinden gelinmesi gereken önemli zorluklar içermektedir. Ancak, gençlik derecesinin yönetilmesi, uygun kültür ortamının seçilmesi ve sıvı ortamlar, farklı ışık spektrumları, özellikle de geçici daldırma sistemleri gibi yenilikçi yaklaşımların kullanılması, bu zorlukların aşılması ve ticari ölçekte ceviz mikroçoğaltımının uygulanabilirliğinin artırılması için büyük bir potansiyel sunmaktadır. Gelecekte yapılacak araştırmaların, bu alandaki bilgi birikimini artırmaya ve ceviz mikroçoğaltımını daha verimli ve sürdürülebilir hale getirmeye odaklanması gerekmektedir.

4. MİKROÇOĞALTIMDA YER ALAN AŞAMALAR

Başarılı bir mikroçoğaltım protokolü, her bir bitki için kendine özgü gereksinimlere sahip, dikkatle planlanmış ve optimize edilmiş dört temel aşamadan oluşur.

4.1. Aseptik Kültürün Başlatılması

Bitki materyalini kontamine eden mikroorganizmalardan arındırarak steril bir ortamda kültür başlatılması en önemli aşamalardan biridir. Yüzey sterilizasyonu ve uygun kültür ortamlarının kullanılması, kontaminasyonu önlemek ve sağlıklı gelişim sağlamanın anahtarıdır. *Juglans* türlerinin *in vitro* çoğaltılmasında başarı, genellikle uygun eksplant seçimine bağlıdır. Eksplant seçimi, uygulanacak *in vitro* çoğaltım tekniği ile doğrudan ilişkilidir. Genellikle,

somatik embriyogenez, kallus oluşumu, köklenme, çimlenme ve sürgün organogenezi gibi süreçlerin başlatılması için genç dokular tercih edilir. Dolayısıyla, istenilen *in vitro* çoğaltım yöntemi dikkate alınarak yapılan eksplant seçimi, *Juglans* türlerinde başarılı bir çoğaltım sürecinin temelini oluşturmaktadır. Nitekim; Şirin (2014), uygun fizyolojik dönemin ve eksplantın seçiminin, kültürlerdeki tanen ve diğer toksik bileşiklerin zararlı etkilerinin üstesinden gelinmesi, kabul edilebilir bir sürgün çoğalma oranının sağlanması ve seçilmiş sert kabuklu meyve klonlarının mikroçoğaltımında köklenmiş sürgünlerin son derece önemli olduğunu vurgulamıştır. Olgun ceviz ağaçlarından alınan eksplantlarla yapılan mikroçoğaltım çalışmasında iç kontaminasyonun önemli bir sorun olduğu bilinmektedir. Ayrıca, yüzey sterilizasyonu aşamasında dokularda oksidasyon sonucu oluşan koyulaşmanın sürgün oluşumunda büyük bir azalmaya neden olduğunu ve bu sorunun dezenfeksiyona daha dayanıklı ancak yarı odunsu olan genç sürgün eksplantları kullanılarak bu problemin aşılabileceğini belirtilmektedir (Leal ve ark.2007).

Besleyici formülasyonun da *in vitro* başlatma üzerinde önemli bir etkisi olduğu kanıtlanmıştır. Fakat, literatürde çelişkili sonuçlar rapor edilmiştir. DKW formülasyonu, *in vitro* kültür sonuçlarını iyileştirmek amacıyla geliştirilmiş ve birçok araştırmacı (Heile -Sudholt ve ark. 1989, Revilla ve ark.1989, Yegizbayeva ve ark., 2021) tarafından doğrulanmıştır. Buna karşılık, bazı araştırıcılar (Gruselle, R, Lone, I.A)(Gruselle, Lone) MS (1962) formülasyonunu kullanarak daha iyi sonuçlar elde etmişlerdir. Bu durum, *in vitro* oluşumun başarısını artırmak için uygun kültür ortamı seçiminin önemli bir faktör olduğunu göstermektedir. Örneğin, *J. regia* fidelerinin nodal gövde segmentlerinden koltuk altı tomurcuk uzaması, 0,4 µM BA ve 0,8 µM NAA içeren Murashige ve Skoog (MS) ortamında başarılı bir şekilde sağlanmıştır (Chalupa, 1981). Benzer şekilde, Gruselle ve diğerleri (1987), bir MS ortamında 4,4 ve 8,9 µM BA'nın *J. regia* nodal eksplantları için uygun olduğunu belirtmişlerdir.

4.2. Sürgün Oluşturma

Bu aşamada, başlatılan kültürler, büyüme regülatörleri ve uygun kültür ortamı kullanılarak çok sayıda mikro sürgün elde etmek için çoğaltılır. Bu aşamanın amacı, yeterli sayıda genetik olarak özdeş sürgün üretmektir. Çeşitli araştırmalar, *Juglans* türlerinin mikro çoğaltım potansiyeline sahip olduğunu göstermektedir (Sommers vd, 1982; Driver ve Kuniyuki, 1984; ve diğerleri). Şirin (2014) Kaman 1 çeşidinin MS ortamına eklenen 0.5 mg L-1 BAP ve 0.5 mg L-1 İBA konsantrasyonları ile en çok sürgün oluşumu sağlayan ortam olduğu; eksplant başı yaprak sayısının 3.00 ile 5.33 adet arasında değiştiğini saptamıştır. Sekmen ve ark. (2017), ceviz'in *in vitro* koşullarda çoğaltım protokolü oluşturabilmek için, Chandler çeşidinin sürgünlerinde bir göz bulunan nodal segmentleri eksplant olarak kullanmıştır. DKW, DKW–C ve MS besin ortamları içerisinde ise üçer farklı hormon konsantrasyonları ile 9 farklı kültür oluşturmuştur. Yapılan çalışmada en iyi mikroçoğaltım sonucunun, DKW–C besin ortamı içerisinde 1 mg/L BAP + 0,5 mg/L IBA + 1 mg/L GA3 hormonları ile aktif kömür ilavesi yapılan ortamda %45 oranında sürgün gelişiminin olduğunu belirtmiştir. Yegizbayeva ve ark. (2021) Özbek çeşidi Ideal ve Çin çeşidi Liaohe çeşidinin sürgün büyüme hızını 1 ve 1,5 mg/L'lik 6-benzilaminopurin (BAP) konsantrasyonlarında MS ve DKW ortamlarında karşılaştırmıştır. DKW ortamında sürgün büyümesi yavaşlamış, yapraklar sararmış ve bazı sürgünler kararmıştır. DKW ortamına

FeEDDHA ve floroglusinol eklenmesi, sürgün büyüme hızını artırmış ve yüksek kaliteli materyal elde edilmesini sağlamıştır. Sonuç olarak, zenginleştirilmiş DKW ortamı, ceviz Ideal ve Liaohe-1'in mikroklonal çoğaltılması için en uygun besin ortamı olarak belirlenmiştir Dirlik ve ark. (2022), paradox ceviz anacına ait nodları kullanarak birim eksplant başına düşen en yüksek sürgün sayısını 1.05 sürgün/eksplant olarak 4 mg L-1 BAP içeren DKW ortamında olduğunu belirlemiştir. Özelçi (2024), Kozdere ve Chandler çeşitlerinde DKW ortamında sürgün uzaması, sürgün sayısı ve yaprak sayısı ölçümlerinde MS ortamına göre en iyi sonuçları vermiş ve istatiksel olarak fark bulunduğunu bildirmiştir. Dolayısıyla, cevizlerde *in vitro* sürgün çoğalmasını etkileyen çeşitli faktörler bulunmaktadır ve optimizasyon, tür ve genotipe özeldir.

4.3. Mikro Sürgünlerin Köklendirilmesi

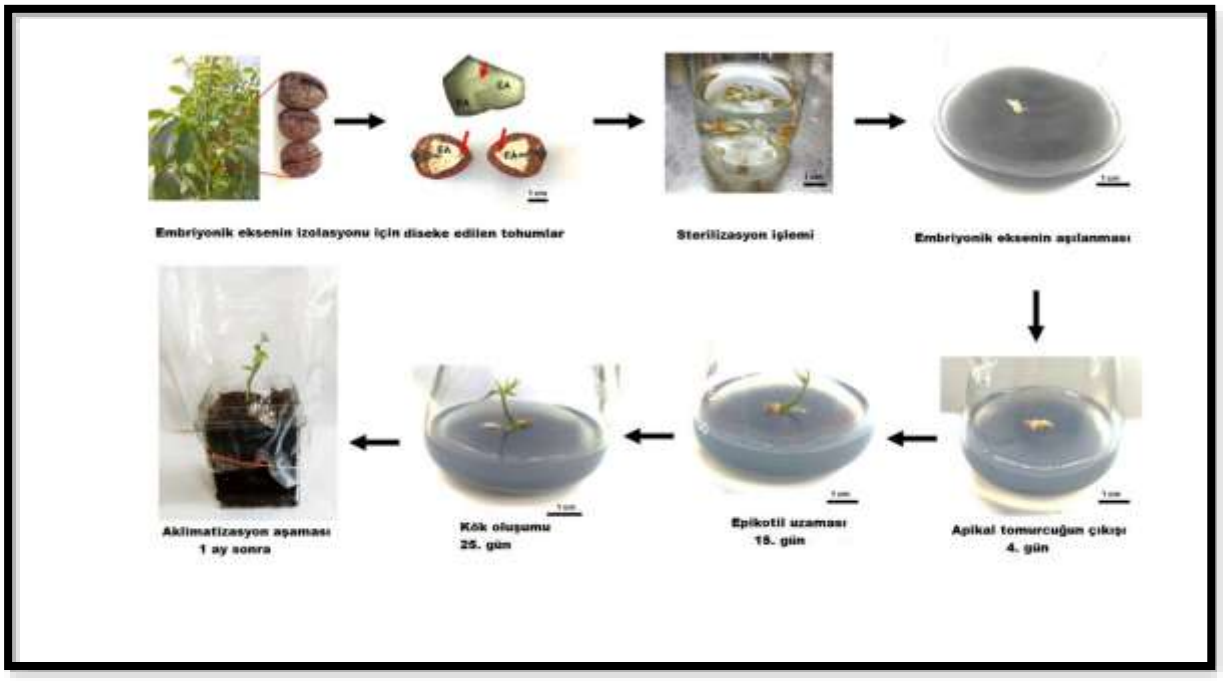
Ceviz türlerinin mikroçoğaltımında karşılaşılan temel zorluklardan biri, düşük köklenme oranlarıdır. Bu sorunu aşmak için çeşitli yaklaşımlar denenmiştir. Bunların özeti aşağıda belirtilmiştir. Jay-Allemand ve ark. (1992), ¼ DKW besin ortamı ve vermikülit kombinasyonunun kök uzamasını ve ikincil kök gelişimini desteklediğini, köklenme oranını önemli ölçüde (%15-50) artırdığını ve birincil kök sayısını katladığını göstermiştir. Vermikülitin, kök penetrasyonu ve havalanma açısından jelrite üstün olduğu, fakat sadece su ile kullanıldığında yetersiz köklenmeye neden olduğu belirtilmiştir. Caboni ve Damiano (2006), ½ DKW ortamında 10 µM IBA kullanımı ve 10-12 günlük karanlık uygulamasının (indüksiyon aşaması) başarılı bir köklenme için önemli olduğunu vurgulamışlardır. İndüksiyon aşamasından sonra mikro sürgünlerin hormonsuz bir ortama aktarılması da önemli değere sahiptir. Zarghami ve Salari (2015) yaptıkları çalışmada, Chandler, Hartely ve Z60 ceviz çeşitleriyle sürgün çoğaltımı için 1,5 mg/L BAP ve 0,01 mg/L IBA içeren bitki büyümeyi düzenleyici kullanarak en iyi sonucu elde etmiştir. Tuan ve ark. (2017) ise, farklı besin ortamları ve bitki büyüme düzenleyicileri ile yaptıkları çalışmada, Rugini ortamının taze ağırlığı artırdığını, katı ortamın sürgün yayılımı için daha uygun olduğunu ve 2,2 µM BA'nın en iyi sonuçları verdiğini belirlemişlerdir. Ayrıca, 12 µM IBA içeren yarı katı ortamlarda 5 günlük karanlığın köklenme için gerekli olduğu ve ¼ DKW + Vermikülit ile ¼ MS + Vermikülit ortamları arasında önemli bir fark bulunmadığı sonucuna varmışlardır. Kök ekspresyonu alt fazında kullanılan karbon kaynağına daha fazla dikkat edilmiştir. Sükroz açık ara en çok kullanılan karbon kaynağıdır ve çoğalma aşamasında olduğu gibi aynı konsantrasyonu korur. İndüksiyon sırasında olduğu gibi, bir karbon kaynağının varlığı köklerin *in vitro* gelişimi için öneme sahiptir. *J. nigra* No.23x *J. regia* hibrit klonu için sükrozun köklenme üzerinde sürgün büyümesinden daha büyük bir etkisi olduğu bildirilmiştir (Chenevard, D ve ark. 1995). Dolayısıyla, genellikle, nispeten yüksek sükroz konsantrasyonu (117 mM ile 153 mM arasinda) en iyi köklenme başarısını vermektedir (Vahdati K, ve ark. 2022). Bu çalışmalar, ceviz mikro çoğaltımında köklenme oranını optimize etmek için besin ortamı kompozisyonunun, karbon kaynağının, bitki büyüme düzenleyicilerinin karbon kaynağının ve karanlık uygulaması gibi faktörlerin köklenmeyi etkilediğini göstermektedir.

4.4. Doku Kültürü ile Yetişen Bitkilerin Pişkinleştirilmesi ve Sahaya Aktarılması

Köklenen mikro sürgünler, kontrollü koşullarda pişkinleştirildikten sonra dış ortama uyum sağlamaları gerçekleştirilir. Bu süreç, başta nem ve sıcaklık gibi çevresel faktörlere kademeli olarak alıştırılmayı hedefler. Pişkinleştirme tamamlandıktan sonra, bitkiler dış ortama aktarılmaya hazır hale gelir. Cevizin dış koşullara aktarma üzerine çok az çalışma yapılmasına rağmen *in vitro* ceviz bitkilerinin mikro sürgünlerinin kalitesinin, stoma özelliklerinin ve su tutma kapasitesinin cevizin pişkinleşmesi sırasında önemli rol oynadığı kanıtlanmıştır (Vahdati, ve ark. 2004, Maleki Asayesh ve ark., 2017, Asayesh ve ark. 2017). Bununla birlikte, cevizin köklenme kapasitesinin düşük olması nedeniyle, yalnızca köklü mikro sürgünlerin hayatta kalma olasılığı vardır. Ancak bu durum hayatta kalmayı sağlamak için her zaman yeterli değildir. Mikro sürgünlerin köklenmesine ek olarak, bu aşamanın üstesinden gelmek için sağlıklı ve bol miktarda yaprağın olması gereklidir (McGranahan ve ark., Yegizbayeva ve ark., Licea-Moreno ve ark., 2016).

İn vitro'da üretilen stomaların işlevsel olmadığı ve iklimlendirme sırasında ölümlerin ana nedeni olduğu varsayılmaktadır. Nitekim, Mj209x Ra melez klonların çoğaltılması için gerçekleştirilen mikroçoğaltım protokolü ile, yetişkin ağaçlarınkine benzer anormal olmayan stomalar elde etmek mümkün olmuştur (Licea-Moreno ve ark., 2016). Tam işlevselliklerine ulaşmak için stomaların oluşumu gereklidir. Genel olarak, ilk iki hafta boyunca yüksek bağıl nem (>%80) gereklidir. Daha sonra, bağıl nemin azaltılması hayatta kalan mikro sürgünlerin güçlenmesine katkıda bulunur. Aklimatizasyonun bağlaması sırasında doğrudan güneş ışığından ve düşük sıcaklıklardan (<16° C) kaçınılması da tavsiye edilir.

Sonuç olarak, başarılı bir mikroçoğaltım protokolü, bu dört aşamanın her birinin dikkatli bir şekilde yönetilmesini ve optimize edilmesini gerektirir. Her aşamadaki başarı, nihai olarak, sağlıklı ve genetik olarak özdeş bitkilerin üretilmesiyle sonuçlanır. Bu da, bitki yetiştiriciliğinde verimliliği artırmaya ve bitki türlerinin korunmasına önemli katkılar sağlar.



Şekil 1. Embriyonik eksenin eksplant olarak kullanıldığı ceviz kültürünün in vitro kurulması ve iklime alıştırılması (kırmızı ok; embriyo ve EA; embriyonik eksen). (Sharma ve Kumar 2024)

5. CEVİZ MİKROÇOĞALTIMININ ENGELLERİ

Eksplantlardaki fenolik bileşenin oksidasyonuna duyarlılık, eksplantların içindeki kirlilik, kültür ortamına uyum sağlama, köklenme ve toprağa aktarımla ilgili zorluklar, ceviz mikroçoğaltımının en önemli sorunlarıdır (Kepenek ve Kolağası 2016).

5.1. Sterilizasyon

İn vitro ortamda yapılacak olan mikroçoğaltım yöntemlerinde ilk aşama sterilizasyon olup, her bitki için uygun protokolün bulunması çalışmanın başarıya ulaşması için oldukça önemlidir. Dışardan alınan eksplantların *in vitro* koşullarında kontaminasyona yol açmaması için en etkili sterilizasyon yönteminin tespit edilmesi gerekmektedir. Bu konu ile ilgili birçok genotipte farklı araştırıcılar çeşitli sterilizasyon maddelerini farklı dozlarda kullanmışlar ve farklı sonuçlar elde etmişlerdir (tablo 3). Kültür ortamında kullanılan eksplantların iç kısımlarında bulunan mikroorganizmalar uzaklaştırılamadığından, yüzey sterilizasyonu bazen yetersiz kalabilmektedir. Sterilizasyonun yeterince başarılı olmaması durumunda, bu mikroorganizmalar eksplantla rekabete girerek ortamda çoğalmaya başlar. Bunun sonucunda eksplantların büyümesi yavaşlar, ardından nekroz gelişir ve eksplantlar kaybedilir (Kane, 2003).

Cevizlerde yüzey sterilizasyon işlemi yaygın ve kabul görmüş bir işlemdir. Ceviz için, yaygın olarak benimsenen prosedür; eksplantlar 20-30 saniye boyunca %50- 70 (v/v) etanol (EtOH) ile muamele edilir ve ardından daldırılır %0,1 – %15 (h/h) sodyum hipoklorit (NaOCl) ile %0,01 Tween 20 ilavesiyle eksplantlar ile 10- 20 dakika muamele edilir daha sonra bunu steril ortamda üç durulama (5 dk.) takip etmektedir. *J. regia*'nın nodal segmentlerinin bulaşık olmayan kültürünün, eksplantlar 10-20 dakika boyunca %1 NaOCl ve 2-3 damla Tween-20 ile işlendiğinde başarılı bir şekilde oluşturulduğu gözlemlenmiştir (McGranahan ve ark., 1988). Pijut (1997), *J. cinerea*'nın nodal segmentleri için en iyi sterilizatörlerin 15-20 dakika boyunca işlendiğinde %0,8 (v/v) NaOCl ve 15% Clorox ağartıcısı olduğunu bildirmiştir. Roschke ve Pijut (2006), *J. regia* sürgünlerini musluk suyunda 30 dakika ve ardından %70 etanolde 30 saniye yıkadıkları bir çalışma yürütmüşlerdir. Bhat ve ark., (2022), eksplantları 5 dakika boyunca %0,1 $HgCl_2$ ile mazru bırakıp ardından 10 saniye boyunca %70 etanol ile uygulanmış *Juglans regia*'nın kontaminasyonsuz nodal kültürlerini başarıyla oluşturabilmişlerdir. Juyal ve ark. (2024) de yapmış olduğu G1 ve G2 ceviz çeşitlerinde nodal eksplantta farklı sürelerde sterilizasyon aşamasında tabi tuttuktan sonra Bhat ve ark., (2022) ile aynı sonuçların uyumlu olduğunu bildirmiştir.

Özelçi (2024) ise sterilizasyon aşamasında farklı olarak $CuSO_4$ (Civa klorür) dahil edilmesi sonucunda enfeksiyon oranında sayısal olarak azalma gözlemlediğini belirtmiştir. Yüzey sterilizasyonu için %30 NaClO uygulaması ile $CuSO_4$'ün birlikte kullanılması sayısal olarak en başarılı sonucu vermesine rağmen ceviz çeşitleri arasında kontaminasyon oranı, kararan ve süren sürgün sayılarında farklılıklar gözlemlenmemiştir. Civa klorürün yüzey sterilizasyonunda olumsuz sonuçlar verdiğini bildirmiştir. Tablo 3'te çeşitli türler için benimsenen sterilizasyon protokolleri gösterilmektedir.

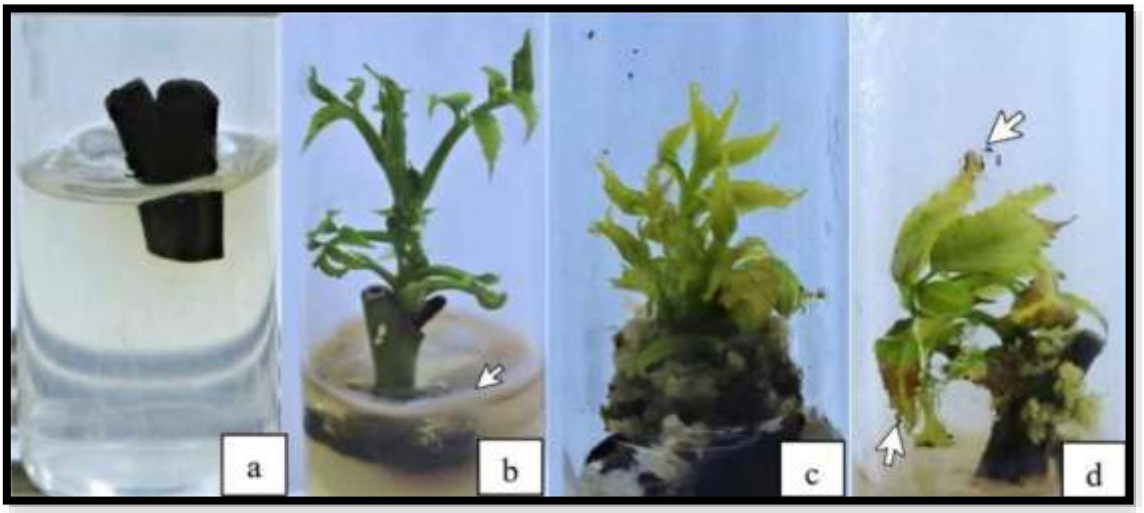
5.1.Kontaminasyon

Kontaminasyonlar, ekzojen ve endojen mikroorganizmalardan kaynaklanabilir. Bitki kültürleri, çok çeşitli bakteri, mantar ve viral organizmalar tarafından kontamine olabilir ve bunların çoğu türe özgüdür (Varghese & Joy, 2016). Bu kontaminantlar, etkilerini hemen gösterebileceği gibi, uzun süre herhangi bir belirti vermeyebilir (Ray & Ali, 2016). *İn vitro* bitki kültürlerinde kontaminasyondan kaynaklanan kayıpların yaklaşık %20-55'i bakterilerden kaynaklanmaktadır (Tekielska vd, 2019).

Araziden toplanan veya mikrobiyal kontaminasyon olasılığı olan bitki dokularıyla yapılan çalışmalarda etil alkol ve/veya çamaşır suyuna ek olarak ilave sürfaktan ile yüzey sterilizasyonu gerekmektedir. Konsantrasyon ve maruz kalma süresi kullanılan eksplant türüne bağlı olarak deneysel olarak belirlenir (Leelavathy ve Sankar, 2016). Fu ve ark., (2003), *Carya illinoensis* (Pikan cevizi) bitkisi üzerinde yaptıkları çalışmada, en uygun sterilizasyon yönteminin önce bitkinin %70'lik EtOH'de bekletilmesi ve ardından %0,2'lik $HgCl_2$'de (birkaç damla Tween 20 eklenerek) 15 dakika karıştırılması ve ardından steril distile su ile 10 kez durulanması olduğunu belirtmişlerdir. Ayrıca besin ortamına penisilin ve streptomisin eklenmesinin kontaminasyonu önlediğini bulmuşlardır (Fu ve ark, 2003). Leal ve ark., (2007), tam verim çağındaki ceviz ağaçlarından aldıkları eksplantlarla yapılan mikroçoğaltım deneylerinde iç kontaminasyonun önemli bir sorun olduğunu belirtmişlerdir. Ayrıca, yüzey sterilizasyonu aşamasında dokularda

oksidasyon sonucu oluşan koyulaşmanın sürgün oluşumunda büyük bir azalmaya neden olduğunu ve bu sorunun dezenfeksiyona daha dayanıklı ancak yarı odunsu olan genç sürgün eksplantları kullanılarak aşılabileceğini belirtmişlerdir (Leal ve ark., 2007)

Kontaminasyon kayıpları genotip, kültür ortamı gibi faktörler arasındaki olası etkileşime göre belirlenmiştir (Yegizbayeva ve ark.,2021). Gruselle ve Boxus (1990) ayrıca üç saf ceviz türü ve melez Paradox arasında farklı enfeksiyon yüzdeleri kaydetti, kontaminasyon eksplantların yüzdesi 0 ile %67,8 arasında değişkenlik gösterdiğini bildirmiştir. Mikroorganizmalar, bitkiler de dahil olmak üzere ökaryotlarda her yerde bulunur, endo ve ektosimbiyont olarak hareket eder, çoğu yaşamları için gereklidir (Berg ve ark., 2014), bu nedenle her genotip kendi mikrobiyomunu getirebilir. Aynı zamanda, bu mikrobiyom, mevsim, konum ve yaş gibi birçok faktörden etkilenerek değişebilir, hatta bitkilerin farklı organları arasında bile değişebilir (Thomas ve ark., 2008).



Şekil 2. Ceviz kültüründe karşılaşılan sorunlara örnekler şunlardır: a) kararma b) kontaminasyon c) vitrifikasyon d) nekroz (Dirlik ve ark., 2022)

Tür/çeşit	Eksplantlar	Çalışma	Dezenfektanlar ve dozaj	Yöntem	Kaynak
J. regia L. Yalova-1, Sebin, Bilecik, KR 1, KR-2, Sen-2, 07-KOR-1, Tokat-1, Kaman-1, Kaman-5	Olgunlaşmamış meyve	Somatik embriyogenez	%3.75 sodyum hipoklorit	Meyveler, %3.75 (v/v) sodyum hipoklorit içinde 25 dakika daldırılarak sterilize edilmiştir, ardından steril damıtılmış suda üç 5 dakikalık durulama yapılmıştır.	Şan ve Dumanoğlu (2006)
Kaman-5 J. *regia* .L	Sürgün ve yaprak	Adventif kök rejenarasyonu ve mikroçoğaltım	Sürgünler için: %70 etanol, %15 çamaşır suyu çözeltisi	Sürgünler için: sürgünler akan musluk suyu altında 30 dakika yıkanır. Sürgünler kesitler halinde kesilir ve %70 etanolde 30 saniye yıkanır, %15 ağartıcı solüsyonunda 20 dakika artı yörünge çalkalayıcıda %0.01 Ara dezenfekte edilir ve 30 saniye boyunca dört kez steril suda durulanır.	Roschke ve Pijut (2006
			Yapraklar için: %10 ağartıcı solüsyonu	Yapraklar için: eksplantlar akan musluk suyunda 5 dakika boyunca yüzey yıkanır, bir süre sterilize edilir. %10 çamaşır suyu çözeltisinde 10 dakika bekletilir ve dört kez steril su ile durulanır.	
J. regia .L	Embriyo,kotiledon, Sürgün,yaprak, apikal ve aksiller tomurcukları	mikroçoğaltım	Embriyo için: %5 NaOCl Kotiledon için: %5 NaOCl Sürgün,yaprak, apikal ve aksiller tomurcukları:%5NaOCl ardından %0.05 HgCl	Embriyo için: 15 dakika boyunca NaOCl çözeltisinde bekletilir Kotiledon için: 25 dakika boyunca %5 NaOCl çözeltisinde bekletilir. Sürgün,yaprak,apikal ve aksiller tomurcukları için: 20 dakika boyunca %5 NaOCl çözeltisinde ve ardından %0.05 HgCl çözeltisinde 5 dakika boyunca bekletilir. Sterilize edilmiş eksplantlar otaklavlanmış çift damıtılmış su ile 3-4 ke yıkanır.	Fatima ve ark. 2018
J. regia .L	Nodal eksplant	Mikroçoğaltım	%0,1 $HgCl_2$	Eksplantları 5 dakika boyunca %0,1 $HgCl_2$ ile işleyerek ve ardından 10 saniye boyunca %70 etanol ile işlenir	Bhat ve diğerleri (2022)
Kozdere, Zengibar ve Chandler ceviz çeşitleri	Aksiller tomurcuklar	mikroçoğaltım	NaCIO % 20, 30 ,40 Ve NaCIO % 20, 30 ve 40 + % 3 $CuSO_4$	NaCIO %20, 30 ve 40 konsantrasyonlarında kullanılmış ve çözeltilere 3-4 damla Tween 20 ilave edilmiştir. 20 dakika NaClO'da ve devamında %70'lik etil alkolde 1 dakika bekletilmiştir. Ardından üç kez beş dakika steril saf su ile yıkanmıştır. Bu mikroçelikler %3'lük $CuSO_4$ çözeltisinde 20 dakika bekletilmiştir.	Özelçi (2024)
			Genç yapraklar için: % 70 etanol	1 dakika boyunca %70 Etil alkol ile muamele edilir, musluk suyu	Juyal ve ark. (2024)

G1 ve G2	Genç yapraklar ve nodal eksplant	mikroçoğaltım	%5 NaClO %0.1 $HgCl_2$	altında yıkanır 2 dakika boyunca hafif deterjan (Teepol) ile muamele edilir, musluk suyuyla iyice yıkanır Yüzey aktif madde (Tween-20) ile 2-3 dakika yıkanır, musluk altında durulanır. Mantar ilacı (Baristin) 196 (m) 5 dakika boyunca verilen tedavi, damıtılmış madde ile durulanmıştır.	
			Nodal eksplant için:	Akan musluk suyu ile durulanır 2 dakika boyunca %70 Etil alkol (v/) ile muamele edilir, musluk suyu ile durulanır 2 dakika boyunca hafif deterjan (Teepol) ile muamele edilir, deterjan izlerini yeniden azaltacak şekilde iyice kurulanır 1Kashl Yüzey aktif madde (Tween 20) işlemi 20 dakika boyunca verildi, damıtılmış su ile yıkanır. 30 dakika boyunca mantar ilacı (Bavistin) 196 (a/h) ile tedavi edilir. Damıtılmış su ile iyice durulanmış Nadir süreler için HgCl (%0,1) ve NaOCl (%0,5) ile sterilize edilmiştir.	

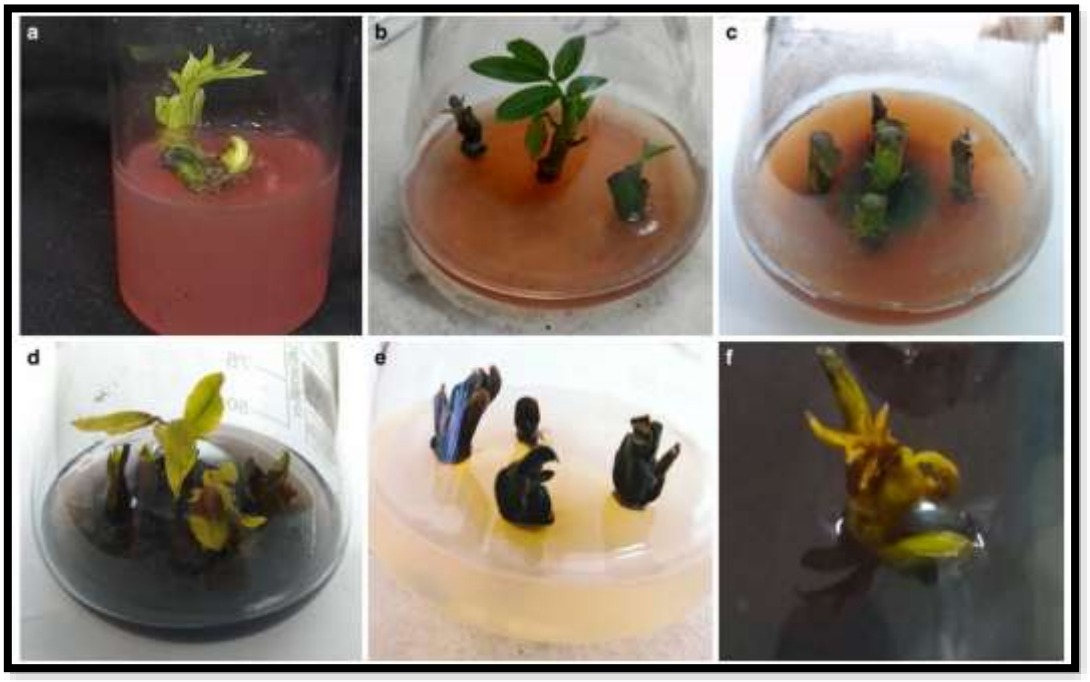
Tablo 3. Eksplantların sterilizasyonu için kullanılan yöntemler

5.2.Kararma

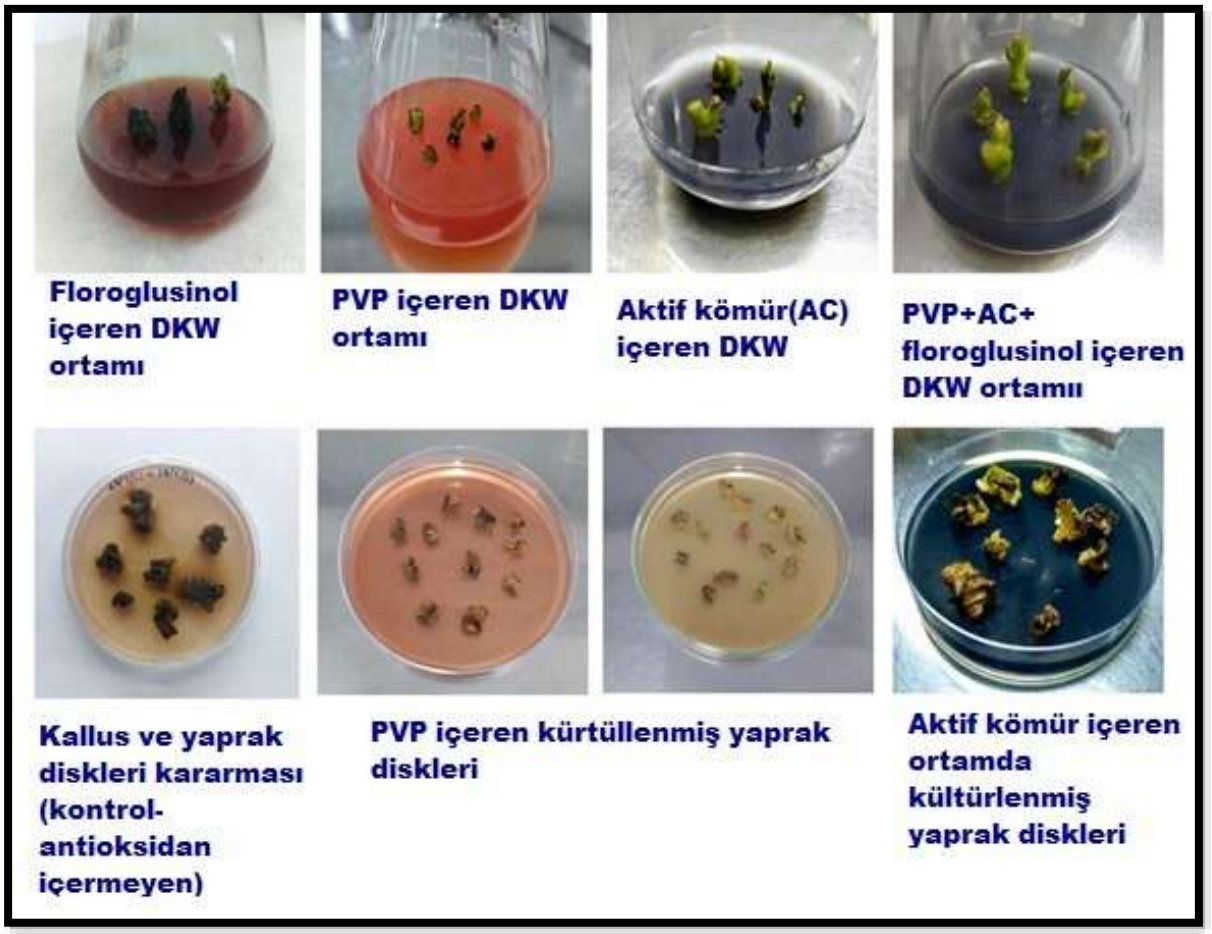
Ceviz bitkilerinin *in vitro* rejenerasyonunda karşılaşılan en önemli zorluklardan biri, fungal ve bakteriyel kontaminasyonun yanı sıra, eksplantların ve ortamların oksidatif veya fenolik gerekçelerle kararmasıdır (şekil 3). Cevizdeki en önemli fenolik madde juglone'dur (5-hidroksil-1, 4-naftokinon); serbest radikal oluşumundaki kimyasal reaktivitesi ve hasarı nedeniyle, aşılama bölgelerinde nekroz, apoptoz ve hücre ölümü yoluyla dokular üzerinde yıkıcı bir etkiye sahiptir (Jones, 2001 Solar ve ark., 2006). Ortamın esmerleşmesi, polivinil pirolidon (PVP), sitrik asit, askorbik asit, aktif kömür, tiyoüre, L-sistein, glutamin, aspargin, arginin gibi maddeler eklenerek veya sık sık alt kültürleme (Pierik., 1987; Rout ve ark., 1999) (şekil 4) veya aşılamadan sonra kültürleri bir ya da iki gün tamamen karanlıkta inkübe ederek üstesinden gelinebilen eksplantların kesilmiş yüzeyinden sızan polifenollerin oksidasyonunun sonucudur; çünkü polifenol oksidaz aktivitesinin ışık tarafından indüklendiği bulunmuştur (Pittet ve Moncousin, 1981). Bu durum, doku kültürlerinin başarısını önemli ölçüde etkilemektedir. Kararmayı azaltmak amacıyla, farklı araştırmacıların farklı konsantrasyonlarda kullandıkları bu maddelerle elde edilen sonuçlar değişkenlik göstermiştir. Bu durum, etkili bir kontrol stratejisi geliştirmek için daha fazla araştırma yapılması gerektiğini açıkça ortaya koymaktadır. Bu araştırmalar, ceviz bitkilerinin *in vitro* çoğaltılmasında verimliliği artırmak için hayati önem taşımaktadır (Pierik, 1987). Ehteshamnia ve Gulami (2014) üç farklı strateji geliştirerek uyguladığı çalışmada Chandler ve Jamal olmak üzere iki ceviz çeşidi için DKW,

aktif kömürle (AC) zenginleştirilmiş DKW ve askorbik asit (AA) ile desteklenmiş MS kültür ortamlarının mikro kesimlerin yerleşimi üzerindeki etkileri incelenmiştir. Sonuçları ise AC ile zenginleştirilmiş DKW ortamının, diğer ortamlara göre daha uygun olduğunu göstermiştir. İkinci çalışmada, aynı ceviz çeşitlerinin mikro kesimlerinin, DKW bazal ortamında ve AC/AA içeren DKW ortamında 48 saat arayla üç kez alt kültüre alınması değerlendirilmiştir. AC içeren DKW ortamında alt kültüre alınan mikro kesimler, AA içeren DKW ortamındakilere göre daha iyi sonuçlar vermesine rağmen, aradaki fark istatistiksel olarak anlamlı bulunmamıştır. Üçüncü deneyde ise, mikro kesimler kültüre alınmadan önce damıtılmış su, polivinil pirolidon (PVP) ve AA çözeltilerinde 2 saat bekletilmiştir. PVP'ye batırılan mikro kesimler, diğer gruplara göre daha başarılı bir yerleşim göstermiştir. Sonuçlar, İran cevizi mikro kesimlerindeki kararma gibi problemin, belirtilen yöntemlerin farklı kombinasyonları kullanılarak başarıyla kontrol altına alınabileceğini ortaya koymaktadır. Melatonin, askorbik asit veya sitrik asit gibi antioksidanlar oksidatif stresi azaltabilir ve fenolik bileşik oksidasyonunu engelleyebilir. Aktif kömür veya PVP gibi adsorbanlar fenolik bileşiklere bağlanabilir ve onları daha az toksik hale getirebilir.

Karanlıkta yetiştirilen dokularda kararma, ışıkta yetiştirilen *in vitro* kültürlere göre daha düşüktür (Escobar ve ark., 2008). Kararmanın kapsamı, ortamın temel bileşimini ve bitki büyüme hormonlarının türünü veya içeriğini değiştirerek azaltılabilir (Jones ve Saxena, 2013).



Şekil 3. a) DKWf'de sürgün tomurcuğu başlangıcı; b) DKWm'de sürgün tomurcuğu başlangıcı; c) DKW besiyerinde kahverengileşme; d) WPM'de yaprakların solması; e) MS besiyerinde eksplantların kahverengileşmesi; f) WPM'de engellenen büyüme (Sharma vd. 2025).



Şekil 4. Ceviz çeşidi 'Chandler'da eksplant kahverengileşmesini ve in vitro oluşumunu önlemek için farklı antioksidanların etkisi (Sharma vd. 2025).

5.3. Aklimatizasyon

Mikro çoğaltılan bitkilerin başarılı bir şekilde aklimatize edilmesi ve daha sonra araziye aktarılması, *in vitro* teknolojisinin ticari olarak değerlendirilmesi açısından önemli bir adımdır. Doku kültürü yayılımındaki en büyük zorluklardan biri, bitkilerin laboratuvardan seraya veya tarlaya taşındığında yüksek ölüm oranıdır (Kumar ve Rao, 2012). Bu, bahçecilikte yaygın bir sorundur ve *in vitro* çoğaltımdan sonra bitkiciklerin hayatta kalmasını sağlamak için etkili protokoller geliştirmeye yönelik devam eden araştırmalar vardır (Aliniaeifard ve ark., 2020). *In vitro* bitkiler, doğal ortamlara, seraya ve tarlaya kıyasla farklı CO_2 konsantrasyonlarında yetiştirilir. Doku kültürü bitkileri, adapte edilmiş sera bitkilerine kıyasla daha yüksek stoma yoğunluğu ve indeksine sahip yuvarlak ve açık stomalara sahiptir. Öte yandan, su kaybı oranları adapte edilmiş ve sera bitkilerinden önemli ölçüde daha yüksektir (Joshi ve ark., 2006; Bertolino ve ark., 2019). Yüksek ve düzensiz stoma yoğunluğu ve stoma boyutundaki çeşitlilik, yüksek stres altında yaprakların hızla solmasıyla ilişkili olabilir. Ancak, mikroçoğaltılan cevizin iklime alıştırılmasının, ilk iki haftada yüksek nem isteği ve zor köklenme nedeniyle bitkilerin

hızla kuruması veya hastalıklara karşı duyarlılığı nedeniyle zor bir prosedür olduğu bildirilmiştir. Preece ve Sutter (1991) ve Sutter ve ark. (1992), toprağa transfer sırasında kökleri desteklemek ve korumak için sorbarodlar (soğukta kıvrılmış selülozdan yapılmış bir silindirden oluşan ve selüloz kağıdına sarılmış yapı) ve bitkilerin kurumaya karşı direncini artırmak için havalandırılmış kültür kabından oluşan serada ve açık alanda mikroçoğaltılmış bitkilerin iklime alıştırılmasını incelemiştir. Bu şekilde yetiştirilen bitkilerin, *ex vitro* koşullara transfer edildiğinde daha iyi hayatta kalma gösterdiği görülmüştür. Sorbarodlar, bitkilerin uygun şekilde işlenmesi için gerekli korumayı ve kolaylığı sağlamıştır. Leal ve ark. (2007) sera koşullarında (bağıl nem %100 ve sıcaklık 18 ila 20°C aralığında) mikro bitkilerin iklimlendirme süresine başlanarak hem in vitro hem de *ex vitro* işlemler kullanılarak başarılı köklenme oranına ulaşabileceğini bildirmiştir.

Kumar ve Shama (2025) *İn vitro* rejenere edilmiş bitkiler, bir aylık sağlam kök ve sürgün oluşumu süresi sonrasında başarılı bir şekilde iklime alıştırmada bitkiler öncelikle 10 dakika boyunca %1,0 (w/v) CAPTAN fungisit ile muamele edilip ardından 30 dakika boyunca akan musluk su altında tutulmuştur. Daha sonra bitkiler, 24^{+}–2 °C ve %90 bağıl nemde tutulan, önceden steril 1:1:1 kum, toprak ve hindistan cevizi torfu karışımını içeren iklimlendirme ortamına aktarılmıştır. 25-30 gün sonra yeni yaprakların oluşumu gözlemlenmiş ve ardından %60,0'lık bir hayatta kalma oranı gösteren saha koşullarına aktarılmıştır.

Aklimatizasyon sırasında köklenme başarısı ve hayatta kalma, kök başlatma aşamasına getirilen mikro sürgünlerin kalitesine büyük ölçüde bağlıdır. McGranahan ve Driver (1987) 'Paradox' için çoğaltmadan elde edilen 3 ila 10 cm boyundaki güçlü mikro sürgünlerin kullanılmasını tavsiye etmiştir. McGranahan ve Driver (1987) İran cevizinin iklimlendirilmesi için bu tanımı genişletmiş ve rafine etmiş, sadece apikal uçlarında nekroz ve/veya yaprak dökümü olmayan mikro sürgünlerin iklimlendirme aşamasında hayatta kalmasının muhtemel olduğunu belirtmiştir. Licea-Moreno (2016) da Mj209x Ra melez fidan klonları için, yeşil ve bol yapraklı sağlıklı ve güçlü mikro sürgünlerin köklenmeye ve pişkinleşme sırasında *ex vitro* koşulların üstesinden gelmeye daha hazır olduğunu belirtbildirmiştir.

6. DİĞER FAKTÖRLER

Sıcaklık, su alımını ve besin metabolizmasını etkileyerek ve enzimatik faaliyetleri teşvik ederek veya engelleyerek adventif köklenmeyi etkileyebilir (Geiss ve ark., 2018) Sıcaklığın *in vitro* ceviz köklenmesi üzerindeki etkisi hakkında çok az araştırma vardır Payghamzadeh ve Kazemitabar 2011). *J. nigrax J. regia* 'A35' köklenmesi 22ºC'de (%60) 27°C'ye (%45) göre daha fazla olmuştur (Dolcet-Sanjuan ve ark. 2004) Benzer şekilde, Vahdati ve ark. (2004) 22ºC'deki indüksiyonun 'Sunland' (%94'e kars1 %50), 'Chandler' (%42'ye karsi %13) ve 'Vina'da (%25'e karsi %3) 30° C'ye göre daha fazla köklenme sonuçlandığını bulmuştur. Genel olarak, 20-28°C aralığındaki sıcaklıklar ceviz kök indüksiyonu için faydalı olmuştur (Leslie ve McGranahan, G.H. 2009).

Hangi tür ve genotiplerin köklenmesinin en zor olduğu konusunda farklılıklar vardır. Nitekim Gruselle ve Boxus (1990) aynı kültür koşullarını kullanarak *J. regia* için hibrit 'Paradox' klonlarından (sırasıyla %46,4 ve 2,9) daha iyi köklenme başarısı (%64,8) ve mikro sürgün başına daha fazla kök (4,22) elde etmiştir. Bunun yanında Dolcet-Sanjuan ve ark. (2004) ceviz

melezlerinin (*J. nigrax J. regia*) klonlarnin *J. regia* klonlarından daha kolay köklendiğini gözlemlemiştir. Bununla birlikte, Jay-Allemand ve ark. (1992) *J. major* klonlarının ve *J. regia* hibritlerinin *J. sieboldianax J. regia, J. nigra*'dan daha yüksek köklenme yüzdelerine sahip olmasına rağmen *J. nigra* klonları arasında da çarpıcı farklılıklar gözlemlenmiştir. *In vitro* protokollerin düşük tekrarlanabilirliği, aynı genotiplerin ve değişkenlerin değerlendirildiği ve aynı protokollerin izlendiği durumlarda bile farklı laboratuvarlardan elde sonuçların karşılaştırılmasını oldukça karmaşık hale getirmektedir (Yegizbayeva ve ark. 2021)

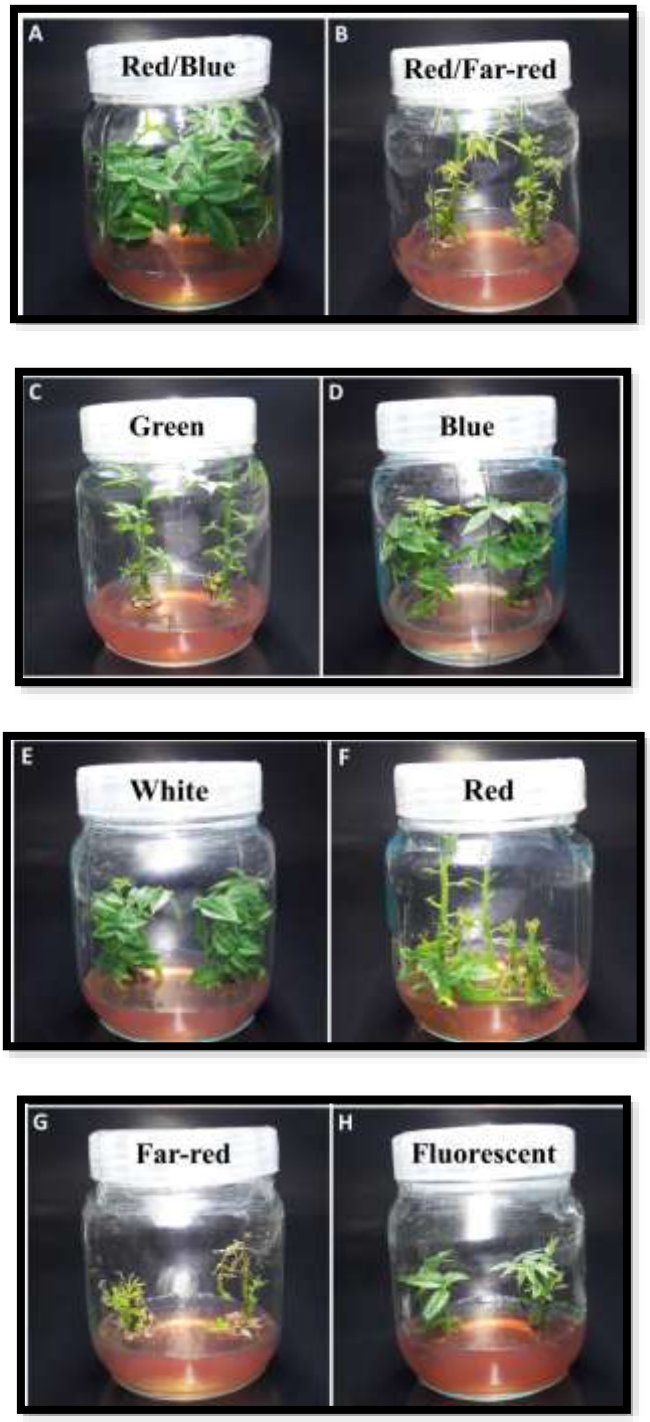
Kültür ortamının fiziksel desteği de köklenme başarısını etkiler. Leslie ve ark. (2005) jelleşmiş kültür ortamının sıvıdan daha iyi olduğunu bulmuştur. Jelrite ve Kobe Agar arasında da farklılıklar gözlemlenmiştir. Jay-Allemand ve ark. (1992) kök uzamasını ve ikincil köklerin gelişimini teşvik etmek için *in vitro* ekspresyon ortamında vermikülit kullanılmasını önermiştir. Ortamdaki nispeten düşük tuz konsantrasyonlarının mikro sürgünlerin köklenmesini arttırdığı bilinmektedir (Murashige, 1979). Pijut (1997), mikro çeliklerin köklendirilmesinde ½ MS ortamını kullanmıştır. Scaltsoyiannes ve ark. (1997) sürgünlerde kök indüksiyonu için ¼ konsantrasyonda makro element içeren DKW bazal ortamını kullanmıştır. Ayrıca, NO_3/NH_4 oranı 0,1'den 3,0'a yükseldiğinde, eksplant başına kök sayısında bir artış olduğunu bildirmiştir. Hyndman ve ark. (1982) KNO_3 ve NH_4NO_3 konsantrasyonunda bir azalmanın köklenme yüzdesini artırmada belirleyici faktör olduğunu ifade etmişlerdir.

İn vitro çoğaltmada ışık önemli bir faktördür. Son yıllarda farklı ışık kaynaklarının etkileri ile ilgili birçok çalışma yürütümüştür. Işık, *in vitro* doku kültürü uygulamaları ve *ex vitro* iklimlendirme sırasında üretilen bitkicikler için önemli bir süreç olan fotosentezde önemli bir rol oynar. Doku kültürü uygulamalarında, floresan ışıklar, yüksek basınçlı sodyum ışıklar, metal halojenür ışıklar ve akkor ışıklar dahil olmak üzere yapay ışık kaynakları kullanılmıştır (Dutta Gupta ve Jatothu, 2013; Cavallaro ve ark, 2022). Floresan ışıklar doku kültürü odalarında en yaygın kullanılan ışıklardır (Economou ve Read, 1987). Işık spektrumlarının yoğunluğunu ve bileşimini kontrol etme ve ayarlama olanakları sınırlıdır ve bu parametreler sabit olmayıp doku kültürü bitkilerinin büyümesi sırasında değişir (Bantis ve ark, 2016). Kırmızı ve uzak kırmızı ışıkların düşük yoğunluğu nedeniyle, çok az fotosentetik olarak aktif radyasyon yayarlar (PAR= %20-30). Bu ışıkların dalga boyu genellikle yeşil ve mavi bölgededir (Miler ve ark, 2019). Doku kültürü bitkilerinin üretiminde floresan ışıkların kullanımı ayrıca elektrik tüketimiyle ilişkili önemli maliyetlere neden olur. Bu nedenle, bitki doku kültürü laboratuvarlarında başarılı ticari mikro çoğaltma için, üretim verimliliğini artırmak, maliyetleri düşürmek ve doku kültürü bitkilerinin kalitesini iyileştirmek için etkili bir ışık kaynağına ihtiyaç vardır.

Fotosentetik sistemin uygunsuz gelişimi ve *in vitro* kültür sırasında stomaların bozulması, bitki dokusunun bir dizi morfolojik ve fizyolojik bozukluğuna yol açabilir (Urban ve ark., 2017). Doku kültürü yapılan bitkiler *in vitro* da normal görünse de, aktif olarak fotosentez yapma olasılıkları düşüktür (Askari ve ark., 2022). Doku kültürü bitki üretiminin büyük ölçekteki eksikliklerinin üstesinden gelmek için, *in vitro* koşullarda yeni çevre kontrol sistemlerinin geliştirilmesi gereklidir.

Ceviz çoğaltma sürecinde önemli bir adım, ceviz doku kültürü bitkilerinin *in vitro* pişkinleştirilmesidir (Vahdati ve ark., 2021). *In vitro* pişkinleştirme, doku kültüründe yetiştirilen bitkilerin *ex vitro* saha koşullarına adapte edildiği bir işlemdir. Bu işlem anormalliklerin

kademeli olarak üstesinden gelinmesini ve *ex vitro* koşullarına adaptasyonu içerir (McCartan ve ark., 2004). *In vitro* kuruma, bitkilerin nakilden hemen sonra ölmesine yol açabilen hızlı su kaybının sonucudur. Bu nedenle, doku kültürü ceviz bitkilerinde verimli stomaların gelişimi hayati önem taşır. Morfogenez ve ilgili konular, esas olarak mavi, kırmızı ve uzak kırmızı ışık spektrumları aralığındaki fotonlar tarafından aktive edilen çeşitli fotoreseptörler tarafından düzenlenir (Griffin ve Toledo-Ortiz, 2022). Son yıllarda, ışık yayan diyotlar (LED'ler), doku kültürü bitkilerinin büyümesi ve gelişmesi için potansiyel bir alternatif ışık kaynağı olarak kullanılmıştır. LED'ler, bitkilerin ihtiyaçlarına uygun ışık kalitesinin manipüle edilmesine olanak tanır (Trivellini ve ark., 2023). Geleneksel sistemlerle karşılaştırıldığında, LED aydınlatma sistemleri dayanıklılık, küçük boyut, uzun çalışma ömrü, nispeten soğuk yayma yüzeyi, elektrik giriş akımıyla doğrusal bir foton çıkışı ve spektral bileşimi kontrol etme yeteneği gibi benzersiz avantajlara sahiptir (Brown ve ark., 1995). Fotosentez ışık spektrumundan doğrudan etkilenir ve fotosentez bitki büyümesi için gereken karbonhidratları sağladığından, farklı ışık spektrumlarının doku kültürü eksplantlarının fotosentetik performansını etkileyebileceği varsayılmıştır (şekil 5).



Şekil 5. Farklı ışık kaliteleri altında yetiştirilen 'Chandler'ın *in vitro* eksplantlarının morfolojisi: (A) Kırmızı ve mavi ışığın kombinasyonu (70:30), (B) kırmızı ve uzak kırmızı ışığın kombinasyonu (70:30), (C) yeşil (530 nm'de dalga boyu tepe noktası), (D) mavi (460 nm'de dalga boyu tepe noktası), (E) beyaz ışık (400-700 nm), (F) kırmızı (660 nm'de dalga boyu tepe noktası), (G) Uzak kırmızı ışık (730 nm'de dalga boyu tepe noktası), (H) floresan ışık (380-750 nm) (Saeedi ve ark., 2023).

Farklı karbon kaynakları, farklı odunsu türlerin rizogenezini etkileme kabiliyetlerini göstermiştir. Cevizin kök ekspresyonu aşamasında çoğunlukla sükroz kullanılmış olsa da, diğer karbon kaynaklarının da uygun olduğu kanıtlanmıştır. Licea-Moreno ve ark. (2012), Mj209x Ra melezinin köklenmesi için kök ekspresyon kültür ortamına fruktoz eklemiş ve genotipe bağlı olarak en iyi uygulama için %57,4 ila %90,9 köklenme oranı elde etmiştir. Genel olarak, fruktozun kök oluşumu için glukoz veya sükrozdan daha iyi bir destekleyici olduğu bildirilmiştir (Licea-Moreno ve ark., 2015).

7. SONUÇ

Bitki ıslah yöntemleri, bitkilerin vejetatif olarak çoğaltılabilme yeteneğine sahip olması durumunda başarılı ve etkilidir. Bu nedenle, cevizin vejetatif çoğaltımının zorluğu göz önüne alındığında, cevizin farklı vejetatif çoğaltım yöntemlerini araştırmak ve bunlarla ilgili farklı veriler toplamak çok önemlidir. Günümüzde, ceviz geleneksel olarak aşılama ile güvenilir bir şekilde çoğaltılsa da, bu uygulamanın başarısı çevresel ve içsel faktörlerden etkilenir. Bunun yanında, hipokotil, epikotil ve mikro/mini aşılama teknikleri oldukça etkili yöntemler olarak tanıtılsa da bu yöntemlerin optimizasyonu için daha fazla araştırmaya ihtiyaç duymaktadır.

Mikro çoğaltma, kısa bir süre içinde (yaklaşık bir yıl) minimum eksplant miktarlarıyla sayısız bitki üretmeyi sağlayan en değerli çoğaltma yöntemi olarak kabul edilir. Şu anda, dünya çapında yalnızca birkaç önemli şirket ve araştırmacı, cevizleri doku kültürüyle çoğaltma protokollerine ve yeteneğine sahiptir. Doku kültürü üretiminin başarısında çeşitli faktörler rol oynar ve ceviz kültürünün doku kültürü üretiminden sonra bile en kritik sorun, bunların arazi koşullarına adaptasyonudur. Bütün bu süreçlerle ilgili yapılan çalışmalarda başarılı sonuçlar elde edilse de birçok durumda bu sonuçların geçerliliği olmamaktadır. Özellikle klonal ceviz anaçlarının mikro çoğaltımında bu problemlerin çözümüne dönük daha fazla araştırmaya ihtiyaç vardır.

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PEANUT (*Arachis hypogaea* L.) CULTIVATION AND ITS IMPORTANCE IN TÜRKİYE

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ABSTRACT

Peanut belongs to the Leguminosae family and is an economically important oil, feed and food crop. It is widely grown in tropical and subtropical regions of the world. Although peanut kernels are the most important product of the peanut plant, all parts of the plant are useful and can be used in various ways. Peanut seeds are a rich source of nutrients and have various health benefits. The seeds contain 40-55% oil, 20-35% protein and 10-20% carbohydrates. They also provide 567 kcal of energy from 100 g of seeds. Being a legume, peanut increases the nitrogen content of the soil by fixing the free nitrogen of the air through special Rhizobium bacteria in the roots. Thus, it allows the use of less nitrogenous mineral fertilizers in the areas where it is grown and provides economical and ecological contribution. According to 2022 figures, 54,238,560 tons of product was obtained from 305,362,630 decares of land in the world, while the average yield was 177.62 kg/da. In the same year, while 186,340 tons of product was obtained from 457,000 decares in Turkey, the average yield was 407.74 kg/da, well above the world average. According to TUIK data, 70% of the peanut production in Turkey is realized in Adana and Osmaniye provinces. These provinces are followed by Şırnak, Antalya, Gaziantep and Kahramanmaraş. In 2017, 165,330 tons were produced on 419,495 decares of area, while this figure was realized as 185,137 tons on 460,098 decares of area in 2023. When peanut is analyzed according to their usage areas, they are an important raw material for the oil industry in the world. However, its use in the oil industry is not preferred in our country. In recent years, it is seen that peanuts are generally consumed as a food in our country, although peanut butter and peanut flour for use in bakery products have become widespread in our country. The main problems in peanut production are high input costs, drying problems, price instability, climate change and water scarcity. As a solution to these problems; drought resistant varieties, mobile drying systems, cooperatives and cooperative support can be offered. This presentation aimed to discuss the production status of peanuts in the world and in Turkey and the problems encountered in peanut production and their solutions.

Keywords: Peanut, Leguminosae, Oil, Production, Production problems

YER FISTIĞI (*Arachis hypogaea* L.) YETİŞTİRİCİLİĞİ VE TÜRKİYE'DEKİ ÖNEMİ

ÖZET

Yer fıstığı Leguminosae (Baklagiller) familyasından olup, ekonomik açıdan önemli bir yağ, yem ve gıda ürünüdür. Dünyanın tropikal ve subtropikal bölgelerinde yaygın olarak yetiştirilir. Yer fıstığı tohumları yer fıstığı bitkisinin en önemli ürünü olmasına rağmen, bitkinin tüm kısımları faydalıdır ve çeşitli şekillerde kullanılabilir. Yer fıstığı tohumları, zengin bir besin kaynağıdır ve sağlığa çeşitli faydaları vardır. Tohumları %40-55 yağ, %20-35 protein ve %10-20 karbonhidrat içerir. Ayrıca 100 gr tohumdan 567 kcal enerji sağlarlar. Baklagillerden olduğu için yer fıstığı, köklerindeki özel *Rhizobium* bakterileri vasıtasıyla, havanın serbest azotunu bağlayarak, toprağın azot içeriğini artırır. Böylece, yetiştirildiği alanlarda daha az azotlu mineral gübre kullanımına imkân verip, ekonomik ve ekolojik katkı sağlar. 2022 yılı rakamlarına göre dünyada 305 362 630 dekarlık alandan 54 238 560 ton ürün elde edilirken, ortalama verim 177.62 kg/da olarak gerçekleşmiştir. Aynı yıl ülkemizde 457 000 dekardan 186 340 ton ürün elde edilirken, ortalama verim dünya ortalamasının hayli üzerinde olarak 407.74 kg/da olarak gerçekleşmiştir. TÜİK verilerine göre, Türkiye'de yapılan yer fıstığı üretimin % 70'i Adana ve Osmaniye illerinde gerçekleşmektedir. Bu illeri Şırnak, Antalya, Gaziantep ve Kahramanmaraş illeri takip etmektedir. 2017 yılında 419 495 dekar alanda 165 330 ton üretim yapılırken 2023 yılında bu rakam 460 098 dekar alanda 185 137 ton olarak gerçekleşmiştir. Yer fıstığı kullanım alanlarına göre değerlendirildiğinde, dünyada yağ sanayisi için önemli bir ham maddedir. Fakat ülkemizde yağ sanayisinde kullanımı tercih edilmemektedir. Son yıllarda ülkemizde yer fıstığının, yer fıstığı ezmesi ve özellikle unlu mamullerde kullanılmak üzere yer fıstığı unu olarak kullanımı yaygınlaşsa da genellikle çerez olarak tüketildiği görülmektedir. Son yıllarda yer fıstığı üretiminde başlıca; yüksek girdi maliyetleri, kurutma sorunu, fiyat istikrarsızlığı, iklim değişikliği ve su kıtlığı gibi sorunlar vardır. Bu sorunlara çözüm olarak ise; kuraklığa dayanıklı çeşitler, mobil kurutma sistemleri, kooperatifleşme ve kooperatif desteği gibi uygulamalar sunulabilir.

Bu bildiride, yer fıstığının dünyadaki ve Türkiye'deki üretim durumu, yer fıstığı üretiminde karşılaşılan sorunlar ve çözüm önerileri tartışılmıştır.

Anahtar Kelimeler: Baklagil, Yer fıstığı, Üretim, Üretim sorunları

1. GİRİŞ

Yer fıstığı, Leguminosae (Baklagiller) familyasından olup tohumları için yetiştirilen yağ ve protein kaynağı olarak önemli bir endüstri bitkisidir. Yer fıstığı ekonomik açıdan önemli bir yağ tohumu, yem ve gıda ürünüdür ve dünyanın tropikal ve subtropikal bölgelerinde yaygın olarak yetiştirilir. Yer fıstığının botanik adı olan *Arachis hypogaea* Linn., yabani ot anlamına gelen Yunanca 'arachos' ve toprak altı/yer altı odası anlamına gelen hypogaea kelimelerinden türetilmiştir ve toprakta meyve/bakla üreten bir yabani ot/bitkiyi ifade eder. 30-50 cm boyunda büyüyen ve 2/5 fillotakside (iki zıt çift; terminal yaprakçık yok) tetra foliat yapraklar taşıyan tek yıllık, otsu bir bitkidir (Prasad vd 2011). Yer fıstığı tohumları yer fıstığı bitkisinin en önemli ürünü olmasına rağmen, bitkinin tüm kısımları faydalıdır ve çeşitli şekillerde kullanılabilir.

Yer fıstığının en önemli ürünü olan yer fıstığı tohumları zengin bir besin kaynağıdır ve çeşitli sağlık yararları sağlar. Tohumları %40-55 yağ, %20-35 protein ve %10-20 karbonhidrat içerir. 100 gr tohumdan 567 kcal enerji sağlarlar (Arıoğlu, 2007). Yer fıstığı yağı, palmitik (%7-12), oleik (%40-50) ve linoleik (%25-35) olmak üzere yedi yağ asidi içerir ve toplam yağ asitlerinin yaklaşık %90'ını oluştururlar. %80'den fazla oleik asit içeren yüksek oleik hatlar da mevcuttur. Ayrıca, tohumları kalsiyum, fosfor, demir ve çinko gibi mineraller; E gibi vitaminler ve tiamin, pantotenik asit, riboflavin, foliatlar ve niasin gibi B-kompleks grupları; p-kumarik asit ve resveratrol gibi antioksidanlar açısından iyi bir kaynaktır ve biyolojik olarak aktif polifenoller, flavonoidler ve izoflavonlar içerir. Yağ çıkarıldıktan sonra elde edilen fıstık unu, hayvancılık ve kümes hayvanları için yüksek proteinli zengin bir yemdir. Birincil bileşenler ham protein (%45,6), şeker (%32,50), yağ (%2,5), lif (%8,3) ve küldür (%5,0). Ayrıca lizin, metiyonin, sistein, treonin ve arginin gibi amino asitlerin ve kalsiyum, fosfor, sodyum ve potasyum gibi minerallerin zengin bir kaynağıdır.

Baklagillerden olduğu için yer fıstığı köklerindeki özel *Rhizobium* bakterileri vasıtasıyla havanın serbest azotunu bağlayarak toprağın azot içeriğini artırır. Böylece, yetiştirildiği alanlarda daha az azotlu mineral gübre kullanımına imkân verir.

Dünyada yer fıstığı üretim bakımından yağlı tohumlu bitkiler arasında dördüncü sırada yer almaktadır. 2022 yılı rakamlarına göre dünyada 305.362.630 dekarlık alandan 54.238.560 ton ürün elde edilirken ortalama verim 177,62 kg/da olarak gerçekleşmiştir (FAO, 2022). Aynı yıl ülkemizde 457.000 dekardan 186.340 ton ürün elde edilirken, ortalama verim dünya ortalamasının hayli üzerinde olarak 407,74 kg/da olarak gerçekleşmiştir. Yer fıstığı kullanım alanlarına göre değerlendirildiğinde dünyada yağ sanayisi için önemli bir ham maddedir. Fakat ülkemizde yağ sanayisinde kullanımı tercih edilmemektedir. Ayrıca ülkemizde son yıllarda yer fıstığının, yer fıstığı ezmesi ve unlu mamullerde yer fıstığı unu olarak kullanımı yaygınlaşsa da genellikle çerez olarak tüketildiği görülmektedir (Şahin, 2014).

Yer fıstığı tohumunda yüksek miktarda riboflavin, tiamin, nikotinik asit ve E vitamini bulunmakla birlikte A, C ve D vitaminlerinin miktarı yok denecek kadar azdır. Yer fıstığının kavrulması işlemi sırasında tiamindeki azalmaya karşılık niasin ve riboflavin vitaminleri miktarlarında önemli bir değişme olmadığı rapor edilmiştir (Anonim, 2006). Yapılan araştırmalar sonucunda yer fıstığının, resveratrol (3, 4', 5-trihidroksi-stilben), fenolik asitler, flavonoidler ve fitosteroller gibi biyoaktif bileşikler bakımından zengin olduğu, ayrıca koenzim Q10 ve arjininin içeriğinin de yüksek olduğu saptanmıştır (Özalp ve Kürklü, 2020).

Resveratrol; kanser, kardiyovasküler hastalıklar, nörolojik hastalıklar gibi birçok kronik hastalığın temelinde bulunan inflamasyona karşı koruyucudur (Arya vd., 2016). Yer fıstığının içerdiği çoklu doymamış yağ asitleri (ÇDYA) miktarının fazla, doymuş yağ asitleri (DYA) miktarının ise düşük olduğu, ayrıca birçok vitamin, mineral ve fenolik bileşiklerden zengin olması nedeniyle kardiyovasküler hastalıklardan, Alzheimer, Parkinson gibi sinir hücresi kaybına neden olan nörodejeneratif hastalıklara ve çeşitli kanser türlerine kadar birçok hastalığın önlenmesinde ve tedavisinde etkili bir gıda olduğu belirtilmektedir (Chen vd., 2005; Delmas vd., 2006).

Yer fıstığı kolesterol içermemesi ve kompleks karbonhidrat olan posa içeriği bakımından zengin olması nedeniyle iyi bir besin kaynağıdır. Bunlara ek olarak yer fıstığı tohumlarının ham protein içeriğinin %22-30 civarında olması, vejetaryenler ve veganlar için sağlıklı bir diyetsel protein kaynağı olarak değerlendirilmektedir (Mutegi vd., 2013).

Yer fıstığı, 20 amino asidin tümünü farklı oranlarda içermekle birlikte önemli bir aminoasit olan arjininin en önemli kaynağı olma özelliğini taşımaktadır. Protein sindirilebilirliğine göre düzeltilmiş amino asit skoruna (Protein digestibility corrected amino acid score [PDCAAS]) göre yer fıstığı ve soya gibi diğer baklagillerin büyüme, gelişme ve sağlıklı bir yaşam sürdürülmesi için et ve yumurtadan sonra gelen protein kalitesi yüksek bir gıda olduğu belirtilmektedir (FAO, 2002). Bitkisel kaynaklı protein bakımından zengin olan yer fıstığının, içerdiği posa ve çeşitli biyoaktif bileşenlerden dolayı da sağlık üzerine olumlu etkileri bulunmaktadır (Wu vd., 2009).

Yer fıstığı, dünya çapında 100'den fazla ülkede farklı tarımsal ekolojik ortamlarda yetiştirilmektedir. Ancak, ana yetiştirme, toplam yer fıstığı alanının ve üretiminin büyük bir kısmını oluşturan Asya ve Afrika'nın gelişmekte olan ülkeleriyle sınırlıdır.

Hem gelişmiş hem de gelişmekte olan ülkelerde fıstık tüketim modelinde gözle görülür bir farklılık vardır. Gelişmekte olan ülkelerde üretilen fıstığın çoğu, iç tüketim ihtiyaçlarını karşılamak için yağ çıkarmak üzere işlenirken, ABD gibi gelişmiş ülkelerde çoğunlukla bir gıda kaynağı olarak tüketilir. Yıllar geçtikçe, gelişmekte olan ülkelerde bile, şekerleme sınıfı fıstıklara yönelik artan uluslararası pazar talepleri ve diğer daha ucuz alternatif yağların bulunabilirliği ile eğilim daha çok gıda kaynağına doğru kaymıştır. Afrika'da fıstık kavrulmuş, haşlanmış veya çiğ olarak ve fıstık ezmesi olarak tüketilir. Arjantin ve Brezilya'da büyük miktarda şekerleme fıstığı kavrulmuş kuruyemiş olarak veya fıstık şekerlemesi gibi atıştırmalık yiyecekler olarak paketlenmiş halde tüketilir. ABD'de fıstık tüketimi çoğunlukla fıstık ezmesi, paketlenmiş atıştırmalık kuruyemişler (tuzlu, tuzsuz, aromalı ve balla kavrulmuş) ve fıstık şekerlemeleri şeklindedir.

Fıstık, dünyanın en büyük bitkisel yağ kaynaklarından biridir. Amerika Birleşik Devletleri Tarım Bakanlığı (USDA) veri tabanlarına göre, fıstık dokuz büyük yağlı tohum bitkisi arasında bitkisel yağ üretiminde dünya çapında beşinci sıradadır (http://www.fas.usda.gov/psdonline/psdHome.aspx, 2025). Fıstık yaygın olarak bir yağlı tohum mahsulü olarak görülse de fıstıkların kullanımı ülkeden ülkeye büyük ölçüde değişmektedir. Bazı ülkelerde üretimin büyük kısmı yağ için işlenirken, Amerika Birleşik Devletleri gibi ülkelerde fıstıklar öncelikle gıda olarak kullanılır. Ayrıca yetiştirildiği ülkelerde çiftçilerin nakit gelirinin de önemli bir kaynağıdır.

2. DÜNYA'DA YER FISTIĞI ÜRETİMİ

Dünya'da en fazla yer fıstığı üretimi yapan ülkelerin üretim alanları, üretim miktarları ve verim değerleri Tablo 1'de verilmiştir.

Tablo 1. Dünyada en fazla yer fıstığı üretimi yapan ülkeler

Ülkeler	Üretim Alanı (da)	Üretim Miktarı (ton)	Verim (kg/da)
Dünya	305.362.630	54.238.560,13	177,62
Türkiye	457.010	186.340	407,74
Malavi	4.000.000	350.000	87,50
Arjantin	4.064.770	1.346.166	331,18
Kamerun	4.500.000	500.000	111,11
Mali	4.789.670	442.679	92,42
Kongo	5.100.000	486.389	95,37
ABD	5.606.600	2.525.670	450,48
Burkina Faso	6.237.690	559.064,4	89,63
Çad	7.626.420	829.431	108,76
Gine	8.542.870	1.025.144,1	120
Nijer	10.037.620	670.613,5	66,81
Tanzanya	10.200.000	710.000	69,61
Myanmar	11.941.610	1.741.377,8	145,82
Senegal	12.251.720	150.1498	122,55
Sudan	30.000.000	2.500.000	83,33
Nijerya	34.000.000	4.284.000	126
Çin	44.400.000	18.329.500	412,83
Hindistan	57.047.400	10.134.990	177,66

(FAO, 2022)

2022 yılında dünyada 305.362.630 dekar alandan 54.238.560,13 ton yer fıstığı elde edilmiş olup dünya verim ortalaması 177,62 kg olarak gerçekleşmiştir (FAO, 2022). Dünya yer fıstığı üretimine baktığımızda en fazla üretimin, Afrika ve Asya ülkelerinde gerçekleştiği görülmektedir. Ancak Afrika ülkelerindeki üretim alanları fazla olmasına rağmen, dekardan

elde edilen verimin çok düşük düzeylerde kalmasından dolayı üretim miktarı istenilen düzeye ulaşamamıştır. Özellikle Nijer ve Tanzanya 10 milyon dekar üretim alanına sahipken, dekara elde edilen verimin 66 kg civarında olması nedeniyle üretim miktarı 700 bin ton civarında kalmıştır. Dünya'da en fazla yer fıstığı üreten ülkelere baktığımızda Hindistan ve Çin'in ilk sıraları aldığı görülmektedir. Özellikle Çin'de yetiştirilen yer fıstığının verim değeri (412,83 kg/da) ABD'den (450,48 kg/da) sonra ikinci sıradadır. Türkiye'de yer fıstığı üretim alanı 457 bin dekar iken verim, dünya ortalamasının çok üzerindedir (407,74 kg/da). Bu durum ülkemiz iklimi ve toprak yapısı yer fıstığı tarımı için çok uygun olduğunun önemli bir göstergesidir.

3. YER FISTIĞININ TÜRKİYE'DEKİ ÜRETİM DEĞERLERİ

Tablo 2. Türkiye'de en fazla yer fıstığı üretimi yapılan illerin ekim alanı, üretim miktarı ve verim değerleri

İller		2017	2018	2019	2020	2021	2022	2023
Türkiye	Ekim Alanı	419495	443342	424211	547747	579192	457010	460098
	Üretim Miktarı	165330	173835	169328	215927	234167	186340	185137
	Verim	394	392	401	394	404	408	402
Adana	Ekim Alanı	236399	239584	213527	270169	274914	222229	208442
	Üretim Miktarı	97788	98834	90424	113460	116917	92539	89011
	Verim	414	413	423	420	425	416	427
Osmaniye	Ekim Alanı	132605	130275	132881	149157	144613	115821	113238
	Üretim Miktarı	50157	47632	50373	53554	55146	48330	44060
	Verim	378	367	379	359	381	417	389

Şırnak	Ekim Alanı	5000	20000	24000	63750	75575	53000	68150
	Üretim Miktarı	2250	9000	9600	24946	29696	19783	24150
	Verim	450	450	436	391	393	373	374
Antalya	Ekim Alanı	10880	10672	12460	14595	16872	17059	17592
	Üretim Miktarı	3703	3855	4639	5614	6555	6830	7040
	Verim	340	361	372	385	389	400	400
Gaziantep	Ekim Alanı	1160	3000	3000	5757	6221	10000	13800
	Üretim Miktarı	464	1200	1100	2253	2445	4284	5989
	Verim	400	400	367	391	393	428	434
Kahramanmaraş	Ekim Alanı	8425	8425	9350	10631	11855	11975	13905
	Üretim Miktarı	2853	2849	3305	3787	4296	4454	5177
	Verim	339	338	353	356	362	372	372

(TÜİK, 2024)

TÜİK verilerine göre, Türkiye'de yapılan yer fıstığı üretimin %70'i Adana ve Osmaniye illerinde gerçekleşmektedir. Bu illeri Şırnak, Antalya, Gaziantep ve Kahramanmaraş illeri takip etmektedir. Ancak, son yıllarda Şırnak ilinde gerçekleşen yer fıstığı üretiminde önemli bir artış görülmektedir. 2017 yılında 419.495 dekar alanda 165.330 ton üretim yapılırken 2023 yılında bu rakam 460.098 dekar alanda 185.137 ton olarak gerçekleşmiştir. 2017 ve 2023 yıllarında gerçekleştirilen üretim alanları ve miktarlarına baktığımızda önemli bir değişikliğin olmadığı görülmektedir. Ancak, 2019 yılında Türkiye'de yer fıstığı üretim alanı 424.211 dekar ve üretim 169.328 ton iken bu rakam, 2020 yılında 547.747 dekar ve 215.927 tona çıkmıştır. Yer fıstığı tarımının en fazla yapıldığı Adana'da, yer fıstığı üretim alanları 2020 yılında bir önceki yıla

kıyasla yaklaşık %30'luk bir artış göstermiştir. Bunun yanı sıra Şırnak'taki üretim alanı 2017 yılında 5000 dekardan, 2020 yılında yaklaşık %1300'lük bir artış göstermiş ve 63.750 dekarlara çıkmıştır. 2021 yılında ülkemizde 579.192 dekar alanda 234.167 ton yer fıstığı üretimi yapılmış ve bu artışa en fazla katkı sağlayan yine Adana ve Osmaniye illeri olmuştur. Adana'da yer fıstığı üretimi yapılan alanda çok fazla bir değişiklik olmazken, Şırnak'ta 2021 yılındaki üretim miktarı 2020 yılına göre daha da artarak 63.750 dekar 24946 ton üretimden ve 75.575 dekar ve 29.696 tona ulaşmıştır.

4. YER FISTIĞI ÜRETİMİNDE SORUNLAR

4.1.İKLİM DEĞİŞİKLİĞİ VE SU SIKINTISI

İklim değişikliği sonucu temiz su kaynaklarının azalması nedeniyle her geçen gün temiz su kaynaklarına ulaşım zorlaşmaktadır. Yer fıstığı gibi yaz döneminde yetiştirilen ürünler su kıtlığı sorunundan daha fazla etkilenmektedir. Çünkü yer fıstığı tarımının yapıldığı dönemde vejetasyon süresinin önemli bir kısmında yağmur yağmamakta ve bitkilerin su ihtiyacı sulama yapılarak sağlanmaktadır. Bu bağlamda yer fıstığı tarımının salma su yöntemi yerine, damla sulama yöntemiyle sulanması teşvik edilmelidir. Ayrıca, bu sorunun üstesinden gelebilmek için kuraga dayanıklı yeni çeşitlerin geliştirilmesi ve üretime aktarılması da teşvik kapsamına alınması sağlanmalıdır.

4.2. GİRDİ MAALİYETİNDEKİ SÜREKLİ ARTIŞ

Yer fıstığı tarımındaki girdilerde sürekli bir artış söz konusudur. Bunların başında, tarla kirası gelmektedir. Çiftçi tarlaya ekim yapmadan alacağı ürünün yarısını tarla kirası olarak vermek durumunda kalmaktadır. Bunun yanı sıra mazot, gübre ve sulamada kullanılan elektrik fiyatlarında da her geçen yıl önemli artışlar olmakta ancak, üretici bu artışları fiyata yansıtamamaktadır. Bu nedenlerle, yer fıstığı tarımı yapan üreticilere kooperatifler tarafından vade farksız gübre ve mazot sağlanması üreticiye önemli katkı sağlayacaktır.

4.3. İKİNCİ ÜRÜN TARIMINDA KURUTMA PROBLEMİ

Yer fıstığı üretiminin yaklaşık %30'u ikinci ürün olarak gerçekleşmektedir (İşler ve Gözüyeşil, 2016). Yer fıstığı tarımında ürünlerin kurutulması doğal yollarla güneşe sermek suretiyle yapılmaktadır. Ancak, bu durum ikinci ürün yetiştiriciliğinin hasadında sorunlara neden olmaktadır. Çünkü ikinci ürün hasadında, hasatlar yağmurlu döneme denk gelebilmekte ve bu durum yer fıstığı meyvelerinin kısa sürede kurumasını engelleyebilmektedir. Nemli kalan yer fıstığı meyvelerinde kayıplar ve daha önemlisi aflatoksin oluşumu meydana gelmektedir. Bu sorunun üstesinden gelebilmek için römorklu kurutma sistemlerinin üretime dahil edilmesi önemli faydalar sağlayacaktır.

4.4. YER FISTIĞINDA FİYAT İSTİKTARININ OLMAMASI

Yer fıstığı tarımını etkileyen en önemli faktör, üretim yılları arasında bir fiyat istikrarının olmaması diye söylemek mümkündür. Çünkü tüketim oranında yıllar arasında çok fazla farklılıklar olmamasına rağmen üretim miktarlarında değişiklikler olmaktadır. Bu durum yer fıstığının fiyatını doğrudan etkilemektedir. Bazı yıllar üreticinin birim alandan elde ettiği gelir üretim maliyetinden bile az olabilmektedir. Bunun önüne geçebilmek için yer fıstığı üreticilerinin ürün planlamasını yapmasına yardımcı olacak, tüccar ile fiyat dengesini ayarlayacak ve üretilen yer fıstığının farklı şekillerde işlenip tüketiciye sunulmasını sağlayacak bir kooperatifin kurulması gerekmektedir.

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PLANT PRODUCTION AND AGRICULTURAL STRUCTURE IN THE PROVINCE OF KIRŞEHİR

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ABSTRACT

Kırşehir is a city located in the Central Anatolia Region and stands out due to the distinct effects of its continental climate. In Kırşehir, winters are cold and rainy, while summers are hot and dry. The city's annual average temperature is 11.5°C, and the average relative humidity is 63 %. Annual rainfall varies between 350 and 500 mm, with an average of 385.4 mm. The rainfall distribution in the province is irregular; the least amount of rainfall occurs during the summer months, when irrigation is most needed. With the end of the rainfall at the beginning of the summer months in Kırşehir, the vegetation that comes to life in the spring quickly turns yellow and dries; this causes the land to have a steppe texture in the summer season. Although Kırşehir has a surface area of 657.012 hectares and is rich in terms of irrigable land, only 9.3% of the total agricultural land can be irrigated; only 42.176 hectares out of 454.720 hectares of agricultural land are effectively irrigated. In Kırşehir, barley ranks first in terms of cereal production, with barley fields covering approximately 40 % of the province. The main reason for this is that barley is largely used as animal feed, making it the most preferred cereal by local farmers. Barley is followed by wheat and oats. Chickpeas, beans, and red and green lentils are produced in Kırşehir among the legumes. Kırşehir ranks 3rd in Turkey for chickpea and green lentil production. Sugar beets, sunflowers for oil and snacks, and potatoes are the main industrial crops grown in the province. The production of forage crops is of great importance in supporting animal husbandry and addressing the deficit in quality roughage. The main forage crops in Kırşehir include silage maize, alfalfa, vetch, and sainfoin. Additionally, the cultivation of medicinal and aromatic plants is also gradually developing in the province.

Keywords: Kırşehir province, cereals, industrial crops, cultivation area

KIRŞEHİR İLİNDE BİTKİSEL ÜRETİM VE TARIMSAL YAPI

ÖZET

Kırşehir, İç Anadolu Bölgesi'nde yer alan ve karasal ikliminin belirgin etkileriyle öne çıkan bir şehirdir. Kırşehir'de kışlar soğuk ve yağışlı, yazlar ise sıcak ve kurak geçer. Şehirde yıllık ortalama sıcaklık 11.5 °C, ortalama nispi nem oranı %63'tür. Yıllık yağış miktarı 350 ile 500 mm arasında değişmekte olup, ortalama yağış 385.4 mm'dir. İlde yağış dağılımı düzensizdir; en az yağış, sulamaya en çok ihtiyaç duyulan yaz aylarında gerçekleşmektedir. Kırşehir'de yaz aylarının başlangıcından itibaren yağışların sona ermesiyle, ilkbaharda canlanan bitki örtüsü kısa sürede sararıp kurur; bu durum arazinin yaz mevsiminde bozkır dokusuna sahip olmasına yol açar. Kırşehir, 657.012 hektarlık yüzölçümüne sahip olup, sulanabilir arazi bakımından zengin olmasına rağmen, toplam tarım arazisinin yalnızca % 9.3'ü sulanabilmekte; 454.720 hektarlık tarım alanından yalnızca 42.176 hektarı etkin bir şekilde sulanmaktadır. Kırşehir'de tahıl üretimi açısından birinci sırayı arpa alır; arpa ekili alan, ilin yaklaşık % 40'ını oluşturur. Bunun başlıca nedeni, arpaların büyük oranda hayvan yemi olarak kullanılmasıdır, bu yüzden bölge çiftçileri tarafından en çok tercih edilen tahıl türüdür. Arpayı, buğday ve yulaf izlemektedir. Kırşehir'de yemeklik tane baklagiller arasında nohut, fasulye, kırmızı ve yeşil mercimek üretilmektedir. Nohut ve yeşil mercimek üretiminde Kırşehir, Türkiye genelinde 3. sırada yer almaktadır. Şeker pancarı, yağlık ve çerezlik ayçiçeği ile patates ise ilde yetiştirilen başlıca endüstri bitkilerindendir. Hayvancılığın desteklenmesi ve kaliteli kaba yem açığının giderilmesi amacıyla yem bitkileri üretimi büyük önem taşımaktadır. Kırşehir'de başlıca yem bitkileri arasında silajlık mısır, yonca, fiğ ve korunga yer almaktadır. Ayrıca, ilde tıbbi ve aromatik bitki yetiştiriciliği de giderek gelişmektedir.

Anahtar Kelimeler: Kırşehir ili, tahıllar, endüstri bitkileri, ekim alanı

GİRİŞ

Kırşehir ili, Türkiye'nin İç Anadolu Bölgesi içinde yer alan Orta Kızılırmak Havzası'nda konumlanmaktadır. İl, Coğrafi koordinatları ise, 34 derece 10 dakika doğu boylamı ve 39 derece 08 dakika kuzey enlemidir. Bu konum, bölgenin hem iklimsel hem de coğrafi özelliklerini belirleyen önemli bir faktördür. Kırşehir'in en yüksek rakımlı bölgelerinden biri olan Göllü Dağı (1.745 metre) gibi dağlık alanlar bulunurken, ilin en düşük rakımlı yerleri ise 850 metreye kadar inen Kızılırmak Vadisi ve çevresidir (Anonim, 2024a).

Kırşehir yöresi, Orta Anadolu'nun jeolojik yapısında önemli bir yere sahip olan Orta Anadolu Masifi'nin bir parçasıdır. Bu bölge, Türkiye'nin en büyük masiflerinden biri olan "Kırşehir Masifi" içerisinde yer alır. Kırşehir Masifi, Türkiye'deki dokuz büyük masiften biri olmasının yanı sıra, yüzölçümü bakımından en geniş olanıdır. Kırşehir ili, Kızılırmak nehrinin oluşturduğu büyük yay şeklindeki alanın içinde konumlanmıştır. Coğrafi sınırları incelendiğinde; kuzeyde Delice Irmağı Vadisi, batıda Kaman-Kılıçözü Vadisi ve doğuda Seyfe Gölü'nün çöküntü alanı ile çevrili olduğu görülür. Bu çöküntü ve vadiler, bölgenin hem doğal sınırlarını belirlemekte hem de rakım açısından daha alçak kesimleri oluşturmaktadır. Söz konusu jeolojik yapı, bölgenin yer şekilleri, tarım alanları ve su kaynakları üzerinde belirleyici bir rol oynamaktadır (Anonim, 2024a).

Kırşehir tarımı, İç Anadolu Bölgesi'nin karasal iklimi ve bozkır ekosisteminin etkisiyle şekillenmiş; zamanla hem geleneksel hem de modern tarım yöntemlerini bir araya getiren bir yapı kazanmıştır. İlde bitkisel üretimin büyük bölümünü tarla bitkileri oluşturur. Buğday, arpa ve nohut başta olmak üzere tahıllar ve baklagiller ön plandadır. Ayrıca şeker pancarı ve ayçiçeği gibi endüstriyel ürünlerin üretimi de önemlidir. Kırşehir merkez ile Kaman çevresindeki alanlarda, kuru tarıma uygun ürünler olan buğday, arpa, mercimek ve nohut yaygın şekilde yetiştirilir. Öte yandan, Hirfanlı Barajı gibi su kaynaklarının sağladığı imkânlarla sulanabilir arazilerde ayçiçeği, şeker pancarı, domates ve çeşitli yem bitkilerinin üretiminde artış gözlemlenmiştir (Anonim, 2024b). Son yıllarda sera faaliyetlerine verilen destekle birlikte elma ve ceviz gibi meyve yetiştiriciliği ile bağcılık alanlarında da önemli gelişmeler yaşanmıştır. Bu çalışmanın amacı; Kırşehir ilinde bitkisel üretim ve tarımsal yapısını ortaya koymaktır.

Şekil 1. Kırşehir İlinin Türkiye'deki yeri ve konumu

Kırşehir İli ve İlçeleri Hakkında Genel Bilgiler

Kırşehir, merkez ilçe dâhil olmak üzere toplam yedi ilçeden oluşan bir ildir ve Türkiye İstatistik Kurumu'nun (TÜİK) 2024 verilerine göre toplam nüfusu 244.546'dır. İl genelinde tarım ve hayvancılık en önemli geçim kaynaklarıdır. Akçakent ilçesinin nüfusu 3.438 olup, 2024 yılında 1.280 kişi tarımla uğraşmaktadır; ilçede tahıl, yağlık ayçiçeği ve yem bitkileri üretilmekte, ayrıca büyükbaş ve küçükbaş hayvancılık yapılmaktadır. Nüfusu 6.918 olan Akpınar ilçesinde 2.168 kişi tarım sektöründe çalışmakta; 208.253 dekar ekilebilir arazi, 100.837 dekar çayır-mera ve 27.534 dekar ormanlık alan bulunmakta, toplamda 46.710 adet büyük ve küçükbaş hayvan varlığı mevcuttur. Boztepe ilçesi 5.229 nüfuslu olup, 2.167 kişi tarımla uğraşmaktadır; 25.500 dekar sulanabilir araziye rağmen sulama yetersizliği verimi düşürmektedir. İlçede kültür ırkı sığırların artışı ve modern mandıraların kurulması hayvancılığa ilgiyi artırmıştır. Çiçekdağı'nın nüfusu 13.908, tarımla uğraşan kişi sayısı ise 3.157'dir; yüksek rakımlı coğrafyasında tahıl, bakliyat ve ayçiçeği gibi ürünlerin üretimi yaygındır. 33.469 nüfusa sahip Kaman ilçesinde 4.940 kişi tarımla uğraşmakta; 807.776 dekar kültür arazisinin 49.510 dekarında sulu tarım yapılmakta ve polikültür tarım uygulanmaktadır. Mucur ilçesi 18.235 nüfusa sahip olup, 3.390 kişi tarımla uğraşmaktadır; toplam 788.100 dekar tarım arazisinin 27.904 dekarında modern yöntemlerle buğday, arpa, ayçiçeği, mercimek ve pancar yetiştirilmektedir. Kırşehir'in en büyük nüfusa sahip ilçesi olan Merkez ilçede 163.349 kişi yaşamaktadır ve 2024'te 4.289 kişi tarımla uğraşmaktadır; toplam 1.156.120 dekar tarım arazisinin %52,8'inde tarla bitkileri, %0,7'sinde sebze, %0,5'inde ise meyve yetiştirilmekte, kalan %46'sı ise sulama olanaklarının kısıtlılığı nedeniyle nadasa bırakılmaktadır. Başlıca ürünler arpa, buğday, patates, şeker pancarı ve ayçiçeğidir.

Kırşehir'in Tarımsal Arazileri: Kullanım Durumu ve Sulama Kapasitesi

Kırşehir ilinin toplam 657 bin hektarlık arazi varlığının 455 bin hektarı tarıma elverişli olup, bu alanın büyük bir bölümü kuru tarım arazisidir (Tablo 1). İşlemeli tarım yapılabilen I., II., III. ve IV. sınıf toprakların toplamı 302.792 hektardır ve bu da tarım arazilerinin yaklaşık %69'unu oluşturmaktadır. Kullanılan tarım alanlarının %66,2'sinde tarla bitkileri, %0,6'sında sebze ve %0,9'unda meyve yetiştiriciliği yapılmaktadır. Kırşehir'in uzun yıllar yıllık ortalama yağış miktarı yaklaşık 380 mm'dir ve bu yağışların büyük kısmı ilkbahar aylarında düşmektedir (Kıymaz, 2011). Bu durum, tarımsal üretimi önemli ölçüde sınırlamaktadır. Tarım arazilerinin yalnızca %9,2'sinde sulama yapılabildiğinden, bölgede yoğun olarak kuru tarım uygulanmakta ve 159 bin hektar (%32,4) alan nadasa bırakılmaktadır. Ayrıca, 45 bin hektarlık tarıma elverişli alan kavaklık, söğütlük gibi tarım dışı amaçlarla kullanılmaktadır (Çizelge 1). Ormanlık, fundalık ve tarıma elverişsiz alanlar ise ilin arazi varlığının 75.406 hektarını (%11,6) kapsamaktadır (Yavuz vd, 2020).

Tablo 1. Kırşehir ilinin kullanım durumuna göre arazi dağılımı (Yavuz vd, 2020)

KULLANIM DURUMU	KIRŞEHİR	
	ALANI (ha.)	%
1.Kültür arazisi varlığı	454.720	69.2
a-Tarla ürünleri ekim alanı	240.323	58.4
b-Nadas alanı	158.947	28.9
c-Bağ alanı	1.850	0.4
d-Meyve bahçesi alanı	3.500	1.0
e-Sebze ekim alanı	5.000	1.3
f-Tarıma elverişli olup kullanılmayan alan	45.100	10
2.Çayır-mer'a alanı	129.027	19.2
3.Orman fundalık alanı	24.706	3.8
4.Tarıma elverişsiz alan	50.700	7.8
TOPLAM	657.012	100

Kırşehir, sulanabilir arazi potansiyeli açısından zengin olmakla birlikte, fiilen sulanan alanlar bakımından oldukça yetersiz bir durumdadır. Toplam 454.720 hektarlık tarım arazisinin yalnızca 42.176 hektarında aktif sulama yapılmaktadır. İl genelinde yıllık 3.221 hm^3 yüzey suyu ve 75 hm^3 yeraltı suyu olmak üzere toplam 3.296 hm^3 su potansiyeli bulunmasına rağmen, tarım arazilerinin sadece %9,3'ü sulanabilmektedir (Anonim, 2025c). Sulanan alanların 31.642 dekarlık kısmı devlet eliyle, 10.534 dekarlık kısmı ise halk sulaması yoluyla gerçekleştirilmektedir. Toprak yapısı ve topoğrafik koşullar göz önüne alındığında, mevcut tarım arazilerinin %80'ine denk gelen 366.222 hektarlık kısmı sulanabilir nitelikte olmasına rağmen, bu alanların yalnızca küçük bir bölümü sulanabilmektedir (Anonim, 2025c).

Kırşehir İlinin İklimsel Özellikleri ve Doğal Bitki Örtüsü

Kırşehir ili, karasal iklimin belirgin özelliklerini taşımaktadır. Kış mevsimi soğuk ve kar yağışlı geçerken, yazlar sıcak ve kurak olmaktadır. Yağışlar genellikle sonbahar ve ilkbahar aylarında düşmektedir. İç Anadolu'yu çevreleyen Toroslar ve Kuzey Anadolu Dağları, Karadeniz ve Akdeniz'in ılıman iklim etkilerinin iç bölgelere ulaşmasını engellediğinden, Kırşehir'de sert karasal iklim koşulları hakimdir.

İlin yıllık ortalama sıcaklığı 11,5 °C, ortalama nispi nem oranı ise %63'tür. Yıllık yağış miktarı 350–500 mm arasında değişmekte olup, ortalama 385,4 mm olarak gerçekleşmektedir (Anonim, 2020). Yağışların büyük bölümü ilkbahar aylarında görülürken, tarımsal faaliyetlerin yoğunlaştığı yaz aylarında yağış miktarı oldukça düşüktür. Bu durum, tarımsal üretim açısından

önemli bir dezavantaj oluşturmaktadır. Ayrıca ilde yağış dağılımı düzensizdir. Kırşehir'de ortalama rüzgar hızı 2,8 m/sn olup, egemen rüzgar yönleri kuzeybatı, kuzey ve kuzeydoğudur. En hızlı rüzgarlar ise güneydoğudan esmektedir.

Yaz aylarının kurak geçmesi nedeniyle, ilkbaharda yeşeren otlar yaz sonunda kurur ve il genelindeki araziler bozkır görünümüne bürünür. Kırşehir, İç Anadolu Bölgesi'nin bozkır kuşağı içinde yer almakta olup, orman örtüsünden büyük ölçüde yoksundur. İlin doğal bitki örtüsünü genellikle step (bozkır) bitkileri oluşturmaktadır. Ormanlık alanlar ilin yüzölçümünün sadece %3,7'sini kaplamaktadır (Anonim, 2024b).

Doğal koşullar nedeniyle kendiliğinden orman oluşumu sınırlı olan ilde, orman alanlarının artırılması ancak bilinçli ağaçlandırma çalışmalarıyla mümkün olabilmektedir. Çiçekdağı'nın kuzey kesimleri ile Akçakent ilçesi çevresinde meşe, karaçam, ardıç ve sedir türlerinden oluşan ormanlık alanlar bulunmaktadır. Bu ormanlar; karaçam, sedir ve kavaktan oluşan verimli korular, karaçam ve sedirden meydana gelen bozuk korular ile meşe ağaçlarından oluşan baltalık formundadır. İlçelere göre orman varlığı incelendiğinde; en geniş ormanlık alana Akçakent sahipken, bunu Çiçekdağı, Merkez İlçe, Kaman ve Mucur ilçeleri takip etmektedir (Anonim, 2024b).

Kırşehir'de Tarımsal Üretim ve Bitkisel Ürünler Analizi

Kırşehir ilinde en fazla ekim alanına sahip olan tahıl türü 1.231 bin ha ile arpadır. Kırşehir ilinde besi hayvancılığında arpa, rasyonlarda önemli bir yer tutmakta ve bu durum, arpanın ilde temel bir kesif yem olarak öne çıktığını göstermektedir. Arpanın bu önemi, TÜİK verilerine de yansımıştır. 2000-2011 yılları arasında Türkiye genelinde arpa üretimi %18 oranında azalırken, Kırşehir'de bu oran %21 artış göstermiştir. Türkiye genelinde ortalama arpa verimi dekara 265 kg iken, TR71 bölgesinde bu rakam 295 kg'a ulaşmıştır. Özellikle Kırşehir ve Nevşehir illerinde arpa tane verimi 300 kg/da 'nın üzerinde gerçekleştiği yıllar olmuştur Tüik verilerine göre 2024 yılında arpanın ortalama verimi 205 kg/da olarak gerçekleşmiştir. Dekara verimlerde 2024 yılındaki bu değişiklik arpa tarımının yapıldığı yıldaki toprak, iklim ve tarımsal uygulamalar gibi birçok faktör etki ettiğinden yıllara göre ortalama verimdeki değişiklik normaldir. İl genelinde 252 bin ton arpa üretilmiştir. Kırşehir'de yürütülen entansif hayvancılıkta arpa tanesi yoğun şekilde değerlendirilmektedir. Arpa tarımını öne çıkarmaktadır (Kır, 2024)

Tablo 3: Kırşehir İli Tahıl Üretim Verileri (Anonim, 2024b)

	Ekilen Alan(da)	Ortalama Verim(kg)	Üretim Miktarı(ton)
Buğday (Durum)	55.358	252	13.925
Buğday	725.796	228	165.144
Mısır	3.724	678	2.526
Arpa	1.231.493	205	252.412
Çavdar	2.460	312	767
Yulaf	44.326	315	13.978
Tritikale	3.037	337	1.022

Kırşehir genelinde 1.231 bin ha alandan 252.412 ton arpa, 781.154 da alandan 179.069 ton buğday, 44.326 da alandan 13.978 ton yulaf, 3.724 da alandan 2.526 ton mısır, 2.460 da alandan 767 ton çavdar ve 3.037 da alandan 1.022 ton ile tritikale danesi elde edilmiştir (Anonim, 2024b). Kırşehir ili tahıl üretimi olarak ilk sırayı arpa alır (Tablo3). Arpa ekilen alan olarak ilin neredeyse %60'lık kısmışını oluşturur. Bunun sebebinin ağırlıklı olarak hayvan yemi olarak kullanılmasından dolayı bölge çiftçisinin en çok tercih ettiği tahıldır. Son yıllarda yaz sıcaklarının ve rüzgarların buğday üzerindeki olumsuz etkileri buğday üretimini düşürmektedir. Üçüncü sırada ise yulaf gelir. Yulaf çiftçiler tarafından büyük oranla hayvan yemi olarak üretilir. Son yıllar üretim verilerine bakıldığı zaman yulaf tarımının artışı gözlenmektedir.

Kırşehir'de baklagil tarımı son yıllarda Tarım ve Orman Bakanlığı'nın sağladığı tohum ve ürün desteklemelerindeki artışlar sayesinde önemli ölçüde gelişme göstermektedir. 2024 yılı TÜİK verilerine göre, Kırşehir nohut üretiminde Türkiye genelinde ilk sırada yer almaktadır. İl genelindeki üretim verilerine göre, 2024 yılında toplam 38.569 ton nohut üretilmiştir ve bu miktar, ilde en fazla üretilen baklagil olmasını sağlamıştır (Anonim, 2024b) (Tablo 3). Çiftçilerin nohuda yönelmesinde en önemli etkenlerden biri, nohudun toprağa azot kazandırma özelliğidir. Ayrıca, münavebe (ürün rotasyonu) sisteminde önemli bir yere sahip olması da nohut ekimini teşvik eden unsurlar arasındadır. Bu nedenlerle, son yıllarda nohut tarımı Kırşehir'de ön plana çıkmıştır. Kırşehir il genelinde baklagil tarımı kapsamında kırmızı mercimek 1.247 dekarlık, yeşil mercimek ise 130.823 dekarlık alanda yetiştirilmektedir. Yeşil mercimek, ekim alanı bakımından önemli bir yer tutmakta ve ildeki baklagil üretimi içinde geniş bir paya sahiptir (Tablo 3). Fasulye tarımı ise 2.390 dekarlık alanda yapılmakta olup, il genelinde sınırlı düzeydedir (Anonim, 2024b). Fasulye üretiminin düşük olmasının başlıca nedeni, bölgede sulama olanaklarının yetersizliğidir. Su ihtiyacı yüksek olan bu ürün, yeterli sulama desteği sağlanmadığında istenilen verim düzeyine ulaşamamakta ve bu durum toplam üretimi olumsuz etkilemektedir (Tablo 3).

Tablo 4: Kırşehir İli Baklagil Üretim Verileri (Anonim, 2024b)

	Ekilen Alan(da)	Ortalama Verim(kg)	Üretim Miktarı(ton)
Fasulye	2.390	181	432
Nohut	354.836	109	38.569
Mercimek(Kırmızı)	1.247	83	103
Mercimek(Yeşil)	130.823	66	8693

Kırşehir'de sanayi kuruluşlarının azlığı, endüstri bitkilerinin üretimini de olumsuz yönde etkilemektedir. İlde en fazla ekim alanına sahip endüstri bitkisi, 92.340 dekarlık alanda yetiştirilen yağlık ayçiçeğidir (Tablo 5). Kırşehir'de endüstri bitkileri arasında işlenme imkânı bulunan tek ürün ise şeker pancarıdır. Bu nedenle, şeker pancarı ekim ve üretim miktarı bakımından diğer endüstri bitkilerine göre öne çıkmaktadır. Ekilen alan bakımından; Şeker pancarı ikinci sırada (34.432 da), patates üçüncü sırada (33.967 da), ayçiçeği (çerezlik)

dördüncü sırada (12.714 da) ve aspir son sırada (11.112 da) alanda tarımı yapılmaktadır (Anonim, 2024b) (Tablo 5).

Tablo 5: Kırşehir İli Endüstri Bitkileri Üretim Verileri (Anonim, 2024b)

	Ekilen Alan(da)	Ortalama Verim(kg)	Üretim Miktarı(ton)
Ayçiçeği(Yağlık)	92.340	127	11.702
Ayçiçeği(Çerezlik)	12.714	122	1.548
Aspir	11.112	99	1.098
Patates	33.967	3.047	103.510
Şeker Pancarı	34.432	7.427	255.713

Kırşehir'de üretilen yem bitkileri arasında, mısır silajı 17.775 dekarlık alanda 97.885 ton ile en büyük üretim alanına sahipken, yonca 17.424 dekarda 35.268 ton ile ikinci sıradadır. Korunga 17.134 dekarda 6.769 ton üretimle üçüncü sıradadır. Fiğ (yeşil ot) 14.166 dekarda 12.370 ton üretimle dördüncü sıradadır. Diğer fiğler 12.780 dekarda 2.812 ton üretimle beşinci sırada yer almaktadır. Yulaf 9.930 dekarda 7.046 ton üretimle altıncı sırada gelirken, tritikale 3.367 dekarda 2.694 ton üretimle yedinci sıradadır. Macar fiğ 2.731 dekarda 2.485 ton üretimle sekizinci sıradadır. Adi fiğ 1.349 dekarda 1.146 ton üretimle dokuzuncu sıradadır. Yemlik bezelye 430 dekarda 955 ton üretimle onuncu sırada yer almaktadır. Son olarak, çayır otu 185 dekarda 204 ton üretimle en küçük alana sahip yem bitkisi olarak on birinci sıradadır. (Anonim, 2024b). Kırşehir ilinde yem bitkileri yetiştiriciliği, toplam 9.3 bin hektar alanda yapılmaktadır ve bu alanlarda 169.934 ton kaliteli kaba yem üretilmiştir (Anonim, 2024b). Kır (2024) göre Kırşehir ilinin toplam hayvan birim sayısı 247.000 olup, bu hayvanların ihtiyaç duyduğu kaliteli kaba yem miktarı 1.127.000 tondur. Kırşehir ili Aksaray, Kırıkkale, Nevşehir ve Niğde illerinden arasında kaliteli kaba yem açığına sahip il konumundadır. İl genelinde kaba yem açığı olmasına rağmen, arpa ekim alanının fazla olması ve entansif hayvancılıkla bağlantılı olarak arpa tanesi, hayvan beslenmesinde yoğun bir şekilde kullanılmaktadır (Kır, 2024).

Tablo 6: Kırşehir İli Yem Bitkileri Yeşil Ot Üretim Verileri (Anonim, 2024b)

	Ekilen Alan(da)	Ortalama Verim (kg)	Üretim Miktarı (ton)
Adi Fiğ	1.349	850	1.146
Macar Fiğ	2.731	910	2.485
Diğer Fiğ	12.780	220	2.812
Fiğ (Yeşil Ot)	14.166	686	12.370
Yonca (Yeşil Ot)	17.424	2.024	35.268
Korunga (Yeşil Ot)	17.134	395	6.769
Yulaf (Yeşil Ot)	9.930	710	7.046
Tritikale (Yeşil Ot)	3.367	800	2.694
Mısır (Silaj)	17.775	5.507	97.885
Çayır Otu (Yeşil Ot)	185	1.103	204
Bezelye (Yemlik)	430	2.221	955

Kırşehir ilinde bahçe bitkileri üretimi, tarımsal ürün deseninde az bir yer kaplamaktadır. Bahçe bitkileri üretiminde, meyve oranı %1.5, sebze oranı ise %0.5'lik bir alanı kaplamaktadır. Meyve üretiminde başlıca yetiştirilen ürünler arasında ceviz, üzüm, badem, elma, kayısı yer almaktadır. Ceviz üretimi 26.809 dekar alanda yapılırken, üzüm 5.276 dekar, badem 1.653 dekar, elma 1.062 dekar ve kayısı ise 109 dekar alanda yetiştirilmektedir. Ayrıca, sebze üretiminde kavun 1.734 dekar, domates ise 872 dekar alanda tarımı yapılan başlıca ürünlerdendir (Anonim, 2024b). Son yıllarda ise, seracılık faaliyetlerinde de önemli bir artışlar gözlemlenmektedir.

SONUÇ

Kırşehir ilinin tarımsal üretimi, genel olarak tahıl, baklagil ve endüstri bitkileri yetiştiriciliği üzerine yoğunlaşmaktadır. Kırşehir'de en fazla ekim alanına sahip tahıl türü arpa olup, bu ürün bölgedeki tarımsal yapının temel taşlarından biridir. Arpa üretimi, hayvancılıkla doğrudan bağlantılı olarak, besi hayvancılığında önemli bir kesif yem kaynağı olarak kullanılmaktadır. Kırşehir, Türkiye genelinde arpa üretiminde artış gösteren iller arasında yer almakta ve verim açısından öne çıkmaktadır. Baklagil üretimi de önemli bir yer tutar, özellikle nohut, Türkiye'deki en büyük üretim alanına sahip ürünlerden biridir. Son yıllarda mercimek ve fasulye üretimi de yapılmakla birlikte, fasulye üretiminin sınırlı olmasının başlıca nedeni sulama eksiklikleridir. Endüstri bitkileri arasında ise şeker pancarı ve ayçiçeği öne çıkmaktadır; ancak sanayi kuruluşlarının azlığı, bu ürünlerin işlenmesinde kısıtlamalara yol açmaktadır. Bahçe bitkileri üretimi ise meyve ve sebzelerle sınırlı olup, özellikle ceviz, üzüm ve badem gibi ürünlerle çeşitlenmiştir. Kırşehir'de son yıllarda seracılığın artış göstermesi, tarımsal üretimin çeşitlenmesine katkı sağlamaktadır. Yine de, Kırşehir'in tarımsal üretimi, sulama altyapısının iyileştirilmesi ve sanayi bitkileri üretiminin artırılması ile daha verimli hale getirilebilir.

Baklagil üretimi (özellikle nohut) ve seracılıkta yaşanan artışlar, Kırşehir'in tarımsal üretimini çeşitlendiren ve sürdürülebilirliğini artıran gelişmeler olarak öne çıkmaktadır

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DETERMINATION OF FACTORS INFLUENCING THE CHOICE OF AGRICULTURAL FACULTY: A CASE STUDY OF KIRŞEHİR AHİ EVRAN UNIVERSITY

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ABSTRACT

This research was conducted to determine the factors affecting students in choosing the Faculty of Agriculture. In this context, the main material of the study is the data obtained from Kırşehir Ahi Evran University Agricultural Faculty students. Online survey forms were used as data collection tools in the research. The survey was applied to a total of 346 agricultural faculty students. While examining the socio-demographic structure, percentage rates and frequency tables were used. In order to determine the perspective of the students towards the profession, 5 Likert type scales were used. Questions using Likert scale in the survey form were subjected to reliability analysis. In the analysis of data, percentage ratios, mean scores and standard deviations were calculated and were summarized in the tables. It was also assessed by a chi - square fit test to see if there was a meaningful fit between the answers to the questions on the Likert scale. As a result of the evaluation of the surveys, significant differences in the students' preference for the Faculty of Agriculture according to gender were only preferred by male students at a higher level in terms of field of interest and job opportunities. In the Faculty of Agriculture, the lowest voluntary preference was from Science High School graduates, while the highest level came from students who graduated from normal high schools. It was determined that preferences with family advice were significantly low. It was determined that students who preferred the Horticulture department were significantly high in terms of job opportunities and areas of interest. Due to insufficient exam scores, the mandatory preference was observed in the Agricultural Biotechnology department.

Keywords: Faculty of Agriculture, preference, job opportunities

ZİRAAT FAKÜLTESİ TERCİHİNDE ETKİLİ FAKTÖRLERİN BELİRLENMESİ: KIRŞEHİR AHİ EVRAN ÜNİVERSİTESİ ÖRNEĞİ

ÖZET

Bu araştırma, Ziraat Fakültesine devan eden öğrencilerinin tercihlerinde etkili faktörleri belirlemek amacıyla yapılmıştır. Bu kapsamda Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi öğrencilerinden elde edilen veriler araştırmanın ana materyalini oluşturmaktadır. Araştırmada veri toplama aracı olarak online anket formları kullanılmıştır. Anket toplam 346 Ziraat Fakültesi öğrencisine uygulanmıştır. Sosyo-demografik yapı incelenirken yüzde oranlar ve frekans tablolarından faydalanılmıştır. Öğrencilerin mesleği tercih nedenini belirlemek amacıyla 5'li likert tipi ölçek kullanılmıştır. Anket formunda likert ölçeği kullanılan sorular, güvenilirlik an analizine tabii tutulmuştur. Verilerin analizinde yüzde oranlar, ortalama puanlar ve standart sapmalar hesaplanarak tablolarda özetlenmiştir. Ayrıca likert ölçeğindeki sorulara verilen cevaplar arasında anlamlı bir uyum olup olmadığı ki -kare uygunluk testine tabi tutularak değerlendirilmiştir. Anketlerin değerlendirilmesi sonucunda, Öğrencilerin cinsiyete göre Ziraat Fakültesi tercihinde önemli farklılıklar sadece ilgi alanı ve iş imkanları yönünden erkek öğrenciler tarafından daha yüksek düzeyde tercih edilmiştir. Ziraat Fakültesi tercihinde kendi isteğiyle tercihte en düşük Fen Lisesi mezunları iken en yüksek düzey ise normal liselerden mezun olan öğrencilerden gelmiştir. Aile tavsiyesiyle tercihler önemli düzeyde düşük olduğu belirlenmiştir. Bahçe Bitkileri bölümü tercih eden öğrencilerin iş imkânı ve ilgi alnı yönünden önemli düzeyde yüksek olduğu belirlenmiştir. Sınav puanı yetersizliği nedeniyle mecburen tercih durumu ise Biyosistem Mühendisliği bölümünden gözlenmiştir.

Anahtar Kelimeler: Ziraat Fakültesi, tercih, iş olanakları

GİRİŞ

Ziraat mühendisleri; bitkisel ve hayvansal üretim ile bu üretim süreçlerine ilişkin hasat, sınıflandırma, ambalajlama, muhafaza, depolama, değerlendirme ve pazarlama gibi faaliyetlerin etüt, planlama, projelendirme, uygulama ve denetiminden sorumlu meslek grubudur (Tüzük, 1991). Tarım faaliyetlerinin kökeni, M.Ö. 8000'li yıllarda Mezopotamya'da ortaya çıkan yerleşik tarım topluluklarına kadar uzanmakta olup, bu topluluklar temel tarımsal uygulamaları başlatarak günümüz ziraat mühendisliğinin tarihsel altyapısını oluşturmuştur. Osmanlı İmparatorluğu döneminde modern tarımsal eğitim faaliyetleri başlamış, Türkiye Cumhuriyeti döneminde ise kurumsal yapı kazanarak gelişimini sürdürmüştür (Çiftçi, C. Y. 2016). Tarım sektörü, yalnızca ekonomik kalkınmanın temel dinamiklerinden biri olmakla kalmayıp, aynı zamanda gıda güvenliğinin sağlanması, kırsal kalkınmanın desteklenmesi ve sürdürülebilir çevre yönetimi açısından da stratejik bir öneme sahiptir. Bu bağlamda, ziraat fakülteleri; bilimsel bilgi üretimi, teknolojik gelişmelerin tarıma entegrasyonu ve nitelikli insan kaynağı yetiştirilmesi noktasında kritik bir rol üstlenmektedir.

MATERYAL VE YÖNTEM

Araştırmanın ana materyalini, Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi'nde 2024-2025 eğitim-öğretim yılında öğrenim gören öğrencilerden online anket yoluyla elde edilen veriler oluşturmaktadır. Bu kapsamda fakültede öğrenim gören 346 öğrenci ile gönüllülük esaslı anket yapılmıştır. Çalışma, iki bölümden oluşmaktadır. İlk bölümde ankete katılan öğrencilerin demografik özelliklerini belirlemek amacıyla çoktan seçmeli sorulara yer verilmiştir. Bu bölümdeki sorulara verilen cevaplar frekans tabloları ve yüzde hesaplamalarla özetlenerek yorumlanmıştır. İkinci bölümde ise ankete katılan öğrencilerin ziraat fakültesini tercih nedenlerini belirlemek amacıyla 5'li Likert tipi sorulara yer verilmiştir. Bu bölümdeki sorulara verilen cevaplar yüzde oranlar, ortalama puanlar ve standart sapmalar hesaplanarak tablolarda özetlenmiştir. Ayrıca bu ölçekteki sorulara verilen cevaplar arasında anlamlı bir uyum olup olmadığı ki-kare uygunluk testine tabi tutularak değerlendirilmiştir. Veri toplama aracı olarak kullanılan anket formunda Likert ölçeği kullanılan sorular, güvenilirlik analizine tabii tutulmuştur. Yapılan güvenilirlik analizi sonucunda bulunan Cronbach's Alpha (α) değerleri 0,70 den büyük olduğu için oldukça güvenilirdir (Akgül ve Çevik, 2003).

BULGULAR VE TARTIŞMA

Sosyo-demografik yapı

Araştırmada ankete katılan öğrencilerin sosyo-demografik özellikleri incelenerek aşağıda özetlenmiştir. Ankete 346 öğrenci katılmış olup katılım sağlayan öğrencilerimizin 196 kişisi erkek ve 150 kişisi ise kadınlardan oluşmaktadır. Ankete katılan öğrencileri oransal olarak ifade edildiğinde ise yaklaşık %56.6'sı erkeklerden %43.4'ü ise kadınlardan oluşmaktadır (Tablo 1).

Tablo 1. Kırşehir Ahi Evran Ziraat Fakültesi öğrenci sayısı ve ankete katılım oranları

	Öğrenim gören		Ankete Katılan		Ankete Katılım oranı (%)
	Kişi	Yüzde (%)	Kişi	Yüzde (%)	
Erkek	714	67,2	196	56,6	
Kadın	347	32,7	150	43,4	
Toplam	1061	100,0	346	100,0	

Öğrencilerimize mezun oldukları lise çeşidi için sorulara verilen cevaplara ilişkin veriler Tablo 2'de verilmiştir. Türkiye'de lise ve dengi okullarda okuyan öğrenci sayısı Millî Eğitim Bakanlığı verilerine göre resmi liselerde öğrenci sayısı 4 milyon 159 bin 331, açık öğretim liselerinde 1 milyon 75 bin 550 ve özel liselerde ise 562 bine öğrenci eğitim görmektedir. Millî Eğitim Bakanlığı verilerine göre 8432 adet lise ve dengi okulda eğitim verilmektedir. Türkiye genelinde 2898 adet Anadolu Lisesi, 1698 adet İmam Hatip Lisesi, 365 adet Fen Lisesi, 293 Mesleki ve Teknik Lise, 105 adet Güzel Sanatlar Lisesi, 92 adet Sosyal Bilimler Lisesi ve 99 adet Spor Liseleri bulunmaktadır (TUİK, 2025; MEB,2025). Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi'ne devam eden öğrencilerin %66,47'si Anadolu Lisesi, %14.16'sı Diğer Liseler, %6.07'si Fen Lisesi ve %13.01'i Meslek liselerinden mezun olmuşlardır, ayrıca bir kişi ise lise mezuniyet için cevaplama yapmamıştır.

Tablo 2. Ankete katılan öğrencilerin mezun oldukları lise çeşidi dağılımı

Lise türleri	Kişi	Yüzde (%)
Anadolu Lisesi	230	66,47
Diğer Liseler	49	14,16
Fen Lisesi	21	6,07
Meslek Lisesi	45	13,01
Boş	1	0,29
Toplam	346	100

Ankete katılım sağlayan öğrencilerin hangi bölümde okuyorsunuz sorusuna verdikleri cevapların dağılımına ilişkili olarak 86 öğrenci Tarla Bitkileri, 55 kişi Tarım Ekonomisi, 49 Kişi Bitki koruma, 44 kişi Bahçe Bitkileri, 43 Kişi Tarımsal Biyoteknoloji, 36 kişi Biyosistem Mühendisliği, 33 Kişi Zootekni Bölümünden katılım sağlamıştır (Tablo 3).

Tablo 3. Ankete katılan öğrencilerin okuduğu bölüme ilişkin cevap dağılımları

Okuduğu Bölüm	Kişi	Yüzde (%)
Bahçe Bitkileri	44	12,7
Bitki Koruma	49	14,2
Biyosistem Mühendisliği	36	10,4
Tarım Ekonomisi	55	15,9
Tarımsal Biyoteknoloji	43	12,4
Tarla Bitkileri	86	24,9
Zootekni	33	9,5
Total	346	100

Ankete katılım sağlayan öğrencilerin hangi sınıfa devam ediyorsunuz sorusuna belirttikleri cevaplarla ilişkili olarak; en fazla katılımın 1. sınıf öğrencileri olduğunu ve en düşük katılımın ise 4. Sınıf öğrencilerine ait olduğu görülmektedir (Tablo 4). Ayrıca Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi'nde 2024-2025 eğitim döneminde son sınıfa devam eden öğrenci sayısı diğer sınıf sayılarına göre oldukça düşüktür. Tercihler konusunda özellikle 1. Sınıf öğrencilerinin katılımlarının yüksek olması tercih nedenlerinin daha doğru yansımasında da önemli etkisi olacaktır.

Tablo 4. Ankete katılan öğrencilerin devam ettiği sınıfa ilişkin cevap dağılımları

Sınıf	Kişi	Yüzde (%)
1	136	39,3
2	102	29,5
3	69	19,9
4	39	11,3
Total	346	100

Ziraat fakültesini tercih etme nedenleri

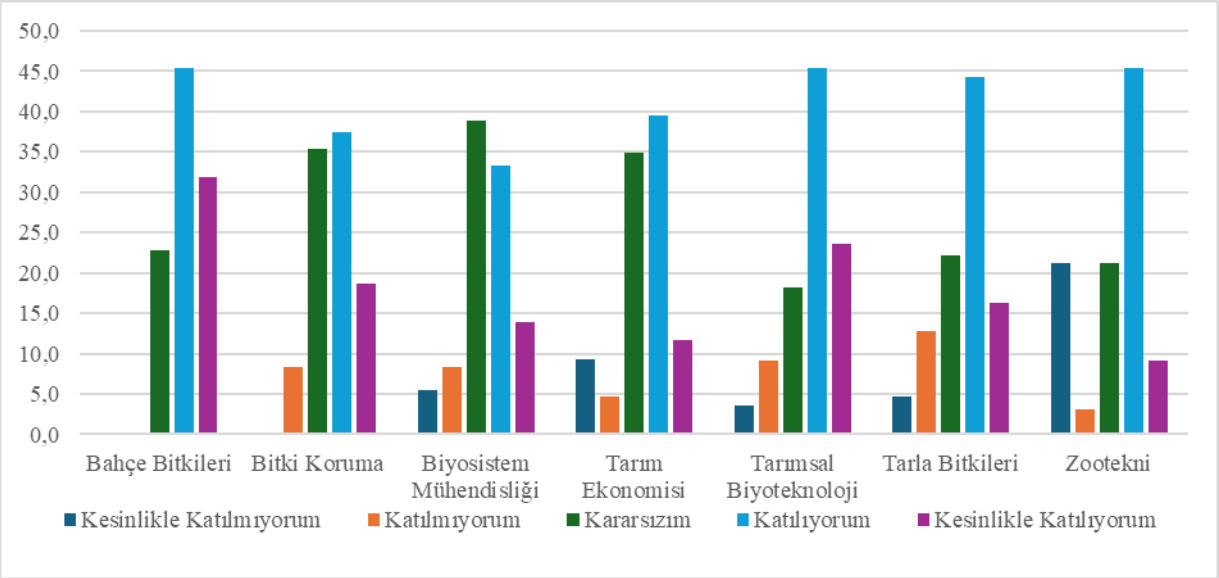
Ankete katılan öğrenciler anketin ikinci kısmında ziraat fakültesini neden tercih ettiklerine dair soruları cevaplamışlardır. Öğrencilerin verdiği cevaplar doğrultusunda Ziraat Mühendisliğinin saygınlığı ve Dünya'da gıda temininde öneminin tercihlerdeki etkisi istatistiksel anlamda önemli olmadığı saptanmıştır.

Tablo 5. Ankete katılan öğrencilerin Ziraat Fakültesini tercihine ait görüş oranları (%) ve önem seviyeleri

Sebepler	1	2	3	4	5	Top.	X^2	p
Saygın bir meslek olması	5,8	15,9	26,4	34,5	17,4	100	31,717	0,134
Geleceğinin parlak olması	3,2	4,1	20,3	43,0	29,4	100	42,906	0,010
Gıda temininde önemli olması	2,3	2,9	7,0	40,3	47,5	100	32,57	0,113
Gelirinin yüksek olması	5,5	7,5	26,7	42,0	18,3	100	46,612	0,004
Kolay iş bulabilmesi	9,3	8,4	31,4	35,5	15,4	100	43,386	0,009
Ailemin yönlendirmesi	23,5	33,0	7,8	25,8	9,9	100	38,072	0,034
İlgi alanıma girmesi	7,9	11,1	11,1	37,0	32,9	100	51,504	0,001
İş imkanlarının çok olması	8,7	15,9	21,4	38,0	15,9	100	56,18	0,000
Puanımdan dolayı	24,5	29,7	9,6	24,8	11,4	100	45,599	0,005

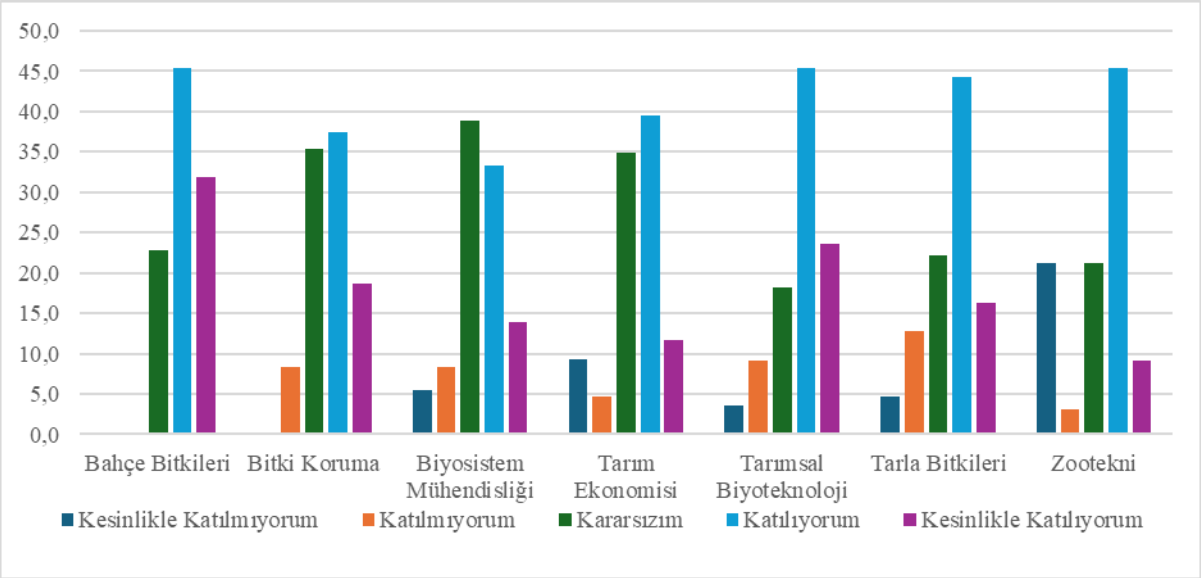
1. Kesinlikle karşıyım, 2. Karşıyım, 3. Fikrim yok, 4. Destekliyorum, 5. Kesinlikle destekliyorum

Ziraat Mühendisliğinin geleceğinin parlak olduğu fikri tercih nedenin önemli etkisi olduğu ve istatistiksel anlamda 0,01 önem seviyesinde anlamlı olduğu saptanmış bölümler arasında farklılıklarda P<0,05 seviyesinde gruplandırma yapılmıştır. Bu fikir en güçlü olduğu bölüm Bahçe Bitkileri, Biyoteknoloji ve Tarla Bitkileri bölümü olurken en düşük olduğu bölüm ise Zootekni bölümü olmuştur.



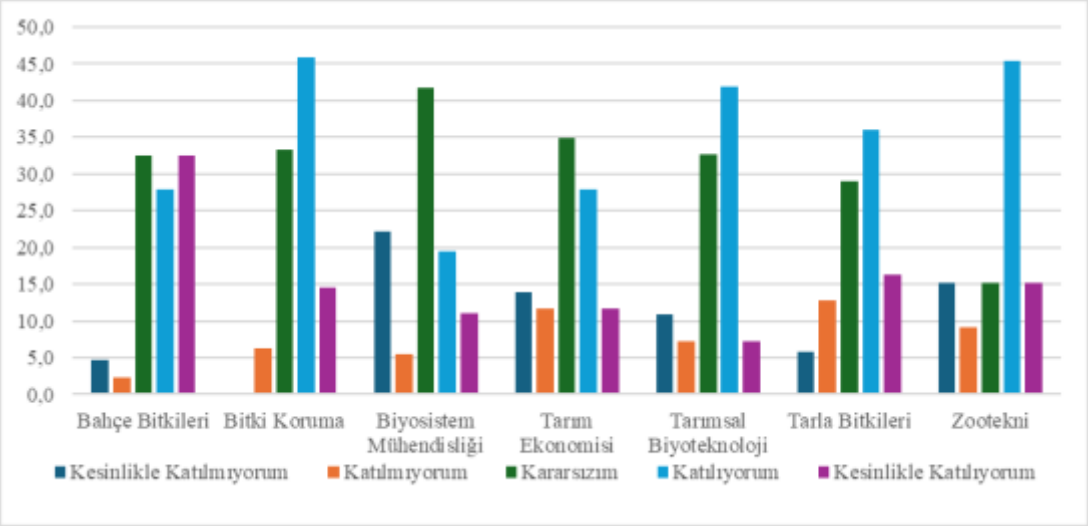
Şekil 1. Ziraat Mühendisliğinin geleceğinin parlaktır fikrinin bölümlere göre dağılım grafiği

Ziraat Mühendisliğinin gelirinin yüksek olduğu fikri ile Ziraat Fakültesini tercih etme nedeni istatistiksel anlamda 0,01 önem seviyesinde anlamlı olduğu saptanmış ve bölümler arasında farklılıklarda P<0.05 seviyesinde gruplandırma yapılmıştır. Bahçe Bitkileri bölümü ziraat mühendisliği mesleği tercinde gelirinin yüksek olduğu düşüncesinden diğer bölümlerin oldukça üzerinde orana sahip olmuş ve en yüksek grupta yer alırken sırasıyla Tarımsal Biyoteknoloji, Bitki Koruma, Tarla Bitkileri, Tarım Ekonomisi ve Biyosistem Mühendisliği ikinci grupta yer almıştır. Zootekni Bölümü öğrencileri ise en düşük bu fikre sahip olan bölüm olmuştur.



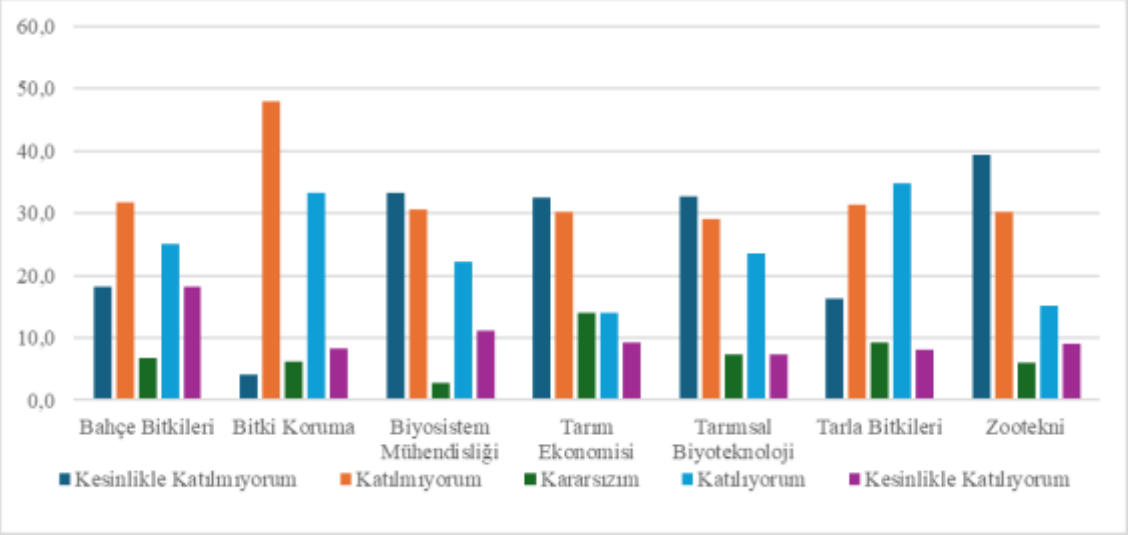
Şekil 2. Ziraat Mühendisliğinin gelirinin yüksek olduğu fikrinin bölümlere göre dağılım grafiği

Ziraat Mühendisliğinde kolay iş bulabilmesi fikri ile Ziraat Fakültesini tercih etme nedeni istatistiksel anlamda 0,01 önem seviyesinde anlamlı olduğu saptanmış ve bölümler arasında farklılıklarda P<0,05 seviyesinde gruplandırma yapılmıştır. Bahçe Bitkileri, Bitki Koruma, Tarla Bitkileri ve Zootekni Bölümü öğrencileri ziraat mühendisliği mesleği tercinde kolay iş bulma fikrinin yüksek olduğu düşüncesinden diğer bölümlerin oldukça üzerinde bir oranla aynı grupta yer almıştır. En düşük grupta ise sırasıyla Tarım Ekonomisi, Tarımsal Biyoteknoloji ve Biyosistem Mühendisliği yer almıştır.



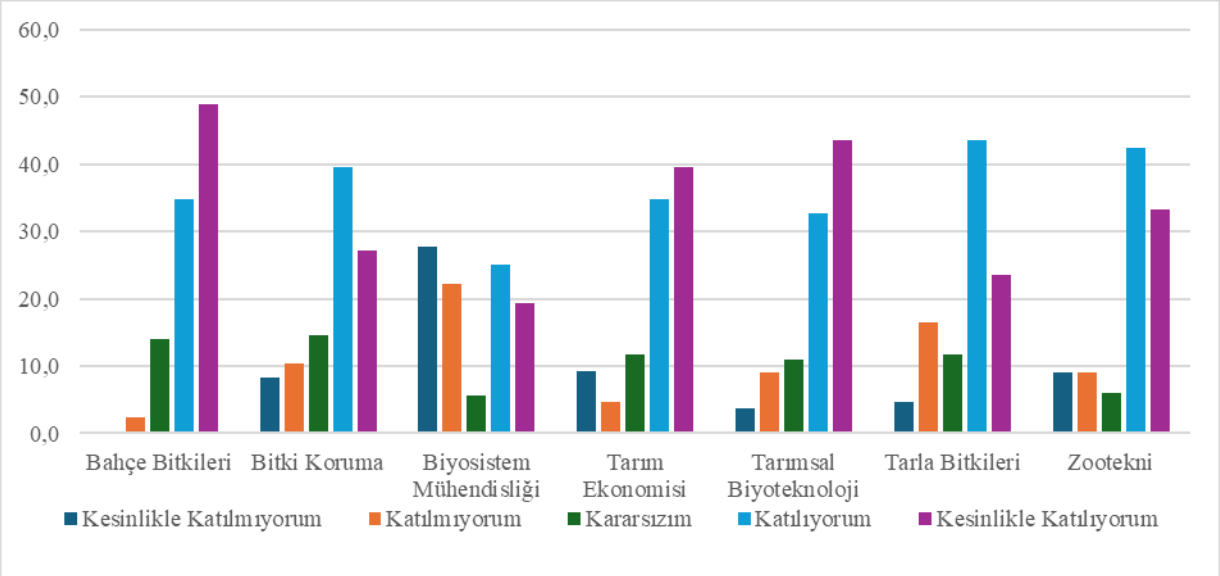
Şekil 3. Ziraat Mühendisliğinin kolay iş bulabilmesi fikrinin bölümlere göre dağılım grafiği

Ziraat Mühendisliğini tercih etmemde ailemin yönlendirmesi etkili olduğu fikri istatistiksel anlamda 0,05 önem seviyesinde anlamlı olduğu saptanmış ve bölümler arasında farklılıklarda $P<0,05$ seviyesinde gruplandırma yapılmıştır. Genel olarak ankete katılan öğrencilerin aile yönlendirmesine katılmadıkları tespit edilmiştir. Ailesinin etkisine en düşük olduğu bölüm ise Zootekni bölümü olduğu görülmektedir. Aile etkisinin diğer bölümlere göre daha yüksek olan bölümler ise Tarla Bitkileri, Bahçe Bitkileri ve Bitki Koruma Bölümleri olmuştur. Ayrıca kolayca iş bulma imkânı ziraat fakültesini tercih eden öğrencilerin cinsiyetine göre farklılık önemli ($P<0.01$) çıkmış ve erkek öğrencilerin tercihinde kolay iş bulma yönünden Kadın öğrencilere göre daha fazla önem verdiğini göstermektedir.



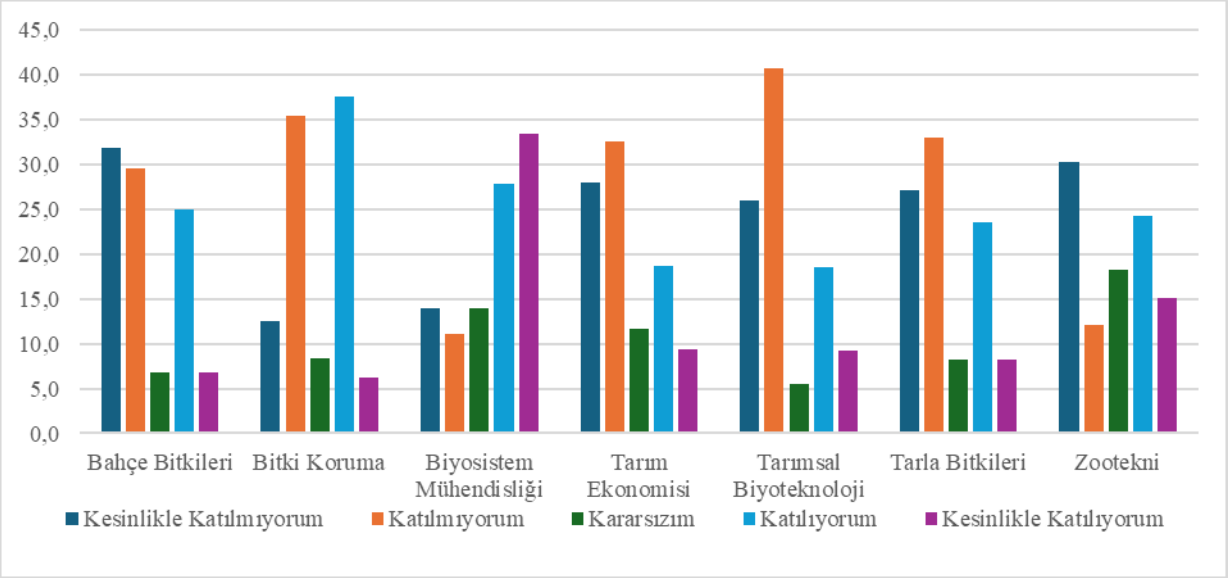
Şekil 4. Ziraat Mühendisliğini seçmemde ailemin yönlendirmesi etkili olduğu fikrinin bölümlere göre dağılım grafiği

Ziraat Mühendisliğini tercih etmemde ilgi alanıma girmesi etkili olduğu fikri istatistiksel anlamda 0,01 önem seviyesinde anlamlı olduğu saptanmış ve bölümler arasında farklılıklarda P<0,05 seviyesinde gruplandırma yapılmıştır. Biyosistem Mühendisliği öğrencileri diğer bölümlerden önemli düzeyde farklılık göstererek ayrı grupta yer almıştır. En yüksek ilgi alanı ile tercih ise sırasıyla Bahçe Bitkileri, Tarımsal Biyoteknoloji ve Tarım Ekonomisi bölümleri olmuştur. Ayrıca ilgi alanına girmesi nedeniyle ziraat fakültesini tercih eden öğrencilerin cinsiyetine göre farklılık önemli (P<0.01) çıkmış ve erkek öğrencilerin tercihinde ilgi alnı yönünden kadın öğrencilere göre daha fazla tercih ettiğini göstermektedir.



Şekil 5. Ziraat Mühendisliğini seçmemde ilgi alanım fikrinin bölümlere göre dağılım grafiği

Ziraat Mühendisliğini tercih etmemde puanımın etkili olduğu fikri istatistiksel anlamda 0,01 önem seviyesinde anlamlı olduğu saptanmış ve bölümler arasında farklılıklarda P<0,05 seviyesinde gruplandırma yapılmıştır. Tarımsal Biyoteknoloji, Bahçe Bitkileri, Tarım Ekonomisi ve Tarla Bitkileri bölümleri kesinlikle etkili olmadığını bildirirken Biyosistem Mühendisliği öğrencileri ise puanı nedeniyle Ziraat fakültesini tercih ettiğini bildirmişlerdir.



Şekil 6. Ziraat Mühendisliğini seçmemde puanımdan dolayı fikrinin bölümlere göre dağılım grafiği

SONUÇ

Bu araştırma, Ziraat Fakültesine devan eden öğrencilerinin tercihlerinde etkili faktörleri belirlemek amacıyla yapılmıştır. Bu kapsamda Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi öğrencilerinden elde edilen veriler araştırmanın ana materyalini oluşturmuştur. Araştırmada veri toplama aracı olarak online anket formları kullanılmış ve ankete toplam 346 ziraat fakültesi öğrencisi katılım sağlamıştır. Anketin değerlendirilmesi sonucunda, ankete katılan öğrencilerin yaklaşık %56,6'sı erkeklerden %43,4'ü ise kadınlardan oluşmaktadır. Ankete katılan öğrencilerin %66,47'si Anadolu Lisesi, %14.16'sı Diğer Liseler, %6.07'si Fen Lisesi ve %13.01'i Meslek liselerinden mezun olduğunu bildirmişlerdir. Ankete katılan 346 öğrencinin 86'sı Tarla Bitkileri, 55'i Tarım Ekonomisi, 49'u Bitki Koruma, 44'ü Bahçe Bitkiler, 43'ü Tarımsal Biyoteknoloji, 36'sı Biyosistem Mühendisliği ve 33'ü Zootekni Bölümünden katılım ile sağlamıştır. Ayrıca en yüksek katılımın 1.sınıf öğrencilerine ait olduğu görülmektedir.

Öğrencilerin cinsiyete göre Ziraat Fakültesi tercihinde önemli farklılıklar sadece ilgi alanı ve iş imkanları yönünden erkek öğrenciler tarafından daha yüksek düzeyde tercih edilmiştir. Ziraat Fakültesi tercihinde kendi isteğiyle tercihte en düşük Fen Lisesi mezunları iken en yüksek düzey ise normal liselerden mezun olan öğrencilerden gelmiştir. Aile tavsiyesiyle tercihler önemli düzeyde düşük olduğu belirlenmiştir. Bahçe Bitkileri bölümü tercih eden öğrencilerin iş imkânı ve ilgi alnı yönünden önemli düzeyde yüksek olduğu belirlenmiştir. Sınav puanı yetersizliği nedeniyle mecburen tercih durumu ise Biyosistem Mühendisliği bölümünden gözlenmiştir. İş imkânı, kolay iş bulma ve gelir seviyesinin yüksek olması tercih nedenini önemli düzeyde artırmıştır.

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DETERMINING THE PERSPECTIVES OF AGRICULTURAL FACULTY STUDENTS ON THEIR PROFESSION: A CASE STUDY OF KIRŞEHİR AHİ EVRAN UNIVERSITY

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ABSTRACT

This research was conducted to determine the perspective of the students of agriculture faculty towards the profession of agricultural engineering. In this context, the main material of the study is the data obtained from Kırşehir Ahi Evran University Agricultural Faculty students. Online survey forms were used as data collection tools in the research. The survey was applied to a total of 346 agricultural faculty students. While examining the socio-demographic structure, percentage rates and frequency tables were used. In order to determine the perspective of the students towards the profession, 5 Likert type scales were used. Questions using Likert scale in the survey form were subjected to reliability analysis. In the analysis of data, percentage ratios, mean scores and standard deviations were calculated and were summarized in the tables. It was also assessed by a chi -square fit test to see if there was a meaningful fit between the answers to the questions on the Likert scale. As a result of the evaluation of the surveys, it was determined that there were no differences in the perspectives of the students towards the profession according to gender, while there were significant ($P<0.05$) differences between departments and classes. While the students of the Department of Horticulture and Agricultural Biotechnology had a significantly more positive perspective on the agricultural engineering profession, the least positivity was observed from the students of the Department of Animal Science.

Keywords: Faculty of Agriculture, education, professional perspective

ZİRAAT FAKÜLTESİ ÖĞRENCİLERİNİN MESLEĞİNE BAKIŞ AÇILARININ BELİRLENMESİ: KIRŞEHİR AHİ EVRAN ÜNİVERSİTESİ ÖRNEĞİ

ÖZET

Bu araştırma, Ziraat Fakültesi öğrencilerinin ziraat mühendisliği mesleğine bakış açısını belirlemek amacıyla yapılmıştır. Bu kapsamda Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi öğrencilerinden elde edilen veriler araştırmanın ana materyalini oluşturmaktadır. Araştırmada veri toplama aracı olarak online anket formları kullanılmıştır. Anket toplam 346 Ziraat Fakültesi öğrencisine uygulanmıştır. Sosyo-demografik yapı incelenirken yüzde oranlar ve frekans tablolarından faydalanılmıştır. Öğrencilerin mesleğe bakış açısını belirlemek amacıyla 5'li likert tipi ölçek kullanılmıştır. Anket formunda likert ölçeği kullanılan sorular, güvenilirlik analizine tabii tutulmuştur. Verilerin analizinde yüzde oranlar, ortalama puanlar ve standart sapmalar hesaplanarak tablolarda özetlenmiştir. Ayrıca likert ölçeğindeki sorulara verilen cevaplar arasında anlamlı bir uyum olup olmadığı ki -kare uygunluk testine tabii tutularak değerlendirilmiştir. Anketlerin değerlendirilmesi sonucunda, Öğrencilerin cinsiyete göre mesleğe bakış açılarında farlılıklar olmadığı saptanırken bölümler ve sınıflar arasında önemli ($P<0.05$) farklılıklar olduğu tespit edilmiştir. Bahçe Bitkileri ve Tarımsal Biyoteknoloji Bölümü öğrencileri ziraat mühendisliği mesleğine bakış açılarının önemli düzeyde daha olumlu iken en düşük olumluluk ise Zootekni Bölümü öğrencilerinden gözlenmiştir.

Anahtar Kelimeler: Ziraat Fakültesi, eğitim, mesleki bakış

GİRİŞ

Ziraat fakülteleri, tarım ve hayvancılık gibi kritik sektörlerde uzmanlaşmış profesyoneller yetiştiren önemli akademik kurumlardır. Ziraat mühendisleri; lisans veya uzmanlık alanlarına göre, bitki, tohumluk, gübre, toprak, sulama suyu, tarım ilacı, yem, gıda, tarım alet ve makinaları, su ürünleri, bitki hastalık ve zararlıları, tarım ürünleriyle ilgili sıvı ve katı atıklar, tarım ürünleri üzerindeki ilaç kalıntıları konularında araştırma, kalite kontrolu, standart ve yönetmeliklere uygunluk gibi amaçlarla fiziksel, kimyasal ve mikrobiyolojik kontrol ve analizler yapmak üzere laboratuvar kurmaya ve işletmeye yetkilidirler (Tüzük, madde 11). Ziraat mühendisliği, yalnızca ülke ekonomisi için değil, aynı zamanda küresel gıda güvenliği, çevre sürdürülebilirliği ve doğal kaynakların yönetimi gibi temel alanlar için de büyük bir öneme sahiptir. Ancak, bu alanda eğitim gören öğrencilerin mesleklerine bakış açıları, meslek seçimleri ve geleceğe yönelik beklentileri, zaman içinde değişebilen dinamiklerdir. Bu değişimler, ekonomik, toplumsal ve sektörel faktörlerle doğrudan ilişkilidir. Ziraat mühendisliği gibi dinamik bir alanda, tarım politikalarındaki değişiklikler, iş gücü piyasasında yaşanan dönüşümler ve teknolojik gelişmeler öğrencilerin mesleklerine yönelik tutumlarını etkileyebilmektedir. Ayrıca, tarım sektöründeki istihdam fırsatları ve mezunların kariyer beklentileri de bu bakış açılarını şekillendiren önemli faktörler arasında yer almaktadır.

MATERYAL VE YÖNTEM

Araştırmanın ana materyalini, Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi'nde 2024-2025 eğitim-öğretim yılında öğrenim gören öğrencilerden online anket yoluyla elde edilen veriler oluşturmaktadır. Bu kapsamda fakültede öğrenim gören öğrencilerden 346 kişi ile gönüllülük esaslı anket yapılmıştır. Çalışma, iki bölümden oluşmaktadır. İlk bölümde ankete katılan öğrencilerin demografik özelliklerini belirlemek amacıyla çoktan seçmeli sorulara yer verilmiştir. Bu bölümdeki sorulara verilen cevaplar frekans tabloları ve yüzde hesaplamalarla özetlenerek yorumlanmıştır. İkinci bölümde ise ankete katılan öğrencilerin ziraat mühendisliği mesleğine bakış açısını belirlemek amacıyla 5'li Likert tipi sorulara yer verilmiştir. Bu bölümdeki sorulara verilen cevaplar yüzde oranlar, ortalama puanlar ve standart sapmalar hesaplanarak tablolarda özetlenmiştir. Ayrıca bu ölçekteki sorulara verilen cevaplar arasında anlamlı bir uyum olup olmadığı ki-kare uygunluk testine tabi tutularak değerlendirilmiştir. Veri toplama aracı olarak kullanılan anket formunda Likert ölçeği kullanılan sorular, güvenilirlik analizine tabii tutulmuştur. Yapılan güvenilirlik analizi sonucunda bulunan Cronbach's Alpha (α) değerleri 0.70'den büyük olduğu için oldukça güvenilirdir (Akgül ve Çevik, 2003).

BULGULAR VE TARTIŞMA

Sosyo-demografik yapı

Araştırmada ankete 346 öğrenci katılmış olup katılım sağlayan öğrencilerimizin cinsiyetine ilişkin soruya verdikleri cevaplar doğrultusunda 196 kişisi erkek ve 150 kişisi ise kadınlardan oluşmaktadır. Ankete katılan öğrencileri oransal olarak ifade edildiğinde ise yaklaşık %56.6'sı erkeklerden %43.4'ü ise kadınlardan oluşmaktadır (Tablo 1). Anketin online hazırlanması nedeniyle gönüllülük esaslı olması nedeniyle herhangi bir oran hedefimiz bulunmamaktadır.

Tablo 1. Kırşehir Ahi Evran Ziraat Fakültesi öğrenci sayısı ve ankete katılım oranları

	Öğrenim gören		Ankete Katılan		Ankete Katılım oranı (%)
	Kişi	Yüzde (%)	Kişi	Yüzde (%)	
Erkek	714	67,3	196	56,6	
Kadın	347	32,7	150	43,4	
Toplam	1061	100,0	346	100,0	

Öğrencilerimize mezun oldukları lise çeşidini belirlemek için sorulan sorulara verilen cevaplara ilişkin veriler Tablo 2'de verilmiştir. Anketimize katılım sağlayan Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi öğrencilerinin %66.47'si Anadolu Lisesi, %14.16'sı Diğer Liseler, %6.07'si Fen Lisesi ve %13.01'i Meslek liselerinden mezun olduklarını bildirmişlerdir.

Tablo 2. Ankete katılan öğrencilerin mezun oldukları lise çeşidi dağılımı

Lise türleri	**Kişi**	**Yüzde (%)**
Anadolu Lisesi	230	66,47
Diğer Liseler	49	14,16
Fen Lisesi	21	6,07
Meslek Lisesi	45	13,01
Boş	1	0,29
Toplam	346	100

Ankete katılım sağlayan öğrencilerin hangi bölümde okuyorsunuz sorusuna verdikleri cevapların dağılımında 86 öğrenci Tarla Bitkileri, 55 kişi Tarım Ekonomisi, 49 Kişi Bitki koruma, 44 kişi Bahçe Bitkileri, 43 Kişi Tarımsal Biyoteknoloji, 36 kişi Biyosistem Mühendisliği, 33 Kişi Zootekni Bölümünden katılım sağlamıştır (Tablo 3). En düşük katılım Zootekni ve Biyosistem Mühendisliği bölümünden gözlenirken bu sonuçların fakültede bölümlere göre öğrenci dağılımı ile de uyumlu olduğu görülmektedir.

Tablo 3. Ankete katılan öğrencilerin okuduğu bölüme ilişkin cevap dağılımları

Okuduğu Bölüm	Kişi	Yüzde (%)
Bahçe Bitkileri	44	12,7
Bitki Koruma	49	14,2
Biyosistem Mühendisliği	36	10,4
Tarım Ekonomisi	55	15,9
Tarımsal Biyoteknoloji	43	12,4
Tarla Bitkileri	86	24,9
Zootekni	33	9,5
Total	346	100

Ankete katılım sağlayan öğrencilerin hangi sınıfa devam ediyorsunuz sorusuna belirttikleri cevaplarla ilişkili olarak; en fazla katılımın 1. sınıf öğrencileri olduğunu ve en düşük katılımın ise 4. Sınıf öğrencilerine ait olduğu görülmektedir (Tablo 4). Ayrıca Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi'nde 2024-2025 eğitim döneminde son sınıfa devam eden öğrenci sayısı diğer sınıf sayılarına göre oldukça düşüktür. Fakültede bölümlerin sınıf mevcudiyeti dikkate alındığında en fazla öğrencinin 1. ve 2. sınıflarda olduğu görülmektedir.

Tablo 4. Ankete katılan öğrencilerin devam ettiği sınıfa ilişkin cevap dağılımları

Sınıf	Kişi	Yüzde (%)
1	136	39,3
2	102	29,5
3	69	19,9
4	39	11,3
Total	346	100

Ziraat mühendisliği mesleğine bakış açıları;

Ankete katılan öğrenciler anketin ikinci kısmında ziraat mühendisliğine bakış açılarının belirlenmesi hedefleyen soruları cevaplamışlardır. Öğrencilerin verdiği cevaplar doğrultusunda

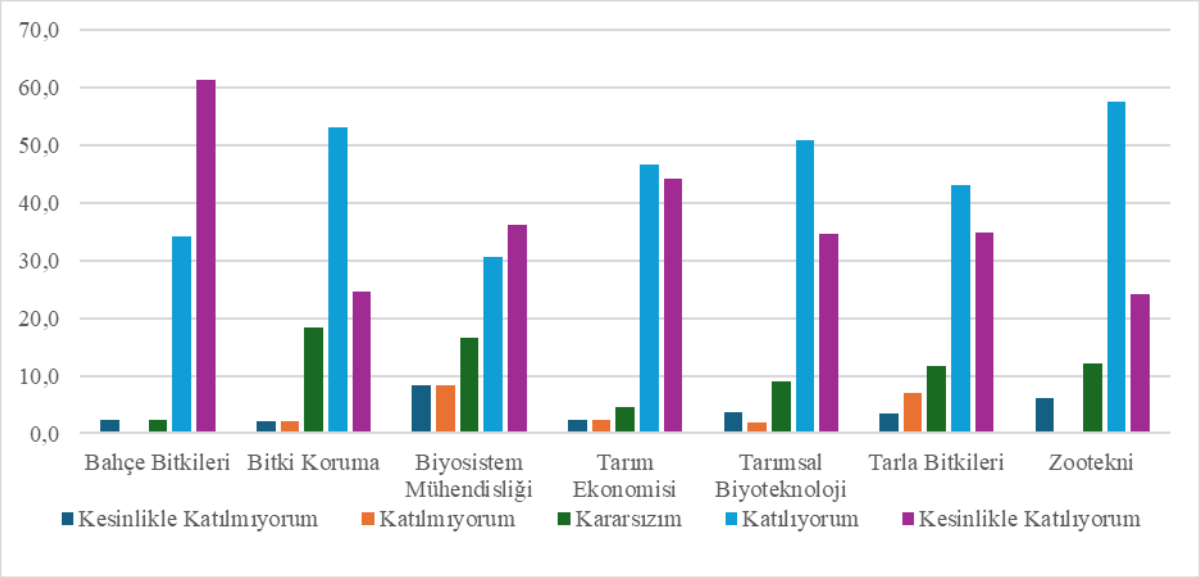
özel sektörde çalışma istekleri ile tarımsal üretimi geliştirme hedeflerim var sorularına verdikleri cevapların istatistiksel anlamda önemli olmadığı saptanmıştır (Tablo 5).

Tablo 5. Ankete katılan öğrencilerin ziraat mühendisliğine bakış açılarına ilişkin sorulara verilen cevapların oranları (%) ve önem seviyeleri

Sorular	1	2	3	4	5	Top.	X^2	p
Ziraat fakültesini okumaktan memnunum	3,8	3,5	10,7	45,1	37,0	100	37,579	0,038
Okuduğum bölümden memnunum	2,9	3,5	14,7	40,5	38,4	100	43,105	0,010
Ziraat Mühendisi olmak beni heyecanlandırıyor	4,3	4,6	15,0	48,3	27,7	100	33,007	0,104
Tarım Bakanlığında çalışmak istiyorum	11,6	12,2	30,5	27,0	18,6	100	41,976	0,013
Özel Sektörde çalışmak istiyorum	11,0	6,1	33,6	34,2	15,1	100	28,791	0,228
Akademik çalışma istiyorum	13,3	15,0	30,6	24,3	16,8	100	45,617	0,005
Ziraat Mühendisliği yapmak istemiyorum	24,0	29,5	27,5	13,6	5,5	100	57,347	0,001
Aldığım teorik dersler mesleğim için yeterlidir	7,5	10,4	23,7	42,8	15,6	100	42,519	0,011
Aldığım uygulamalı dersler mesleğim için yeterlidir	9,9	10,1	22,0	38,8	19,1	100	53,812	0,001
Eğitim aldığım süreçte mesleğime ilgim arttı	3,2	3,5	14,5	49,3	29,6	100	50,869	0,001
Tarımsal üretimi geliştirme hedeflerim var	9,3	8,4	31,4	35,5	15,4	100	30,556	0,167
Çevreme mesleğimi tavsiye ederim	1,5	0,6	2,3	46,5	49,1	100	40,659	0,018

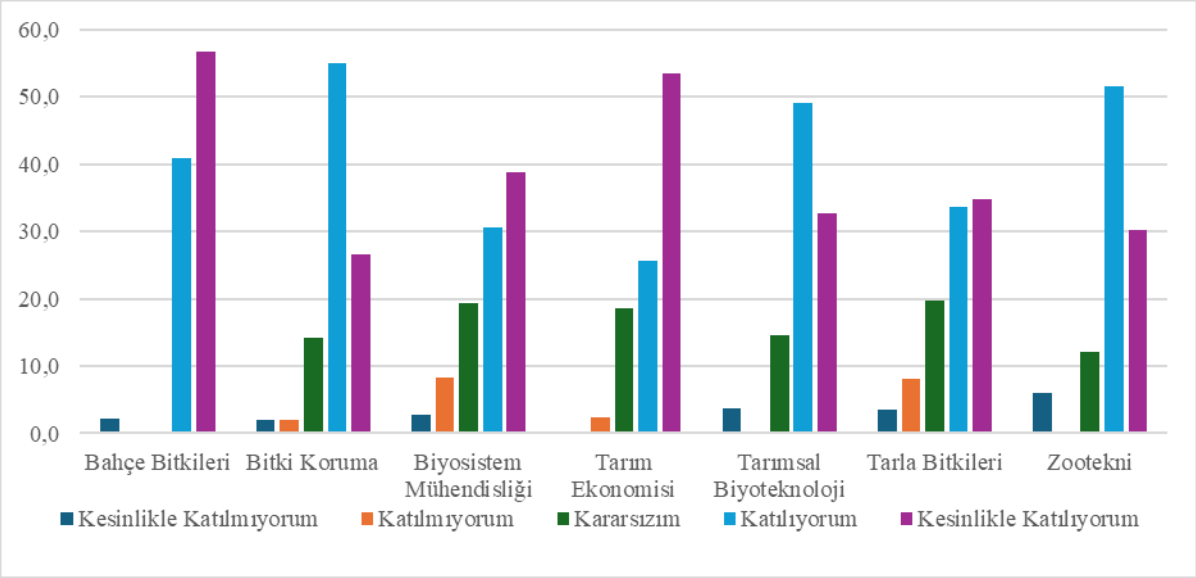
1: Kesinlikle karşıyım, 2: Karşıyım, 3: Fikrim yok, 4: Destekliyorum, 5: Kesinlikle destekliyorum

Ziraat fakültesinde okumaktan memnunum sorusuna verilen cevapların bölümlere göre $P<0.05$ önem seviyesinde anlamlı olduğu saptanmıştır. Bahçe bitkileri ve Tarım Ekonomisi bölümü öğrencileri önemli düzeyde diğer bölümlerden farklıdır ve en yüksek düzeyde memnuniyet grubunda yer almıştır. En düşük memnuniyet grubunda ise Biyosistem Mühendisliği bölümü öğrencileri yer almıştır. Tüm bölümlerde kararsızım seçeneğinin az olduğu ve genel olarak %65'in üzerinde memnuniyet olduğu gözlenmiştir. (Şekil 1). Ziraat fakültesinde memnuniyet oranı sınıf ilerledikçe artarken sadece 3.sınıfta düştüğü gözlenmiştir.



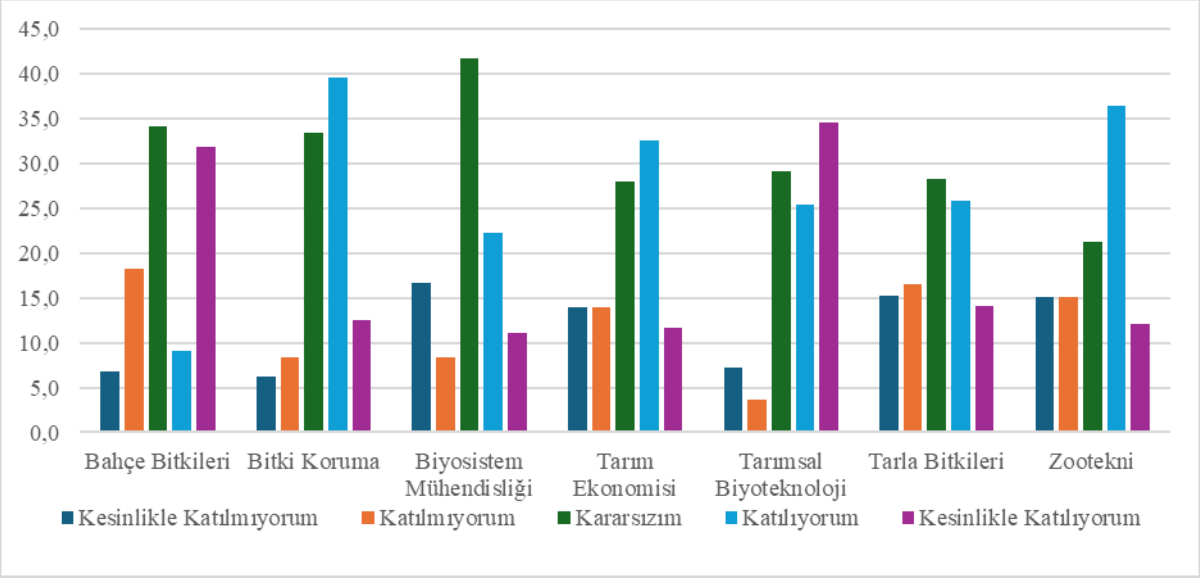
Şekil 1. Ziraat fakültesini okumaktan memnunum fikrinin bölümlere göre dağılım grafiği

Okuduğu bölüm için memnuniyete verilen cevaplar neticesinde cevapların önemli düzeyde farklılıklar gösterdiği ve bu farklılıklarında $P<0.01$ önem seviyesinde anlamlı olduğu saptanmıştır. Bölümler bazında yapılan ortalamaların karşılaştırılmasında Bahçe bitkileri bölümü %95'in üzerinde memnuniyet oranıyla en memnun grupta yer almıştır. Bitki koruma, Tarımsal Biyoteknoloji ve Zootekni bölümü ikinci memnuniyete sahip bölümler olmuştur. Karasızlık oranı en düşük orana ulaşırken memnuniyetsizlik de önemli düzeyde düşüktür. En yüksek memnuniyetsizlik ise Biyosistem mühendisliği ve Tarla bitkileri bölümünden saptanmış olsa da her iki bölümde de memnuniyet oranı %68'in üzerindedir (Şekil 2). Öğrencilerin bölümlerinden memnuniyeti oranı sınıf ilerledikçe artarken sadece 3.sınıfta düştüğü gözlenmiştir.



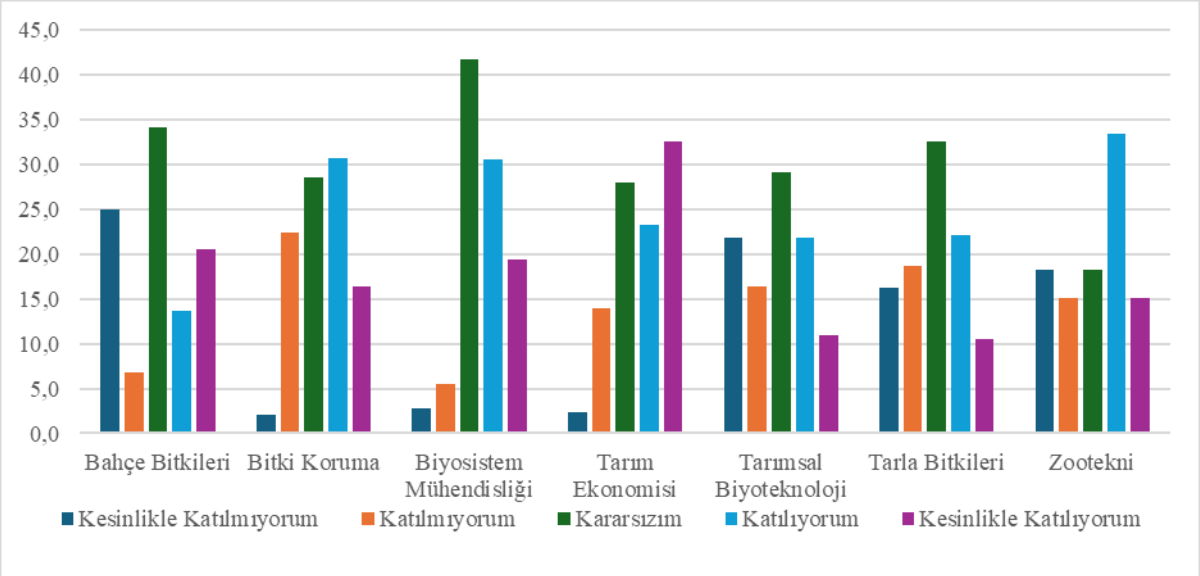
Şekil 2. Okuduğum bölümden memnunum fikrinin bölümlere göre dağılım grafiği

Öğrencilerin mezuniyet sonrası çalışmak istedikleri kurum sorulduğunda Tarım Bakanlığı önemli düzeyde talep görmüş ve bölümler arasında farklılıklar istatistiksel anlamda önem ($P<0,05$) göstermiştir. Tarımsal biyoteknoloji ve bitki koruma bölümü Tarım bakanlığında çalışma hedefi daha yüksek olmuştur. Tarla bitkileri ve Zootekni Bölümü öğrencileri diğer bölümlere göre en yüksek katılmama oranı gösterirken Biyosistem mühendisliği ise en kararsız düşünceye sahip olduğu gözlenmiştir (Şekil 3). Öğrencilerin tarım bakanlığında çalışma talebi oranı sınıf ilerledikçe artarken sadece son sınıfta en yüksek düzeye ulaşmaktadır. Ayrıca özel sektörde çalışma istekleri ise en yüksek 1.sınıf iken en düşük ise 4.sınıf olarak ortaya çıkmıştır.



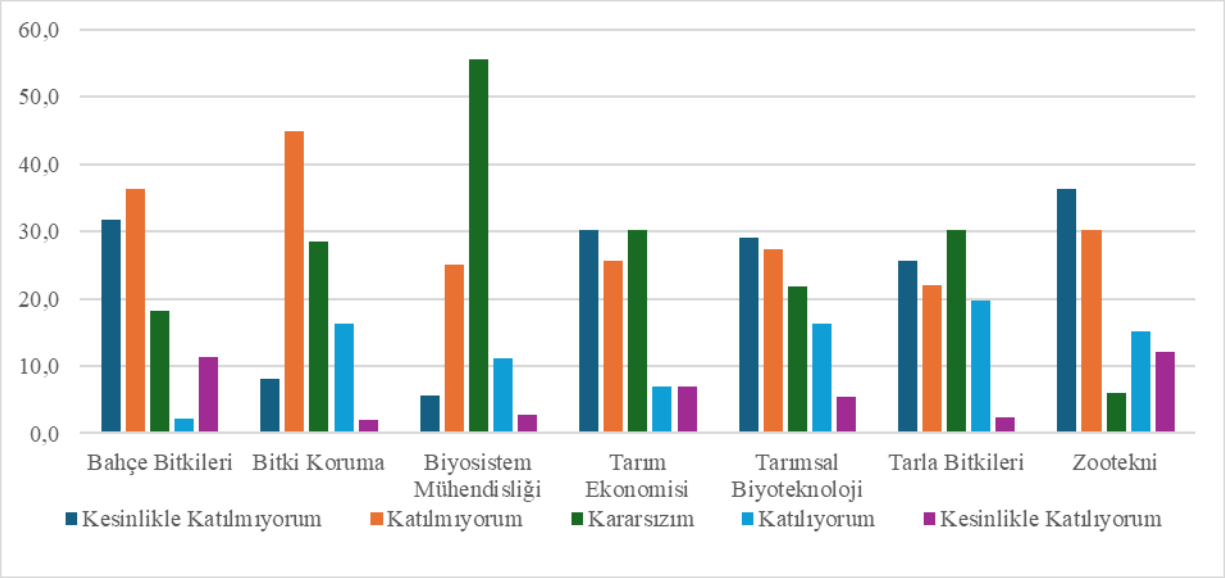
Şekil 3. Tarım Bakanlığında çalışmak istiyorum fikrinin bölümlere göre dağılım grafiği

Akademisyen olma isteklerine verdikleri cevaplara göre bölümler arası farklılıklar istatistiksel anlamda önemli olduğu saptanmıştır. Tarım ekonomisi ve Biyosistem mühendisliği bölümü öğrencilerinde akademisyenlik isteği ağırlık gösterirken Tarımsal biyoteknoloji ve tarla bitkileri bölümü öğrencileri en düşük seviye taleplerini dile getirmişlerdir. En yüksek karasızlık ise Biyosistem mühendisliği ve Bahçe bitkileri öğrencilerinden gözlenmiştir (Şekil 4). Akademisyen olma isteği en yüksek oranlarının 1.sınıf öğrencilerinden elde edilirken en düşük oranlar ise 4. sınıflardan elde edilmiştir.



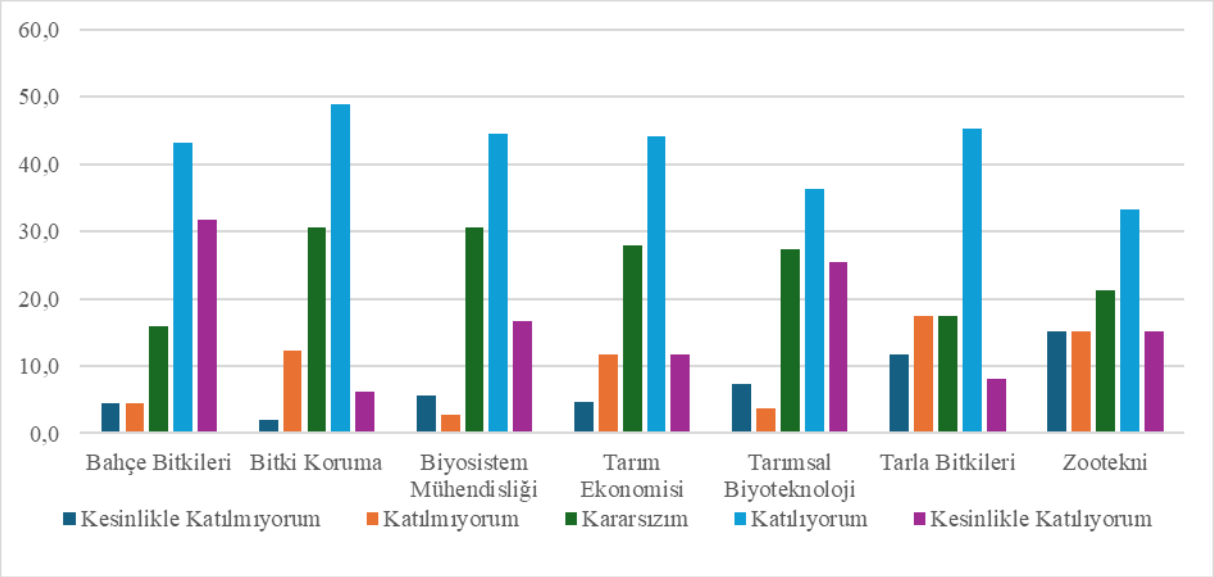
Şekil 4. Akademik çalışmak istiyorum fikrinin bölümlere göre dağılım grafiği

Öğrencilere yöneltilen ziraat mühendisliğini yapmak istemiyorum seçeneğine verilen cevaplar bölümler arasında önemli ($P<0.01$) farklılık göstermiştir. Önemli düzeyde bölüm öğrencileri buna karşı olmalarına karşın Biyosistem öğrencilerinde kararsızlık oranı %55.6 ile oldukça yüksektir. Bahçe bitkileri ve Bootekni bölümü öğrencileri bu düşüncenin önemli düzeyde karşı olduğu görülmektedir. Bu sonuç bize öğrencilerin eğitim boyunca mesleklerini yapma isteğini artırdığını da göstermektedir. Ayrıca sınıf ilerledikçe mesleği icra etme isteği de artmaktadır. Genel olarak ziraat mühendisliği mesleğini yürütmeme isteği aldığı hem teorik hem de uygulamalı derslerle, ziraat fakültesi ve bölümünü okuduğuna memnuniyet durumu bakımından önemli ve negatif ilişki gösterirken sadece özel sektörde çalışma isteği ile pozitif ve önemli ilişki göstermiştir.



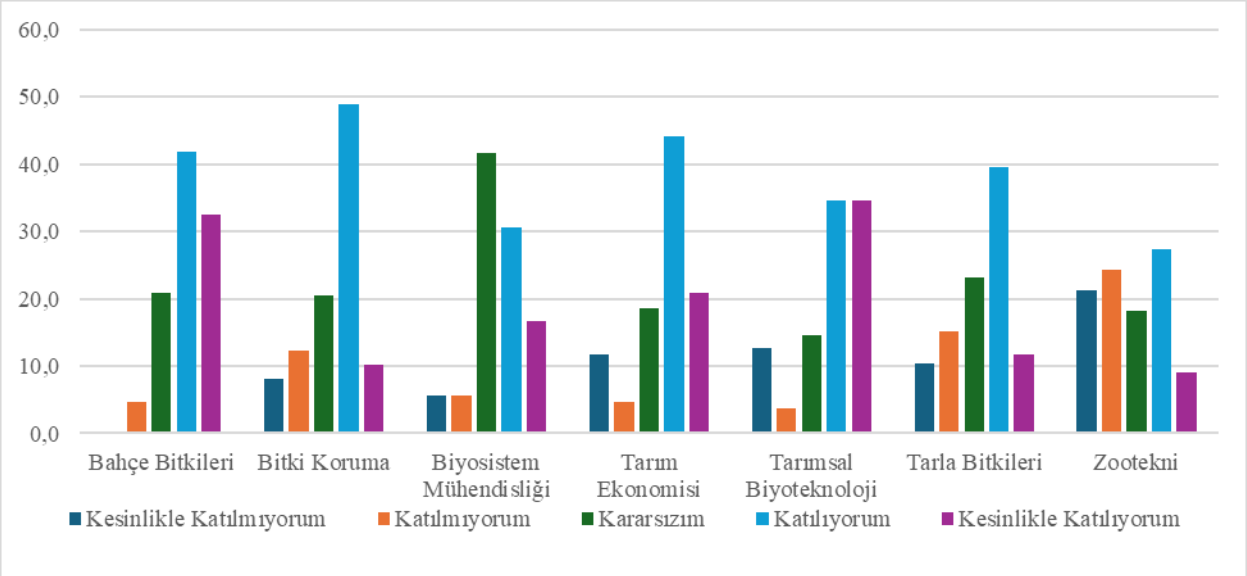
Şekil 5. Ziraat Mühendisliği yapmak istemiyorum fikrinin bölümlere göre dağılım grafiği

Öğrencilerin teorik derslerde aldıkları eğitimin meslekleri için yeterli midir sorusuna verdikleri cevap bölümler arasında farklılık göstermiş ve bu farklılıkta $P<0.01$ önem seviyesinde anlamlı çıkmıştır. Bahçe bitkileri bölümü teorik derslerinin yeterliliği konusunda en yüksek grupta yer almıştır. Tarımsal biyoteknoloji ve Biyosistem Mühendisliği ikinci memnun grupta yer alırken en düşük grupta ise Zootekni ve Tarla Bitkileri bölümü yer almıştır. Teorik derslerin yeterliliği konusunda en yüksek oranlar 4. sınıf öğrencilerinden gözlenmiştir.



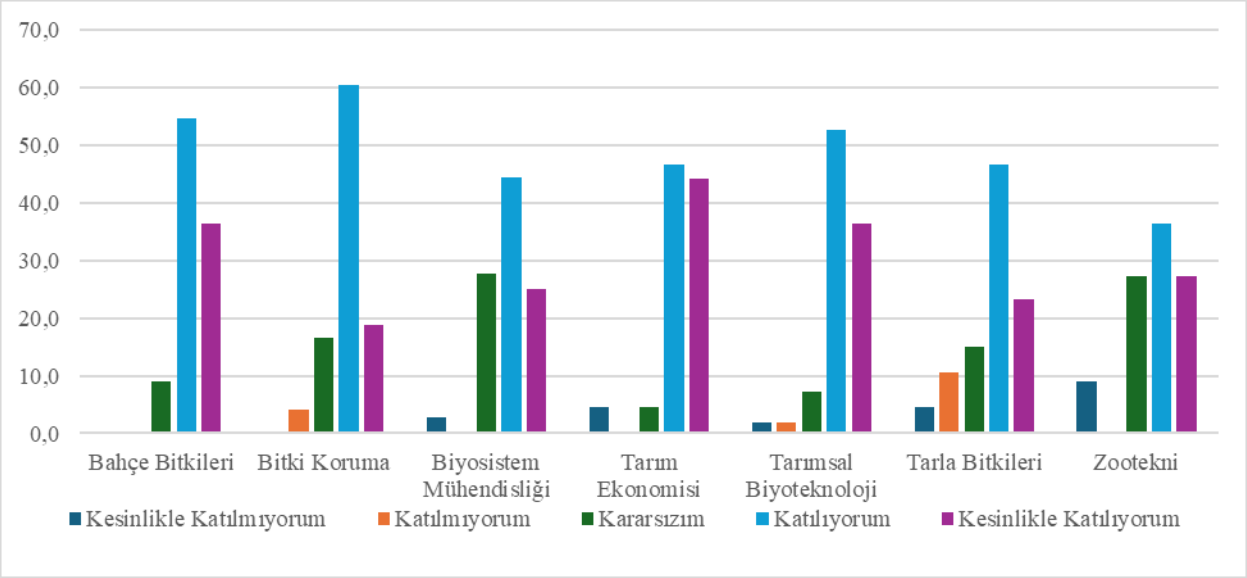
Şekil 6. Aldığım teorik dersler mesleğim için yeterlidir fikrinin bölümlere göre dağılım grafiği

Öğrencilerin uygulama derslerinin meslekleri için yeterli midir sorusuna verdikleri cevap bölümler arasında farklılık göstermiş ve bu farklılıkta P<0.01 önem seviyesinde anlamlı çıkmıştır. Bahçe bitkileri, Tarımsal biyoteknoloji ve Tarım Ekonomisi bölümü yeterliliğinde en üst grupta yer almıştır. En düşük grupta ise Zootekni bölümü yer almış ve ankete katılan zootekni öğrencilerinin yarıya yakını bu konuda yetersizliği tercih etmiştir (Şekil 7). Ayrıca özellikle 3. sınıf öğrencilerinin uygulamaların yetersizliği konusunda daha yüksek düzeyde fikir beyan etmişlerdir.



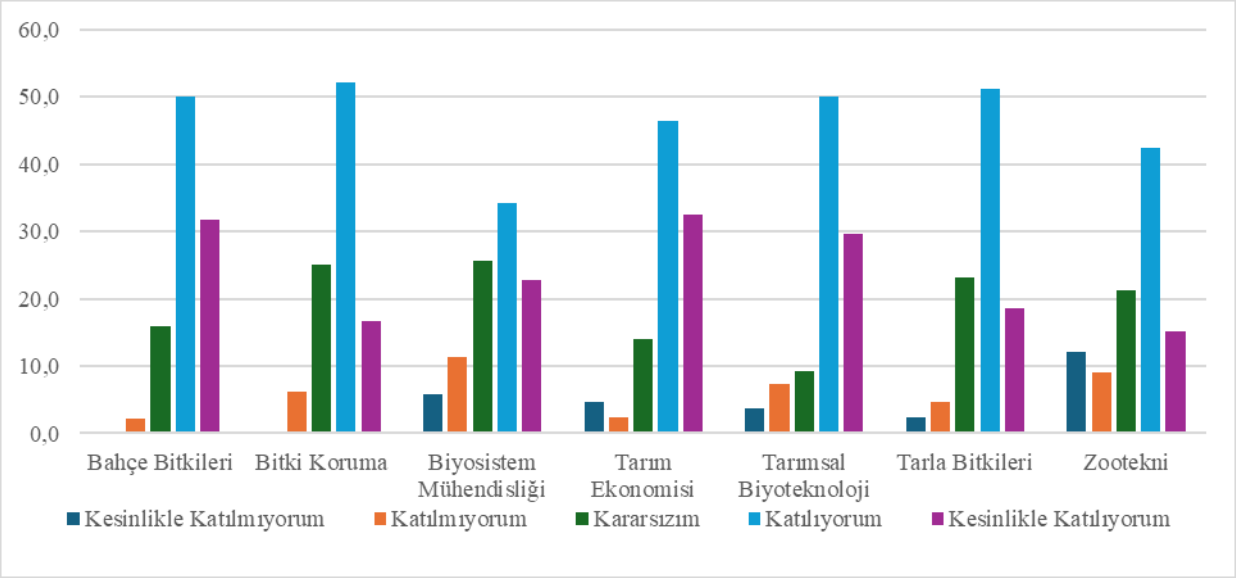
Şekil 7. Aldığım uygulamalı dersler mesleğim için yeterlidir fikrinin bölümlere göre dağılım grafiği

Eğitim aldığım süreçte mesleğime ilgim arttı sorusuna verilen cevap ile bölümler arasında önemli farklılık olduğu ve bu farklılığında P<0.01 önem seviyesinde anlamlı olduğu saptanmıştır. Bahçe Bitkileri, Tarım Ekonomisi ve Tarımsal Biyoteknoloji bölümü öğrencileri neredeyse %90 civarında olumlu düşünceleri ile en yüksek grupta yer almıştır. En yüksek olumsuz düşünce ise Tarla Bitkileri bölümü öğrencileri tarafından verilmiştir. Karasızlık oranı ise Biyosistem Mühendisliği ve Zootekni bölümünde %25'in üzerinde olmuştur (Şekil 8). Mesleğe ilgi artışı 1.sınıfta %70 civarında iken son sınıfta bu oran %90 seviyelerine yaklaşmıştır.



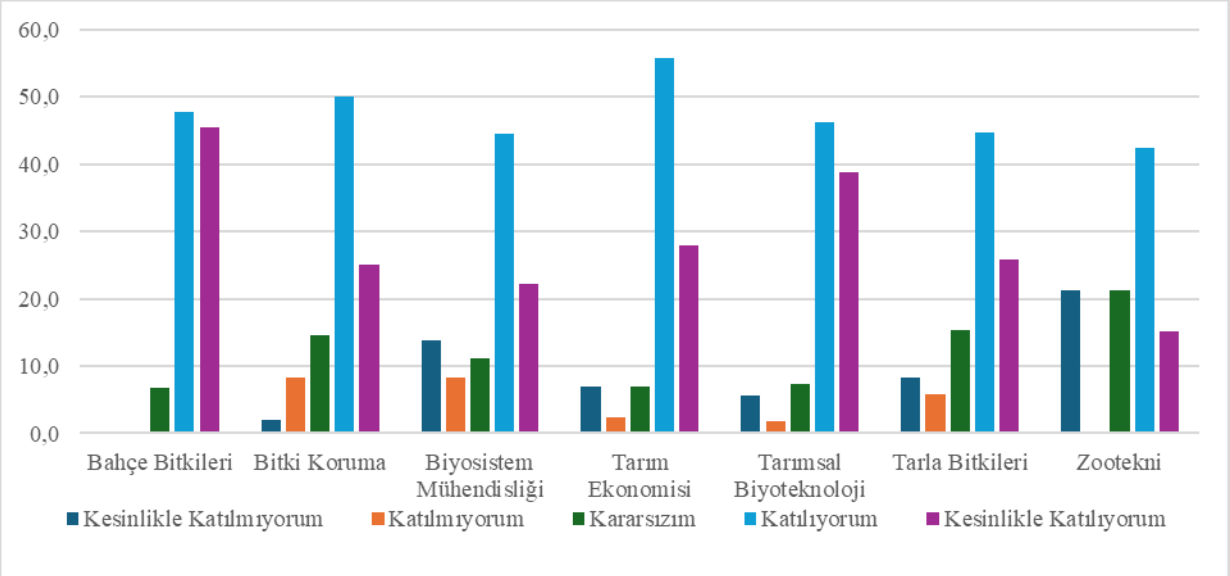
Şekil 8. Eğitim aldığım süreçte mesleğime ilgim arttı fikrinin bölümlere göre dağılım grafiği

Tarımsal üretimi geliştirme hedeflerim var sorusuna verilen cevap ile bölümler arasında önemli farklılık olduğu ve bu farklılığında P<0.01 önem seviyesinde anlamlı olduğu saptanmıştır. Bahçe Bitkileri, Tarımsal Biyoteknoloji ve Tarım Ekonomisi bölümü öğrencileri olumlu düşünceleri ile en yüksek grupta yer almıştır. Zootekni ve Biyosistem Mühendisliği bölümü ise bu düşünceye en düşük düzeyde katılan grupta yer almıştır. Ayrıca tarımsal üretimi geliştirme isteği ve gücü 3.sınıfta en düşük düzeylerde tespit edilirken son sınıflarda bu oran %80'lere yaklaşmıştır.



Şekil 9. Tarımsal üretimi geliştirme hedeflerim var fikrinin bölümlere göre dağılım grafiği

Çevreme mesleğimi tavsiye ederim fikri bölümler arasında önemli farklılık olduğu ve bu farklılığında P<0.01 önem seviyesinde anlamlı olduğu saptanmıştır. Bahçe Bitkileri bölümü öğrencileri diğer bölümlerin öğrencilerine göre oldukça yüksek düzeyde tavsiye edeceklerini belirtmişlerdir. Tarımsal Biyoteknoloji ve Tarım Ekonomisi bölümü öğrencileri ise çevrelerine mesleklerini tavsiye etme konusunda ikinci grupta yer almıştır. Öğrenciler 1.sınıfta %80 düzeyde çevresine mesleğini tavsiye edeceğini belirtirken bu oran 2. ve3. sınıflarda gerilemiş ve 4. sınıfta %85'lere ulaşmıştır.



Şekil 10. Çevreme mesleğimi tavsiye ederim fikrinin bölümlere göre dağılım grafiği

Sonuç ve Öneriler

Bu araştırma, Ziraat Fakültesi öğrencilerinin ziraat mühendisliği mesleğine bakış açısını belirlemek amacıyla Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi öğrencilerinden elde edilen veriler kullanılmıştır. Araştırmada veri toplama aracı olarak online anket formları kullanılmıştır. Anket toplam 346 Ziraat Fakültesi öğrencisine uygulanmıştır. Sosyo-demografik yapı incelenirken yüzde oranlar ve frekans tablolarından faydalanılmıştır. Öğrencilerin mesleğe bakış açısını belirlemek amacıyla 5'li likert tipi ölçek kullanılmıştır. Anketlerin değerlendirilmesi sonucunda, Öğrencilerin cinsiyete göre mesleğe bakış açılarında farlılıklar olmadığı saptanırken bölümler ve sınıflar arasında önemli (P<0.05) farklılıklar olduğu tespit edilmiştir. Bahçe Bitkileri ve Tarımsal Biyoteknoloji bölümü öğrencileri ziraat mühendisliği mesleğine bakış açılarının önemli düzeyde daha olumlu iken en düşük olumluluk ise Zootekni bölümü öğrencilerinden gözlenmiştir. Genel olarak Ziraat Fakültesinde okuyan öğrencilerin yaklaşık %95 düzeyinde çevresine mesleği tavsiye edeceğini bildirmiştir. Ayrıca bu sonuçla ilgili olarak Ziraat Fakültesi'nde okumaktan memnun olanların oranı %82 düzeyinde gerçekleşmiştir. Karasızlık oranının yüksek olduğu (%33-%30 aralığında) sorular ise özel sektörde çalışma, tarımsal üretimi geliştirme, akademisyen olma ve Tarım Bakanlığı'nda çalışmadır. Ziraat mühendisliği mesleğini yapmak isteyenler %55 seviyesinde kalırken

yapmayı düşünmeyenler ise %20'ye yaklaşmıştır. Öğrencilerin bölüm ders düzenlemesi özellikle uygulamalı derslerdeki memnuniyetler fakülteden, bölümden, çevresine mesleği tavsiye etme, mesleğini sevme ile anlamlı ve pozitif güçlü ilişkili olduğu gözlenmiştir.

FACTORS AFFECTING MEAT QUALITY IN RUMINANT ANIMALS: RED MEAT QUALITY FROM FARM TO TABLE

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ABSTRACT

Meat is one of the basic protein sources rich in essential amino acids used in human nutrition. In addition to essential amino acids, it also contains minerals, vitamins and fatty acids in its structure. A large portion of the meat needed worldwide is obtained from ruminant animals such as cattle, sheep and goats. Today, in addition to increasing the production amounts of meat obtained from such animals, intensive scientific studies are also being carried out to improve the quality characteristics that affect consumer preferences. Meat quality characteristics can be examined in two categories as internal and external quality factors. Internal factors refer to physiological characteristics such as the appearance quality characteristics of meat (colour, texture, amount of intramuscular fat, fat colour, drip and clearance loss, etc.) and eating quality characteristics (softness, flavour, juiciness) that vary according to factors such as the type, breed and gender of the animal. External factors refer to the safety quality characteristics of meat products (microorganism load, physical and chemical residues, food additives). Many features used as quality criteria in meats, including chemical composition, pH, colour, water holding capacity, softness, texture, flavour, spoilage and contamination, can be defined instrumentally. All these features are evaluated as criteria in meeting consumers' expectations of quality meat. Consumers evaluate meats with high marbling rate, bright red colour, hard tissue structure, moderate visible fat content and fresh meat odour as quality meat. On the other hand, meats that have lost their original meat colour specific to the species they belong to, have soft tissue structure, relatively low marbling rate, excessive visual fat content and abnormal meat odour are evaluated as low quality meats. In this review, genetic factors affecting the quality of red meat obtained from ruminant animals, management factors such as slaughter age, slaughter weight, castration, environmental stress factors, animal feeding and feeding strategies, slaughtering of animals and the effects of post-slaughter processes on meat quality are examined.

Keywords: Meat Quality, Ruminants, Quality Parameters, Consumer Preference

RUMİNANT HAYVANLARDA ET KALİTESİNİ ETKİLEYEN FAKTÖRLER: ÇİFTLİKTEN SOFRAYA KIRMIZI ET

ÖZET

Et, insanların beslenmesinde kullanılan esansiyel amino asitler bakımından zengin temel protein kaynaklarından birisidir. Yapısında esansiyel amino asitlerden başka mineral, vitamin ve yağ asitlerini de içerir. Dünya genelinde ihtiyaç duyulan et miktarının büyük bir bölümü sığır, koyun ve keçi türü ruminant hayvanlardan elde edilmektedir. Günümüzde bu tür hayvanlardan elde edilen etlerin üretim miktarlarının arttırılmasının yanında, tüketici tercihlerini etkileyen kalite özelliklerinin iyileştirilmesi için de yoğun bilimsel çalışmalar yapılmaktadır. Et kalite özellikleri içsel ve dışsal kalite faktörleri olarak iki kategoride incelenebilir. İçsel faktörler, hayvanın türü, ırkı ve cinsiyeti gibi faktörlere göre değişen etin görünüm kalite özellikleri (renk, tekstür, kas içi yağ miktarı, yağ rengi, damlama ve tasfiye kaybı, vs.) ve yeme kalite özellikleri (yumuşaklık, lezzet, sululuk) gibi fizyolojik özellikleri ifade etmektedir. Dışsal faktörler ise et ürünlerinin güven kalite özelliklerini (mikroorganizma yükü, fiziksel ve kimyasal kalıntılar, gıda katkı maddeleri) ifade etmektedir. Etlerde kalite kriteri olarak kullanılan kimyasal bileşimi, pH, renk, su tutma kapasitesi, yumuşaklık, tekstür, lezzet, bozulma ve kontaminasyon dahil olmak üzere birçok özellik enstrümantal olarak tanımlanabilmektedir. Tüm bu özellikler, tüketicilerin kaliteli et beklentilerinin karşılanmasında birer kriter olarak değerlendirilmektedir. Tüketiciler, mermerleşme oranı yüksek, parlak kırmızı renkli, sert doku yapısına sahip, orta düzeyde görünür yağ içeren ve taze et kokusuna sahip etleri kaliteli et olarak değerlendirmektedirler. Buna karşın ait olduğu türe özgü orijinal et rengini kaybetmiş, yumuşak doku yapısına sahip, mermerleşme oranı nispeten daha az, aşırı görsel yağ içeren, anormal et kokusuna sahip etler ise düşük kaliteli etler olarak değerlendirilir. Bu makalede ruminant hayvanlardan elde edilen kırmızı etlerin kalitesini etkileyen genetik faktörler, kesim yaşı, kesim ağırlığı, kastrasyon, çevresel stres faktörleri gibi yönetimsel faktörler, hayvan besleme ve yemleme stratejileri, hayvanların kesimi ve kesim sonrası ete uygulanan işlemlerin et kalitesi üzerindeki etkileri incelenmiştir.

Anahtar Kelimeler: Et Kalitesi, Ruminantlar, Kalite Parametreleri, Tüketici Tercihi

1. GİRİŞ

Dünya nüfusunun sürekli artış göstermesi, gıda ihtiyacını da beraberinde getirmektedir. Dünya genelinde doğal kaynakların eşit kullanılamaması, coğrafya ve iklimin elverişsizliği gibi birçok etken dolayısıyla insanların sağlıklı beslenme ve kaliteli gıdaya erişimi konusunda eşitsizlik bulunmaktadır. Fakat insan vücudunda fonksiyonların sağlıklı bir şekilde yerine getirilmesi için ihtiyaç duyulan besin maddelerinin yeterli ve dengeli bir şekilde tüketilmesi gerekmektedir (Wu, 2016). Et; protein, mineral, vitamin ve yağ asitleri açısından zengin olan temel bir gıda maddesidir (Gündüz ve Çayıroğlu, 2024). Bununla birlikte etlerin tercih edilebilirliği ve genel kabul edilebilirliği sahip olduğu kalite parametreleri ile doğrudan ilişkilidir. Etin kimyasal bileşimi ve fiziksel özellikleri etin kalitesini belirlemektedir. Bu özellikler hayvan türü, ırk, bireysel özellikler, cinsiyet, yaş, yetiştirme teknolojileri ile et üretim prosedürü (besleme, taşıma ve kesim koşulları) ve işleme (depolama süresi veya sıcaklık koşulları) gibi diğer faktörlerden etkilenir. Kasın bileşimi, dokusu ve karkasın kesimi, üretimi ve depolanması sırasında gerçekleşen bazı biyokimyasal işlemler esas olarak etin yumuşaklığını etkilerken, yağ içeriğinden etkilenen lezzet, genetik yöntemlerle, büyüme performansı kontrolüyle ve diyet takviyeleriyle manipüle edilebilmektedir (Geletu ve ark. 2021). Söz konusu özellikler gıda işleme endüstrisi ve tüketici tercihlerini etkileyen önemli kalite parametreleridir. Özellikle renk, sululuk, mermerleşme seviyesi ve tat, tüketici memnuniyeti üzerinde oldukça büyük etkilere sahiptir (Önenç ve Ozdogan, 2022; Gündüz ve Çayıroğlu, 2024). Yüksek kaliteye sahip et üretmek için, et kalite özellikleri ve bunları kontrol eden faktörlerin özelliklerini iyi bilmek ve anlamak gerekmektedir (Joo ve ark., 2013; Geletu ve ark., 2021).

Et kalitesi değerlendirme süreci çiğ etin kalite kontrolüyle başlar. Çiğ etin görsel değerlendirmesinde, renk, görünüm, koku ve tat gibi organoleptik niteliklerden yararlanılır. Bu tip duyusal değerlendirmelerinin birçoğu hala insanlar tarafından panel testleri şeklinde yapılmaktadır. Bununla birlikte taze et kalitesi, kompozisyonu, besin maddeleri içeriği, rengi, su tutma kapasitesi, yumuşaklığı, lezzeti, bozulma ve bulaşma dahil olmak üzere bazı özellikler enstrümantal olarak tanımlanabilmektedir (Geletu ve ark., 2021). Et rengi, paketlenmiş et rengi, yağ miktarı ve dağılımı, yağ rengi, etin yüzeyindeki damla miktarı, tepsideki atık sıvı miktarı ve etin dokusu etin görünüm kalite özelliklerini belirler. Bu özellikler, tüketicinin satın alma noktasında kaliteli et seçme kararını büyük ölçüde etkilemektedir (Joo ve ark. 2013).

Bu makalede, çiftlikten sofraya kadar ruminant hayvanlardan elde edilen kırmızı etlerin kalitesini etkileyen faktörler incelenmiştir.

2. ETLERDE KALİTE PARAMETRELERİ

Et kalitesini belirlemede kullanılan göstergeler etin kimyasal, fiziksel ve duyusal özelliklerinin ortaya konulmasında kullanılan parametrelerdir. Bunlar Tablo 1'de özetlenmiştir. Etin protein ve amino asit içeriği, yağ ve yağ asidi içeriği, vitamin ve mineral içeriği kimyasal özellikleri ifade ederken; mermerleşme, pH, pişirme kaybı, kesme kuvveti, rengi, tekstür ve olgunluğu etin fiziksel özelliklerini ifade etmektedir. Yumuşaklık, lezzet, sululuk, tat, koku, görünüm, genel kabul gibi değerler ise etin duyusal özelliklerini ifade etmektedir.

Tüm bu parametreler hayvanın türü, ırkı, bireysel özellikleri, cinsiyeti, yaşı, yetiştirme ve besicilik uygulamaları ile et üretim prosedürü (besleme, taşıma ve kesim koşulları) ve işleme (depolama süresi veya sıcaklık koşulları) gibi faktörlerden etkilenmektedir. Buna göre ruminant hayvanlardan elde edilen etlerin kalitesini etkileyen faktörleri içsel ve dışsal faktörler olarak iki sınıfa ayırmak mümkündür. İçsel faktörler, etin görünüm kalitesi özellikleri (renk, damlama ve tasfiye kaybı, tekstür, kas içi yağ miktarı) ve yeme kalitesi özelliklerini (yumuşaklık, lezzet, sululuk) ifade ederken, dışsal faktörler et ürünlerinin güven kalitesi özelliklerini (mikroorganizma yükü, fiziksel ve kimyasal kalıntılar, gıda katkı maddeleri) ifade etmektedir. Etlerin kalitesini belirleyen faktörleri Tablo 2'de şematize edilmiştir. Tüm bu özellikler, tüketicinin yüksek kaliteli et beklentisine katkıda bulunmaktadır (Joo ve ark. 2013). Tüketiciler kaliteli eti, arzu edilen renge, sert dokulu, daha az damlamaya, yüksek mermerleşmeye, orta düzeyde görünür yağa ve taze et kokusuna sahip et olarak kabul ederler. Buna karşın renk bozulması, yumuşak doku, çok miktarda damlama, daha az mermerleşme, aşırı görünür yağ ve anormal et kokusu düşük kaliteli olarak kabul ederler (Joo ve ark. 2013).

Tablo 1. Et kalitesini değerlendirmede kullanılan parametreler

Kalite özellikleri	Göstergeler
Kimyasal özellikler	Protein ve amino asit içeriği, yağ ve yağ asidi içeriği, vitamin ve mineral içerikleri
Fizikokimyasal özellikler	pH, pişirme kaybı, kesme kuvveti, et rengi, yağ rengi, tekstür, olgunluk
Duyusal özellikler	Yumuşaklık, lezzet, sululuk, tat, koku, görünüm, genel kabul

Tablo 2. Et kalitesini etkileyen faktörler

Faktörler	Başlıca kalite özellikleri
Genetik faktörler	
Tür	Mermerleşme, duyusal özellikler, verim
Irk	Mermerleşme, duyusal özellikler, verim
Cinsiyet	Mermerleşme, duyusal özellikler, verim
Yönetimsel faktörler	
Kesim yaşı/ağırlığı	Mermerleşme, duyusal özellikler, verim
Eneme/kastrasyon	Mermerleşme, duyusal özellikler, verim
Sosyal topluluk	
Çevresel stres faktörleri	
(Sıcaklık ve mevsim etkisi)	Mermerleşme, duyusal özellikler, verim
Diğer yönetimsel faktörleri	Mermerleşme, duyusal özellikler, verim
Besleme ile ilgili faktörler	
Kaba-kesif yem oranı	Mermerleşme, yağ asidi bileşimi, duyusal özellikler
Yem katkı maddesi ilavesi	Mermerleşme, yağ asidi bileşimi, duyusal özellikler
Beslenme planı	Mermerleşme, duyusal özellikler, verim
Üretim sistemleri	Mermerleşme, duyusal özellikler, verim
Kesim öncesi koşullar ve kesim sonrası uygulamalar	
Kesim öncesi koşullar	Renk, görünüm, duyusal özellikler
Kesim sonrası uygulamalar	Renk, görünüm, duyusal özellikler
Et kasının bulunduğu yer	Mermerleşme, yağ asidi bileşimi, duyusal özellikler
Güven kalitesi özelliklerini	Mikroorganizma yükü, fiziksel ve kimyasal kalıntılar, gıda katkı maddeleri vs.

Baik ve ark., (2023)'den uyarlanmıştır.

3. KIRMIZI ETİN BESİNSEL BİLEŞİMİ

Kırmızı etin besinsel kalitesini, içerdiği protein, esansiyel amino asit, mineral ve vitamin miktarları belirler. Etin amino asit profili kaslar veya türler arasında nispeten sabittir. Ancak, kolajen açısından zengin kaslar, yüksek glisin içeriği ve esansiyel olmayan bazı amino asitleri içermesi nedeniyle daha düşük bir besin değerine sahiptir. Kas içi yağ, kas kütlesinin küçük bir kısmını oluşturmasına rağmen, et yağ asidi içeriği ve profili türe, belirli bir kasın anatomik kökenine ve hayvan diyetine göre değiştiğinden insan yağ asidi alımında rol oynar (Listrat ve ark., 2016). Türlere göre kırmızı etlerin kimyasal bileşimi Tablo 4, dana ve kuzu etinin esansiyel amino asitleri içeriği Tablo 5'de verilmiştir. Tablolar incelendiğinde etlerin protein, çinko,

demir, selenyum ve fosforun iyi bir kaynağı olduğu ve A vitamini ve B kompleks vitaminleri açısından da zengin bir kaynak olduğu görülecektir (Geletu ve ark., 2021).

Tablo 3. Et kalitesini etkileyen faktörün etki düzeyleri

	Yağlılık	Sululuk	Renk	Gevreklik	Lezzet	Genel kabul
Irk	***	*	*	*	Ø	*
Cinsiyet	***	Ø	*	*	*	**
Yaş- Ağırlık	****	*	***	**	**	***
İklim ve sezon	**	Ø	*	*	Ø	*
Besleme	****	*	**	*	**	**
Katkı maddeleri	****	***	*	***	*	***
Açlık, stres, nakliye	Ø	**	***	**	*	***
Kesim prosedürü	*	*	**	*	**	*
Kesim yeri dinlenme	Ø	**	****	****	**	***
Kesimde elektrik stimülasyonu	Ø	**	*	***	*	**
Karkas soğutma	Ø	*	*	***	*	**
Depolama	Ø	***	***	****	***	****

Boztepe ve Aytekin, (2025). Ø: Faktörün etkisi yok, *: Çok az etkili, **: Orta düzeyde etkili, ***: Yüksek düzeyde etkili, ****: Mutlak etkili

Ayrıca et önemli miktarda su içerir. Etin yaklaşık %70-76'ini su oluşturur (Sakowski ve ark., 2022). Bu su etin rengi, dokusu ve yüzey görünümü üzerinde önemli bir etkiye sahiptir. Etin su içeriği yağ içeriği ile ters orantılı olarak değişir. Yağ dokusundaki su konsantrasyonunu farklılığı, kas içi yağ içeriğinin farklılığından kaynaklanır. Hayvanların yaşı da et su konsantrasyonun üzerinde etkin rol oynar. Nitekim et su içeriği hayvanların yaşıyla birlikte azalma eğilimi gösterir (Sakowski ve ark., 2022). Etin yapısında bulunan doku suyunun tutulma yeteneği "etin su tutma kapasitesi" olarak ifade edilir ve bu değer çiğ etin görünümü ve çiğneme sırasındaki sululuk üzerinde etkin rol oynar (Geletu ve ark., 2021).

Tablo 4. Türlere göre kırmızı etlerin kimyasal bileşimi

100 g yağsız et	Sığır	Dana	Kuzu	Koyun	Keçi
Su, g	73.10	74.8	72,9	73,2	75
Protein, g	15.0-23.0	24.8	21,9	21,5	20-23
Yağ, g	2.8	1.5	4,7	4,0	1-10
Enerji, kJ	498	477	564	514	122
Kolesterol, mg	50.0	51.0	66	66	63.8
Tiamin	0.04	0.06	0,12	0,16	
Riboflavin, mg	0.18	0.20	0,23	0,25	
Niasin, mg	5.0	16.00	5,2	8,0	
B6, mg	0.52	0.80	0,1	0,8	
B12, mikrogram	2.5	1.60	0,96	2,8	
Pantotenikasit,mg	0.35	1.50	0,74	1,33	
Vitamin A, Mikrogram	<5	<5	8,6	7,8	
Beta-karoten, Mikrogram	10	<5	<5	<5	
Alfa tokoferol, mg	0.63	0.5	0,44	0,2	
Na, mg	51.0	51.0-68.0	69	71,0-74.0	
K, mg	363	335-362	344	244-365	
Ca, mg	4.5	6.5	7,2	6,6	
Fe, mg	1.8	1.1-2.4	2,0	0.99-3,3	3.2
Zn,	4.60	4,2	4,5	3,9-4.2	
Mg, mg	25	24.4-26,0	28,0	18.8-28.0	
P, mg	215	260-275	194	174-290	
Cu, mg	0.10-0.12	0,08-0.10	0,12	0.15-0,22	
Se, mg	17	<10	14,0	<10	

Williams, (2007); Tuncer ve ark., (2025); Sakowski ve ark., (2022); Geletu ve ark., (2021); Gawat ve ark., (2023).

Tablo 5. Dana ve kuzu etinin esansiyel amino asitleri içeriği, g/100 g

Amino asitler	Kategori	Dana eti	Kuzu eti
Lisin	Esansiyel	8.2	7.5
Lösin	Esansiyel	8.5	7.2
İzölösin	Esansiyel	5.0	4.7
Sistin	Esansiyel	1.5	1.5
Treonin	Esansiyel	4.2	4.8
Metiyonin	Esansiyel	2.2	2.4
Triptofan	Esansiyel	1.3	1.2
Fenilalanin	Esansiyel	4.1	3.8
Arginin	Esansiyel	6.4	6.8
Histidin	Esansiyel	2.8	2.9
Valin	Esansiyel	5.6	5.1
Prolin	Esansiyel değil	5.2	4.7
Glutamik asit	Esansiyel değil	14.3	14.5
Aspartik asit	Esansiyel değil	8.9	8.6
Glisin	Esansiyel değil	7.2	6.8
Trosin	Esansiyel değil	3.3	3.3
Serin	Esansiyel değil	3.9	3.8
Alanin	Esansiyel değil	6.3	6.2

Geletu ve ark., (2021).

4. RUMİNANTLARDA ET KALİTESİNİ ETKİLEYEN FAKTÖRLER

4.1. Genetik faktörler

Ruminant hayvan etlerinde kalite hayvanın türü, ırkı ve cinsiyet et kalitesini etkilemektedir (Guerrero ve ark., 2013). Büyüme ve yağlanma sırasında, sırasıyla kas dokusunda bir büyüme (kas-kemik oranında artış) ve ardından yağ dokusunda bir büyüme (yağ-kas oranında artış) meydana gelir (Clinquart ve ark., 2022). Bununla birlikte, bu evrim olgunluklarına bağlı olarak et kalitesi ırklar arasında bile değişkenlik gösterir. Örneğin, Charolais, Limousine ve Belçika Mavisi gibi geç olgunlaşan ırklar, az yağlı ağır karkaslar üretmektedir. Buna ilaveten sütçü sığır ırkları daha yüksek iç yağ depolarına sahipken, et verim yönlü ırkları daha yüksek deri altı yağ depolarına sahiptir (Clinquart ve ark., 2022).

Et kalitesi ve özellikleri bakımından hayvan türleri arasındaki farklılıklar daha homojen olduğu düşünülen küçükbaş hayvan türleri arasında bile belirgin olarak kendini göstermektedir. Nitekim yapılan çalışmalar, koyun etinin keçi etine göre kas içi yağ içeriğinin daha yüksek, daha yumuşak ve daha baskın bir aromaya sahipken, daha düşük kuru madde ve protein içeriğine sahip olduğunu göstermiştir. Ayrıca koyun eti keçi etine göre daha açık renkli, daha

yumuşak, daha zayıf su tutma kapasitesi gösterirken pişirme kaybının daha fazla olduğu ifade edilmektedir. Koyun ve keçi etine ait bazı kalite özelliklerinin karşılaştırması Tablo 6'da verilmiştir. Tablo 6 incelendiğinde koyun etinin keçi etine göre kuru madde ve protein içeriği düşük, kas içi yağ miktarı daha yüksektir. Et rengi bakımından koyun eti keçi etine göre daha açık renklidir. Ayrıca koyun etinin pişirme kaybı keçi etine göre daha fazla olduğu görülmektedir.

Hayvan ile ilgili et kalitesini etkileyen faktörlerden biriside ırktır. Irkların et kalitesi üzerine etkisi karkas morfolojisindeki kas ve yağ dokusunun çeşitliliğinden kaynaklanmaktadır. Ancak et kalitenin etkileyen faktörler ile ilgili sonuçları ırk üzerinden değerlendirilebilmek için hayvanların yaş, kilo ve olgunluk derecelerinin aynı olması gerektiğine vurgu yapılmaktadır. Kural olarak, hayvanlarda ırkın pH, renk, doku ve duyusal özellikler gibi enstrümantal ve duyusal et kalitesi üzerindeki etkisinin az olduğu söylenebilir. Çoğu farklılık muhtemelen kaslılık seviyelerindeki farklılıklardan kaynaklanmaktadır (Guerrero ve ark., 2014). Hayvan ırkları arasında et kalitesi bakımından farklılığa sebep olan etkenlerden birisi de kas içi yağ asidi profili farklılığıdır. Özellikle melez sığırların yağ asidi bileşimindeki farklılıklar, kas içi yağ içeriğindeki farklılıklardan ziyade genetik farklılıklar ileri geldiği değerlendirilmektedir (Guerrero ve ark., 2014).

Tablo 6. Koyun ve keçi etine ait bazı kalite özelliklerinin karşılaştırması

Özellikler	Koyun	Keçi
Kuru madde	Daha düşük	Daha yüksek
Protein	Daha düşük	Daha yüksek
Kas içi yağ miktarı	Daha yüksek	Daha az
Et rengi	Daha açık renkli	Daha koyu
Pişirme kaybı	Daha fazla	Daha az

Babiker ve ark. (1990).

Türkiye'de mevcut koyun ırkları arasında Kıvırcık kuzularının et kalitesi ilk sırada yer alırken, bunu Karayaka, Dağlıç gibi koyun ırkları takip etmektedir. Sığırlarda ise Angus, Hereford, Limuzin, Şarole gibi kültür ırkların et kalitesi açısından değerli ırklar olarak kabul edilmektedir (Boztepe ve Aytekin, 2025).

Ivanović ve ark. (2014), aynı yaş grubundaki Balkan Keçisi ve Sırp Beyaz Keçilerinde et kalitesi özelliklerini karşılaştırdıkları çalışmalarında, ırkın etin kimyasal birleşimi, sertliği, yağ asidi kompozisyonu, bazı amino asitler, çinko ve bakır içeriği bakımından farklılık gösterdiğini bildirilmişlerdir. Migdał ve ark. (2021), aynı yaş aynı rasyon ile beslenen Karpat ve Saanen keçisi etlerinin kimyasal bileşim, amino asit, yağ oranı, renk ve duyusal özellikler bakımından farklılıklar olduğunu bildirmişlerdir. Benzer şekilde Xie ve ark. (2012) da aynı yaş grubunda ve aynı rasyonla yetiştirilen sığır ırklarının bazı et kalitesi parametreleri bakımından farklılık gösterdiğini bildirmişlerdir.

Hayvanların cinsiyetleri arasındaki et kalitesi farklılıkları tam olarak anlaşılamamış olmakla birlikte bunun kanda dolaşan cinsiyet hormonlarının farklı düzeylerinden kaynaklandığına inanılmaktadır (Boztepe ve Aytekin, 2025).

Beside erkek hayvanlarla çalışmanın daha hızlı büyüme ve daha yağsız karkaslar elde etmek başta olmak üzere bazı avantajları vardır (Hopkins ve Mortimer, 2014). Erkeklerde testislerden salgılanan testosteron hormonu, kaslardaki protein sentezini, insülin duyarlılığını ve lipit profilini iyileştirmektedir. Öte yandan, dişilik hormonu olan östrojenin kas yapımını olumsuz etkilediği ve daha fazla yağ kazanımını uyardığı belirtilmektedir (Kutay ve ark., 2024). Hormonların etkisi nedeniyle, daha kaslı bir yapıya sahip olan erkek hayvanların eti, dişi hayvanlarınkine göre dokusal olarak daha kabul edilebilir olarak değerlendirilmektedir. Ayrıca, et kalitesinin ve yağ asidi bileşiminin de cinsiyete bağlı olarak değiştiği vurgulanmaktadır (Kutay ve ark., 2024).

Et kalitesi üzerinde cinsiyetin etkisi (erkek, dişi ve enenmiş) esas olarak depolanan yağ miktarı, depolanma yeri, büyüme hızı ve karkas verimi ile ilişkilidir. Karkas özellikleri ırka nazaran cinsiyetten daha fazla etkilenir. Benzer şekilde, dişiler daha erken gelişim gösterdiklerinden erkeklerden daha fazla etkilenirken, düveler ara bir konumda kalır (Geletu ve ark., 2021). Cinsiyetin etkisinden kaynaklı olarak karkasın konformasyonu ve yağ içeriğinde oluşan farklılıklar, et kalitesi özelliklerinden pH, renk, yumuşaklık ve diğer parametreleri de etkileyebilmektedir. Cinsiyetin özellikle de etin yağlılığı ve yumuşaklığı üzerinde olumlu etkileri olduğu değerlendirilmektedir (Pogorzelska-Przybyłek ve ark., 2020).

4.2. Yönetimsel faktörler

Hayvanın kesim anındaki yaşı ve ağırlığı et kalitesini etkileyen faktörlerden birisidir. Bir hayvanda ırk, cinsiyet, diyet, hastalık vb. durumlar aynı olması durumunda yaş arttıkça canlı ağırlıkta artacağı için bu iki faktör bir arada değerlendirilmesi daha uygun olacaktır (Geletu ve ark., 2021). Yaşlı hayvanların etinde miyoglobin ve demir seviyeleri daha yüksektir. Bu da daha koyu renkli kas oluşumuna neden olmaktadır (Poveda-Arteaga ve ark., 2023). Belhaj ve ark. (2021) hayvanların kesim yaşının nihai pH ve et rengi üzerinde etkili olduğu, kesim yaşı ilerledikçe parlaklığın azaldığını, kırmızılığın ise arttığını bildirmişlerdir. Araştırıcılar renkte yaşanan bu farklılıkların yaş ilerledikçe demir ve miyoglobinin artmasıyla ilgili olabileceğini bildirmişlerdir. Przegalińska-Gorączkowska (2012) yaptıkları çalışmalarında, düşük canlı ağırlığa (20-30 kg) sahip kuzuların, yüksek canlı ağırlığa (30-40 kg) sahip kuzulara göre daha iyi bir yağ asidi profili meydana getirdiğini bildirmişlerdir. Benzer bir çalışmada iki aylık yaşta ve 8.7 kg ve 13.6 kg ağırlığındaki kuzularda bazı et kalite kriterlerini inceleyen Palidori ve ark. (2017), 5 aylık olan hayvanların etlerindeki yağ ve protein oranının 2 aylı yaştakilere göre daha yüksek olduğunu, et renginin ise daha koyu olduğunu bildirmişlerdir.

Hayvanlarda kesim yaşının et kalitesi üzerine etkisini olumlu yönde kullanmak için ırklara göre uygun kesim ağırlığının belirlenmesi önerilmektedir (Boztepe ve Aytekin, 2025). Bunu yaparken hem erken kesim hem de geç kesimle ilgili olumsuzlukların önlenmesi de göz önünde bulundurulmalıdır. Nitekim erken kesimlerde besi sonu canlı ağırlığa ulaşılamadığından ekonomik bir kayıp söz konusu olabilir. Aksine geç kesimde ise yemden yararlanma oranının

azalması ile birlikte karkas yağ oranının artması, et kalitesi ve maliyetini olumsuz yönde etkileyebilir (Geletu ve ark., 2021).

Hayvanları hadım etme ve çevre, sığır etinin kalitesini ve miktarını etkiler. Hadım etme, kalite sınıfını iyileştirdiği için sığır etinin kalitesini önemli ölçüde etkiler. Hadım etme yöntemi (yarı hadım etme veya tam hadım etme) sığır etinin kalitesini ve miktarını etkiler. Danaları yarı hadım etme, tam hadım etmeye kıyasla daha yüksek et verimi üretir. Ayrıca, yarı hadım edilmiş sığırlar, hadım edilmemiş sığırlara kıyasla daha yüksek kas içi yağ içeriğine ve daha düşük kesme kuvvetine (daha yüksek yumuşaklık) sahip et üretirler (Baik ve ark., 2023).

Hayvanların gruplar halinde, birbirleriyle etkileşime girmeleri ve ilişki içerisinde bulunmaları kendi içlerinde baskın olan veya pasif olan hayvan gruplarının ortaya çıkmalarına neden olur. Sığırlarda, baskınlıkla ilgili etkileşimler stres, morluklar ve fiziksel yaralanmalara neden olur. Sığır besi yeri sistemleri; yemlik, suluk, gölgelik, dinlenme ve yatma yerleri gibi temel kaynaklara erişim açısından rekabet olan alanlar hayvanlar için rahatsızlıklara ve buna bağlı biyolojik maliyetlere neden olabilir. Bu da bu hayvanlardan elde edilecek etlerin kalitesinde problemlere sebep olabilir (Guerrero ve ark., 2013). Partida ve ark. (2007) ve Miranda de La Lama ve ark. (2009) sosyal baskınlık endeksine göre sınıflandırdıkları sığırlarda, hayvanların sosyal statüsünün karkas veya et kalitesi parametreleri üzerinde hiçbir etkisi olmadığını, ancak duyusal et kalite sonuçları bakımından biraz farklılık olabileceğini bildirmişlerdir. Baskınlıkla ilgili yapılan çalışmalardan elde edilen sonuçlar, işletmelerde hayvanları yaş, ırk, cinsiyet, ağırlık ve vücut boyutu gibi özellikler bakımından homojen gruplar oluşturulması gerektiğini göstermektedir.

Stresin nihai et kalitesi üzerindeki etkilerini anlamak için, kesimden sonra ette glikojen ve laktik asit ile pH düşüşü arasındaki ilişkiyi anlamak önemlidir. Et kalitesinin önemli belirleyicisi pH'dır. Kaliteli etlerde kesim sonrası 24 saat dinlendirildikten sonraki nihai pH değeri, genellikle 5.4–5.7 arasındadır. Bu değer canlı hayvanlarda 7.1'dir (Boztepe ve Aytekin, 2025). Sıcaklık veya soğuk stresi, özellikle kesimden hemen önce hayvanların fiziksel ve psikolojik durumları üzerinde farklı etkilere sahip olabilir ve bu da yüksek pH ve daha koyu, sert ve kuru bir et elde edilmesine sebep olabilir. Sıcak ortamlar vücudun ısı dağılımını bozabilir ve hayvan stresini artırabilirken, soğuk ortamlar ise kas titremesini artırabilir ve bu da kesim öncesi glikojen rezervlerini hızla tüketebilir. Hayvanların kışın kesilmesi, sert ortalama sıcaklıklar (-3.3 °C) ve düşük bağıl nem (%57.73) nedeniyle daha açık renkli ve daha yüksek pH'ya sahip et üretilmesine neden olabilir (Poveda-Arteaga ve ark., 2023).

Sığırlarda, yüksek ortam sıcaklıkları, deri altı depo yerine, iç depolarda daha fazla kas mermerleşmesi ve yağ birikimini destekleyebilir. Ancak, yüksek ortam sıcaklıkları aynı zamanda daha koyu renkli et üretilmesine de yol açabilir. Yapılan çalışmalarda ortalama günlük sıcaklığın 35 °C olduğu ülkelerde etlerin yaklaşık %60'ının koyu renkli olduğu belirlenmiştir (Gregory, 2010). Bu gibi yerlerde bölgeye adapte olmuş, sıcaklığa toleranslı olan hayvan ırkları yetiştirilmesinin yanında hayvanlar için gölgelikler oluşturulması koyu renkli et üretim sıklığını azaltabilir.

Metabolizmayı etkileyen çevresel faktörler hayvanlarda yağ birikimini etkileyebilir. Kronik ısı stresi durumunda hayvanlarda beta oksidasyon azalır ve lipit birikimini artar. Soğuk stresinde ise tam tersi bir etki söz konusudur. Yani hayvanlar vücut sıcaklığını korumak için daha fazla

enerji sağlamak amacıyla lipit oksidasyonunu arttırırlar (Schumacher ve ark., 2022). Dolayısıyla soğuk havalarda hayvanların enerji gereksinimleri artar. Hayvanlar bu enerjiyi hem metabolizmayı dinamik tutarak ısı üretmek hem de deri altında yağ biriktirerek fazla enerjiyi yalıtmak için kullanırlar. Bu nedenle kış aylarında beslenen hayvanların eti daha yağlı olur. Bitki örtüsünün bol olduğu ilkbahar ve yaz aylarında taze otlarla beslenen hayvanların etlerinin yağ asidi bileşimi ve rengi de farklılık gösterir. Hayvanların enerji metabolizması kış aylarında daha aktiftir ve bunun sonucunda salınan laktik asit etin pH'ını düşürerek rengini ve dokusunu etkiler. Ayrıca yaz aylarında aşırı sıcaklıklardan dolayı strese giren hayvanların eti de bu durumdan olumsuz etkilenmektedir (Kutay ve ark., 2024). Kuzu etinin yaz ve kış mevsimlerindeki özellikleri değerlendiren Miranda ve ark (2009) incelenen özellikler üzerinde mevsimin önemli etkileri olduğunu bildirmişlerdir. Kışın kesilen kuzuların eti, daha koyu renk, daha yüksek nihai pH, daha sert et ve daha düşük su tutma kapasitesine sahip olduğu belirlenmiştir.

Hayvanlar genel olarak soğuktan ziyade sıcaktan daha fazla strese girdiği görülmektedir. Sığırları 18 °C'den yüksek sıcaklıklarda kesime tabi tutmak, hayvanın ısı stresini arttırmada problemlere neden olabilir. Bu da etin daha koyu, daha sert ve daha kuru olma olasılığını artırabilir. Sığır eti renk değerlerini korumak için soğuk günlerde gereksiz stres faktörlerinden kesinlikle kaçınılmalıdır. Kesim öncesi koşullar, sıcaklık kaynaklı stresi azaltmak ve et rengini iyileştirmek için hayvanlara konforlu bir ortam sağlamalıdır (Poveda-Arteaga ve ark., 2023).

4.3. Besleme ile ilgili faktörler

Birçok durumda etin kimyasal bileşimi ve besleme değeri, hayvanların beslenme stratejileri ve besleme planları ile manipüle edilebilmektedir. Hatta rasyon değişiklikleri veya rasyona katkı maddesi ilavesi, etin bileşimi ve kalitesi üzerinde en derin etkilere sahip anahtar faktördür. Bu nedenle hayvan besleme bilim insanları karkas verimini ve randımanını iyileştirme gayretlerine ek olarak, et kalitesini de ön plana çıkaran, etkili hayvan besleme stratejileri geliştirebilir. Bu stratejiler insanların kaliteli ve güvenilir kırmızı ete ulaşmasına katkıda bulunabilir.

Hayvanlarda büyüme esas olarak kas hücrelerinin çoğalması ve büyümesi yoluyla gerçekleşmektedir. Bu hücrelerin oluşumu için proteine ihtiyaç vardır. Rasyonda kullanılan hammaddenin türüne ve miktarına bağlı olarak hem hayvanın performansı hem de etin kalitesi etkilenebilmektedir (Önenç ve Özdoğan, 2022).

Hayvanların beslenmesinde kullanılan yemler, etin renk, koku ve lezzet kalitesi üzerinde önemli etkilere sahiptir ancak etkileri et yağında daha belirgindir (Geletu ve ark., 2021). Besicilikte canlı ağırlık kazancı artırmak için rasyondaki kesif yem miktarının arttırılması, karkasta daha fazla yağ birikimine neden olmaktadır (Önenç ve Özdoğan, 2022; Schumacher ve ark., 2022). Vestergaard ve ark. (2000), kesif yem esaslı bir rasyonla beslenen danalarda merada beslenen hayvanlara kıyasla daha fazla yağlanma olduğunu bildirmiştir. Benzer şekilde Dıáz ve ark. (2002), kesif yem esaslı rasyonla beslenen kuzularda merada beslenen kuzulara göre daha fazla yağlılık sergilediğini belirlemişlerdir.

Et kalitesi üzerinde rasyonun kaba ve kesif yem içeriği de etkin rol oynamaktadır. Nitekim French ve ark. (2001), otla beslenen hayvanlardan elde edilen sığır etinin kesif yemle beslenen

hayvanlardan elde edilen etlere göre yumuşaklık, sululuk ve lezzet açısından daha düşük değere sahip olduğunu bildirmişlerdir. Diğer bir ifade ile araştırıcılar, kesif yemlerle beslenen hayvanların kaba yemlerle beslenen hayvanlara göre daha yumuşak ve daha iyi aromaya sahip et üretildiğini bildirmişlerdir.

Kutay ve ark. (2024) rasyonun enerji içerinin artması ile kaslar arasındaki yağ miktarının arttığını, bunun bir sonucu olarak etin sululuğu ve yumuşaklığının iyileşebileceğini ifade etmişlerdir. Buna ilaveten, danaların ot silajı ile beslenmeleri halinde karkasta yağlılığın arttığı, buna karşın silaj ve kesif yemle beslenen hayvanlarda yağlılığın azaldığı da ifade edilmektedir (Kutay ve ark., 2024). Rasyondaki temel besin bileşenlerinin dışında aromatik maddeler de etin duyusal özelliklerini değiştirir. Kekik ve biberiye gibi kuvvetli aromaya sahip bitkilerin etin tadını ve kokusunu iyileştirdiği bilinmektedir (Kutay ve ark., 2024).

Rasyonlara ilave edilen yem katkı maddeleri, kullanım amaçlarından bağımsız olarak, etin fizikokimyasal yapısında değişikliklere neden olabilmektedir. Bu konuda yapılan bir çalışmada (Ornaghi ve ark (2020) doğal katkı maddelerinin, et rengi ve su tutma kapasitesini etkilemediğini, ancak etin nihai pH değeri, tekstürü, yumuşaklığı, lipid oksidasyonunu ve genel kabul edilebilirliği önemli ölçüde etkilediğini bildirmişlerdir.

Hayvanları besleme planları et kalitesi üzerinde önemli etkilere sahiptir. Özellikle sütten kesim yaşı ve bakım-besleme uygulamaları et kalitesi üzerinde önemli etkilere sahiptir. Sakız ırkı kuzuları yapay süt ve doğal süt besleyen Simitzis ve ark. (2024), iki grup arasında pH, renk, su tutma kapasitesi ve kesme kuvveti değerleri gibi et kalite özelliklerinde önemli bir fark olmadığını ancak etin raf ömründe iyileşme olduğunu bildirmişlerdir. Benzer çalışmada Ripoll ve ark. (2019), oğlaklarda yapay süt ile beslemenin etin pH değerini artırdığı bu durumunda dokusal parametreleri değiştirerek kesme kuvvetini azalttığı ve yapışkanlığı artırdığı bildirmişlerdir. Pateiro ve ark. (2013) farklı yaşlarda sütten kesilerek 9-9.5 yaşa kadar standart besleme uyguladığı danalarda, sütten kesim yaşının etin kuru madde, protein ve kül değerleri bakımından farklılık olmadığı, ancak, erken yaşta sütten kesilen hayvanlarda kas içi yağ miktarının daha yüksek olduğunu bildirmişlerdir. Araştırıcılar, yedi aylık sütten kesilen hayvanların etlerinin diğer gruplara göre daha kırmızı ve daha yumuşak olduğunu bildirmişlerdir.

Ruminantların karkas ve et kalitesini etkileyen faktörlerden biriside üretim sistemleridir. Hayvancılıkta üç tip üretim sisteminden bahsedebiliriz. (1) Ekstansif üretim sistemi, (2) entansif üretim sistemi ve (3) yarı entansif üretim sistemi.

Ekstansif üretim sistemi meralarda otlatmayı ve hayvanların genellikle yeşil alanlarda büyümelerini ve bu geniş arazi alanındaki mevcut meralarda beslenmelerini içerir. Bu tip üretim sisteminde üretilen etlerin kalitesi bir bakıma meranın kalitesi ile ilişkilidir. Bu üretim sisteminde daha koyu renkli, daha yağsız ve daha iyi bir yağ asidi profiline sahip karkas elde edildiği değerlendirilmektedir (Santos ve ark., 2021). Bu da lezzet ve sağlık arasında denge arayan sağlık bilincine sahip tüketiciler için sığır etindeki en önemli özelliklerden biridir.

Entansif üretim sisteminde sığırların otlatılmadığı ve tamamıyla yoğun beslenmeye tabi tutulduğu bir sistemdir. Üretimin yoğunlaşmasıyla birlikte hayvan başına kullanılabilir alan azalmaktadır. Bu üretim sisteminde daha parlak et üretilmektedir. Bununla birlikte, ırk ve

genetik yapı da sığır eti renginde önemli bir rol oynar (Santos ve ark., 2021). Yoğun üretim sisteminin sağladığı daha yüksek enerjili bir rasyon, daha yüksek miktarda deri altı yağ ve kas içi yağ üretilmesini sağlar. Yağlanma süresi arttıkça, kas içi yağ birikimi de artar (Santos ve ark., 2021). Ayrıca yoğun olarak yetiştirilen sığır etinin yağ asidi profili de daha iyidir ve bu profil yem hammaddeleri tercihi ile iyileştirilebilir (Santos ve ark., 2021).

Yarı entansif üretim sistemi, hem ekstansif hem de entansif sistemleri birleştiren bir üretim sistemidir. Örneğin, hayvan büyümesinin ilk aşamasında mera beslemesine tabi tutulur, ardından hayvanların kesif yem ile beslendiği bir besi dönemi takip eder. Aynısı, hayvanın besi boyunca hem otlatılması hem de kesif yem ile beslenmesinin birlikte yapıldığı üretim için de geçerlidir. Bu besicilikte uygulanan en yaygın üretim sistemidir. Bunun birkaç nedeni vardır, özellikle meranın mevsimselliği, beslenme ihtiyaçlarını karşılamak için kesif yem kullanımını gerektirir. Bu sistemde üretilen etler daha açık kırmızı renkte, daha düşük lezzet yoğunluğunda, daha yağlı, daha yumuşak ve daha sulu etlerdir (Santos ve ark., 2021).

4.4. Kesim öncesi koşullar ve kesim sonrası uygulamalar

Hayvanlarda kesim öncesi stresin kaslardaki glikojen miktarını azalttığı, bunun sonucunda daha yüksek pH ve dolayısıyla daha koyu etin yanı sıra yumuşaklık, sululuk, lezzet, beğeni ve raf ömrü açısından daha düşük kaliteli etin oluşmasına yol açtığı iyi bilinmektedir (Santos ve ark., 2021). Kesim gönderilen hayvanlar yükleme, taşıma, ani ortam değişikliği, mevsim koşulları, açlık, susuzluk, yorgunluk gibi birçok faktörün etkisiyle stres yaşamaktadır. Hayvanlarda özellikle rutin taşıma, kesimhane ağıl ortamı koşulları ve kesim operasyonları sırasında işçilerin veya diğer hayvanların yaptığı sesler ve hareketlere karşı duyarlılık artabilir. Hayvanlarda stresin oluşturduğu olumsuzlukları önlemek açısından, kesim öncesi aynı grupta barındırılan hayvanları aynı partide nakletmek önerilmektedir (Poveda-Arteaga ve ark., 2023).

Hayvanın kesim öncesi strese girmesi glikojen rezervlerinin azalmasına laktik asit oluşumunun kısıtlanmasına, etin pH değerinin yükselmesine koyu kesiklere yol açabilecek olan enzimlerin, kortizollerin ve katekolaminlerin hızlı bir şekilde salınmasını neden olmaktadır. Stres sonucu etin duyusal kalitesi ve kimyasal birleşiminde meydan gelebilecek olan olumsuzluklar tüketici tarafından memnuniyetsizlikle sonuçlanır. Özellikle hayvanların kesim yerine nakilleri esnasında oluşan stres, kesim padoklarında kalış süresi ve padokta maruz kaldıkları istenmeyen davranışlar bu hayvanlardan elde edilen etlerin özellikle renklerinde olumsuzluklara neden olmaktadır (Poveda-Arteaga ve ark., 2023).

Kesim sırasında sığırlara, elektrikle veya darbeli sersemletme uygulandığında, etin glikojen konsantrasyonları arasında farklılık olsa bile, et rengi, 24 saat sonraki pH değeri, su tutma kapasitesi ve pişirme kaybı bakımından sersemletilmeyen hayvanlara göre daha iyi sonuçlar verdiğini bildirmişlerdir Önenç ve Kaya (2004).

Taşıma ve bekletme sırasında hayvanların rastgele karıştırılması, koyu, sert ve kuru karkas elde etme olasılığını artırabilir. Aksine hayvanları yetiştirildikleri sosyal gruplarda tutmak etlerin rengini iyileştirebilir. Uzun taşıma ve uzatılmış bekletme süreleri, sığırların glikojen rezervlerini önemli ölçüde azaltabilir ve bu hayvanların etinde daha düşük L^*, a^* ve b^* değerleri oluşturabilir. Ancak, hayvanların uzun mesafeler boyunca taşınması gerekiyorsa,

glikojen rezervlerinin kesimden önce yenilenebilmesi ve et kalitesi sorunlarının en aza indirilebilmesi için yeterli ölçüde yem ile uzun ve sessiz bir bekletme önerilmektedir. Kesimhane operasyonlarını, hayvan refahını ve et rengini optimize etmek için sığırlarla doğrudan temas halinde olan çalışanlara hayvan işleme hakkında basit ve sürekli bir eğitim programı da sağlanmalıdır. Ek olarak, koyu, sert ve kuru karkas riskini azaltmak için sersemletme işleminin hassas bir şeklide ve yalnızca eğitimli personel tarafından yapılması gerekir (Poveda-Arteaga ve ark., 2023).

Kesimden sonra ette meydana gelen kimyasal olaylar sıcaklıkla birlikte daha hızlı gerçekleşir. Etin kimyasal yapısını etkileyen enzimler sıcaklığa duyarlıdır ve karkasın hızla soğutulması bu enzimlerin aktivitesini yavaşlatacaktır. Ayrıca bu işlem mikroorganizmaların aktivitelerini sınırlayacağı için besin madde kaybını ve renk değişimini de azaltacaktır (Kutay ve ark., 2024). Karkasların uzun süre bozulmadan saklanması insan sağlığı açısından önemlidir. Etler genellikle 4 °C'de saklanır. Ancak kesimden sonra karkas sıcaklığını hızla bu dereceye düşürmek etin yapısına zarar verebilir. Bu tip zarar gören etler daha serttir, tadı kötüdür ve yüksek su kaybına sahiptir (Kutay ve ark., 2024). Etleri dondurarak saklama etin yumuşaklığını artırabilir ancak bu durum su tutma kapasitesi, renk ve lezzet gibi et kalite parametreleri üzerine olumsuz etkiler meydana getirebilmektedir. Dondurarak saklama yönteminin et kalitesi üzerinde etkisi, dondurma oranı, depolama sıcaklığı ve süresine bağlı olarak değişen kristalleşme boyutu ve dağılımına göre değişmektedir (Kutay ve ark., 2024). Derin dondurma ve depolama sıcaklığının (–50 °C, –60 °C ve –80 °C) kuzu etinin kalitesi ve tazeliği üzerine etkisini araştıran Choi ve ark. (2018), derin dondurmada, normal dondurmaya göre daha az sızdırma olduğunu bildirmişlerdir. Muela ve ark. (2015), kuzu etlerinde depolama süresi ve teşhir süresi arttıkça et kalitesinde genel bir düşüş olduğunu bildirmişlerdir.

Tüketiciye sunulmak üzere hazırlanan ete uygulanan işlemler etin özelliklerini etkileyebilir. Fiziksel elektriksel uyarım, kuru dinlendirme, kuru kürleme, yüksek basınçla işleme işlemleri uygulanırken; kimyasal fermantasyon, tütsüleme, kürleme ve marine etme gibi teknikler kullanılır. Ete uygulanan elektriksel uyarım gevrekliği, etin rengini, tadını ve kokusunu iyileştirir; mermerleşmeyi daha belirgin hale getirir, olgunlaşma süresini kısaltır ve raf ömrünü uzatır (Kutay ve ark., 2024). Etleri kuru kürleme domuz etinin sindirilebilirliğini kötüleştirirken; sert, buruşuk, koyu kahverengi ete neden olur. Yüksek basınçla işleme besin değerlerini kaybetmeden etin sindirilebilirliğini ve dokusunu iyileştirirken kuzu etinde kararmaya neden olur. Etin fermente edilmesiyle oluşan alkol, ketonlar ve aldehitler belirli bir aroma sağlar (Kutay ve ark., 2024).

Kesim sonrası işlemlerden birisi olan paketleme sistemleri üzerine Kowalczyk ve ark. (2024) yürüttüğü çalışmada dana etlerini vakumlu paketlemenin modifiye atmosfer paketlemeye göre önemli ölçüde daha düşük lipid oksidasyon değeri gösterdiği ve daha yüksek yumuşaklığa sahip olduğu bildirmişlerdir. Benzer şekilde Berruga ve ark. (2005) vakumla paketlenen kuzu etinin, modifiye atmosfer altında paketlenen ete göre istenilen duyusal özellikleri daha iyi koruduğu ifade etmişlerdir.

Hayvan vücudunda aşırı çalışan kaslar daha fazla kasıldıkları için daha sert hale gelir. Ruminant hayvanların ön kolları ve arka bacakları daha fazla çalıştıkları için diğer kısımlara nazaran daha sert bir yapıya sahiptir. Ancak, memelilerde sırttaki en az aktif kas olan M. longissimus dorsi,

en yumuşak yapıya sahip kaslardır (Kutay ve ark., 2024). Bu kasta biriken kas içi yağ miktarı mermerleşme olarak bilinir. Mermerleşme karkas kalitesinin önemli bir belirleyicisi ve lezzetin öngörücüsü olup kas sıkılığı, lezzet ve sululuk ile yakından ilişkilidir. Et kalitesinin değerlendirilmesinde çok önemli bir faktördür. Pişirme sırasında eti suyla dolduran yağlı katmanlar nedeniyle sululuk ve yumuşaklık gibi lezzet özelliklerini etkiler (Geletu ve ark., 2021).

4.5. Güven kalite özellikleri

Ette mikroorganizma varlığı ve seviyesi taze et için en önemli güven kalite özelliğidir. Etlerde güven ayrıca fiziksel ve kimyasal kalıntılar, gıda katkı maddeleri ve et ürünlerinin hayvansal olarak tanımlanmasını da içerir. Genel olarak tüketiciler et güvenliğini, etin bozulmasının en hızlı göstergeleri olan görsel ve koku değerlendirmeleriyle değerlendirirler. Ancak bunlar güvenilir göstergeler değildir. Etin bakteriyel patojenlerin taşıyıcısı olarak önemi halk sağlığı açısından önemlidir. Bu nedenle, birçok ülkede etin işlenmesinde çok sıkı güvenlik uygulamaları geliştirilmiştir. Tehlike Analizi Kritik Kontrol Noktası (HACCP) sistemi, et zinciri içindeki et güvenliği yönetim sisteminin temelini oluşturur (Geletu ve ark., 2021).

Geçmişte, kaliteli et denildiğinde, et ürünlerinin duyusal algıları, tazeliği ve güvenilirlik yönleriyle daha yakından ilişkiliyken, son zamanlarda insan sağlığıyla ilgili beslenme, refah ve işlevsellikle ilişkilendirilmektedir. Sonuç olarak, tüketiciler ette bulunan yüksek yağ ve kolesterol içeriğini istenmeyen ve sağlıksız olarak görebilirler. Ancak et zengin bir protein, esansiyel amino asit, mineral ve vitamin kaynağı olduğu için besleyicidir (Geletu ve ark., 2021).

Son yıllarda tüketicilerin etin nasıl üretildiğine ilişkin endişelerinde önemli bir artış olmuştur. Hayvan refahı konusundaki endişeler dünya çapında büyük ölçüde artmıştır ve hayvanların 'organik' yetiştirilmesinde önemli bir gelişme olmuştur. Tüketiciler, hayvanların insani koşullar altında yetiştirilmesini, taşınmasını ve kesilmesini talep etmektedir. Ayrıca, tüketiciler satın aldıkları etin etik açıdan sağlam üretim sistemlerinden elde edildiğinden emin olmak istemektedir. Sonuç olarak, çiftçilerin, veteriner hekimlerin, paketleyicilerin ve bilim insanlarının çiftlikte ve kesim tesisinde hayvan refahının nasıl değerlendirileceği ve denetleneceği konusunda daha fazla bilgi sahibi olmaları gerekmektedir.

5. SONUÇ

Et, insanların sağlıklı ve dengeli beslenmesi için gerekli olan temel besin maddelerinin önemli bir kaynağıdır. Et kalitesini etkileyen faktörlerin bilinmesi etin kaliteye göre değerlendirildiği ülkelerde hem üreticiler hem de tüketiciler açısından önemli hale gelmiştir. Tüketicilerin kırmızı et alırken dikkat ettikleri duyusal kalite parametreleri, et rengi, görünüm, görsel yağ miktarı, fiyatı, hangi hayvandan elde edildiği, varsa markası ve görsel sunumudur. Tüketim sırasında ise yumuşaklık, lezzet ve sululuk gibi kalite parametreleri ön plana çıkmaktadırlar. Dolayısıyla kaliteyi etkileyebilecek tüm değişkenler hakkında bilgi sahibi olan bir tüketici kırmızı et alım tercihlerini kolaylıkla değiştirebilmektedir. Et kalitesini etkileyen faktörler bir bütün olarak değerlendirildiğinde, kaliteli ürün elde edebilmek için ahırdan sofraya kadar üretim zincirinin her aşamasında üretim ve işleme prosedürlerine titizlikle uyulması gerekmektedir.

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EXAMINATION OF THE LANDSCAPE POTENTIAL OF WITHIN THE SCOPE OF RURAL TOURISM ACTIVITIES IN SAVCILI BÜYÜKOBA (KIRŞEHİR/KAMAN) VILLAGE

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ABSTRACT

Savcılı Büyükoba Village, located in Kaman district of Kırşehir province, is a village with significant potential in tourism and agriculture. It is one of the villages bordering the Hirfanlı Dam Reservoir among the villages of Kaman district. It is one of the border places of Hirfanlı Dam Reservoir among the villages of Kaman district. It also stands out with its active agricultural activities throughout the province and district.In addition, it has been observed through previous studies that there is a high demand for the village to eliminate the picnic and recreation needs in the summer throughout the province and district.The local people's perspective on tourism is positive. When we look at the village in general: The presence of water due to its border with the Hirfanlı Dam, the microclimatic climate feature due to its south-facing position, the presence and diversity of its agricultural potential, the fact that its population structure is young and crowded compared to other villages and towns, highlight the existence of the village's rural tourism potential. Within the scope of rural tourism activities and potential, the current situation in the village is investigated, promoted and developed. It is aimed to reveal and promote the rural landscape potential of Savcılı Büyükoba village with correct, sustainable tourism and recreation plans. It is aimed to bring cultural landscape values to the village through rural tourism activities from non-agricultural economic activities and to reduce the migration effect. It is aimed to reveal the rural landscape features of Savcılı Büyükoba village depending on rural tourism activities, to provide economic investments with new job opportunities and to increase the contribution of the village to the provincial and district economy. The main material of the study is the borders of Savcılı Büyükoba Village and its rural tourism potential. As a method, it includes literature review, study area visits, photo shooting, field synthesis, data collection and evaluation stages.

As a result; Savcılı Büyükoba Village has an important place in our Kaman district and the province in terms of both rural tourism and agricultural potential. With this study, the rural landscape potential of the village was transformed into rural tourism activities and its gains were revealed.

Keywords: Kaman, Savcılı Büyükoba, rural tourism, landscape

KIRSAL TURİZM FAALİYETLERİ KAPSAMINDA SAVCILI BÜYÜKOBA (KIRŞEHİR/KAMAN) KÖYÜNÜN PEYZAJ POTANSİYELİNİN İNCELENMESİ

ÖZET

Kırşehir ili Kaman ilçesinde bulunan Savcılı Büyükoba Köyü, turizm ve tarımda önemli bir potansiyele sahip köyüdür. Kaman ilçe köyleri arasında Hirfanlı Baraj Göletine sınır köylerden biridir. İl ve ilçe genelinde aktif olarak zirai faaliyetleri ile de ön plana çıkmaktadır. Ayrıca il ve ilçe genelinde yazın piknik ve rekreasyon ihtiyaçlarının giderilmesi için köye yoğun bir talebin olduğu daha önce yapılan çalışmalar ile gözlemlenmiştir. Yerel halkın turizme olan bakış açısı olumludur. Genel olarak köye baktığımızda: Hirfanlı Barajına sınır oluşu ile su varlığı, tarımsal potansiyelinin varlığı ve çeşitliliği, güney bakarlı olmasıyla mikroklimatik iklim özelliği, nufüs yapısının diğer köy ve kasabalara göre kalabalık ve genç oluşu köyün kırsal turizm potansiyeli varlığını ön plana çıkarmaktadır. Kırsal turizm faaliyetleri ve potansiyeli kapsamında köydeki mevcut durum araştırılarak, tanıtılması ve geliştirilmesi hedeflenmektedir. Savcılı Büyükoba köyünün kırsal peyzaj potansiyelinin doğru, sürdürülebilir turizm ve rekreasyon planlamaları ile ortaya çıkarılması ve tanıtılması amaçlanmıştır. Kültürel peyzaj değerlerinin tarımdışı ekonomik faaliyetlerden kırsal turizm faaliyetleriyle köye kazandırılması ve göç etkisinin azalması hedeflenmiştir. Kırsal turizm faaliyetlerine bağlı olarak Savcılı Büyükoba köyünün kırsal peyzaj özelliklerinin ortaya çıkarılması ile yeni iş olanaklarıyla ekonomik yatırımların sunulması ve köyün, il ve ilçe ekonomisine katkısının arttırılması amaçlanmıştır. Çalısmanın ana materyalini Savcılı Büyükoba Köyü sınırları ve kırsal turizm potansiyeli oluşturmaktadır. Yöntem olarak; literatür taraması, çalışma alanı ziyaretleri, fotoğraf çekimleri, alan sentezi, ve verilerin toparlanması, değerlendirme aşamalarını kapsamaktadır.

Sonuç olarak; Savcılı Büyükoba Köyü, Kaman ilçemizde ve ilde gerek kırsal turizm gerekse tarım potansiyeli olarak önemli bir yere sahiptir. Yapılan bu çalışma ile köyün kırsal peyzaj potansiyelinin kırsal turizm faaliyetlerine dönüştürülerek kazanımları ortaya konmuştur.

Anahtar Kelimeler: Kaman, Savcılı Büyükoba, kırsal turizm, peyzaj

1. GİRİŞ

Kırsal alanlar, kent yaşamının stresinden bunalan insanların en çok tercih ettiği doğaya dönük alanların başında gelmektedir. Kırsal alanlarda gerçekleştirilecek rekreasyon ve turizm etkinlikleri doğayla uyumlu, bütünleşik ve sürdürülebilir olmalıdır. Diğer türlü kırsal alanlarda bazı olumsuz etkilerin oluşması söz konusudur. Bu etki sadece o alanda değil aynı zamanda yerli ve yabancı faydalanıcıların kırsal turizm deneyim kalitelerini etkileyecektir. Bu nedenle kırsal alanlarda gerçekleştirilen turizm ve rekreasyon etkinliklerin alanın kırsal ekolojisine uyum sağlaması gerekir.

Kırsal alanları koruma ve kullanma dengesinin kurulabilmesi ancak sürdürülebilir turizm ve rekreasyonel planlama ile mümkündür. Kentsel veya kırsal alanların birbirinden farklı doğal, ekolojik ve sosyo-kültürel yapıları, planlama aşamalarında iyi analiz edilerek ortaya konulmalıdır. Her alanın kendine özgü değerleri korunarak ve geliştirilerek ortaya çıkarılmadır. Bu nedenle uygulanacak turizm ve rekreasyon planlama çalışmalarında alanın ekolojik, kırsal özellikleri, turizm ve rekreasyon talep ve gereksinimleri ile kaynak potansiyelleri ortaya çkarılmalıdır. Bu araştırmada; Kırşehir ili içinde gerek tarımsal faaliyetleri gerekse Hirfanlı Barajı varlığı ile turizm, rekreasyon kapasitesi olan Savcılı Büyükoba Köyünün kırsal peyzaj potansiyeli araştırılmıştır.

Literatür özeti

Bu yayın; Duran Gökalp (2016) tarafından yayınlanan “Savcılı Büyükoba Örneğinde (Kaman/Kırşehir) Kırsal Peyzaj Özelliklerinin Kırsal Kalkınma Açısından Araştırılması” doktora tezinden üretilmiştir.

Peyzaj “doğa, insan, kültür gibi çevreye ilişkin tüm canlı ve cansız materyalleri ekolojik amaçlar doğrultusunda değerlendiren, çevreyi korumayı, doğayı insan yaşamına ve yaşam ortamlarına adapte etmeyi amaçlamıştır” (Yazgan, 2014: 30)

Kırsal peyzaj; İnsanın doğa içinde, kentsel amaçları dışındaki çeşitli uğraşlarını sürdürdüğü çevrenin genel görünümüdür. Bu uğraşılar daha çok tarımsal olabileceği gibi, sanayi ile ilgili yada rekreasyonel olabilir. Uğraşı amaçlarına göre, doğa ile ilişkileri dengeli yada dengesiz sonuçlar ortaya koymaktadır (Koç ve Şahin 1999).

Kırsal turizm kavramı genel olarak tüm turizm türlerini içerisinde barındırmaktadır. Doğal alanlarda, az nüfus yoğunluğu olan yerleşimlerde ve ormancılık, tarım ve geleneksel uğraşlarla turizm aktivitelerinin ilişkili olduğu alanlarda yapılmaktadır.

Kırsal turizm "yerel halkın geleneklerini ve yaşam biçimlerini tanımak, kırsal karakterdeki aktivitelere katılmak, kültürel ve tarihi çevreyi tanımak amacıyla kırsal alanlara yapılan seyahat" olarak tanımlanabilir (Blangy ve Vautier 2001).

Kırsal turizm, doğal kaynaklar, kültürel miras, kırsal yaşam tarzı ve yerel ekonomik etkinliklerle bütünleştirilmiş bir turizm türüdür. Öyle ki kırsal turizmin gerçekleştirildiği kırsal alanlar sahip oldukları kültürel peyzaj özelliklerinin yanı sıra doğal peyzaj elemanların sayısı ve çeşitliliği (su, vista, topografya, bitki örtüsü, temiz hava vb.) ile de her türlü rekreasyonel faaliyetler için uygun ortamlardır. Bu nedenle doğal varlıklar kırsal turizme hammadde oluşturmakta olup, aynı zamanda

da insanların seyahatlerini yönlendiren çekici bir güçtürler (Kiper, Özyavuz ve Korkut,2011, 22).

2. MATERYAL VE YÖNTEM

Bu çalışmanın ana materyalini; Kırşehir İli Kaman İlçesi Savcılı Büyükoba Köyü sınırları içinde kalan alanın kırsal turizm ve peyzaj potansiyeli oluşturmaktadır. Yöntemi; veri toplama ve toplanan verilerin analiz edilerek değerlendirilmesidir. İller Bankası'ndan (2011) elde edilen araştırma alanı sayısal haritası ArcGIS 10.1 ortamına aktarılarak turizm haritası elde edilmiştir.

3. GELİŞME

Köyün coğrafi konumu ve yerleşimi

Kırşehir ili Kaman ilçesinde bulunan Savcılı Büyükoba köyü Kaman ilçesine 16 kilometre, il merkezine ise 58 kilometre uzaklıkta yer almaktadır. Köy 1946-1971 yılı arasında Bucak Merkezi, 1971-2004 yılları arasında Belediye olarak hizmet vermiştir. Fakat nüfusu 2000 altında olduğu için 30 Mart 2014 yerel seçiminden sonra 6360 sayılı yasanın geçici 2. maddesi gereği yeniden köy olmuştur. Köyün toplam sınır alanı:

- Mücavir Alanı: 52,137 da
- Yüzölçümü: 36.999 km²
- İmar Alanı: 15,000 da'dır.

Şekil 1. Köyün uydu görüntüsü yeri ve Türkiye'deki konumu

Köy sınırları içinde kalan kırsal peyzaj özellikleri rekreasyon ve turizm açısından potansiyeli incelendiğinde, Savcılı Büyükoba köyü araştırma alanı olarak belirlenmiştir. Bu potansiyeller;

- Hirfanlı Baraj Gölü ile su varlığı
- Ulaşım-erişilebilirlik
- Tarımsal peyzaj özellikleri

- Sosyo-kültürel değerleri
- Topoğrafik özellikleri
- Jeolojik (Granit taş) oluşumlardır.

Şekil 2. Savcılı Büyükoba köyünün genel görüntüsü

Köyün arazi varlığı

Köyün arazi varlığı alanları ve kullanımı çizelge 1'de yer almaktadır.
Çizelge 1. Arazi varlığı (Anonim 2014)

KÖY ADI	TARLA	MER'A	BAĞ BAHÇE MEYVE	YERLEŞİM ALANI	MEZARLIK OKUL CAMİ	YOL	TOPLAM
S.Büyükoba (da)	32.396,74	2.517,00	3.164,96	169,22	38,52	70,00	38.356,44

Çizelge 1'de köyün 32.396,74 da tarım alanıdır. Bağ bahçe alanı 3,164 da, mera alanı 2517 da olup, toplam arazi valığı 38.356,44 da'dır.

Köyün arazi kullanım biçimi

Ekonomik yaşamda temel ekonomik aktivite % 82,27'lik istihdam payıyla tarım ve hayvancılıktır. Köy hanesinin % 75'inin işleyeceği toprağı vardır. Hanelerin arazi büyüklüğü en fazla 1100 dekar, en az arazi büyüklüğü ise 3 dekar olmuştur. Köyde hane başına ortalama arazi büyüklüğü 50 dekardır.

Köyde uygulanan münavebe şekli ilk yıl arpa-buğday, ikinci yıl nadas (ayçiçeği-nohut) olmaktadır. Sulu tarım alanlarında ise sebzecilik, bağcılık ve meyvecilik ön plandadır. Köyün arazi kullanım biçimi çizelge 2'de verilmiştir.

Şekil 3. Köyün tarımsal faaliyetler görüntüsü (Orijinal 2015)

Çizelge 2. Arazi kullanım biçimi (Anonim 2014)

S.Büyükoba Arazi Kullanım Biçimi	
Arazi Kullanımı	**Dekar (da)**
Hububat	16650
Endüstri Bitkileri	500
Baklagil	950
Tarla Toplam	**18100**
Ceviz	870
Elma	31
Vişne- Kiraz	24
Meyveler(Diğer)	110
Meyve Toplam	**1035**
Domates	80
Patlıcan	120
Biber	20
Hıyar	80
Sebzeler (Diğer)	690
Sebze Toplam	**990**
Bağ	220
Karpuz-Kavun	350
NADAS	11701
TOPLAM	**32396**
ÇAYIR-MERA	**2517**

Köyün yöresel tatları

Köyün yöresel yemek kültüründe bölgesel tatlar bulunmaktadır. Çizelge 3'te yöresel tatları ayrıntılı olarak verilmiştir. Ayrıca yetiştirilen yaş meyve ve sebze mahsullerinin kurutulması hemen hemen her hanede yapılmaktadır. Evde yapılan salça, üzüm pekmezi, bulgur, kurutulmuş sebze ve meyve türleri bu ürünler arasındadır.

Çizelge 3. Yöresel lezzetler (2014)

Yemekler	Hamur İşleri	Tatlılar
• Besmeç • Yeşil Domates Kavurması • Sazan Balığı • Çılbır • Ekirli Pilav • Soğuk Aş • Tane Kavurma	• Kömbe • Yufka Ekmek • Baklava • Su Böreği • Lelek • Basmaç	• Aside • Pekmez • Pelise • Hoşaf • Kurtulmuş Meyveler

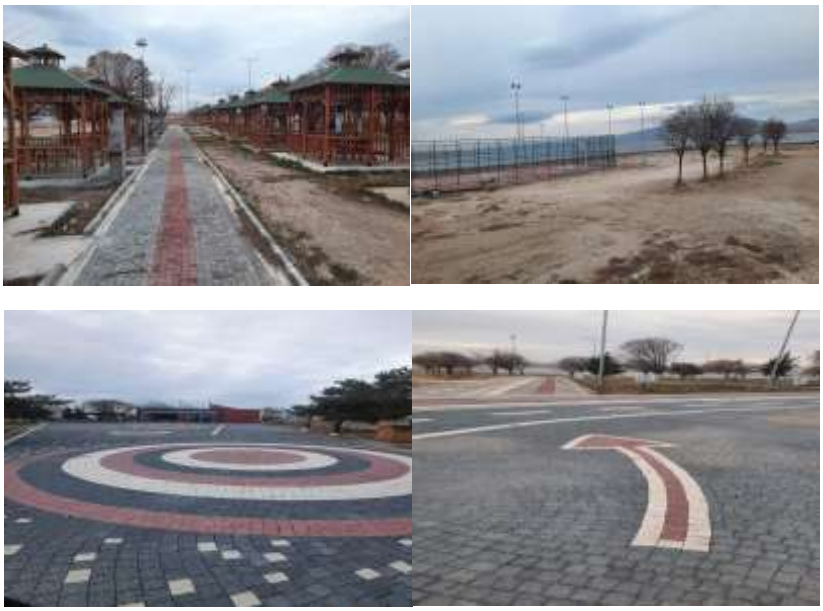
Köyde yapılan çalışmalar (Duran Gökalp, 2016)

Köyün rekreasyon ve turizm alanları

Kavram olarak turizm köy için bilinen bir kavramdır. Köyün konum olarak Hirfanlı Barajı gölüne kıyısının olması nedeniyle rekreasyon faaliyetleri yapılmakadır (Şekil 4).

Şekil 4. Köy baraj kıyısının eski hali (Orjinal 2015)

Köydeki turizm faaliyetleri il içinde bilinmekte ve yetkili kurumlarında gündeminde olmaktadır. Bu nedenle 2024 yılında İl Valilik bütçesi ile köyün su kenarında çevre düzenleme, piknik alanları, spor tesisi, restoran-kafe yapılarak kullanıcıların hizmetine yeniden açılmıştır (Şekil 5).



Şekil 5. Köy baraj kıyısının yenilenmiş hali (Orjinal 2024)

Çizelge 4. Köyün kırsal peyzaj değerleri

Doğal peyzaj özellikleri				Tarihi değer		Spor olanakları			Yemek kültürü		
Su varlığı	Yaban hayatı	Tarımsal doku	Kükürtlü su kaynağı	Sualtı tarihi varlığı	Öküztaşı (taşınmış)	Su sporları	Doğa yürüyüşü	Amatör balıkçılık	Gastronomik lezzetler	Hamur işleri	Geleneksel tarımsal ürünler

Yerinde yapılan çalışmalar (Duran Gökalp, 2016)

- **Turizme yönelik konaklama**

Turizm faaliyetleri genellikle günübirlik rekreasyon aktiviteleri için kullanıldığından konaklama ihtiyacı olmamaktadır. Ayrıca il ve ilçe merkezine köyün yakın olması nedeniyle konaklama ihtiyacı geri planda kalmaktadır. Köyde pansiyon yoktur. Ancak baraj kıyısında kamp alanları planlanabilir.

- **Hamam**

Köyün içinde hamam olarak kullanılan doğal kükürtlü su kaynağı bulunmaktadır. Su kaynağı kükürtlü olup belli bir noktadan çıkmaktadır. Jeotermal suyun sıcaklığı MTA tarafından yapılan ölçümlerle 19–34,5 ºC ve 5.5 lt/sn debi akışkanlık ile el yakmayan derecededir (mta.gov.tr.

Erişim tarihi: 08.09.2024). Köy halkı hamamı: çamaşır, halı-kilim yıkama yeri ve yıkanma ihtiyaçlarını gidermek için kullanmaktadır. Yapılan incelemelerde hamamın bakımsız olduğu yerinde görülmüştür.

Şekil 6. Hamam (Orjinal 2024)

- **Delikli taş**

Kayalık alanda iklim şartları nedeniyle kendiliğinden oluşmuş üst üste iki delikli parçadır. Köyde yaşayan halk tarafından dilek dileyerek taş içinden geçilince dileğin gerçek olacağına inanılır. Ancak köy dışında çok fazla bilinmemektedir (Şekil 7).

Şekil 7. Delikli taş (Orjinal 2015)

- **Hirfanlı Baraj Gölü (Kırşehir) Turizm Merkezi Sınırı**

25687 sayılı ve 31.12.2004 tarihinde Kültür ve Turizm Bakanlığı'nın Resmi Gazetedeki 2004/ 8321 sayılı Bakanlar Kurulu Karar ile, Hirfanlı Barajı'nın kıyı kenarının büyük bir bölümü turizm merkezi olarak ilan edilmiştir. Savcılı Büyükoba köyünün Hirfanlı Baraj Gölü Turizm Merkezi sınırları içinde kalan kısmı, doğal ve kültürel peyzaj varlığı olarak kırsal turizm için büyük bir potansiyel oluşturmaktadır.

Tuz gölünün kuzey doğusundan geçen ve Kızılırmak nehri üzerinde bulunan büyük bir baraj gölüdür. Hirfanlı Barajı Turizm alanın eni 13 km, uzunluğu 75 km'dir (Anonim 2007).

Şekil 8. Hirfanlı barajı sınır çizgisi (Anonim 2011)

Gölette farklı balık türleri yetiştirilmektedir. Bu balıklar; sazan, kefal, kaya, gümüşbalığı ile kepenek türleridir. Balık lokantası kültürü de vardır. Göl suyu tatlı olduğu için tatlı su balıkları yaşamaktadır. Kaman'a 19 kilometre uzaklıktaki tesislere günübirlik ulaşım mümkündür. Su, kumsal, balık varlığı ile bölge insanının deniz ve plaj özlemini azda olsa karşılama durumundadır.

Şekil 9. Savcılı Büyükoba köyü Hirfanlı Barajı kırsal turizm aktiviteleri

Köyden Hirfanlı Barajı kıyısı rekreasyon alanlarına uzaklık 5 km'dir. Bu alana ulaşım yolu asfalt ve kolaydır. Su varlığından köy halkı yüzme, piknik, dinlenme, tarım ve balıkçılık, sulama faaliyetleri ile fayda sağladıklarını yapılan toplantılarda söylemişlerdir (Şekil 9). Su varlığı Hirfanlı Baraj kıyısında sınırı olan tüm köyler ile ortak kullanım alanları bulunmaktadır.

3. SONUÇ

Savcılı Büyükoba Köyü, Kaman ilçemizde ve ilde gerek kırsal turizm gerekse tarım potansiyeli olarak önemli bir yere sahiptir. Yapılan bu araştırma ile köyün kırsal peyzaj potansiyelinin varlığı sürdürülebilir kırsal turizm faaliyetlerine dönüştürülerek kazanımları ortaya konmuştur.

Değerlendirme analizlerine göre; Savcılı Büyükoba köyünün tarımsal ve turizm açısından zengin bir çerçeveye sahip olduğu görülmüştür. Mevcut kırsal turizm potansiyel unsurları

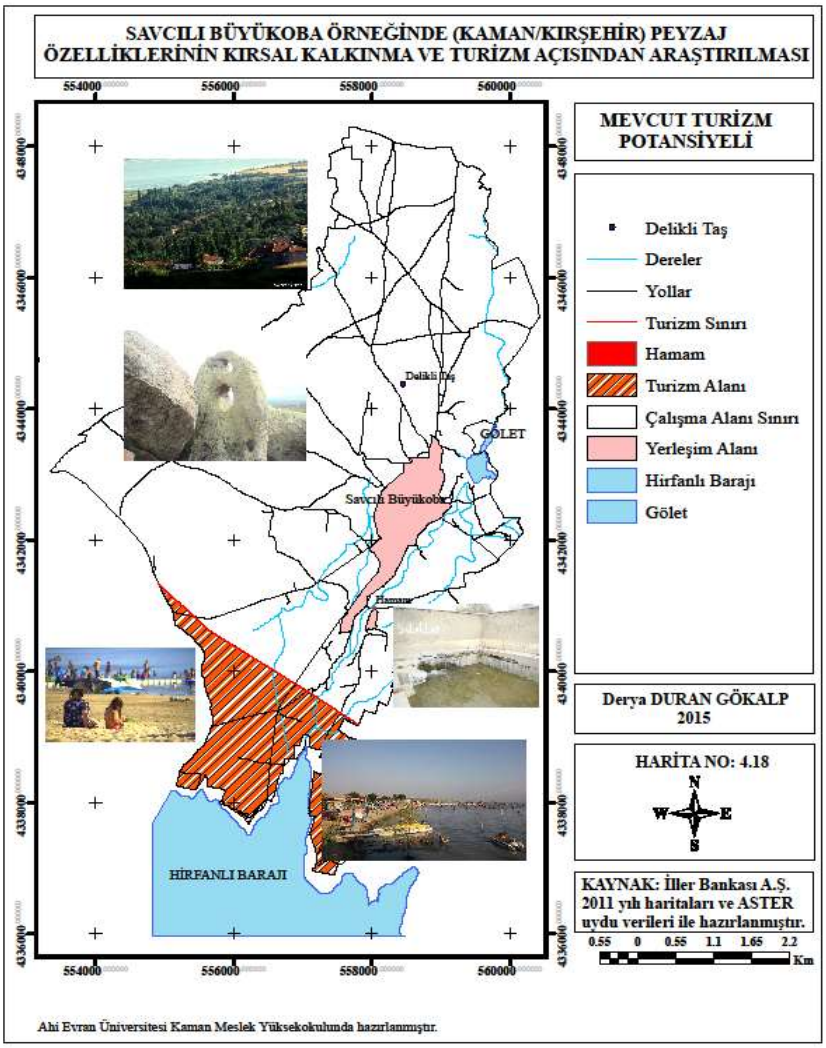
Harita 4.18 de ortaya konulmuştur. ArcGIS ortamında oluşturulan haritanın araştırma alanını tanımak, bilgi edinmek isteyen yerel halk ve turistlere öncülük etmesi planlanmıştır.

Savcılı Büyükoba Köyü'nde

- Tarımsal ürün deseni ve üretim potansiyeli,
- Yeşil alan varlığı,
- Su varlığı (Hirfanlı Barajı, Gölet, Hamam)
- Rekrasyon alan varlığı,
- Jeolojik yapısı ve granit taş varlığı,
- Turizm alanı olması,
- Köy halkının kırsal turizm faaliyetlerini benimsemesi kırsal turizm potansiyelinin ve uygulanabilirliğini ortaya koymaktadır.

Savcılı Büyükoba köyünde gerçekleştirilecek olan planlı kırsal turizm faaliyetlerine köyde özellikle su kenarında yapılması ile olumlu ve sıcak bakmaktadır. Köyde yaşayan yerel halka göre turizm; tatil yapmak, gezmek, bir yerden başka yere gitmek, denize girmek, piknik yapmak, eş-dost ziyareti gibi faaliyetleri tanımlamaktadır.

Kumsal olması nedeniyle yerel halk ve kullanıcılar tarafından kıyı kenarı plaj olarak adlandırılmaktadır. Plajda, piknik alanları restoran, spor sahaları ile günlük ihtiyaçların karşılanabileceği alanlar yer almaktadır. "Bozkırın plajı" olarak bilinen Savcılı Büyükoba`ya yetkililer ile yapılan görümeler neticesinde yılda yaklaşık olarak 30 bin araç giriş yapmaktadır.



Şekil 10. Mevcut turizm potansiyeli haritası (Duran Gökalp, 2016)

Harita 4.18'e göre Savcılı Büyükoba Köyü araştırma alanının mevcut turizm potansiyeli incelendiğinde; Delikli taş, Hamam gibi turizm potansiyeli olan noktaların coğrafi yerleri işaretlenmiştir. Köyün yerleşim alanı sınırları taranarak alan içindeki konumu belirlenmiştir. Ayrıca Hirfanlı Baraj Gölü Turizm Alanının, Savcılı Büyükoba Köyü sınırı içine giren alanı taralı olarak, turizm faaliyetleri de görsel olarak gösterilmiştir. Göletin konumuda sınır içinde konumlandırılmıştır. Araştırma alanı içinde bulunan yollar, dereler ve sınırlar çizgi olarak gösterilmiştir.Kırsal alanların planlanmasında; yerel halkın, turizm potansiyeli ve ekonomik kazançlarını arttırmak için kalkınma projelerine katılımı sağlanmalı ve kırsal ölçekte planlama geliştirilmesi, sürdürülebilirliği desteklenmelidir.

Sonuç olarak; bu araştırmada doğal ve kültürel peyzaj potansiyeli kapsamında geliştirilebilecek tüm önerilere bakıldığında, Savcılı Büyükoba köyü için sürdürülebilir kırsal peyzaj planlama unsurlarının seçimiyle kırsal turizm aktivitelerinin uygulanabilirliği görülmüştür.

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GLANDULAR TRICHOMES AS MODEL STRUCTURES IN PHYTOCHEMICAL BIOSYNTHESIS RESEARCH

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ABSTRACT

This review provides a comprehensive synthesis of the value of plant glandular trichomes—microscopic chemical factories on the plant surface—as model structures for phytochemical biosynthesis research. Based on an extensive survey of recent literature, the article first catalogues the extraordinary morphological and anatomical diversity of trichomes across taxa, linking species-, organ- and developmental stage-specific patterns to adaptive ecological strategies. It then dissects the high-flux biosynthetic routes for terpenoids, phenylpropanoids, alkaloids and unusual fatty-acid derivatives that operate within trichome cells, summarising current insights into subcellular compartmentation and metabolite trafficking. Focusing on developmental genetics, the paper clarifies how HD-ZIP IV (Wo), bHLH (SlMYC1) and MYB-like transcription factors, together with jasmonate signalling, coordinate trichome biogenesis with metabolic output. The methodological strengths of microscopy, laser-capture micro-dissection, multi-omics platforms and CRISPR-based gene editing are highlighted, underscoring their capacity to interrogate and re-engineer single-cell factories. Application-oriented sections discuss how enhanced trichome density or rewired metabolite profiles can increase innate pest resistance, optimise the yield of high-value natural products and lay the groundwork for ‘designer trichomes’ that enable sustainable in planta bioproduction. By identifying knowledge gaps—such as the need to characterise trichome-specific promoters, transporters and understudied species—the review proposes a forward-looking research agenda. Overall, it positions glandular trichomes as a unifying model for single-cell systems biology and as a versatile platform for next-generation metabolic engineering, with far-reaching implications for sustainable agriculture, pharmaceuticals and the flavour-fragrance industries. In doing so, it offers researchers not only an updated conceptual framework but also practical guidelines for translating trichome biology into tangible technological innovations.

Keywords: Glandular trichomes, Secondary metabolites, Terpenoids, Metabolic engineering, Plant defence

FİTOKİMYASAL BİYOSENTEZ ARAŞTIRMALARINDA MODEL YAPILAR OLARAK SALGI TÜYLERİ

ÖZET

Bu çalışma, bitki yüzeyinde mikroskobik kimyasal fabrikalar olarak görev yapan salgı tüylerinin (glandular trikomlar) fitokimyasal biyosentez araştırmalarındaki model değerini kapsamlı biçimde incelemektedir. Literatür taramasına dayalı olarak hazırlanan makalede, öncelikle farklı taksonomik gruplarda görülen salgı tüylerinin morfolojik ve anatomik çeşitliliği ele alınmış; tür-, organ- ve gelişim evresi-spesifik varyasyonların ekolojik uyum stratejileriyle ilişkisi tartışılmıştır. Ardından trikom hücrelerinde yüksek düzeyde işleyen terpenoid, fenilpropanoid, alkaloid ve yağ asidi türevli yolaklar ayrıntılı olarak analiz edilmiş; hücre altı bölgeleme ve metabolik trafik mekanizmaları üzerindeki son bulgular sentezlenmiştir. Gelişimsel ve hormonal kontrolün genetik temeline odaklanan makale, Wo/HD-ZIP IV, SlMYC1 ve MYB benzeri transkripsiyon faktörleri ile jasmonat sinyalinin trikom biyogenezi ve metabolit akışını nasıl eşzamanlı yönettiğini açıklığa kavuşturmuştur. Mikroskopi, laser-yakalama mikrodiseksiyon, çoklu omik (transkriptomik-proteomik-metabolomik) ve CRISPR yaklaşımlarının salgı tüyü biyolojisinde sunduğu metodolojik avantajlar vurgulanmış; bu araçların tek hücre düzeyinde metabolik mühendislik tasarımları için potansiyeli değerlendirilmiştir. Son bölümde, yükseltilmiş trikom yoğunluğu veya yeniden programlanmış metabolit profilleri sayesinde haşere direncinin artırılması, yüksek değerli doğal ürün üretiminin optimize edilmesi ve "tasarım trikomları" aracılığıyla sürdürülebilir biyoprodüksiyon senaryoları tartışılmıştır. Ayrıca, az çalışılmış türlerde trikom işlevselliğinin aydınlatılması, trikom-özgül promotörlerin keşfi ve ürün taşınımını düzenleyen taşıyıcı proteinlerin karakterizasyonu gibi gelecek araştırma gündemleri önerilmiştir. Bu yönüyle makale, sürdürülebilir tarım, eczacılık ve koku-lezzet endüstrileri için stratejik yenilik fırsatlarını ortaya koymaktadır.

Anahtar Kelimeler: Salgı tüyü, Sekonder metabolit, terpenoid, Metabolik mühendislik, Bitki savunması

1. INTRODUCTION

Plant glandular trichomes are specialized epidermal appendages that serve as microscopic chemical factories on the plant surface. Approximately one-third of all vascular plant species develop glandular trichomes (Chang et al., 2024), and these structures contribute a significant portion of a plant's secondary metabolite profile. Glandular trichomes typically consist of a stalk and a secretory head of one or more cells, and they actively synthesize, secrete, and sometimes store a diverse array of phytochemicals. These compounds include essential oils, resins, and other specialized metabolites valued as fragrances, flavors, or pharmaceuticals. Evolutionarily, many trichome-derived substances function in plant defense – deterring herbivores, inhibiting pathogens, or mitigating abiotic stresses – even though humans also exploit them for industrial uses (Glas et al., 2012). Because of their prolific biosynthetic activity and accessible location on plant surfaces, glandular trichomes have become model structures to investigate the cellular biology of phytochemical production. In this review, we survey the structural and functional diversity of glandular trichomes across plant taxa, their roles in producing various classes of natural products, the major biosynthetic pathways housed in these "mini-factories" and the genetic regulation of their development and metabolic output. We also discuss modern techniques used to study glandular trichomes and highlight applications in biotechnology and medicinal plant improvement.

2. STRUCTURAL AND FUNCTIONAL DIVERSITY OF GLANDULAR TRICHOMES

Glandular trichomes are multicellular secretory structures that arise from protodermal (epidermal) cells and exhibit remarkable diversity in form, size, and distribution on plant organs (Muravnik, 2020). They vary from tiny capitate trichomes with a single-celled glandular head to larger peltate trichomes with a multicellular head, often on a short stalk. Capitate trichomes typically consist of a basal cell, a stalk cell, and a single secretory head cell, whereas peltate trichomes have a broader head of many secretory cells sitting on one or two stalk cells (Jing et al., 2014; Muravnik, 2020).

Individual plants often bear multiple trichome types – for example, tomato (*Solanum lycopersicum*) has eight distinct trichome forms (four glandular and four non-glandular) on its stems and leaves (Flood, 2019). The density and placement of glandular trichomes can vary by species and organ, reflecting adaptive strategies.

Functionally, glandular trichomes serve as combined structural and chemical defense units for plants. They act as physical barriers (hairs that impede insect movement or create a boundary layer on the leaf) and as sites of concentrated chemical release, often deterring pests upon contact (Bergau et al., 2015). Many trichomes secrete sticky or noxious substances that can trap, repel, or poison herbivorous insects. At the extreme, carnivorous plants like sundews (genus *Drosera*) have evolved glandular trichomes that exude mucilaginous enzymes to capture and digest insects (Bergau et al., 2015; Flood, 2019). More commonly, however, the secretions are defensive or protective: for instance, glandular hairs on *Urtica dioica* (stinging nettle) inject irritants as a deterrent (though these are technically cystolithic trichomes), and those on *Tithonia* and *Solanum* species exude insecticidal resins. Trichome secretions also protect against

microbial pathogens – many contain antifungal or antibacterial compounds that suppress infection on the plant surface. In addition to biotic defense, glandular trichomes help plants cope with abiotic stresses. They can secrete UV-absorbing flavonoids or other phenolics that form a chemical sunscreen, and their presence on the surface may reflect excess light and reduce leaf temperature or water loss. Indeed, the formation of glandular trichomes in different lineages is thought to be driven by the need to protect plants from herbivores, pathogens, intense light (UV-B), and heat (Muravnik, 2020).

Despite this functional diversity, a unifying feature of glandular trichomes is their extraordinary capacity to synthesize and accumulate specialized metabolites. These secretory cells are metabolically hyperactive, often producing and storing compounds at concentrations that would be cytotoxic elsewhere in the plant. To manage this, many glandular trichomes have evolved internal or external storage compartments. In some types, the secreted product is compartmentalized in a subcuticular storage cavity (a space between the cell wall and cuticle) – as seen in the large peltate glands of mint and cannabis, where a dome-like cuticle retains the essential oil or resin that the head cells produce. Storing the metabolites in an extracellular cavity prevents autotoxicity to the producing cells and allows accumulation of high concentrations (Tanney et al., 2021). Other trichomes continuously exude their products to the plant surface (forming a coating of exudate such as the sticky sugar esters on wild tobacco leaves) or sequester them in vacuoles within the trichome cells. From a structural standpoint, the secretion mechanism can thus differ: some glandular hairs release their contents only when the cuticle ruptures or when the trichome is mechanically damaged, whereas others slowly seep out products through microscopic pores or along the sides of the trichome. Additionally, glandular trichomes are often short-lived "expendable" organs – certain types secrete a burst of metabolites and then senesce or reload, corresponding to what Werker (1993) classified as "short-term" vs "long-term" glandular hairs based on secretion timing (short-term glands quickly unload a one-time secretion, whereas long-term glands can repeatedly secrete over time) (Ascensão et al., 1999; Muravnik, 2020). This dynamic aspect highlights that glandular trichomes are not static storage structures but actively metabolizing and sometimes transient organs. Overall, the structural variability (unicellular vs. multicellular, capitate vs. peltate, presence or absence of a storage cavity, etc.) underpins a wide range of functional roles across plant species.

3. ROLE IN PHYTOCHEMICAL BIOSYNTHESIS ACROSS DIFFERENT TAXA

Glandular trichomes are truly natural cell factories, responsible for much of the chemical diversity that plants produce for defense, signaling, and interaction with their environment. Across the plant kingdom, these glands have independently evolved in many lineages and often converged on similar functions. They are especially prominent in certain families – for example, the mint family (*Lamiaceae*) is characterized by abundant peltate glandular trichomes that produce essential oils, while the sunflower family (*Asteraceae*) often has capitate trichomes that secrete bitter terpenoids and other deterrents. In fact, some of the most famous plant natural products come from glandular trichomes: the antimalarial sesquiterpene lactone artemisinin is produced in the capitate trichomes of *Artemisia annua* (wormwood), and the psychoactive

cannabinoids (THC, CBD) of Cannabis sativa are synthesized in stalked glandular trichomes on the female flowers (Chang et al., 2024). These examples underscore how trichomes act as biofactories for important pharmaceuticals and bioactive compounds.

Notably, multiple classes of phytochemicals are made in trichomes, and a single plant may deploy trichomes to produce different compounds in different organs. For instance, *Solanum* species (nightshades) have glandular trichomes that exude acylsugars (sugar esters) as a sticky insect trap on leaves, while other trichomes on the same plant emit volatile terpenes that repel pests. In wild tomatoes (*Solanum habrochaites*, *S. pennellii*), high densities of type IV and VI glandular trichomes correlate with increased insect resistance due to the cocktail of acylsugars and terpenoids they secrete. By contrast, the cultivated tomato has fewer glandular trichomes and correspondingly lower levels of these defensive chemicals, illustrating how domestication can reduce natural chemical defenses (Huchelman et al., 2017).

Across different taxa, glandular trichomes often fulfill ecological roles such as: (i) Herbivore Defense – deterring feeding or oviposition by insects via toxic or antifeedant metabolites (e.g. nicotine and related alkaloids in tobacco can exude onto leaf surfaces, and numerous terpenes produced by trichomes deter herbivory) (Glas et al., 2012); (ii) Pathogen Defense – secreting antimicrobial agents (e.g. thymol and carvacrol in thyme trichomes are strongly antifungal); (iii) Attraction of Pollinators or Mutualists – in some plants, glandular trichomes produce floral oils or scents that attract pollinators or predators of herbivores. For example, species of *Dalechampia* and *Calceolaria* have glandular hairs on flowers that secrete oils collected by specialized bees, and some carnivorous plants use sweet exudates from trichomes to lure prey. Thus, while defense is a primary role, trichome metabolites can also mediate beneficial interactions.

Importantly, glandular trichomes are often metabolically specialized for certain compound classes within a given species. This means a particular trichome type usually produces a limited set of related compounds in very high amounts (Huchelman et al., 2017). This specialization is evident in the chemical profiles across taxa: Lamiaceae trichomes predominantly make monoterpenes and other volatile terpenoids (which give culinary herbs like basil, oregano, and mint their aroma), Asteraceae trichomes often produce sesquiterpene lactones and other bitter compounds (contributing to the medicinal bitterness of chamomile, feverfew, etc.), and *Solanaceae* trichomes may generate phenylpropanoid derivatives, acylsugars, or methylketones as defense chemicals (Huchelman et al., 2017). Even alkaloids – a class more commonly associated with internal secretory cells – can be found in glandular trichomes of some taxa. For instance, a histochemical study of thyme (Thymus) detected alkaloids localized specifically in both capitate and peltate trichome cells (staining positive with Dragendorff's reagent) while the rest of the leaf tissue was free of alkaloids (Jing et al., 2014). This indicates that alkaloid biosynthesis or accumulation in those species is compartmentalized in the trichomes. In tobacco (*Nicotiana*), certain nicotine-related alkaloids and diterpenes (like cembranoids) are present in trichome exudates, contributing to the plant's sticky defensive coating.

In summary, throughout the plant kingdom glandular trichomes are repeatedly used as sites of high-yield production of specialized metabolites crucial for survival. Some genera (e.g. Mentha, Lavandula, Cannabis) have been effectively "domesticated" for their trichome products –

peppermint oil, lavender oil, or cannabis resins – emphasizing the value of these structures. Glandular trichomes, though varied in morphology across taxa, universally function as micro-chemical reactors that enhance plant fitness by deploying chemical defenses and other ecologically relevant compounds on the plant's exterior.

4. MAJOR BIOSYNTHETIC PATHWAYS IN GLANDULAR TRICHOMES

Glandular trichomes are biochemically versatile, capable of synthesizing compounds from all major classes of plant secondary metabolites. Key pathways for terpenoids, phenolics, and alkaloids (among others) are often highly active in trichome cells, sometimes in a unique or modified form compared to the same pathways in other tissues. A remarkable feature is that trichomes tend to channel metabolic flux into a narrow set of end-products (the compounds that define that plant's chemical profile) in extraordinary quantities (Huchelman et al., 2017). Below we provide an overview of the major phytochemical classes produced in glandular trichomes and the biosynthetic routes involved, noting that these pathways frequently intersect with primary metabolism and are tightly regulated within the trichome.

4.1. TERPENOIDS

Terpenes and terpenoids (isoprenoids) are arguably the most common class of compounds in glandular trichomes. These include monoterpenes (C_10), sesquiterpenes (C_15), and diterpenes (C_20), which often constitute essential oils, resins, and gums. In trichomes of many aromatic plants (mint, basil, sage, etc.), monoterpenes like menthol, limonene, and pinene are synthesized via the plastid-localized MEP (methylerythritol phosphate) pathway, whereas sesquiterpenes like patchoulol or artemisinin derive from the cytosolic mevalonate (MVA) pathway – though cross-talk between the two pathways can occur. For example, studies in snapdragon flowers showed that the plastidial MEP pathway was supplying precursors for both monoterpene and sesquiterpene biosynthesis in glandular cells (Huchelman et al., 2017), highlighting the metabolic flexibility of trichomes. The typical terpenoid biosynthetic machinery in trichomes includes terpene synthase enzymes (e.g., menthone synthase in peppermint trichomes; amorpha-4,11-diene synthase in Artemisia gland cells) that convert universal C_5 building blocks (IPP/DMAPP) into cyclic or acyclic terpene skeletons, often followed by cytochrome P450 monooxygenases and specialized transferases to produce oxidized, polyoxygenated terpenoids. Trichome cells are often enriched in organelles needed for terpene biosynthesis: they harbor abundant leucoplasts (plastids without pigments) for monoterpene synthesis and well-developed smooth endoplasmic reticulum for sesquiterpenes and diterpenes that require P450s (Muravnik et al., 2020). Notable examples of terpenoids from trichomes include the essential oils of herbs (rich in mono- and sesquiterpenes), the glandular resins of conifers and Cannabis (rich in diterpenoid and terpenophenolic resins), and defensive terpenes in tomato (e.g. zingiberene and α-tomatine in wild tomato type VI trichomes). The yields are impressive – some peppermint cultivars exude >1% of leaf dry weight as monoterpene oil from trichomes. Because terpenoids are volatile or semi-volatile, they often

evaporate or diffuse from trichomes, forming a chemical plume that deters insects or attracts pollinators, depending on context.

4.2. PHENOLICS AND PHENYLPROPANOIDS

Glandular trichomes of many species produce compounds derived from the phenylpropanoid pathway, which transforms phenylalanine into a variety of aromatic metabolites. These include simple phenylpropanoids (such as eugenol, chavicol, etc.), flavonoids, and related polyphenols. In basil (*Ocimum basilicum*), for instance, peltate trichomes accumulate phenylpropanoid aroma compounds like chavicol and methyl eugenol in addition to terpenes (Huchelman et al., 2017; Türkay et al., 2023; Türkay et al., 2024). Some trichomes secrete flavonoid aglycones or flavonoid glycosides onto the surface; these can act as UV protectants or antimicrobial agents. Glandular trichomes of Teucrium species secrete sticky flavonoids that form a crust on the leaf. The enzymes of phenolic biosynthesis (e.g., phenylalanine ammonia-lyase (PAL), cinnamate 4-hydroxylase, and various reductases and transferases) have been found to be highly expressed in trichome cells of phenolic-rich plants (Huchelman et al., 2017). In some cases, the phenolics from trichomes contribute to plant taste and pigmentation – e.g., *Cannabis* trichomes produce not only cannabinoids but also flavonoids that can color the resin; *Pelargonium* glandular hairs secrete quercetin derivatives that end up on the leaf surface. An important subset of phenolics in trichomes are the phenylpropanoid volatiles (like vanillin, isoeugenol) that add to floral or leaf scents. These often arise from the shikimate/phenylpropanoid pathway and might be formed in concert with terpenes. In basil, coordinated regulation of phenylpropanoid and terpenoid synthesis in trichomes has been observed, indicating these pathways can be co-activated to produce a particular blend of metabolites (Huchelman et al., 2017).

4.3. ALKALOIDS

While many plant alkaloids are made in internal tissues (e.g. roots or phloem) and stored in vacuoles, there are cases where glandular trichomes participate in alkaloid biosynthesis or secretion. The pyridine alkaloid nicotine, for instance, is synthesized in tobacco roots but it can be transported to leaf trichomes and concentrated in trichome exudate along with sugary compounds – forming a toxic mix on the leaf surface of *Nicotiana*. Certain tropane alkaloids (like scopolamine) in genus *Datura* have been suggested to effuse from young stem trichomes. Direct evidence comes from histochemical studies: in Thymus species, glandular trichomes tested positive for alkaloids, indicating these cells either produce or accumulate alkaloidal compounds (Jing et al., 2014). Another example is the ergot alkaloids found on some grasses: an intriguing recent discovery showed endophytic fungi living in grass glandular trichomes produce ergot alkaloids on the surface (Steiner et al., 2015), effectively using the trichome as a delivery structure. In general, alkaloid presence in trichomes is less common than terpenes or phenolics, but when it occurs, it adds a potent layer of chemical defense (since many alkaloids are neurotoxic or feeding deterrents). As analytical techniques improve, new alkaloids localized to trichomes continue to be identified. The biosynthetic pathways for alkaloids in trichomes follow the same core enzymatic steps as elsewhere (e.g., decarboxylation of amino acids, BIA

pathway for benzylisoquinoline alkaloids, etc.), but often the final steps or regulation might be tailored to trichome expression. For instance, a atropa species might express a final O-methyltransferase for scopolamine predominantly in its trichomes if that's where the plant deploys the compound.

4.4. SPECIALIZED LIPIDS AND OTHERS

In addition to the classic categories above, glandular trichomes produce various unusual metabolites. Acyl sugars (sugar esters of fatty acids) are produced in high quantities by trichomes of wild tomatoes and some petunias as a sticky defense; these are synthesized by acyltransferases that are expressed almost exclusively in the glandular head cells. Methylketones (e.g., 2-tridecanone and 2-undecanone) are secreted by type VI trichomes of certain *Solanum* species; they derive from fatty acid pathways and have strong insecticidal activity (e.g., against whiteflies) (Huchelman et al., 2017). Cardenolides and other defensive steroids can also accumulate in trichome exudates in some *Apocynaceae* and *Solanaceae*. Essentially, if a plant benefits from having a defensive or communicative chemical at its surface, evolution often routes that compound's production into a glandular trichome. This partitioning is advantageous because the toxic or deterrent compound is confined to an expendable external cell, protecting the rest of the plant from harm while maximizing impact on the target (herbivore, microbe, etc.).

It is noteworthy that glandular trichomes often exhibit a degree of metabolic compartmentalization. Within a single trichome cell, different organelles handle different steps: plastids, cytosol, ER, vacuoles, and the apoplast may all be involved in a single compound's biosynthesis. For example, in *Cannabis* trichomes, cannabinoid biosynthesis starts in the cytosol (with phenolic precursors), continues in plastids (where the terpenoid moiety is made), and finishes in the apoplastic space of the secretory cavity where the two parts condense to form THCA, which then accumulates under the cuticle (Tanney et al., 2021). Such multi-step routing requires transporters or facilitators to shuttle intermediates between compartments. This level of metabolic orchestration is part of what makes glandular trichomes excellent model systems for studying the integration of biosynthetic pathways within a single cell type.

In summary, glandular trichomes are hotspots of secondary metabolism, adept at producing terpenoids, phenylpropanoids, alkaloids, and other specialized compounds. The major biosynthetic pathways operating in trichomes are the same core pathways found in plants at large, but in trichomes they are often upregulated and optimized to funnel precursors into a narrow set of outputs. This results in the accumulation of particular chemicals in amounts rarely seen in normal cells. Understanding these pathways in the trichome context has practical implications (as discussed later) for metabolic engineering and enhancing the production of high-value plant metabolites.

5. GENETIC AND MOLECULAR REGULATION OF PHYTOCHEMICAL PRODUCTION IN GLANDULAR TRICHOMES

The development of glandular trichomes and the regulation of their metabolic activity are tightly controlled by genetic networks. Research in recent years has begun to unravel the molecular players that specify where and how glandular trichomes form, as well as those that activate the biosynthetic pathways within trichome cells. This section discusses (a) the genetic control of glandular trichome development (how plants decide to make a glandular trichome and ensure it becomes a secretory cell type), and (b) the regulatory mechanisms that govern phytochemical biosynthesis in trichomes (transcription factors, signaling pathways, etc. that turn on the production of secondary metabolites).

5.1. DEVELOPMENTAL REGULATION OF GLANDULAR TRICHOMES

Plants use a combination of general and specialized regulators to initiate glandular trichomes. In the model plant Arabidopsis thaliana, trichome development (though non-glandular in this species) is controlled by a well-known network of transcription factors: an R2R3 MYB (GLABRA1), bHLH proteins (GL3/EGL3), and a WD40 repeat protein (TTG1) form a complex that activates trichome formation, while single-repeat MYBs (TRY/ CPC) act as inhibitors to create spacing patterns. In plants with multicellular glandular trichomes like tomato, tobacco, and Artemisia, homologous networks exist but with additional layers of regulation for the multicellular and glandular character. A key regulator in tomato is the *Woolly (Wo)* gene, which encodes an HD-ZIP IV transcription factor. Wo is essential for the formation of both glandular and non-glandular trichomes in tomato (and likely in many other species with multicellular trichomes). Mutations in Wo (such as the classical woolly mutant of tomato) result in a near hairless phenotype, whereas overexpression leads to excess trichome formation – indicating Wo has a dose-dependent, positive role in trichome initiation and development. Another crucial regulator in tomato is a basic helix–loop–helix (bHLH) transcription factor called SlMYC1. Recent studies showed that SlMYC1 is necessary for the development of the most abundant glandular trichomes (type VI) in tomato: CRISPR knockout lines completely lacked type VI trichomes (Xu et al., 2018). Interestingly, when SlMYC1 was knocked out, a novel aberrant trichome type appeared (termed type “VII-like”), suggesting that other factors initiate a prototrichome that fails to fully differentiate without SlMYC1 (Flood et al., 2019). This bHLH likely works in concert with MYB partners and hormonal signals (similar to how Arabidopsis GL3 works with GL1). Indeed, SlMYC1 is part of the jasmonate signaling pathway – as a JA-responsive bHLH, it connects herbivore stress signals to both trichome development and compound production.

Only a few trichome-specific regulators have been characterized so far, and the field is rapidly evolving. A breakthrough in 2024 identified two tomato genes, *Gland Cell Repressor 1* and *2* (*GCR1*, *GCR2*), which encode MYB-like transcription factors that act as negative regulators of glandular fate. These *GCR* genes are expressed in early developing trichomes and prevent excessive gland cell formation; when both are knocked out, tomato develops enlarged glandular trichomes (implying more secretory cells per trichome). Notably, homologs of *GCR* in tobacco and petunia appear to have a similar repressive role, suggesting a conserved mechanism across

species. The *GCR* repressors are part of a two-step regulatory process: they themselves are kept in check by an upstream repressor (in tomato, a *TOE1* homolog, part of the *AP2* miR172 pathway) that relieves inhibition at the right time. On the flip side, positive regulators like Leafless (LFS) in tomato have been proposed to promote gland formation, being the targets that *GCR* represses In tobacco, a MIXTA-like MYB transcription factor has been implicated in trichome formation on leaves (MIXTA is known in petunia for epidermal cell patterning and likely has parallels in trichome cell patterning) (Chang et al., 2024).

Hormonal regulation is another key aspect: jasmonic acid (JA) strongly induces glandular trichome development in many species. JA-deficient tomatoes have fewer trichomes and lower terpene production, while application of JA or its mimic can increase trichome numbers and chemical output. This effect is partly mediated by JA-responsive transcription factors such as SlMYC1 (which, as noted, is JA-inducible and necessary for trichome development). Conversely, gibberellins (GA) and other hormones can modulate trichome initiation in species-specific ways – e.g., applying GA to peppermint was found to increase trichome density and essential oil yield by upregulating biosynthetic genes (Huchelman et al., 2017). Cytokinin and auxin signaling have also been linked to trichome initiation in some studies, although JA is the dominant positive signal for glandular trichomes associated with defense. In summary, the developmental fate of a glandular trichome is determined by a network of transcription factors (MYB, bHLH, HD-Zip, etc.) operating under the influence of plant hormone signals and possibly small RNAs. Many of these regulators have dual roles, affecting both the physical development of the trichome and the activation of metabolic pathways within.

5.2. REGULATION OF PHYTOCHEMICAL PRODUCTION

Once a glandular trichome cell is formed, it must activate the suite of enzymes required to produce its specialized metabolites. This is achieved through trichome-specific or trichome-enhanced expression of biosynthetic genes, controlled by developmental and environmental cues. Often the same transcription factors that drive trichome development continue to upregulate secondary metabolism genes in those trichomes. A striking example is again *SlMYC1* in tomato: knockdown of *SlMYC1* (which allowed a few trichomes to still form) led to a drastic reduction in the expression of terpene synthase genes and a corresponding drop in monoterpene levels, even in plants that still had glandular trichomes present (Flood et al., 2019). This demonstrates that *SlMYC1* is required not only for making the trichome itself but also for turning on the terpenoid biosynthetic pathway within that trichome. Similarly, in Artemisia annua, a bHLH transcription factor (AaMYC2) and an AP2/ERF factor (AaERF1, also called ARTF1) have been identified that bind to promoters of artemisinin pathway genes (like *ADS*, *CYP71AV1*) and enhance their expression specifically in trichome cells, especially under JA stimulation. Other transcriptional activators such as WRKYs and MYBs (e.g., AaWRKY9 in *Artemisia*, or TcMYB2 in *Camellia* trichomes for tea catechins) have been found to orchestrate the production of particular compounds.

Frequently, these regulatory genes are part of inducible defense pathways. When a plant is attacked or stressed, signals like JA, salicylic acid, or abiotic stress signals can elevate the production of trichome chemicals. For instance, wounding or herbivory triggers a JA burst that

in tomato not only prompts more trichomes but also increases the output of terpenes and acylsugars from existing trichomes. Trichomes can even serve as "sensor" cells; tomato type VI trichomes store jasmonic acid (in its active form JA-Ile) and upon being touched or damaged by insects, they release it, thereby alerting the plant and systemically enhancing defense responses (Flood et al., 2019). This implies a feedback loop where trichome-produced JA can amplify its own biosynthetic pathways in a positive reinforcement cycle.

On the genomic level, plants often cluster genes for particular trichome-produced metabolites. For example, in some wild tomatoes, the genes encoding enzymes for acylsugar biosynthesis are physically grouped in the genome, allowing coordinated regulation. A notable case is a cluster of several methylketone synthesis genes in *Solanum habrochaites* (discovered to underlie insect resistance); by introgressing this cluster into cultivated tomato, researchers enhanced glandular methylketone output and pest resistance (Huchelman et al., 2017). Such gene clusters likely share regulatory sequences that trichome-specific transcription factors recognize. Comparative genomics has revealed that related species often have conserved blocks of trichome metabolism genes – for example, *Nicotiana* and *Solanum* (both Solanaceae) have some syntenic regions for trichome diterpene biosynthesis, hinting at an evolutionary conservation of regulatory modules.

Apart from transcription factors, post-transcriptional and enzymatic regulation also fine-tune phytochemical production. Glandular trichomes express specific microRNAs and RNA-binding proteins that can modulate the stability of mRNAs for pathway enzymes (this area is still being explored). At the enzyme level, the compartmentalization we discussed means that transporters and enzyme allostery play roles. Trichomes express unique transport proteins to move metabolites or precursors: for instance, an ABC transporter in petunia (PhABCG1) exports volatile phenylpropanoids from cells, and in tobacco a glandular-specific lipid transfer protein (NtLTP1) is required for secretion of hydrophobic diterpenes to the outside (Huchelman et al., 2017). Disrupting these transport processes can cause accumulation of products in the wrong place or feedback inhibition of the pathway. Thus, the molecular regulation of trichome biosynthesis includes not just turning genes on, but also ensuring their products are efficiently moved and stored.

In summary, the genetic and molecular regulation of glandular trichomes operates on two synergistic fronts: morphogenesis (driven by a network of developmental genes influenced by hormones) and metabolic pathway activation (driven by both the developmental network and by specialized metabolic regulators). Only a handful of master regulators (like Wo, SlMYC1, AaMYC2, etc.) have been characterized to date, and current research continues to identify new ones (e.g., the *GCR* repressors) (Chang et al., 2024). A deeper understanding of these regulatory circuits is not only of fundamental interest (elucidating how a plant cell differentiates into a high-output producer of secondary metabolites), but also of practical value for engineering plants with enhanced natural product output.

6. METHODS AND TECHNIQUES FOR STUDYING GLANDULAR TRICHOMES

Investigating glandular trichomes requires an integrated approach, as one must examine both their structural traits and their complex chemistry. Fortunately, because trichomes are external and often abundant, they are amenable to a variety of microscopy, molecular, and analytical techniques. Here we outline key methods used in glandular trichome research, ranging from visualization of trichome anatomy to omics technologies for profiling their genes and metabolites.

6.1. MICROSCOPY AND IMAGING

Microscopy is fundamental for characterizing trichome morphology and development. Light microscopy (bright-field or differential interference contrast) is used to observe trichome form on plant surfaces and in section. For example, simple visual examination under light microscopy distinguishes capitate vs peltate trichomes and can reveal contents (e.g., refractive droplets of oil in a gland head). Histochemical staining techniques can localize classes of chemicals in situ – as demonstrated by Dragendorff's reagent staining of alkaloids in *Thymus* trichomes, producing an orange color specifically in the secretory cells (Jing et al., 2014). Fluorescence microscopy and confocal laser scanning microscopy are used to probe trichome cellular structure; many glandular metabolites (like chlorogenic acid or flavonoids) are autofluorescent and can indicate distribution within the trichome. Researchers also use fluorescent dyes to test membrane integrity or the presence of cuticular holes in glands. For surface architecture, scanning electron microscopy (SEM) provides high-resolution images of trichome shape, density, and the presence of subcuticular spaces or pores. SEM has been extensively used to survey trichome types on new plant species and to monitor trichome development (e.g., capturing images of a developing multicellular trichome at different stages). Transmission electron microscopy (TEM) goes further to visualize ultrastructure: it can show the dense cytoplasm of secretory head cells, the enlarged plastids filled with lipid vesicles (terpenoid precursors), abundant smooth ER, and the cuticle layer bulging to form a storage cavity (Tanney et al., 2021). TEM also allows observation of the mode of secretion – for instance, vesicles fusing with the plasma membrane to release contents into the cell wall space. Newer imaging methods like 3D electron tomography and atomic force microscopy have also been applied to special cases (e.g., mapping the thickness of the cuticle over a gland or the turgor pressure within a secretory cell).

6.2. TRICHOME ISOLATION AND CELL-SPECIFIC ANALYSIS

A major advantage in trichome research is that trichomes and their exudates can be harvested relatively easily from the plant surface (Glas et al., 2012). This allows scientists to study trichome chemistry and genetics in relative isolation from the rest of the leaf. Methods for isolating trichomes include mechanical brushing or shaving of leaves (to physically remove the trichomes), solvent washing (a quick dip in solvent can strip off surface exudates or even knock off trichome glands), and more refined techniques like laser capture microdissection (LCM). In LCM, microscopic laser cuts can excise individual glandular trichome cells from tissue sections

for downstream RNA or metabolite analysis – this has been used in plants like Medicago to profile trichome-specific gene expression. Another innovative approach is flow cytometry for trichome cells: researchers have exploited natural autofluorescence of glandular trichome cells (due to their rich metabolites) to separate them. For example, Bergau et al. (2015) dissociated tomato leaf cells and used fluorescence-activated cell sorting (FACS) to collect developing trichome cells, enabling transcriptomic analysis of trichomes at different maturation stages (Huchelman et al., 2017). Additionally, density gradient centrifugation can pellet trichomes from a leaf homogenate (since trichomes often have distinct size/density). Once isolated, trichome-rich preparations can be subjected to omics analyses (detailed below) or biochemical assays. It is also possible to isolate the exuded compounds specifically – for instance, by gentle rinsing of the leaf with solvent or by using tiny capillaries to sample the droplets under the trichome cuticle in species like *Cannabis*. The ease of trichome/exudate collection has been a boon: it has "permitted a detailed study of their metabolites, as well as the genes and proteins responsible for them" (Glas et al., 2012), essentially allowing researchers to link chemistry with gene expression in the same cell type.

6.3. OMICS TECHNOLOGIES (TRANSCRIPTOMICS, PROTEOMICS, METABOLOMICS)

Modern high-throughput methods have revolutionized the study of glandular trichomes. Transcriptomic profiling (RNA-seq) of isolated trichomes or trichome cells identifies which genes are highly expressed relative to non-trichome tissue. Such studies have uncovered transcripts for all enzymes of certain pathways, confirming that (for example) mint peltate gland cells contain the full suite of monoterpene biosynthetic genes, or that in Lavandula, genes for both terpene and phenolic synthesis are co-expressed in glands. A comparative trichome transcriptome analysis in different mint species helped explain differential menthol production by correlating gene expression levels of key pathway enzymes. There are now trichome transcriptome datasets for many species, compiled in resources like the TrichOME database (a comparative omics database for plant trichomes). This database allows researchers to query genes of interest across multiple trichome transcriptomes to find common regulators or enzymes. On the protein side, proteomic analyses of trichomes have been attempted, though obtaining sufficient material is challenging. In one case, Champagne and Boutry (2013) performed proteomics on glandular trichomes of a non-model plant, identifying many abundant enzymes and unique proteins in the trichome cells. Proteomics can reveal, for instance, specialized isoforms of enzymes or abundant carrier proteins (like the aforementioned lipid transfer protein in tobacco trichomes). Metabolomics is, of course, central – using GC-MS, LC-MS, NMR, and other analytical chemistry techniques to profile the compounds present in trichomes. Coupling metabolomic data with transcript profiles helps assign functions to genes (e.g., if a certain unknown cytochrome P450 is highly expressed in trichomes at the same time a unique compound appears, it hints that the P450 may be responsible for that compound's synthesis). A comprehensive approach is exemplified by a multi-omics study on tomato glandular trichomes. Balcke et al. (2017) integrated transcriptomics, proteomics, and metabolite analysis and found that tomato glandular trichomes have distinct central metabolism geared towards producing large amounts of sucrose and amino acids to support rapid specialized

metabolite synthesis. This kind of systems biology approach can identify bottlenecks in pathways or unusual metabolic adaptations in trichomes (for example, an upregulation of glycolysis to provide extra acetyl-CoA for terpenoid biosynthesis) (Huchelman et al., 2017).

6.4. GENETIC AND GENOMIC APPROACHES

To understand gene function in trichome development and metabolism, researchers employ genetic approaches such as mutants, transgenics, and gene editing. Classical mutant screening has identified numerous "hairless" or "excess hair" mutants in plants like *Arabidopsis*, tomato, cucumber, and others – these often correspond to key regulators (e.g., hairless in tomato is an allele of *Woolly*). Modern CRISPR-Cas9 gene editing has allowed targeted knockout of suspected trichome genes (for instance, knocking out candidate transcription factors like SlMYC1 (Flood et al., 2019) or metabolic genes to test their role in trichomes). Coupled with trichome-specific phenotypic assays (like measuring metabolite changes or trichome counts in the edited lines), this yields functional validation. Virus-induced gene silencing (VIGS) is another tool used particularly in species that are not easy to transform; VIGS in *Nicotiana* has been used to transiently silence genes in trichomes (for example, silencing a terpene synthase to see if a particular compound disappears from the exudate). On the flip side, overexpression of genes (often using trichome-specific promoters to target expression to trichomes) can be used to enhance certain pathways or trichome development. For instance, overexpressing a positive regulator like Wo or SlMYC1 in tomato results in a higher density of glandular trichomes and elevated levels of their metabolites (Chang et al., 2024). The availability of reference genomes for plants with glandular trichomes (e.g., the tomato genome, the tobacco genome, the cannabis genome, etc.) has accelerated discovery of gene candidates by enabling QTL mapping and genome-wide association studies for trichome traits. If a particular wild species has an exceptionally high metabolite from trichomes, crossing it with a low-producing line and doing QTL analysis can pinpoint genetic loci underlying the difference. This strategy was used with wild tomato species, leading to the identification of loci controlling acylsugar production and trichome density, which turned out to be clusters of metabolic genes (Huchelman et al., 2017).

6.5. ANALYTICAL CHEMISTRY AND FUNCTIONAL ASSAYS

Finally, specialized analytical techniques are employed to link structure with function. Gas chromatography-mass spectrometry (GC-MS) is the workhorse for volatile compounds: by enclosing a single leaf or even an intact plant in a chamber, one can sample the headspace to analyze trichome-emitted volatiles. Alternatively, individual trichomes or isolated exudate can be directly analyzed – for example, a single cannabis trichome's contents can be laser-desorbed and sent into a mass spectrometer (techniques like LDI-MS imaging). Liquid chromatography (HPLC/UPLC) helps quantify non-volatile, often more polar trichome compounds (like cannabinoids, glycosides, alkaloids). In the alkaloid-storing thyme trichomes mentioned, GC-MS of leaf extracts confirmed the presence of specific alkaloids in young leaves, correlating with the histochemical stain (Jing et al., 2014). To complement chemical analysis, bioassays are used to test the function of trichome metabolites. For instance, insect feeding trials on plant

lines with different trichome profiles can demonstrate that higher terpene or acylsugar levels (due to a genetic modification) confer greater pest resistance (Huchelman et al., 2017). Microbial growth assays with trichome exudates can show antimicrobial efficacy. Even simple assays like observing whether an insect avoids walking on a leaf with sticky trichomes provide functional insight.

In combination, these methodologies enable researchers to dissect glandular trichomes from the macro scale (distribution on the plant, ecological effects) down to the molecular scale (gene expression networks and enzyme functions). Glandular trichomes have thus become a model for single-cell type analysis in plants – akin to a "plant cell in a test tube" that can be studied in isolation. As new techniques emerge (such as single-cell RNA sequencing, or improved in vivo imaging), our ability to probe the inner workings of glandular trichomes will continue to grow, providing even deeper understanding of how these tiny biochemical factories operate.

7. APPLICATIONS IN PLANT BIOTECHNOLOGY, METABOLIC ENGINEERING, AND PHARMACEUTICAL RESEARCH

The unique properties of glandular trichomes – their capacity for high-level biosynthesis and secretion of valuable natural products – make them attractive targets for biotechnological applications. Harnessing trichomes can lead to crops with improved pest resistance, higher yields of commercially important phytochemicals, and even novel biofactories for drug production. Here we discuss how insights from trichome biology are being applied in agriculture and industry, and the future prospects for engineering these natural factories.

Enhancing Crop Protection: One major application is breeding or engineering crops with higher glandular trichome density or potency to naturally resist pests. Since glandular trichomes are often the first line of chemical defense, increasing their number or the amount of toxin they produce can reduce reliance on pesticides. For example, wild tomato species with dense, sticky trichomes are resistant to whiteflies and aphids, and breeders have introgressed these traits into cultivated tomato. A specific success story involved transferring a sesquiterpene biosynthetic pathway from a wild tomato (*Solanum habrochaites*) into cultivated tomato, which conferred strong resistance to insect herbivores (Huchelman et al., 2017). This was achieved by crossing (and, in modern approaches, by transgenic insertion) of the gene cluster responsible for producing the insect-repellent terpene zingiberene; the resulting plants accumulate the sesquiterpene in their glandular trichomes and are less damaged by pests. Similarly, breeding programs in crops like *Brassica* (mustard greens) and Solanum tuberosum (potato) are exploring wild relatives with more effective trichomes to introduce into elite varieties. In ornamental plants such as chrysanthemums, increasing trichome-borne pyrethrins (natural insecticides) is of interest.

Transgenic approaches have also been demonstrated: overexpressing trichome development regulators can amplify defense. In tomato, simultaneous overexpression of the *HD-Zip* gene Wo and the bHLH SlMYC1 (the "woolly/SlMYC1 module") led to a plant with a carpet of glandular trichomes that produced heightened levels of defensive compounds, significantly improving resistance to insects (Chang et al., 2024). This kind of genetic engineering essentially

turns up the dial on the plant's innate defense factory. Another approach is to engineer the biochemistry of trichomes: for instance, making the trichomes produce a new deterrent compound. A proof-of-concept was shown in tobacco, where researchers engineered trichomes to produce oxime-based volatiles that repel insects, by inserting a *CYP79* gene from maize under a trichome-specific promoter. The transformed tobacco emitted the volatile and showed reduced herbivory. Because trichomes localize toxic compounds away from vital tissues, plants can potentially tolerate higher levels of these bio-pesticides when they are trichome-targeted.

7.1. METABOLIC ENGINEERING FOR HIGH-VALUE COMPOUNDS

Glandular trichomes are often the sites of biosynthesis for plant-derived medicinal compounds. Thus, they present an opportunity for metabolic engineering to boost the supply of these pharmaceuticals. A prominent example is artemisinin from A. annua trichomes – efforts have been made to increase artemisinin yield by genetic means, such as overexpressing key enzymes (ADS, DBR2) or regulatory genes (the *AP2* factor *AaORA*) in the trichomes. Some success has been seen in doubling artemisinin content by transgenic approaches, although industrial production has also turned to synthetic biology in yeast. In *Cannabis*, where cannabinoids (THCA, CBDA) are made exclusively in glandular trichomes, there is intense interest in both classical breeding and biotech to increase cannabinoid yield or tailor the cannabinoid profile for medical applications. Understanding the gene network in cannabis trichomes (which genes control cannabinoid synthase expression, etc.) is guiding breeding for higher THC or CBD strains (Tanney et al., 2021). On the metabolic engineering front, one could foresee inserting the cannabinoid pathway into trichomes of a more easily grown plant or even engineering microbial systems with key elements from trichomes.

Transgenic metabolic engineering in trichomes has been demonstrated in model systems like tobacco – often referred to as a "trichome biofactory" for proof-of-concept. For instance, the production of taxadiene (a precursor of the anti-cancer drug Taxol normally from yew tree bark) was achieved in cultured tobacco cells by introducing a taxadiene synthase (Huchelman et al., 2017). While that was in cell culture, a similar idea is to engineer tobacco plants so that taxadiene accumulates in their glandular trichomes (tobacco trichomes can accumulate diterpenes, so they are a plausible surrogate host). As another example, transgenic mint plants were created to overexpress a cytochrome P450 and reductase, resulting in diversion of the monoterpene pathway to produce a novel compound in the peltate glands (demonstrating that one can reprogram the product profile of trichomes). The choice of promoter is crucial in such efforts; typically trichome-specific promoters (like the promoter of a trichome resin protein or a terpene synthase gene that is only active in gland cells) are used so that the transgene is expressed predominantly in the trichomes. This avoids burdening the rest of the plant with the metabolic perturbation and concentrates the effects in the trichome "factory." Additionally, engineering strategies often try to boost precursor supply for the target pathway: for terpenoids, this might mean upregulating the MEP pathway genes or diverting metabolic flux from primary isoprenoids into specialized terpenes. One study highlighted the importance of drawing from the existing metabolic pools – e.g. sinking more geranyl diphosphate into monoterpenes by

overexpressing a sink enzyme – and understanding the cross-talk between pathways to avoid bottlenecks (Huchelman et al., 2017).

7.2. COMMERCIAL CULTIVATION AND BIOPRODUCT HARVESTING

Beyond genetic engineering, knowledge of trichomes influences agricultural practices. For crops like mint, basil, lavender, and cannabis, growers aim to maximize glandular trichome formation because that directly translates to product yield (essential oil content or cannabinoid content). Horticultural research has shown that certain light spectra or mild stress can induce more trichomes. For instance, UV-B exposure can trigger higher flavonoid accumulation in trichomes as a protective response, so some growers use UV supplementation to enhance output. Similarly, moderate drought or nutrient stress at the right growth stage sometimes increases essential oil concentration by stimulating trichome development. However, these need to be applied carefully to avoid overall crop loss. In cannabis, where a multi-billion dollar industry relies on trichome-produced resin, there is interest in trichome-focused cultivation techniques and even mechanical or chemical elicitors that encourage trichome proliferation (Tanney et al., 2021). One could imagine foliar sprays of jasmonate or other elicitors to temporarily boost trichome density and metabolite production shortly before harvest – indeed, methyl jasmonate treatments have been used in artemisinin production fields to increase yield.

From a pharmaceutical research perspective, glandular trichomes are a treasure trove of natural compounds. Many new lead compounds (antimicrobials, anti-cancer agents, etc.) are discovered by screening trichome exudates from diverse plant species. Because trichomes often produce unique chemistries (sometimes not found elsewhere in the plant), they broaden the chemical diversity available for drug screening. Researchers are exploring under-investigated plants that have interesting traditional uses – often these have prominent aromatic or sticky trichomes – to isolate novel bioactive constituents. Once a valuable compound is identified, trichome-targeted metabolic engineering can be employed to upscale its production. There is also interest in synthetic biology to mimic trichome systems: for example, reconstructing a plant pathway in yeast or *E. coli*. However, certain steps (especially those requiring compartmentalization or membrane-bound enzymes) are challenging to replicate in microbes. In such cases, enhancing the native plant's production via trichomes might be more practical.

7.3. ENVIRONMENTAL AND INDUSTRIAL IMPLICATIONS

By leveraging glandular trichomes, we can develop plants that are more self-reliant in defense (reducing pesticide use) and that yield higher quantities of natural products (reducing the need for chemical synthesis of those products). The essential oils industry, which was valued at over $18 billion in 2020 (Tanney et al., 2021), depends largely on plants with glandular trichomes (like mint, lavender, lemongrass, etc.). Improving trichome productivity in those crops has direct economic benefits. In some cases, breeding has unintentionally reduced trichome counts for aesthetic reasons (e.g., smoother leaves); biotechnology offers a way to reintroduce or amplify those traits without altering the plant's primary characteristics. Glandular trichomes have also been proposed as sites to produce non-native valuable compounds – for example,

engineering a fodder crop to produce an insect pheromone in its trichomes, turning the crop into a pest-confusing agent in the field.

In conclusion, glandular trichomes stand at the intersection of plant defense, natural product chemistry, and biotechnology. They exemplify how a single cell type can be programmed to perform extreme biochemical feats, and they offer a convenient target for scientific manipulation. Ongoing research is making it possible to dial the trichome's output up or down or even change its product mix. As our understanding deepens, we may see the development of "designer trichomes" – plants whose glandular hairs are custom-tailored to produce new compounds on demand. From more pest-resistant crops to sustainable production of medicines and fragrances, the potential applications of glandular trichome research are vast and impactful. Glandular trichomes, once merely an interesting microscopic feature, have now truly achieved "model status" as living laboratories for studying and engineering phytochemical biosynthesis (Chang et al., 2024).

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MORPHOLOGICAL DIAGNOSIS OF GOLDEN CYST NEMATODE (*Globodera rostochiensis)* POPULATIONS IN NIGDE PROVINCE

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ABSTRACT

Potato cyst nematodes (PCNs) are soil-borne pests that damage potato plants in many countries of the world. Especially *Globodera rostochiensis* (Wollenweber, 1923) Skarbilovich, 1959 and *G. pallida* Stone, 1973 (Tylenchida: Heteroderidae) are species that cause serious yield losses in potato plants. Since they are on the quarantine list in Turkey and many parts of the world, they need to be diagnosed correctly and quickly. Since the cysts of the pest survive in the soil for many years, it is very difficult to control. Using varieties resistant to the damage caused by PCN is one of the effective and environmentally safe methods in control. Correct identification of the species and race of the nematode is of great importance in developing potato varieties resistant to PCN. In this study, morphological species identification was made from PCN populations taken from 16 locations in Niğde province. As a result of the identification, all samples were identified as *G. rostochiensis*. In the measurements made, it was determined that the morphological measurement values of all samples were compatible with the reference literature value of *G. rostochiensis*. The study result will contribute to the development of varieties resistant to the detected species and to sustainable agriculture.

Keywords: Cyst Nematode, taxonomy, potato, diagnosis.

NİĞDE İLİ ALTIN KİST NEMATODU (*Globodera rostochiensis*) POPÜLASYONLARININ MORFOLOJİK TEŞHİSİ

ÖZET

Patates kist nematodları (PKN'ler) dünyanın pek çok ülkesinde patates bitkisine zarar veren toprak kökenli zararlılardır. Özellikle *Globodera rostochiensis* (Wollenweber, 1923) Skarbilovich, 1959 ve *G. pallida* Stone, 1973 (Tylenchida: Heteroderidae), patates bitkisinde ciddi verim kayıplarına neden olan türlerdir. Türkiye ve dünyanın pek çok yerinde karantina listesinde olmaları nedeniyle doğru ve hızlı teşhis edilmeleri gerekmektedir. Zararlının kistleri uzun yıllar toprakta canlılığını sürdürmesi nedeniyle mücadelesi oldukça zordur. PKN verdiği zarara karşı dayanıklı çeşitler kullanılması, mücadelede etkili ve çevre için güvenli yöntemlerden birisidir. PKN karşı dayanıklı patates çeşidi geliştirmede nematodun türünün ve ırkının doğru teşhis edilmesi çok büyük önem arz eder. Bu çalışmada Niğde ilinde 16 lokasyondan alınan kist nematodu popülasyonlarının morfolojik tür teşhisi yapılmıştır. Teşhis sonucunda örneklerin tamamı Patates Altın Kist Nematodu (*G. rostochiensis*) olarak tanımlanmıştır. Yapılan ölçümlerde tüm örneklerin morfolojik ölçüm değerleri *G. rostochiensis*'in referans literatür değeri ile uyumlu olduğu tespit edilmiştir. Çalışmanın sonucu, tespit edilen türe karşı dayanıklı çeşit geliştirme çalışmalarına ve sürdürülebilir patates tarımına katkı sunacaktır.

Anahtar Kelimeler: Kist Nematodu, taksonomi, patates, teşhis.

1. GİRİŞ

Patates bitkisi, (*Solanum tuberosum* L.), yıllık 374.7 milyon ton üretimiyle dünyadaki diğer tarımsal ürünler arasında üretim miktarı bakımından buğday, pirinç ve mısırdan sonra dördüncü sıradadır (FAO, 2023). Patates içeriğindeki yüksek besin değeri nedeniyle, yıllık üretimin 5.7 milyon ton olduğu Türkiye'de insanoğlunun yeterli ve dengeli beslenebilmesi için en değerli besinler arasında yer almaktadır (Anonim, Şubat 2025). En fazla patates üretimi 264.830 da alanda 915.734 ton üretimle Niğde ilinde gerçekleşmekte olup, ortalama patates verimi 3.458,00 kg/da' dır (TÜİK, 2024). Niğde patates üretiminde ve ülke ekonomisine katkıda önemli bir yere sahip olmasına rağmen Patates kist nematodu (PKN)'nun tespit edilmesi gelecekteki patates tarımının sürdürülebilirliği için endişe vericidir.

Patates üretimini sınırlayan pek çok hastalık ve zararlı mevcuttur. Bitki paraziti nematodlar, dünya genelinde %10-15 verim kaybına neden olarak patates üretiminde sınırlayıcı faktörlerin başında gelmektedir. Patates bitkisinde bitki paraziti nematod kaynaklı %12 verim kaybı söz konusudur (Lima ve ark., 2018). PKN bulaşık patates alanlarında tespit edilen verim kayıpları %70'e kadar artabilmesine rağmen patojenin durumu hakkında çok az şey bilinmektedir (Sparkes, 2013; Vallejo ve ark., 2020). Nematod kaynaklı zarar ve kayıp oranı popülasyon yoğunluğu, yıllık döl sayısı, patates yetiştirilen sezonun uzunluğu, toprak sıcaklığı ve konukçu bitki türü gibi pek çok faktöre göre değişebilmektedir (Greco, 1993; Sparkes, 2013). *Globodera* spp. patates bitkisinin dünya çapında ekonomik sonuçlar doğuran en önemli karantina zararlıları olarak kabul edildiğinden, birçok biyotik kısıtlama patates üretimini önemli oranda azaltır (Park ve ark., 2019). PKN dünya genelinde patates yetiştiriciliğinde önemli tehdit olup, verim kaybı yanında regülasyon (düzenleme) işlemleriyle ilgili masraflar nedeniyle de önemli ekonomik etkiye sahiptirler (Mimee ve ark., 2019).

PKN içerisinde *G. rostochiensis, G. pallida, G. ellingtonae* ve *G. tabacum* başta olmak üzere dünya çapında tarımı önemli oranda sınırlayan türler saptanmıştır (Subbotin ve ark., 2020).

G. rostochiensis ve *G. pallida* Güney Amerika orjinli olup *G. rostochiensis* 106 ülkede karantina listesinde en çok yer alan bitki paraziti nematod türüdür (Hockland ve ark., 2006). Tüm dünyada *G. rostochiensis, G. pallida*'dan daha fazla yaygınlık göstermektedir (EPPO, 2014). Türkiye'de PKN ilk kez Bolu ili Dörtdivan ilçesinde tespit edilmiştir (Enneli ve Öztürk, 1996). Daha sonraki yıllarda Niğde, Nevşehir, Bolu, Afyonkarahisar, İzmir illerinde de patates yetiştiriciliği yapılan yerlerde varlığı tespit edilmiştir (Evlice ve ark., 2021).

G. rostochiensis ve *G. pallida* kistleri kalıcıdır, yumurtaları yirmi yılı aşkın toprakta canlı kalabilir ve bu nedenle tespit edilen yetiştirme alanlarında yok edilmesi çok zordur (Gartner ve ark., 2021). PKN doğal olarak taşınamaz, farklı lokasyonlara yayılması genellikle fide, fidan, tohumluk materyalin topraklarından ve işlenmiş patateslerde kistler vasıtasıyla olabilir (Jatala ve Bridge, 1990; Lima ve ark., 2018). *G. rostochiensis*'in tarladaki patates bitkisi üst aksamdaki belirtileri; bodur büyüme, yapraklarda sararma, besin elementi eksikliğine benzer semptomlara benzer. Nematodun kendine has semptomlarının olmayışı, yetiştiriciler arasında zararlının farkındalığını azaltır (Price ve ark., 2021).

Dünya genelinde zararlıyla mücadelede dayanıklı çeşit kullanımı ön plana çıkmaktadır ve dayanıklılık çalışmalarında nematodun türü hatta ırkının doğru tespit edilmesi son derece

önemlidir (Gavrilenko ve ark., 2021). Bu sebeple klasik tür teşhisi yanında moleküler teşhiste türleri tespit etmede önerilen tamamlayıcıdır (EPPO, 2017). *G. rostochiensis* ve *G. pallida'*yı ayırt etmede morfolojik teşhis moleküler çalışmalarla teyit edilerek başarılı şekilde uygulanmaktadır (Camacho ve ark., 2017).

Bu çalışmada Niğde ili ve beldelerinde patates yetiştiriciliğinin yoğun olarak yapıldığı tarlalardan elde edilen kist nematodu popülasyonlarının kist ve larvaları morfolojik karekterlerine göre teşhis edilmiştir.

2. MATERYAL VE METOD

Sürvey Çalışması

Arazi çalışmasında Niğde ili ve beldelerinden patates hasadı dönemi ve hemen sonrasında 0-30 cm derinlikten toprak sondası yardımıyla toprak örnekleri alınmıştır (Şekil 1). Alınan örnekler etiketlenerek laboratuvara taşınmıştır. Toprak örneği alınan Patates kist nematodu popülasyonlarının elde edildiği lokasyonlar verilmiştir (Tablo. 1).

Tablo 1. Niğde ilinde toprak örneğinden kist elde edilen lokasyonlar

Örnek No	Köy/Belediye	Enlem-Boylam
P2	Gölcük Belediyesi	38°14'16.2"N-34°26'92.4"E
P4	Tırhan Köyü	38°14'30.5"N-34°42'43.6"E
P6	Niğ- Nev. yolu	38°16'06.6"N-34°44'22.2"E
P8	Tırhan Köyü	38°15'59.8"N-34°44'16.8"E
P9	Orhanlı Belediyesi	38°15'48.3"N-34°44'10.8"E
P11	Alay Belediyesi	38°15'36.5"N-34°43'58.4"E
P12	Ağcaşar Köyü	38°15'33.2"N-34°43'50.6"E
P13	Alay Kasabası	38°15'30.1"N-34°43'43.3"E
P14	Hasaköy Köyü	38°15'28.9"N-34°43'34.8"E
P15	Konaklı Belediyesi	38°15'27.6"N-34°43'27.7"E
P17	Alay Belediyesi	38°15'23.7"N-34°42'49.9"E
P18	Gölcük Belediyesi	38°14'51.5"N-34°42'18.7"E
P22	Alay Belediyesi	38°15'24.1"N-34°43'06.0"E
P30	Yıldıztepe Belediyesi	38°16'04.4"N-34°44'20.5"E
P34	Tırhan Köyü	38°14'35.9"N-34°42'45.5"E
P38	Hasaköy Köyü	38°11'24.0"N-34°47'21.3"E

Kistlerin Elde Edilmesi (Kist Ekstrasyonu)

Araziden alınan toprak örnekleri, laboratuvarda kist ekstrayonu için kurutularak kaba maddeler (taş, dal parçacıkları) temizlenmiştir. Kurutulan örnekten 250 gr alt örnek kist ekstrasyonu için kullanılmıştır. Alt örnek üst kısımda 850 µm çapında, alt kısımda 250 µm çapında olan eleklerden iyice toprak partiküllerinden kistler açığa çıkacak şekilde bol su ile yıkanmıştır (Fenwick, 1940). 850 µm çapındaki elek üzerindeki kaba maddeler uzaklaştırılmıştır. 250 µm çapındaki elekte biriken toprak parçacıkları ve açığa çıkan kistler iyice toz partiküllerinden arındırılarak huni ile kurutma tülüne alınmıştır. Kurutulan toprak örneği binoküler mikroskop (Leica S8AP0) altında *Globodera* spp. kistleri kategorize edilerek +4 C'de kullanılmak üzere saklanmıştır.

Şekil.1 Araziden alınan toprak örneği(a), kistli toprak(b), kistlerin çıkarımı(c), kistlerin görünümü(d)

Kist Nematodları Tür Teşhisi

PKN tür teşhisi morfolojik ve moleküler özellikleri dikkate alınarak yapılabilmektedir (EPPO, 2017). *Globodera* spp. türlerinin morfolojik karekterizasyonunda, kistlerin ve ikinci dönem larvaların (L2) özellikleri dikkate alınır. Kistlerin fenestral bölgesindeki vulva ile anüs arasındaki yükselti sayısı ve uzunluğu, granek oranı ile ikinci dönem larva vücut uzunluğu, kuyruk bölgesi uzunluğu, hyalin uzunluğu, stilet tokmağı, ve stilet uzunluğu kriterleri önemli teşhis karekterleridir (EPPO, 2017).

Kist Nematodları Dişi Birey Vulva Preperatı Çalışması

Globodera türlerinin vulva teşhisi kistlerden yapılmaktadır. PKN kistleri içi yumurtalarla dolu, ölen dişinin vücududur. Kistler önceleri açık renkte, ilerleyen dönemde kahverengi renge dönen uzun yıllar toprakta canlılığını koruyabilen nematodun dayanıklı formudur. Teşhiste vulva preperatı, kistlerin vulva-anüs bölgesini içeren perineal bölgeden yapılmaktadır. PKN kistleri preperat hazırlamadan önce sert yapının kolay kesilmesi için 24 saat süreyle suda bekletilir. Kistler stero mikroskop altında büstri yardımıyla ergin dişi bireyin baş bölgesi, yaklaşık üçte biri vulva kısmına yakın yerden kesilerek vücut içerisindeki yumurtaları dışarı boşaltılır. Kesilen kist parçacığı %15'lik H_2O_2 (Merck, Kat.No. 1.08597.1000) içinde bekletilerek kahverengi kist kesitinin renginin açılması sağlanır. Teşhiste vulva etrafı %45'lik laktik asit ortamında kesilir. Balmumu yüzük yöntemine (Hooper, 1986) göre hazırlanan lamda saf gliserin damlatılan ortama 5-10 adet vulva kesiti yerleştirilerek lamel kapatılır. Lamel ve

lam etrafı hava temasını önleyecek şekilde (Merck, Kat. No, 107961) kapatılarak kalıcı vulva preperatı hazırlanır (Hooper, 1986).

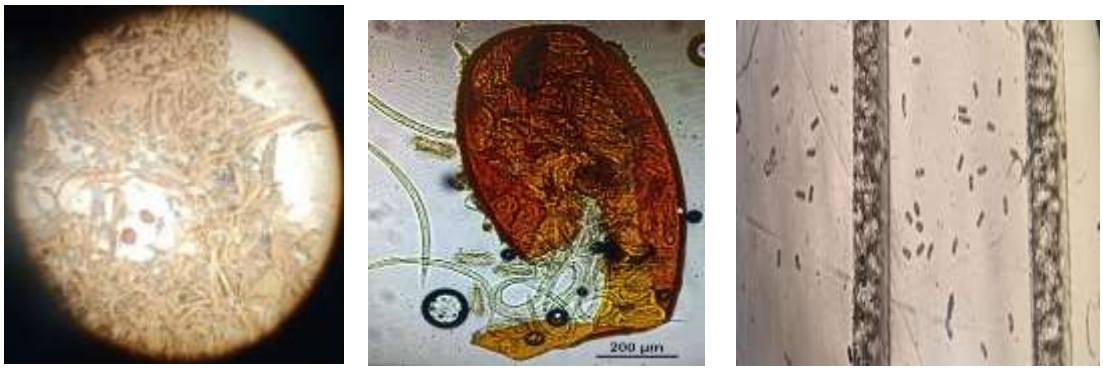
Globodera spp. Dişi Bireylerin Larva Preperatı Çalışması

Globodera spp. ikinci dönem larva preperatı için kistlerden larva fiksasyon işlemi yapılır (Grisse, 1969). Larvalar 65°C'de su banyosunda bekletilerek nematodun dokularına zarar vermeden teşhise hazırlanır. 1 ml TAF (7 ml %40'lık formaldehit, 2 ml trietanolamin ve 91 ml saf su) içerisinde 2 gün bekletilerek fikse edilir. Daha sonra larvalar plastik petriye alınarak kurutulur. Önce 20 kısım 95'lik etanol, 1 kısım gliserin ve 79 kısım saf su içeren çözelti I' den, daha sonra 95 kısım %95'lik etanol ve 5 kısım gliserin içeren çözelti II' den geçirilerek kurutulur. Kalıcı preperat yapımında "Balmumu yüzük" metodu kullanılır (Hooper, 1986). Bu yönteme uygun olarak hazırlanan lamın ortasına saf gliserin damlatılarak içerisine larvalar düzgün şekilde yerleştirilerek üzerine lamel kapatılır. Lam 40°C'lik sıcak plaka aleti üzerinde bekletilerek preperat hazırlanır (Hooper, 1986). Çalışmada PKN ikinci larva dönemi ölçümleri ve dişi nematodların vulva kısımlarına ait ölçümler DM 4000 B LED ışık mikroskobu kullanılarak yapılır. Larva ve vulva ölçüm ve çekimleri LAS IM500 (Leica Application Suite) proğramında gerçekleştirilmiştir. İkinci dönem larva ve kistin vulva alanı kesitlerinin morfolojik teşhiste kullanılan ölçümler *G. rostochiensis'in* sistematikteki teşhis anahtarına göre yapılmıştır (Siddiqi, 2000). Tür düzeyindeki teşhis Golden ve Ellington (1972), Subbotin ve ark.(2010)'a uygun olarak yapılmıştır.

3. BULGULAR VE TARTIŞMA

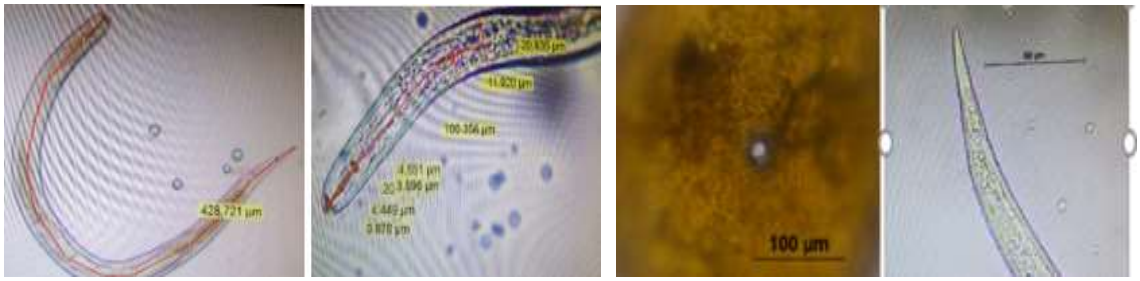
Kist ve Larvalar

Kist nematodu'nun ergin dişileri patates bitkisi dikiminden 6-8 hafta sonra çiçeklenme döneminde köklerde toplu iğne başı büyüklüğünde beyaz, sarı veya kahverengi renkte dikkatlice bakıldığında görülebilmektedir. Bitki köklerinde ölen dişi birey daha koyu renk alarak ilerleyen dönemde dayanıklı formu olan kiste dönüşür. Dişi bireyler önceleri armut şeklinde daha sonraları yuvarlak veya küremsi şekilde görülebilmektedir. Patates bitkisinin vejetasyon dönemini tamamlamasıyla bitki kökleri kuruduktan sonra kökteki kistler toprağa karışır ve uzun yıllar dayanıklı formda toprakta canlılığını korur. Araziden alınan toprak örneklerinden elde edilen kistler, sert yapıda ve açık- koyu kahverengindeydi (Şekil 2). Bitki köklerinde *G. rostochiensis* kistleri kahverengi ve kistlerin ortalama boyu 6.60 mm, eni ise 0.54 mm'dir (Lima ve ark.,2018). Bazen köklerde krem rengi olarak görülen kistler *G. pallida* olarak düşünülebilse de ilerleyen dönemde kahverengine dönüşmektedir. Kistler dişi bireylerin vücududur, kesildiklerinde içerisinde yumurta ve larvalar görülebilir (Şekil 2). Yumurta ve larvalar kist içerinde bulunurlar yumurta paketine sahip değillerdir (EPPO, 2017; Subbotin ve ark., 2010). *G. rostochiensis* ve *G. pallida* kistlerinde larvalar kalıcıdır, yumurtalar yirmi yılı aşkın süre toprakta canlı kalabilir ve bu nedenle nematodun bir kez tespit edildiği alanda yok edilmesi oldukça zordur (Gartner ve ark., 2021).



Şekil 2. Mikroskop altındaki kist (a), L2 dönem larva(b) ve kist içinde yumurtaların(c) görünümü.

Toktay ve ark., (2020) yaptıkları çalışmada ikinci dönem larva ölçümlerinde perineal deseni çevresel fenestrat, kütüküladaki V şeklinde alt yüzey işaretinin yüzeyinde subterminal küçük anüs, kütikül sırtlarını vulva tabanı ile anüs arasında tespit etmişlerdir. Düzensiz yüzey altı noktaları vücudun her yerinde yaygın olarak bulunduğunu ve bazı kistlerin uzun eksenine dik açıyla paralel çizgiler halinde düzenlenmiş olduğunu saptamışlardır (Toktay ve ark., 2020).



Şekil 3. İkinci dönem larva genel görünümü(a), Anterior bölgesi (b), fenestral bölge (c) kuyruk bölgesi (d), görüntüsü

G. rostochiensis'in ikinci dönem larvalarında mikroskop görünümünde, çoğunlukla posteriorde olmak üzere her iki uçta da sivrilen silindirik gövdeye sahipti (Şekil 3a). Baş vücutla boğum oluşturmadan birleşmiş ve labial diski belirgin değildi. İkinci dönem larva teşhisinde en önemli kriterler olan stilet boyu ve şekli açısından larvalar literatürlerde belirtildiği şekilde yuvarlak ve anteriörden basık stilet tokmaklarına sahipti. İkinci dönem larvada stilet belirgin olup, yuvarlak ve anteriordan basık olan stilet tokmakları vardı (Şekil 3b). *Globodera* türlerinin morfolojiye dayalı olarak tür düzeyinde teşhis edilmesi, temel özelliklerinde gözlemlenen değişkenlikler nedeniyle zor olabilmektedir. Median bulb elipsoid şekilde ve valfleri belirgindi. Özefagal bezler vücut uzunluğunun yaklaşık %35'i kadar ventralde bulunmaktaydı. Genital primordiyum hafif posteriörde olmak üzere vücut orta bölgesinde bulunmakta ve lateral alan dört çizgilidir

(Evlice ve ar., 2021). Kuyruk kısmı konik sivri olup uç kısmı yuvarlaktır. Hiyalin bölgesi belirgindir (EPPO,2017; Subbotin ve ark., 2010).

Toktay ve ark., (2020) yılında yaptıkları çalışmada ikinci dönem larva gövdesini ventralde hafif eğik, kuyruk ucu ince bir noktaya doğru sivrilmiş, baş vücudun geri kalanından biraz çıkıntı yapan labial disk ile medial dudaklar boyunca 3-4 halkadan oluştuğunu belirtmiştir. Taramalı elektron mikroskopta labial diskin ve medial dudakların lateral dudaklarla aynı yükseklikte olduğunu, prestoma açıklığını dikdörtgen ve medial dudakların ve labial diskin kalan kısmından marjinal yükseldiğini tespit etmişlerdir. Dudakları dikdörtgen daha büyük boyutlu, bazen düzensiz şekilli ve amfidi taşıdığını, stilet düğmelerini yuvarlak, stilet düğmeleri ile dorsal bez çıkışı arasındaki mesafeyi 3,5-6,5 µm olarak ölçmüşlerdir. Özofageal bezin lobunu vücut uzunluğunun yaklaşık %35'i kadar, genital primordium gövde ortasından biraz sonra, sinir halkasının arkasında boşaltım açığını, median bulb valfini belirgin, anüllerin uzunluğunu gövdenin ortasında, birçok örnekte fazmidi belirsiz, kuyruk ucu pürüzsüz ve halkalı, stilet uzunluğu ve topuz şekli daha önce bildirilenlere benzediğini belirtmişlerdir. (Shahina ve Maqbool 1995; Sirca ve Urek 2004; Subbotin ve Baldwin 2010).

Patates Altın Kist nematodları diğer nematodlarda olduğu gibi teşhiste uzmanlık gerekmekte ölçümler ve gözlemler bir miktar yanıltıcı olabilmektedir. Türlerinin klasik teşhise morfolojiye dayalı olarak tür düzeyinde teşhis edilmesi, larvalarda görülen değişkenlikler nedeniyle zor olabilmektedir. Bu nedenlerden dolayı güvenilir teşhis için kist (vulva) ve ikinci dönem larvalara ait özelliklerin bir arada kullanılması önerilmektedir (EPPO, 2017). Morfolojik ve morfolojik teşhiste türler arası benzerlikler nedeniyle teşhis daha da zordur**.** *Globodera rostochiensis* morfolojik olarak *G. pallida, G. ellingtonae, G. mexicana* ve *G. tabacum*'a büyük benzerlik göstermektedir (Handoo ve Subbotin, 2018). Klasik teşhiste morfolojik ve morfometrik teşhisinde kullanılan birçok karekter olmakla beraber pratikte kistlerde kütikuladaki çizgi sayısı ve granek oranı, ikinci dönem larvalar için stilet uzunluğu ve stilet tokmaklarının şekli büyük önem arz eder (EPPO, 2017; Manduric ve ark., 2004).

Tablo 2. Patates Altın Kist Nematodu larvasının morfolojik ölçüm değerleri (Bkz. Ek)

Yapılan çalışmada ölçümler sonucunda değerlendirmeye alınan 16 popülasyon içerisinde ikinci dönem larva vücut uzunluğu ortalaması 411.70 µm olarak belirlenmiştir. En uzun larva boyu 442.21 µm ile P6 popülasyonunda belirlenirken, en kısa larva boyu ise 359.68 µm ile P40 popülasyonunda tespit edilmiştir. İkinci dönem larvaların teşhisinde stilet boyu ve şekli de teşhiste önemli kriterdir. Stilet boyu açısından bakıldığında ortalama stilet boyu uzunluğu 21,68 µm'dur. En kısa stilet boyu 18,82 µm ile P9 popülasyonunda, en uzun stilet boyu 24,49 µm ile P2 popülasyonunda belirlenmiştir. Teşhiste önemli kriterler olan ortalama kuyruk uzunluğu 46.95 µm olarak tespit edilirken, en uzun kuyruk uzunluğu 54.02 µm ile P18 popülasyonunda, en kısa kuyruk uzunluğu 42.91 µm ile P9 popülasyonunda tespit edilmiştir. Hyalin uzunluğunda en kısa 16.06 µm değeri ile P4 popülasyonunda olurken, en uzun hyalin 26.39 µm ile P2 popülasyonunda tespit edilmiştir. Ortalama hyalin uzunluğu 23.10 µm olarak belirlenmiştir (Tablo 2).

G. rostochiensis'i ve *G. pallida* kıyaslandığında ikinci dönem larvalara ait stilet uzunluğunun daha kısa (21.8 mikron, 19-23 mikron) ve stilet tokmak genişliğinin daha az (3-4 mikron) olduğunu, kistlerdeki sırt deseni sayısının (>14, 16-31), vulva ile anüs arası mesafenin (>55 mikrom, 37-77 mikron) ve Granek oranı (>3, 1.3-9.5) daha yüksek olduğunu, fenestra çapının (<19, 8-20) daha az olduğu bildirilmiştir. *G.rostochiensis* ikinci dönem larvaları stilet tokmakları yuvarlak ve anteriörden basık basık şekilde iken ve *G. pallida* da stilet tokmakları ön yüzeyinde düz ya da anteriordür (EPPO, 2017); Fleming ve Powers, 1998; Subbotin ve ark., 20210; Bačić ve ark., 2013; Altaş ve ark., 2020; Demişbaş Pehlivan ve ark., 2020) Klasik teşhis yapılırken, belirlenen referans aralığının dışına çıkan az sayıda da olsa bireyin olduğu, moleküler olarak teşhis edildiği popülasyonlara da rastlanmaktadır (Oro ve ark., 2010; Inácio ve ark., 2018).Bütün bu morfolojik teşhisler yanında moleküler yöntemle de teşhisin teyit edilmesi önerilmektedir. EPPO'nun 2017 protokolünde de *G. rostochiensis* ve *G. pallida* teşhisinde morfolojik ve moleküler teşhisin bir arada kullanılması önerilmektedir. Bu kriterlerin yanında ikinci dönem larvaların vücut uzunluğu, kuyruk ve hiyalin uzunluğu da sıklıkla kullanılmaktadır. Patates Altın kist nematodu'nun morfolojik teşhisi, çok benzerlik gösteren kist formundaki diğer *Globodera* ve *Heterodera* türleriyle oluşabilecek karmaşayı önlemek için moleküler teşhis yöntemi önem taşır (Inácio ve ark., 2018).

Daha önceki yıllarda yapılan çalışmalarda Niğde, Nevşehir, İzmir, Afyonkarahisar ve Bolu illerinde *G. rostochiensis* varlığını göstermekte olup *G. pallida* varlığına yönelik bir sonuç elde edilmemiştir (Evlice ve ark., 2021). Yapılan bu çalışmada morfolojik olarak 16 adet popülasyonun tamamı *G. rostochiensis* olarak teşhis edilmiş olup *G. pallida* tespit edilmemiştir. Yapılan ölçümler referans literatür ile uyumludur (Fleming ve Powers, 1998; Subbotin ve ark., 2010; Bačić ve ark., 2013; Altaş ve ark., 2020; Pehlivan D. ve ark., 2020; Tokyay ve ark., 2020; Evlice ve ark., 2021). Ulutaş ve ark. (2012) yaptığı çalışmada Türkiyede tespit edilen kist nematodu türü dünyada yaygınlık gösteren *G. rostochiensis* olarak tespit edilmiştir. *G. rostochiensis* 106 ülkeyle karantina listelerinde en çok yer alan bitki paraziti nematod türüdür (Hockland ve ark., 2006).

4. SONUÇ VE ÖNERİLER

PKN karşı mücadelede dayanıklı çeşit kullanımı dünyanın pek çok ülkesinde uygulanmaktadır. Kist nematodları gibi mücadelede dayanıklı çeşitlerin başarıyla uygulandığı zararlılarda tür tespiti daha da önem kazanmaktadır. *G. rostochiensis* ve *G. pallida'* ya karşı geliştirilecek dayanıklı patates çeşitlerinde nematodun türüne özgü dayanıklılık genleri içermelidir. O nedenle türün yanlış tespiti durumunda geliştirilecek çeşit nematoda dayanıklı olmadığı gibi gereksiz maliyet ve emek kaybı yaşanacaktır. Nematodun tür ve ırkının doğru tespit edilerek geliştirilen çeşitler Patates Altın Kist nematoduna karşı mücadelede başarılı sonuçlar vermektedir. *G. rostochiensis* ve *G. pallida*'nın tür teşhisiide morfolojik ve moleküler teşhisin bir arada kullanılması gerekmektedir. Bu durum dayanıklı çeşit geliştirmede önem arz ettiği gibi karantina ve serfitikasyon analizlerinde de önem arz eder. Sonuç olarak Türkiye'de en çok patates üretiminin yapıldığı Niğde ili ve beldelerinden alınan örneklerde 16 adet popülasyondan yapılan morfolojik ölçüm sonuçlarına göre *G. rostochiensis* tespit edilmiştir. *G. pallida*'ya rastlanmamıştır. *G. rostochiensis* popülasyondaki ölçüm değerleri referans literatürle örtüşmektedir. Uzun emek ve maliyet gerektiren kist nematodlarına karşı çeşit geliştirme

çalışmaları içinde tür teşhisi morfolojik, morfometrik ve moleküler çalışmalarla tür teşhisi teyit edilerek yapılması önerilmektedir.

Teşekkür: Bu çalışma "Bazı Patates Çeşitleri Ve Islah Klonlarının Patates Altın Kist Nematodu(*Globodera rostochiensis*, Wollenweber)'na Karşı Reaksiyonunun Belirlenmesi" isimli TAGEM/TBAD/T1/16/A04/P3/P01/2499 nolu proje kapsamında Tarımsal Araştırma ve Politikalar Genel Müdürlüğü tarafından desteklenmiştir.

Çıkar Çatışması Beyanı: Makalede yazaralar aralarında çıkar çatışması olmadığını beyan etmektedirler.

Araştırmacıların Katkı Oranı Beyan Özeti: Yazarlar eşit oranda makaleye katkı sağlamış olduklarını beyan ederler.

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Tablo 1. Niğde ilinde toprak örneğinden kist elde edilen lokasyonlar

Örnek No	Köy/Belediye	Enlem-Boylam
P2	Gölcük Belediyesi	38°14'16.2"N-34°26'92.4"E
P4	Tırhan Köyü	38°14'30.5"N-34°42'43.6"E
P6	Niğ- Nev. yolu	38°16'06.6"N-34°44'22.2"E
P8	Tırhan Köyü	38°15'59.8"N-34°44'16.8"E
P9	Orhanlı Belediyesi	38°15'48.3"N-34°44'10.8"E
P11	Alay Belediyesi	38°15'36.5"N-34°43'58.4"E
P12	Ağcaşar Köyü	38°15'33.2"N-34°43'50.6"E
P13	Alay Kasabası	38°15'30.1"N-34°43'43.3"E
P14	Hasaköy Köyü	38°15'28.9"N-34°43'34.8"E
P15	Konaklı Belediyesi	38°15'27.6"N-34°43'27.7"E
P17	Alay Belediyesi	38°15'23.7"N-34°42'49.9"E
P18	Gölcük Belediyesi	38°14'51.5"N-34°42'18.7"E
P22	Alay Belediyesi	38°15'24.1"N-34°43'06.0"E
P30	Yıldıztepe Belediyesi	38°16'04.4"N-34°44'20.5"E
P34	Tırhan Köyü	38°14'35.9"N-34°42'45.5"E
P38	Hasaköy Köyü	38°11'24.0"N-34°47'21.3"E

Tablo 2. Patates Altın Kist Nematodu larvasının morfolojik ölçüm değerleri

Tür karekterleri	Popülasyon Kodları			
	P2	P4	P6	P8
L2 uzunluğu	433.41±5.86 (423.81-442.04)	415.11±8.66 (403.19-430.39)	442.21±7.02 (427.91-451.59)	437.29±13.30 (418.69-463.09)
L2 uzunluğu/vücut genişliği	22.70±0.21 (22.37-23.10)	22.20±1.86 (19.53-24.75)	23.59±1.73 (21.11-27.82)	24.20±0.75 (23.04-25.51)
L2 uzunluğu/kuyruk uzunluğu	9.90±1.10 (8.25-12.05)	9.31±0.56 (8.50-10.32)	9.50±0.73 (8.47-10.89)	8.35±0.43 (7.81-9.48)
Kuyruk uzunluğu/anüs vücut genişliği	3.42±0.12 (3.11-3.65)	3.61±0.14 (3.51-3.79)	4.29±0.33 (3.89-4.81)	4.53±0.21 (4.16-4.61)
Stylet	24.49±0.64 (23.71-25.82)	22.51±0.29 (22.11-23.15)	21.92±1.02 (20.19-23.69)	23.15±1.05 (21.19-24.79)
Kuyruk uzunluğu	44.74±4.63 (36.81-52.79)	44.76±1.63 (41.51-46.71)	47.04±3.60 (40.81-53.31	52.96±3.56 (46.69-59.01)
Anüsteki vücut genişliği	13.06±0.65 (11.91-14.11)	12.21±0.18 (12.05-12.61)	11.01±0.37 (10.41-11.71)	11.94±0.47 (11.41-12.91)
Vücut genişliği	19.11±0.45 (18.31-19.82)	18.91±1.54 (16.51-21.81)	18.19±1.11 (16.01-19.39)	18.12±0.33 (17.61-18.69)
Hyalin	26.39±0.84 (24.69-27.39)	16.06±2.95 (10.19-19.71)	26.12±0.63 (24.91-26.91)	24.81±1.72 (21.41-27.11)

5.

Tablo devam

Tablo 2. Patates Altın Kist Nematodu larvasının morfolojik ölçüm değerleri

Tür karekterleri	Popülasyon Kodları			
	P9	P11	P12	P13
L2 uzunluğu	430.35±8.27 (416.8-444.78)	428.27±9.32 (412.58-444.85)	424.01±0.43 (423.19-424.69)	427.81±7.07 (414.48-438.67)
L2 uzunluğu/vücut genişliği	24.60±1.49 (22.21-27.42)	24.04±0.68 (22.68-25.01)	21.63±0.61 (20.53-22.66)	22.95±0.02 (22.91-23.02)
L2 uzunluğu/kuyruk uzunluğu	10.03±0.36 (9.53-10.70)	9.42±0.48 (8.55-10.26)	9.43±0.17 (9.11-9.63)	9.19±0.38 (8.49-9.85)
Kuyruk uzunluğu/anüs vücut genişliği	4.11±0.21 (3.73-4.35)	4.06±0.37 (3.31-4.51)	3.52±0.10 (3.34-3.65)	3.73±0.23 (3.35-4.18)
Stylet	18.82±2.22 (16.51-23.31)	18.84±1.19 (17.61-21.21)	21.09±0.21 (20.71-21.29)	22.62±0.26 (22.11-23.01)
Kuyruk uzunluğu	42.91±0.71 (41.49-43.59)	45.56±1.42 (43.31-48.21)	44.92±0.81 (43.91-46.49	46.72±2.76 (42.01-51.59)
Anüsteki vücut genişliği	10.48±0.66 (9.51-11.69)	11.41±0.84 (10.41-13.11)	12.74±0.31 (12.11-13.11)	12.51±0.13 (12.31-12.71)
Vücut genişliği	17.46±1.38 (15.21-20.01)	17.86±0.92 (16.51-19.61)	19.62±0.54 (18.69-20.61)	18.64±0.28 (18.11-19.11)
Hyalin	22.48±1.75 (18.91-24.32)	22.54±0.83 (20.91-23.41)	23.92±1.64 (20.69-25.91)	23.18±1.18 (20.79-24.61)

Tablo devam

Tablo 2. Patates Altın Kist Nematodu larvasının morfolojik ölçüm değerleri

Tür karekterleri	Popülasyon Kodları			
	P14	P15	P17	P18
L2 uzunluğu	428.08±5.63 (417.81-435.03)	394.98±8.08 (382.11-409.91)	391.31±19.13 (361.21-426.81)	359.68±12.85 (334.71-377.51)
L2 uzunluğu/vücut genişliği	21.01±1.05 (19.58-23.07)	19.87±0.06 (19.83-19.91)	20.07±2.46 (16.62-24.80)	18.86±0.54 (18.08-19.94)
L2 uzunluğu/kuyruk uzunluğu	9.38±0.21 (8.98-9.65)	8.56±0.07 (8.44-8.71)	8.01±1.35 (5.34-9.84)	7.14±1.33 (4.92-9.47)
Kuyruk uzunluğu/anüs vücut genişliği	3.88±0.198 (3.51-4.10)	3.50±0.31 (2.91-3.92)	4.76±0.37 (4.11-5.42)	3.87±0.51 (2.93-4.63)
Stylet	22.84±0.40 (22.19-23.61)	21.26±1.476 (18.81-23.91)	20.81±1.489 (18.81-23.71)	21.82±1.07 (19.81-23.49)
Kuyruk uzunluğu	45.81±1.28 (44.01-48.31)	46.11±0.52 (45.31-47.11)	44.86±12.57 (23.91-67.41)	54.02±10.42 (39.81-74.31)
Anüsteki vücut genişliği	11.81±0.62 (10.71-12.79)	13.30±1.11 (12.01-15.49	10.71±0.92 (9.21-12.39)	13.84±1.20 (11.79-16.01)
Vücut genişliği	20.52±1.23 (18.11-22.21)	19.86±0.42 (19.19-20.61)	19.86±1.75 (17.19-23.21)	19.06±0.61 (18.39-20.29)
Hyalin	22.29±1.04 (20.19-23.39)	21.81±1.13 (19.71-23.49)	24.29±5.91 (14.79-35.09)	23.71±2.07 (19.59-26.41

Tablo devam

Tablo 2. Patates Altın Kist Nematodu larvasının morfolojik ölçüm değerleri

Tür karekterleri	Popülasyon Kodları			
	P22	P30	P34	P38
L2 uzunluğu	429.07±5.63 (417.81-435.03)	394.96±8.08 (382.11-409.91)	391.31±19.12 (361.21-426.81)	359.68±12.85 (334.71-377.51)
L2 uzunluğu/vücut genişliği	21.01±1.05 (19.58-23.07)	19.87±0.01 (19.83-19.91	20.07±2.46 (16.64-24.83)	18.86±0.54 (18.08-19.94)
L2 uzunluğu/kuyruk uzunluğu	9.36±0.21 (8.98-9.63)	8.55±0.07 (8.44-8.71)	8.01±1.35 (5.36-9.86)	7.14±1.33 (4.94-9.47)
Kuyruk uzunluğu/anüs vücut genişliği	3.88±0.18 (3.51-4.10)	3.50±0.31 (2.91-3.92)	4.76±0.37 (4.11-5.42)	3.87±0.51 (2.95-4.63)
Stylet	22.82±0.40 (22.21-23.61)	21.26±1.46 (18.81-23.91)	20.81±1.47 (18.81-23.71)	21.82±1.08 (19.88-23.51)
Kuyruk uzunluğu	45.81±1.28 (44.01-48.31)	46.11±0.53 (45.31-47.11)	44.86±12.57 (23.91-67.41)	54.02±10.42 (39.81-74.31)
Anüsteki vücut genişliği	11.81±0.62 (10.71-12.81)	13.30±1.11 (12.01-15.51)	10.71±0.92 (9.21-12.41)	13.82±1.20 (11.81-16.01)
Vücut genişliği	20.52±1.23 (18.11-22.21)	19.86±0.40 (19.21-20.61)	19.86±1.75 (17.21-23.21)	19.06±0.61 (18.41-20.31)
Hyalin	22.31±1.06 (20.21-23.41)	21.81±1.13 (19.71-23.51)	24.31±5.91 (14.81-35.11)	23.71±2.09 (19.61-26.41)

THE POWDERY MILDEWS OF YEDİGÖLLER NATIONAL PARK, BOLU PROVINCE, TÜRKİYE

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ABSTRACT

The powdery mildews (*Erysiphaceae*) are an important group of obligate plant pathogens with an almost worldwide distribution on a wide range of angiosperms. The current study was carried out based on powdery mildew specimens collected from Yedigöller National Park, Bolu Province, Türkiye. Yedigöller National Park, which has seven lakes and numerous streams, has a semi-arid, upper, cold winter Mediterranean climate of daily and seasonal photoperiodism according to Emberger's climate classification.

Plant specimens infected with powdery mildews were collected in the Yedigöller National Park in Bolu Province of Türkiye. Host specimens were prepared according to herbarium techniques. Host plants were identified using the Flora of Turkey and East Aegean Islands. Thin sections prepared from infected host tissue were examined under a Leica DM E light microscope and measured from mounts in tap water. 20 microscopic structures were measured for each sample. Infected host surfaces were photographed using a Leica EZ4D stereo microscope.

As a result of field and laboratory studies, a total of 16 *Erysiphaceae* species were identified: *Erysiphe adunca, E. aquilegiae, E. convolvuli, E. corylacearum, E. heraclei, E. mayorii, E. pisi, E. polygoni, E. tortilis, Golovinomyces valerianae, Neoerysiphe galeopsidis, Phyllactinia fraxini, P. guttata, Po. aucupariae* var. *arcuatispora, Po. helianthemi* and *Po. plantaginis*. Of these, *Podosphaera helianthemi* is a new record for Türkiye mycobiota. The description of the new recorded species is presented and discussed with its macro and micromorphological photographs. All examined specimens were deposited in the Mycological Collection of the Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Landscape Architects, Kırşehir, Türkiye.

INTRODUCTION

The powdery mildews (*Erysiphaceae*) represent a large group of common, obligate plant pathogens of cosmopolitan distribution, usually easily recognizable by their obvious symptoms, i.e. superficial white powdery patches or films of the anamorphic, composed of mycelium, conidiophores and conidia, on leaves, stems and other plant organs. The economic importance of these fungi in phytopathology and plant protection is enormous (Braun and Cook 2012). The host range of powdery mildews consists of almost 10,000 host species worldwide (Amano 1986). With new records added each year, both the number of species and the number of hosts are increasing significantly. In Türkiye, 167 powdery mildews belonging to 18 teleomorphic and anamorphic genera were observed on many different host plants (Kabaktepe et al. 2020; Sesli et al. 2020; Bradshaw et al. 2024).

Studied area Yedigöller National Park is located in the northern part of Bolu Province in the Western Black Sea Region in Türkiye and it includes seven lakes and many streams. According to the Davis's grid square system (1965), the park is situated in the square A3. The climate of the province is a semi-arid, upper, cold winter Mediterranean climate of daily and seasonal photoperiodism according to Emberger's climate classification.

The research area comprises primarily mixed forest vegetation. At lower elevations the forest is dominated by *Carpinus orientalis*, *Fagus orientalis*, *Sambucus nigra*, *Sorbus aucuparia*, *S. torminalis*, *Acer* ssp., *Quercus* spp., *Corylus colurna*, *Cornus mas*, *Alnus glutinosa* and *Populus tremula*. Regions at upper elevations are covered with *Gymnospermae* such as *Abies nordmanniana* subsp. *equi-trojani*, *P. sylvestris*, *Pinus nigra*, and *Taxus baccata*. The understory contains shrubs such as *Rhododendron ponticum*, *Juniperus oxycedrus*, and *Daphne pontica*. The research area is also rich in marshy habitats, and there are aquatic plants in the lake and marsh plants surround the edge of the lake.

The purpose of the current study is to determine the powdery mildews of Yedigöller National Park and make a contribution to mycobiota of Türkiye.

MATERIALS and METHODS

Plant specimens infected with powdery mildews were collected in the Yedigöller National Park in Bolu Province of Türkiye. Host specimens were prepared according to herbarium techniques. Host plants were identified using the Flora of Turkey and East Aegean Islands (Davis 1965–85). Thin sections prepared from infected host tissue were examined under a Leica DM E light microscope and measured from mounts in tap water. 20 microscopic structures were measured for each sample. Infected host surfaces were photographed using a Leica EZ4D stereo microscope. Species were identified using relevant literature (Ellis and Ellis 1987, 1998; Geluta 1989; Braun 1995; Braun and Cook 2012; Bradshaw et al. 2024).

RESULTS

During our study on determining the microfungi on vascular plants in Yedigöller National Park (it is abbreviated as YNP), we collected powdery mildews that infect leaves and stems. As a

result of field and laboratory studies, a total of 16 species belonging to the *Erysiphaceae* family were identified. Of these, *Podosphaera helianthemi* is a new record for Türkiye mycobiota. The list of powdery mildews with their descriptions (for new record only), localities, habitats, host plants, coordinates, altitudes, collection dates, and voucher numbers was arranged below according to the systematics given in Index Fungorum (2025).

Fungi

Ascomycota

Leotiomycetes

Helotiales

Erysiphaceae

Erysiphe adunca (Wallr.) Link

Specimen examined: Bolu Province, YNP, near the İncegöl-Sazlıgöl, on living leaves of *Populus tremula* L. (*Salicaceae*), 40°56′19″N, 31°44′29″E, 901 m, 11.08.2019, GD 1577; Bolu Province, Yedigöller National Park, 40°55′08″N, 31°41′38″E, 1355 m, 08.09.2018, GD 1660.

Erysiphe aquilegiae DC.

Specimen examined: Bolu Province, YNP, roadside, on living stems, petioles and leaves of *Ranunculus* L. sp. (*Ranunculaceae*), 40°53′19″N, 31°41′03″E, 1616 m, 14.07.2019, GD 1964.

Erysiphe convolvuli DC.

Specimen examined: Bolu Province, YNP, near the Atmaca Observation Terrace, under the forest, on living leaves of *Calystegia* R. Br. sp. (*Convolvulaceae*), 40°55′44″N, 31°44′32″E, 1225 m, 22.09.2019, GD 2229.

Erysiphe corylacearum U. Braun & S. Takam.

Specimen examined: Bolu Province, YNP, near the Atmaca Observation Terrace, under the forest, on living leaves of *Corylus* L. sp. (*Betulaceae*), 40°55′44″N, 31°44′32″E, 1225 m, 22.09.2019, GD 2234; Bolu Province, Yedigöller National Park, near the Atmaca Observation Terrace, 40°55′49″N, 31°45′00″E, 1080 m, 22.09.2019, GD 2293.

Erysiphe heraclei DC.

Specimen examined: Bolu Province, YNP, under the forest, on living leaves of *Anthriscus* Pers. sp. (*Apiaceae*), 40°55′76″N, 31°44′04″E, 461 m, 27.06.2018, GD 1314; Bolu Province, Yedigöller National Park, 40°56′49″N, 31°44′51″E, 1166 m, 28.06.2018, GD 1371; Bolu Province, Yedigöller National Park, 40°55′08″N, 31°41′38″E, 1355 m, 08.09.2018, GD 1663.

Erysiphe mayorii S. Blumer

Specimen examined: Bolu Province, YNP, near the İncegöl-Sazlıgöl, under the forest, on living leaves of *Cirsium arvense* (L.) Scop. (*Asteraceae*), 40°56′19″N, 31°44′29″E, 901 m, 11.08.2019, GD 2277.

Erysiphe pisi DC.

Specimen examined: Bolu Province, YNP, on living stems and leaves of *Astragalus* L. sp. (*Fabaceae*), 40°55′76″N, 31°44′04″E, 716 m, 27.06.2018, GD 1975; Bolu Province, YNP, near the İncegöl-Sazlıgöl, under the forest, on living leaves of *Trifolium repens* var. *repens* L. (*Fabaceae*), 40°54′52″N, 31°41′59″E, 1370 m, 11.08.2018, GD 1598.

Erysiphe polygoni DC.

Specimen examined: Bolu Province, YNP, near the Seringöl, on living leaves of *Polygonum* L. sp. (*Polygonaceae*), 40°56′42″N, 31°44′51″E, 785 m, 08.09.2018, GD 1675.

Erysiphe tortilis (Wallr.) Link

Specimen examined: Bolu Province, YNP, roadside, on living leaves of *Cornus mas* L. (*Cornaceae*), 40°56′11″N, 31°44′22″E, 889 m, 03.08.2019, GD 2286.

Golovinomyces valerianae (Jacz.) V.P. Heluta

Specimen examined: Bolu Province, YNP, near the Atmaca Observation Terrace, under the forest, on living leaves of *Valeriana alliariifolia* Adams (*Caprifoliaceae*), 40°55′44″N, 31°44′32″E, 1225 m, 22.09.2019, GD 2231.

Neoerysiphe galeopsidis (DC.) U. Braun

Specimen examined: Bolu Province, YNP, Mengen road, the stream's edge, on living leaves of *Ballota* L. sp. (*Lamiaceae*), 40°57′00″N, 31°44′49″E, 559 m, 03.05.2019, GD 1808.

Phyllactinia fraxini (DC.) Fuss

Specimen examined: Bolu Province, YNP, near the Anıt Karaçam, under the forest, on living leaves of *Fraxinus angustifolia* subsp. *angustifolia* Vahl (*Oleaceae*), roadside, 40°55′40″N, 31°44′59″E, 1143 m, 22.09.2019, GD 2237; Bolu Province, YNP, near the Atmaca Observation Terrace, 40°55′49″N, 31°45′00″E, 1080 m, 22.09.2019, GD 2288; Bolu Province, YNP, near the Atmaca Observation Terrace, 40°55′49″N, 31°45′00″E, 1080 m, 17.09.2021, GD 2515.

Phyllactinia guttata (Wallr.) Lév.

Specimen examined: Bolu Province, YNP, near the Atmaca Observation Terrace, under the forest, on living leaves of *Corylus* sp. L. (*Betulaceae*), 40°55′44″N 31°44′32″E, 1225 m, 22.09.2019, GD 2234; Bolu Province, YNP, near the Atmaca Observation Terrace, under the forest, 40°55′43″N, 31°44′31″E, 1220 m, 18.09.2021, GD 2512.

Podosphaera aucupariae var. ***arcuatispora*** G. Doğan, Erdoğdu & U. Braun

Specimen examined: Bolu Province, YNP, near the Atmaca Observation Terrace, under the forest, on living leaves of *Sorbus aucuparia* L. (*Rosaceae*), 40°55′41″N, 31°44′58″E, 1110 m, 25.09.2022, GD 2563.

Podosphaera helianthemi (L. Junell) U. Braun & S. Takam.

Mycelium on stems and leaves, amphigenous, thin, effuse. Chasmothecia mostly hypophyllous, scattered or in groups, globose, 65–100 µm diam., dark brown. Appendages in the lower half, less then 10, mycelioid, septate, brown up to the upper. Ascus subglobose, ellipsoid, broad ovate, 51–71 × 43–62 µm, sessile, 8-spored. Ascospores ellipsoid-ovoid, 18–22 × 10–14 µm, hyaline, guttulate. Conidia doliiform, 27–30 × 12.8–17.2 µm, hyaline.

Specimen examined: Bolu Province, YNP, on living stems and leaves of *Helianthemum nummularium* subsp. *nummularium* (L.) Mill. (*Cistaceae*), 40°79′80″N, 31°64′55″E, 964 m, 28.06.2018, GD 1354.

Podosphaera plantaginis (Castagne) U. Braun & S. Takam.

Specimen examined: Bolu Province, YNP, near the Kapankaya Observation Terrace, roadside, on living leaves of *Plantago* L. sp. (*Plantaginaceae*), 40°55′40″N, 31°44′12″E, 1290 m, 21.09.2019, GD 2179.

DISCUSSION

In the research area, powdery mildew fungi living as parasites on their hosts are represented by 5 genera and 16 species belonging to these genera. Of these, *Podosphaera helianthemi* is a new record for Türkiye mycobiota. In Türkiye, 167 powdery mildews belonging to 18 anamorphic and teleomorphic genera were observed on many different host plants (Kabaktepe et al. 2020; Sesli et al. 2020; Bradshaw et al. 2024). This study has contributed to the Turkish mycobiota and the number of powdery mildew species in Türkiye has reached 168.

During our research, we observed *Ampelomyces quisqualis* Ces., a hyperparasite on *Erysiphe pisi*. *Ampelomyces quisqualis* is a useful hyperparasite fungus species used as a biological fungicide. This fungus is especially used to control powdery mildew diseases. It attacks and destroys the mycelium and spores of the fungi that cause powdery mildew disease. *Ampelomyces quisqualis* attracts attention as an environmentally friendly biological agent used as an alternative to chemical fungicides in agriculture.

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THE SYMPTOMATOLOGY, EPIDEMIOLOGY, ECOLOGY AND MANAGEMENT PRACTICES OF *RHYNCHOSPORIUM GRAMINICOLA* AS BARLEY LEAF BLOTCH/SCALD PATHOGEN

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ABSTRACT

Barley (*Hordeum vulgare*) is an important crop worldwide not only in terms of production but also in terms of area under cultivation and is a staple cereal widely grown in arid regions. It has a wide range of uses in agriculture, industry and food production. It is used as malt or beer for humans and also as feed for animals such as cattle, sheep and chickens. Barley can improve soil fertility and reduce erosion, both as a source of income for growers and as a sustainable agricultural component in crop rotation. However, several factors affect its production and productivity; among biotic factors, barley leaf spot blotch/scald is one of the most important fungal diseases. The disease agent was first identified as *Marsonia secalis*, but it was later shown to cause scald disease in Rye. Detailed morphology studies revealed the genus *Rhynchosporium*, which contains beaked and two-celled conidia. The disease was renamed *R. secalis*. However, phylogenetic analysis revealed that *R. secalis* is a complex pathogen group consisting of three host-specific species. *R. secalis* on Rye and Triticale; *R. agropyri* on Common Ryegrass; and *R. commune* on Barley, Great Bromine and other *Hordeum* species were identified as the fungal causal agents of "Leaf Spot Blotch/Scald" disease. Nowadays, researchers have suggested that the barley leaf spot blotch disease caused by *R. commune* should be changed from *R. commune* to *R. graminicola* based on the priority of naming. The causal agent of barley leaf blotch, *R. graminicola*, can cause up to 100% yield losses in countries where barley is grown continuously without crop rotation, such as Morocco, Ethiopia, Peru, Colombia, Ecuador, Turkey, Syria and Iran. *R. graminicola* is an overwintering, spore-producing fungus that can survive in agricultural waste such as stalks and straw for up to one year. It can survive on or below the soil surface and after harvest the pathogen can spread through seeds. Disease severity depends on the amount of plant residue on the soil surface and also coleoptiles are infected when infected seeds germinate under favorable conditions. The

disease can cause epidemics in cool vegetation with frequent rains. Secondary inoculum is dispersed by wind-borne rain splash after the formation of the first lesions. Both leaf and spike are infected. Large watery gray-green spots turn white with brown edges as the leaves dry. This disease produces a completely gray form of the symptom on barley. The spots accumulate frequently, killing the whole leaf. Many methods are proposed to control the disease. Of these, planting resistant barley varieties is used as the best method of control. Also biological agents: *Bacillus subtilis, B. polymyxa* and *Paenibacillus polymyxa* are very effective in controlling this disease. Finally, different fungicides are recommended. The aim of this review is to evaluate various findings on the taxonomy, ecology, epidemiology, symptomatology and epidemiology of *R. graminicola* disease agent of barley.

Keywords: Biology, Etiology, *Rhynchosporium graminicola*, Taxonomy

ARPA YAPRAK LEKESİ/YANIKLIĞI PATOJENİ *RHYNCHOSPORİUM GRAMİNİCOLA*'NIN SİMPTOMATOLOJİSİ, EPİDEMİYOLOJİSİ, EKOLOJİSİ VE MÜCADELE YÖNTEMLERİ

ÖZET

Arpa (*Hordeum vulgare*) dünya genelinde sadece üretim miktarı ile değil ayrıca ekim alan açısından önemli bir ürün olup kurak bölgelerde oldukça yaygın yetiştirilen temel bir tahıldır. Tarım, endüstri ve gıda üretiminde geniş bir kullanım yelpazesine sahiptir. İnsanlar için malt ya da bira ve ayrıca sığır, koyun ve tavuk gibi hayvanlar için yem olarak kullanılır. Arpa yetiştiriciler için hem gelir kaynağı hem de ürün rotasyonu içerisinde yer alarak sürdürülebilir bir tarım bileşeni olmasıyla toprak verimliliğini artırabilir ve erozyonu azaltabilir. Bununla birlikte, çeşitli faktörler üretimini ve verimliliğini etkiler; biyotik faktörler arasında, arpa yaprak lekesi/yanıklığı en önemli fungal hastalıklardan biridir. Hastalık etmeni ilk olarak *Marsonia secalis* olarak tanılanmış ancak daha sonra bu etmenin çavdarda yanıklık hastalığına neden olduğu ortaya konulmuştur. Detaylı morfoloji çalışmaları gagalı ve iki hücreli konidileri içeren *Rhynchosporium* cinsini ortaya çıkarmıştır. Hastalık *R. secalis* olarak yeniden adlandırılmıştır. Ancak, filogenetik analizlere göre, *R. secalis*, konukçulara özel üç türden oluşan kompleks bir patojen grubu olduğu belirlenmiştir. Çavdar ve Tritikale'de *R. secalis*; Ayrık otu'nda *R. agropyri*; Arpa, Büyük Brom ve diğer *Hordeum* türlerinde *R. commune* ''Yaprak lekesi/Yanıklığı'' hastalığının fungal etmenleri olarak tespit edilmiştir. Günümüzde, araştırmacılar, *R. commune* tarafından oluşturulan arpa yaprak lekesi/yanıklık hastalığının adlandırma önceliğine dayanarak *R. commune* etmeni yerine *R. graminicola* olarak değiştirilmesini önermiştir. Arpa yaprak yanıklığına neden olan *R. graminicola* etmeni Fas, Etiyopya, Peru, Kolombiya, Ekvador, Türkiye, Suriye ve İran gibi arpanın ekim nöbeti olmaksızın sürekli olarak yetiştirildiği ülkelerde %100'e yakın verim kayıplarına neden olabilir. *R. graminicola*, sap ve saman gibi tarımsal atıklarda bir yıla kadar hayatta kalabilen, kışlayan ve spor üreten bir fungustur. Toprak yüzeyinde veya altında hayatta kalabilir ve hasattan sonra patojen tohumlar aracılığıyla yayılabilir. Hastalık şiddeti toprak yüzeyindeki bitki artık miktarına bağlıdır ve ayrıca enfekteli tohumlar uygun koşullarda çimlendiğinde koleoptil'ler enfektelenir. Hastalık serin ve sık yağmurlu geçen vejetasyonlarda epidemi oluştura bilir. İkincil inokulum, ilk lezyonların oluşumundan sonra rüzgârla taşınan yağmur sıçramasıyla dağılır. Hem yaprak kını hem de başaklar enfektelenir. Büyük sulu gri-yeşil lekeler, yapraklar kurudukça kahverengi kenarlarla beyazlar. Bu hastalık arpa üzerindeki simptomun tamamen gri renkli bir formunu oluşturur. Lekeler sık sık birikir, tüm yaprağı öldürür. Hastalık mücadelesinde birçok yöntem önerilmektedir. Bunlardan dirençli arpa çeşitlerinin ekimi en iyi mücadele yöntemi olarak kullanılmaktadır. Ayrıca biyolojik ajanlardan: *Bacillus subtilis, B. polymyxa* ve *Paenibacillus polymyxa* bu hastalığın kontrolünde oldukça etki göstermektedirler. Son olarak farklı fungisitler önerilmektedir. Bu derleme kapsamında arpa bitkisine arız olan *R. graminicola* hastalık etmeninin taksonomisi, ekolojisi, epidemiyolojisi, simptomatolojisi üzerine çeşitli bulguları değerlendirmek amaçlanmıştır.

Anahtar Kelimeler: Biyoloji, Etiyoloji, *Rhynchosporium graminicola*, Taksonomi.

1. GİRİŞ

Arpa yaprak lekesi/yanıklığı, dünya çapında ılıman ve nemli bölgelerde arpayı etkileyen, verimde %40'a varan düşüşlere ve tane kalitesinde düşüşe neden olan yıkıcı bir hastalıktır (Wondimu vd 2022). *Rhynchosporium commune* olarak adlandırılan hastalık etmeni en son olarak *R. graminicola* olarak revize edilmiştir (Ababa vd 2023). *R. graminicola* polisiklik bir yaşam döngüsüne sahiptir. Hastalığın birinci inokulumu ürün artıkları, enfekte tohumlar ve askosporlardır. İkincil inokulum, enfekte yapraklar üzerindeki konidilerin sıçrama yoluyla yayılmasıyla gerçekleşir (Srivastava vd 2020). İlk hastalık belirtileri yaprak ayaları ve kınları üzerinde su ile ıslanmış lezyonlar olarak ortaya çıkar. Lezyonlar oval ila düzensiz şekildedir ve gri-yeşil renkten belirgin bir kahverengi kenar ile saman rengine dönüşür (Ababa vd 2023). Kontrol yöntemleri arasında direnç materyalleri ve çeşit karışımları bulunur. Son seçenek olarak çeşitli fungisitler önerilmiştir. Ancak, gelişmemiş ülkelerde patojenite testi, tohum uygulamaları, toprak işleme, çeşit karışımları ve biyolojik kontrol genellikle göz ardı edilmektedir. Sonuç olarak, bu çalışma arpa yanıklığı biyolojisi ve kontrol önlemlerinin kapsamlı bir değerlendirmesinin yanı sıra, toprak işleme, ürün rotasyonu, ekim tarihleri ve çeşitlerin etkilerini belirtmeyi içermektedir. Genel olarak bu derleme, arpa yaprak lekesi/yanıklığı hastalığının simptomatolojisi, epidemiyolojisi, ekolojisi ve mücadele yöntemlerini gözden geçirmek üzere tasarlanmıştır.

2. ARPA YETİŞTİRİCİLİĞİNE GENEL BAKIŞ

Arpa (*Hordeum vulgare*) Poaceae familyasına ait 14 kromozomlu, kendi kendine tozlaşan, diploid bir türdür (Bishnoi vd 2022). Arpa çiçekleri, kendine özgü bir balıksırtı deseninde düzenlenmiş başakçık kümeleridir. Her başakçığın uzun ince bir kılçığı vardır, bu da başakların püsküllü görünmesini sağlar. Başakçıklar üçlü kümeler halindedir. Altı sıralı arpada, her salkımdaki üç başakçık da verimlidir; iki sıralı arpada ise sadece ortadaki başakçık verimlidir (Kikuchi & Handa 2009). Arpa tahıllar içerisinde iyi bir protein kaynağı olarak insanoğlunun sağlıklı beslenmesi, yoksulluğu ve açlığı azaltma ve ekosistem dengesini koruma gibi özellikleri nedeniyle dünya ekonomisinde büyük bir öneme sahiptir (Lukinac & Jukić 2022). 2023 yılı dünya tahıl üretim alanı (738.760.312 ha)'nın yaklaşık %6'sı Arpa ekim alanları (4.6254.750 ha)'ndan oluşmuştur (FAOSTAT 2023). Buna ek olarak, 2023 yılı dünya tahıl üretim miktarı (3.102.697.575 ton)'nın yaklaşık %5'i arpa üretimi (145.759.524 ton)'nden oluşmuştur. Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO)'nün, 2023 verilerine göre Türkiye 9.2 milyon ton arpa üretimi ile sırasıyla Rusya, Avustralya, Fransa ve Almanya'dan sonra en fazla arpa üretimine sahip beşinci ülkedir (FAOSTAT 2023).

Arpa, büyüme mevsiminde 15 ila 20 °C gibi nispeten düşük sıcaklıkları tercih eden bir üründür; dünya çapında ılıman bölgelerde yetiştirilir (Hakala vd 2020). En iyi şekilde iyi drene edilmiş toprakta tam güneş ışığı altında yetişir. Tropik ve subtropik bölgelerde, Güney Asya'da, Kuzey ve Doğu Afrika'da ve Güney Amerika'nın And Dağları'nda yiyecek ve saman için yetiştirilir. Kurak bölgelerde sulama gerektirir. Kısa bir büyüme mevsimine sahiptir ve nispeten kuraklığa dayanıklıdır. Arpa, farklı çeşitlere göre değişmekle birlikte, toprak tuzluluğuna diğer tahıllardan daha toleranslıdır (Slafer vd 2024).

3. ARPA YAPRAK LEKESİ/YANIKLIĞI HASTALIK ETMENİNİN TAKSONOMİSİ

Arpa üretim miktarında oldukça önemli seviyelerde düşüşe neden olan birçok abiyotik ve biyotik stres faktörü bulunmaktadır. *Rhynchosporium graminicola*'nın neden olduğu arpa yaprak lekesi/yanıklık hastalığı en önemli biyotik stres faktörlerinden biridir. *R. graminicola*'nın neden olduğu yaprak lekesi/yanıklığı, uzun süreli serin ve yarı nemli hava koşullarına sahip bölgelerde daha önemlidir (Ababa vd 2023).

R. graminicola, taksonomisi kafa karıştırıcıdır. Bunun en önemli sebeplerinden biri *R. graminicola*'nın yıllar içerisinde birçok kez farklı isimlendirilmesinden kaynaklanır (Caldwell 1937). İlk olarak, 1898'de çavdar ve arpada yaprak lekesi/yanıklık hastalık etmeni olarak *Marsonia secalis* (Oud.) tanımlanmıştır. Daha sonraki araştırmacılar arpada bu hastalığa neden olan mantarın alışılmadık gagalı, iki hücreli konidiosporları bulunan ve *Rhynchosporium* olarak adlandırılan yeni bir fungal cinse ait olduğunu belirlemişlerdir (Zaffarano vd 2011; Crous vd 2021). Bundan dolayı *M. secalis* çavdar yaprak lekesi/yanıklık hastalık *etmeni; R. secalis* arpa yaprak lekesi/yanıklık hastalık etmeni olarak yeniden adlandırılmışlardır (Ababa vd 2023). Ancak filogenetik analizler *R. secalis*'in çeşitli Poaceae türlerine özgü üç türden oluşan bir komplekse parçalandığını ortaya koymuş olup arpa yaprak lekesi/yanıklık hastalığının etmeni tekrardan *R. commune* olarak yeniden adlandırılmıştır. Böylece, *Rhynchosporium* cinsine ait *R. secalis* Çavdarda ve Tritikalede; *R. agropyri* Tarla ayrığı (*Agropyron repens*), Sakallı buğday otu (*Agropyron caninum*); *R. commune* arpa, diğer *Hordeum* türleri ve kılçık otu (*Bromus diandrus*)'nda patojenik etmenler olarak bildirilmiştir (Zaffarano vd 2011; Crous vd 2021; Ababa vd 2023). Son çalışmalarda arpa yaprak lekesi/yanıklık hastalığının etmeni olan *R. commune* yerine *Rhynchosporium graminicola* binomial ismin kullanımı tercih edilmiştir (Crous vd 2021).

4. ARPA YAPRAK LEKESİ/YANIKLIĞININ SİMPTOMATOLOJİSİ, EKOLOJİSİ VE EPİDEMİYOLOJİSİ

Adından da anlaşılacağı üzere, *R. graminicola* ve *Mycosphaerella graminicola* tür (*graminicola*) düzeyinde benzerdir, ancak cins düzeyinde farklıdırlar (Ababa vd 2023). Arpa yaprak lekesi/yanıklığı ile Buğday yaprak lekesi/yanıklığının enfeksiyon şekilleri ve spor üretimleri benzerdir (Navathe vd 2022). Arpa yaprak lekesi/yanıklık hastalığı vejetatif büyüme sırasında tek hücre üretir ve bu büyüme aşamasında "Maya" formundadır (Crous vd 2021). Başka bir deyişle, arpa yaprak lekesi/yanıklık hastalık etmeni miselyum gelişimi sırasında tek hücre üretir ve maya da tek hücreli bir mikroorganizmadır (Ababa vd 2023). Buğday yaprak lekesi üç farklı vejetatif büyüme formuna sahiptir. Bu patojenin vejetatif büyüme formunun ilk şekli 3-5 septalı makropiknidiospor olup en yaygın hücre formudur (Zaffarano vd 2011). Makropiknidiospor formunun "Maya benzeri" evresinden sıklıkla bahsedilmiştir. Ancak mayalar tek hücreli organizmalar iken makropiknidiyosporlar çok hücreli oluşumlardır. Miselyum üçüncü vejetatif gelişim formudur (Ababa vd 2023).

Arpa yaprak lekesi/yanıklık hastalığının etmeni *R. graminicola* toprakta iyi yaşayamaz (Paulitz & Steffenson 2010). Bu mantar, mahsul artıklarında (anız ve saman) bir yıla kadar hayatta kalır. Arpa döküntüleri üzerinde kışı geçirir ve spor üretir. Buna ek olarak, patojen tohumda

bulunabilir ve tohumlarla da yayılabilir (Goodwin 2002). Enfekteli sap ve anızlardan yağmurla sıçrayan sporlar fideleri enfekte edebilir. ilk hastalık belirtileri yaprak ayaları ve kınları üzerinde su ile ıslanmış lezyonlar olarak ortaya çıkar (Abang vd 2006). Lezyonlar oval ila düzensiz şekildedir ve gri-yeşil renkten belirgin bir kahverengi kenar ile saman rengine dönüşür (Abang vd 2006). Yağmur sıçraması, hastalığı alt yapraklardan üst yapraklara doğru yaymaya devam ederek daha sonra ortaya çıkan yaprakları, başakları ve taneleri enfekte eder (Zhan vd 2008). Havadaki sporların rüzgâr yoluyla uzun mesafeli yayılımı da gerçekleşebilir. Bu enfeksiyon yolu, enfekte arpa tarlalarının yakınında bulunan arpa tarlaları içinde önemlidir. Hastalık çok döngülü epidemiye sahiptir; bu da büyüme mevsimi boyunca birkaç enfeksiyon döngüsüne neden olabileceği anlamına gelir (Clare vd 2023). Hastalık döngüsü her 14 günde bir tekrar edebilir. Serin ve nemli koşullar hastalığı destekler; ideal sıcaklık aralığı 18-20 ℃'dir ancak 20 ℃'nin üzerindeki sıcaklıklar hastalık gelişimini yavaşlatır (Abang vd 2006).

5. ARPA YAPRAK LEKESİ/YANIKLIĞI İLE MÜCADE

5.1. Karma Ekim

Genetik homojenlik, bitki hastalıkları salgınlarında önemli bir faktördür. Bununla mücadele etmek için, konukçu popülasyonlara değişkenlik kazandırmak amacıyla çoklu tür, hat veya çeşit kombinasyonları önerilmektedir (Finckh vd 2000). Dayanıklı ve duyarlı izojenik hatların, çeşitlerin veya türlerin birleştirilmesi, ikincil hastalık yayılımını azaltarak salgın şiddetini azaltabilir (Abang vd 2006). Bazı modellemeler, yüzeysel spor dağılım gradyanlarına sahip rüzgârla dağılan hastalıklara karşı çeşit kombinasyonlarının kullanılmasının en başarılı yöntemlerden biridir (Finckh vd 2000). Bununla birlikte, çeşit karışımları, fungisit kullanılmadan *R. graminicola* ve *Stagnospora nodorum* gibi sıçrama yoluyla yayılan patojenlere karşı etkilidir (McDonald 2025). İndüklenmiş direncin, konukçu-patojen etkileşimlerinde yüksek derecede özgüllüğe sahip biyotrofik, hava yoluyla bulaşan enfeksiyonlar tarafından oluşturulan salgınları bastırarak etki mekanizmalarında rol oynadığı düşünülmektedir (Abang vd 2006; Zhan vd 2008; Ababa vd 2023). Ticari çeşitler, yanıklık hastalığına karşı daha az özel direnç kaynağına sahiptir, bu da onları yanıklık hastalığına karşı biyotrofik hastalıklara göre daha az etkili hale getirir. Dahası, spesifik olmayan direnç, enfeksiyonu azaltmak için çeşit karışımlarında kullanılabilir. Arpa ve yulaf kombinasyonlarının ve sadece arpa standlarının, arpanın üst yapraklarındaki lekelerin/yanıklığının bulunma oranını azalttığı bilinmektedir (Finckh vd 2000).

5.2. Dayanıklı Çeşit Kullanımı

Arpanın hastalıklara karşı göstermiş olduğu direnç kalitatif ve kantitatif tipler olarak sınıflandırılabilir. Kalitatif direnç, fide büyüme aşamasında yüksek direnç seviyeleri sunan belirli bir gen tarafından yönetilirken, kantitatif direnç, yetişkin bitki aşamasında kısmi direnç seviyeleri sunan birçok geni ifade eder (Ababa vd 2023). Bu genlerin yeni çeşitlerde birleştirilmesi, daha kalıcı hastalık kontrolü için mümkündür. Çeşitli araştırmacılar, arpa çeşitlerinin yaprak lekesi/yanıklığı hastalığına karşı direnci konusunda hemfikirdir. Mücadele yöntemleri, çevre dostu olması ve kullanım kolaylığı nedeniyle direnç materyalini önemli görmektedir (Looseley vd 2012; Wang vd 2014). Çalışmalar, İskandinav ve kuzey Avrupa arpa

türleri yaprak lekesi/yanıklığı hastalığına dirançli oldukları bildirmiştir. Örneğin; İskoç arpasının "Bere" popülasyonu iyi bir aday olarak kabul edilmektedir (Looseley vd 2012). Arpa materyallerinin *R. graminicola* ırkına karşı fide veya spesifik direncini belirlemeye yönelik yapılan çalışmalar her geçen gün artmaktadır (Ababa vd 2023). Fide büyüme aşamasında, arpada *R. graminicola*'ya karşı en son tanımlanan direnç geni olan Rrs18 de dahil olmak üzere birkaç direnç geni tanımlanmıştır (Ababa vd 2023). Basit Dizi Tekrarı (SSR) markörleri HVM54, Bmac0093 b, HVLTPP8, HVM62 ve Bmag0006'nın *R. graminicola* için kantitatif özellik lokusları (QTL'ler) olduğu bulunmuştur (Ababa vd 2023).

Yabani arpa (*H. spontaneum*), yerel çeşitlere kıyasla yaprak lekesi/yanıklığı hastalığına karşı yüksek bir potansiyel dirence sahiptir. Yerel çeşitlerin sadece %0,5'i altı adet *R. graminicola* izolatına karşı dirençli iken, *H. spontaneum* aksesyonlarının %26'sı test edilen tüm izolatlara karşı dirençlidir (Looseley vd 2012). Saha gözlemleri, büyüme alışkanlığının pleiotropik etkisi olarak yorumlanan bir lekesi/yanıklığı hastalığına direnci QTL'sini ortaya çıkarmıştır. Cüceleşme genine sahip secde bitkileri, yağmur sıçramalarından kaynaklanan hastalık bulaşmasına daha duyarlıdır (Wang vd 2014).

5.3. Kültürel Uygulamalar

Çalışmalar azot gübrelemesi, fungisit uygulama zamanı ve ekim tarihi gibi kontrol uygulamalarının buğday ve arpa yaprak hastalıklarının gelişimini etkileyebileceğini göstermiştir (Ababa vd 2023). Yüksek azotlu gübreleme buğday habitusunun yoğunluğunu artırarak mikro iklimi değiştirebilir ve yaprak ıslaklığını artırarak spor çimlenmesini artırabilir (Finckh vd 2000). Tersine, düşük azotlu gübreleme yaprak lekesi şiddetini artırabilir. Yapraklara iki kez uygulanan propikonazol, yaprak lekesi/yanıklığını kontrol etmek ve tane verimi ile kalite kayıplarını en aza indirmek için en etkili ilaç olarak bulunmuştur (Ababa vd 2023). Fungisit uygulama zamanlaması, fungisit uygulamak için en iyi zamanın belirlenmesinde önemlidir. Yaprak nekrozu lekeleri çiçeklenmeden sonra hızla ortaya çıkar ve tek bir fungisit uygulaması etkilidir (Abang vd 2006). Yaprak lekeleri çiçeklenmeden hemen sonra hızla gelişir ve süt büyüme aşamasına kadar katlanarak büyür. Çiçeklenme aşamasında, haşlanma şiddeti verim düşüşleri ile en büyük ilişkiye sahiptir (Finckh vd 2000). Arpa hastalıklarını kontrol altında tutmak için iki ila üç yıllık ürün rotasyonu, toprak işleme ve başıboş arpanın ortadan kaldırılması uygulanır (McDonald 2025). Yüksek düzeyde anız kaynaklı inokulum bulunan tarlalara arpa ekiminden kaçınmak için ürün rotasyonu şarttır. Ancak bazı çalışmalar, ekim nöbetinin arpa yaprak lekesi üzerinde çok az etkisi olduğunu göstermektedir (Ababa vd 2023).

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FUSARIUM WILT AND ROOT ROT ON CHICKPEA

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ABSTRACT

Chickpea is an important legume crop grown in almost every region of Turkey. It is grown in tropical, subtropical and warm climate regions and is the second most important legume crop globally after dry beans. Chickpea is rich in protein, vitamins and minerals and is used in field agriculture as an alternate crop with cereal crops. Although chickpea has an important place among edible grain legumes, its production and yield are not at the desired level. Among the reasons for this, diseases (45%), drought (30%), high temperature (6.25%), frost (6.25%), insect damage (6.25%) and other (6.25%) stress factors can lead to production and yield losses. Fungal diseases are the most important biotic stress factors that can reduce chickpea production and market value. Under favorable conditions, fungal diseases such as root rot/wilt disease, which can cause 50%-70% yield loss, cause difficulties in production and yield. Root rot/wilt disease can be seen at every stage of chickpea cultivation. Plants affected by the disease turn yellow in clusters due to root and root collar rots and plant deaths occur due to drying of these plants in the progressive process. The causal agents of the disease include *Fusarium oxysporum, F. solani, F. moniliforme, Verticillium dahliae, Macrophomina phaseolina, Rhizoctonia solani, Sclerotium rolfsii* and *Sclerotinia sclerotiorum*. Fusarium wilt/root rot is one of the most important diseases affecting chickpeas worldwide. It was first reported in India in 1918, but its etiology has not yet been accurately determined. Fusarium wilt, caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *ciceris*, has become a major factor limiting chickpea production worldwide. The long survival of the pathogen in soil and its high pathogenic variability play a key role in the development and management of the disease, with eight races, 0, 1A, 1B/C, 2, 3, 4, 5 and 6, having been identified so far. These races differ in virulence and aggressiveness on susceptible cultivars, which are affected by the amount of inoculum and environmental conditions required for severe disease. Disease incidence and severity are influenced by pathogen inoculum density, hot soil temperature and susceptibility of the chickpea variety. Effective management of Fusarium wilt requires accurate and rapid identification of the

pathogen and its pathogenic races. Molecular protocols have been developed to aid this process. High-yielding, well-adapted chickpea varieties resistant to the common pathogen race(s) are the most practical and cost-effective individual disease control measure. However, pre-planting diagnosis of the available race(s) of *F. oxysporum* f. sp. *ciceris* using molecular protocols helps to avoid risky soils. This review is not intended as a comprehensive review of the literature on general aspects of Fusarium wilt in chickpea. Rather, it aimed to critically appraise the current knowledge on disease etiology, epidemiology and control strategies.

Keywords: *Cicer arietinum*, Control strategies, Etiology, Epidemiology, *Fusarium oxysporum*

NOHUTTA FUSARİUM SOLGUNLUĞU VE KÖK ÇÜRÜKLÜĞÜ

ÖZET

Nohut, Türkiye'nin hemen hemen her bölgesinde yetişen önemli bir baklagil bitkisidir. Tropikal, subtropikal ve sıcak iklim bölgelerinde yetiştirilmesiyle küresel olarak kuru fasulyeden sonra ikinci en önemli baklagil bitkisidir. Nohut, protein, vitamin ve mineral açısından zengindir ve tahıl ürünleriyle dönüşümlü ürün olarak tarla tarımında kullanılır. Nohut yemeklik dane baklagiller içerisinde önemli bir yere sahip olmasına rağmen üretimi ve verimi istenilen düzeyde değildir. Bunun nedenleri arasında hastalıklar (%45), kuraklık (%30), yüksek sıcaklık (%6.25), don (%6.25), böcek zararı (%6.25) ve diğer (%6.25) stres faktörleri üretim ve verim kayıplarına yol açabilir. Fungal hastalıklar nohut üretim miktarını ve pazar değerini azaltabilen en önemli biyotik stres etmenleridir. Uygun koşullarda %50-%70 oranında ürün kaybına neden olabilen kök çürüklüğü/solgunluk hastalığı gibi fungal hastalıklar nedeniyle üretim ve verimde zorluklarla karşı karşıya kalınmaktadır. Kök çürümesi/solgunluk hastalığı nohut yetiştiriciliğinin her aşamasında görülebilir. Hastalıktan etkilenen bitkiler, kök ve kök boğazı çürüklüklerinden dolayı öbek öbek sararmakta ve ilerleyen süreçte bu bitkilerde kurumalara bağlı olarak bitki ölümleri gerçekleşmektedir. Hastalığın nedensel etmenleri arasında *Fusarium oxysporum, F. solani, F. moniliforme, Verticillium dahliae, Macrophomina phaseolina, Rhizoctonia solani, Sclerotium rolfsii* ve *Sclerotinia sclerotiorum* yer alır. Fusarium solgunluk/kök çürüklüğü, dünya genelinde nohutları etkileyen en önemli hastalıklardan biridir. Bu hastalık ilk olarak 1918 yılında Hindistan'da bildirilmiştir, ancak etiyolojisi henüz doğru bir şekilde belirlenememiştir. Fusarium solgunluğu, toprak kökenli fungus *Fusarium oxysporum* f. sp. *ciceris* tarafından oluşturulan, dünya çapında nohut üretimini sınırlayan önemli bir faktör haline gelmiştir. Patogenin toprakta uzun süre hayatta kalması ve yüksek patojenik varyabilitesi, şimdiye kadar 0, 1A, 1B/C, 2, 3, 4, 5 ve 6 olmak üzere sekiz ırkın tanımlanmış olması, hastalığın gelişimi ve yönetiminde anahtar rol oynar. Bu ırklar, inokulum miktarı ve şiddetli hastalık için gerekli çevresel koşullardan etkilenen duyarlı çeşitler üzerinde virülans ve saldırganlık açısından farklılık gösterir. Hastalık görülme sıklığı ve şiddeti, patojen inokulum yoğunluğu, sıcak toprak sıcaklığı ve nohut çeşidinin duyarlılığından etkilenir. Fusarium solgunluğunun etkili yönetimi, patojenin ve patojenik ırklarının doğru ve hızlı bir şekilde teşhis edilmesini gerektirir. Bu sürece yardımcı olmak için moleküler protokoller geliştirilmiştir. Yaygın patojen ırk(lar)ına dirençli, yüksek verimli, iyi adapte olmuş nohut çeşitleri en pratik ve uygun maliyetli bireysel hastalık kontrol önlemidir. Bununla birlikte, mevcut *F. oxysporum* f. sp. *ciceris* ırk(lar)ının moleküler protokoller kullanılarak ekim öncesi teşhisi, riskli topraklardan kaçınmaya yardımcı olmaktadır. Bu derleme, nohutta Fusarium solgunluğunun genel yönlerine ilişkin literatürün kapsamlı bir incelemesi olarak tasarlanmamıştır. Daha ziyade, hastalık etiyolojisi, epidemiyolojisi ve kontrol stratejileri hakkındaki mevcut bilgilerin eleştirel değerlendirmesini amaçlamıştır.

Anahtar Kelimeler: *Cicer arietinum*, Mücadele stratejileri, Etiyoloji, Epidemiyoloji, *Fusarium oxysporum*

1. GİRİŞ

Nohut gelişmiş ve gelişmekte olan ülkelere yüksek protein sağlayan ve tarla tarımı için hububat rotasyonunda önemli bir role sahiptir. Bu nedenle nohut üretimi dünyada kozmopolit bir dağılıma göstermektedir. Nohut, baklagiller içerisinde kuru fasülye (Phaseolus vulgaris L.)'den sonra dünyada en önemli ikinci baklagil bitkisi (Jiménez-Díaz vd. 2015) olup Güney ve Batı Asya, Doğu ve Kuzey Afrika, Güney Avrupa, Kuzey ve Güney Amerika'nın yanı sıra Avustralya'nın tropik, subtropik ve sıcak iklim kuşaklarında yetiştiriciliği yaygın olarak yapılmaktadır. Nohut üretiminde, çeşitli ülkelerde yapılan çalışmalar, birçok zararlı organizmanın yanı sıra fungal hastalıkları ile ilgili problemleri ortaya çıkarmıştır. Nohutta, kök çürüklüğüne bağlı olarak solgunluk hastalığının nedensel faktörleri arasında abiyotik ve biyotik hastalık etmenlerinin bulunmasından dolayı, bu hastalığın oldukça kompleks bir yapıya sahip olduğu bilinmektedir (Yimer vd. 2018). Bu nedenle solgunluk hastalığı, nohutta, mücadelesi zor ve önemli miktarda verim kaybına neden olan hastalıklardan biridir (Jiménez-Díaz vd. 2015). Dünya genelinde bu hastalık ile ilgili oldukça fazla çalışma bulunmaktadır. Hastalık etmenleri arasında *Fusarium* spp., *Rhizoctonia solani*, *Macrophomina* spp., *Phytophthora* ve nadirde olsa *Sclerotinia* cinsi fungus türleri yer alır. Nohutta, kök çürüklüğüne bağlı olarak solgunluk hastalığının kontrol altına alına bilmesi için öncelikle hastalığa neden olan fitopatojenik fungal etmenlerin biyolojisini ve epidemiyolojisini anlamak çok önemlidir (Agrios 2005). Bu fungal hastalıklardan, toprak kökenli fungusların neden olduğu kök çürüklüğü/solgunluk hastalığı, Türkiye'nin bazı nohut üretim bölgelerinde önemli bir sınırlayıcı faktör haline gelmiştir. Ancak, Türkiye'nin nohut üretim alanlarında önemli verim kayıplarına neden olan toprak kökenli fungal etmenlerin durumunu tam olarak açıklayan kapsamlı bir araştırma bulunmamaktadır. Sonuç olarak, bu çalışma nohut solgunluk/kök çürüklüğü hastalık etmani olan *F. oxysporum* f. sp. *ciceris*'in biyolojisi ve kontrol önlemlerinin kapsamlı bir değerlendirmesinin yanı sıra, toprak işleme, ürün rotasyonu, ekim tarihleri ve çeşitlerin etkilerini belirtmeyi içermektedir. Genel olarak bu derleme, nohut solgunluk/kök çürüklük hastalığının simptomatolojisi, epidemiyolojisi, ekolojisi ve mücadele yöntemlerini gözden geçirmek üzere tasarlanmıştır.

2. NOHUT YETİŞTİRİCİLİĞİNE GENEL BAKIŞ

Nohut (*Cicer arietinum* L.), Fabaceae (Leguminosae) familyasına ait bir bitki türüdür. Nohut bitkisinin Anavatanı Türkiye'nin Güneydoğu Anadolu Bölgesi'dir (Jiménez-Díaz vd. 2015). Nohut, baklagiller içerisinde kuru fasülye (*Phaseolus vulgaris* L.)'den sonra dünyada en önemli ikinci baklagil bitkisi (Jiménez-Díaz vd. 2015) olup Güney ve Batı Asya, Doğu ve Kuzey Afrika, Güney Avrupa, Kuzey ve Güney Amerika'nın yanı sıra Avustralya'nın tropik, subtropik ve sıcak iklim kuşaklarında yetiştiriciliği yaygın olarak yapılmaktadır. Nohut daneleri, lisin aminoasitince zengin protein içeriğinin yanı sıra A, B, C ve D vitaminleri ile birlikte demir (Fe), fosfor (P) ve kalsiyum (Ca) mineralleri açısından da zengin olmasından dolayı insan beslenmesinde oldukça önemli bir besin kaynağıdır (Dubey vd. 2014; Tadesse vd. 2017) Nohut bitkisi bu özelliklerinin yanı sıra buğday, arpa ve yulaf gibi tahıl ürünleri ile birlikte rotasyon bitkisi olarak kullanılması ve havadaki serbest azottan faydalanabilmesi tarla tarımında bu bitkinin önemini daha da arttırmaktadır (Piggin vd. 2015; Mohammed vd. 2017).

Dünyada 2016 yılı verilerine göre 12.650.076 hektar alanda 12.092.948 ton nohut üretimi gerçekleşmiştir (FAOSTAT 2016). Hindistan dünya nohut üretiminin %64.7'sini karşılayarak, dünya nohut üretimi sıralamasında lider konumdadır. Bu ülkeyi sırasıyla Avustralya (%7.2), Myanmar (%4.6), Pakistan (%4.3) ve Türkiye (%3.8) takip etmektedir. Ülkemizde 2017 yılı verilerine göre 3.953.099 dekar alanda, 470.000 ton nohut üretimi yapılmıştır (TUİK 2017). Nohut üretimi, İç Anadolu Bölgesi'nde yoğunlaşmış olup Yozgat'ta 268.186 da alandan 28.418 ton nohut üretimi gerçekleşmiştir (TUİK 2017).

Nohut ekim alanlarında verim kayıplarına yol açan biyotik ve abiyotik stres faktörleri bulunmaktadır (Maruz vd. 2002; Yimer vd. 2018). Nohut verimini etkileyen stres faktörlerini; hastalıklar (%45), kuraklık (%30), yüksek sıcaklık (%6.25), don (%6.25), böcek zararı (%6.25) ve diğer (%6.25) stres faktörleri olarak sıralamak mümkündür (Singh vd. 1994). Dünyada ve ülkemizde nohut verimini etkileyen biyotik stres faktörleri arasında toprak kökenli fungal fitopatojen etmenler önemli bir yer tutmaktadir. Bu güne kadar 55 farklı ülkeden 67 fungus, 3 bakteri, 80 nematod, 22 virüs ve mikoplazma olmak üzere 172 patojenin nohutta hastalığa sebep olduğu rapor edilmiştir (Nene vd., 1996). Dünya genelinde nohut verimini etkileyen en önemli biyotik stres faktörü Aantraknoz hastalığı olup bunu solgunluk ve kök çürüklük hastalığı takip eder. Her iki hastalığın özellikle iklimsel koşulların epidemiler için uygun olduğu durumlarda %100'e varan ürün kayıplarına neden olduğu bilinmektedir (Pande vd., 2005; Jimenez-Díaz et al. 2015).

3. NOHUT SOLGUNLUK/KÖK ÇÜRÜKLÜK HASTALIĞI

Ülkemizde nohut yemeklik dane baklagiller içerisinde önemli bir yere sahip olmasına rağmen üretimi ve verimi istenilen düzeyde değildir. Bunun en önemli nedenlerinden biriside fungal hastalıklardır. Kök çürüklüğü/solgunluk hastalığı, uygun iklim koşullarında, nohutta %50 ile %70 arasında ürün kayıplarına neden olabilmektedir. Nohutta, kök çürüklüğüne bağlı olarak solgunluk hastalığının nedensel faktörleri arasında abiyotik ve biyotik hastalık etmenlerinin bulunmasından dolayı, bu hastalığın oldukça kompleks bir yapıya sahip olduğu bilinmektedir (Yimer vd. 2018). Dünya genelinde bu hastalık ile ilgili oldukça fazla çalışma bulunmaktadır. Ancak ülkemizde, nohutta, solgunluk hastalığının durumu ile ilgili çalışmalar (Bayraktar 2006) kısıtlı sayıda yapılmıştır. Nohutta solgunluk hastalığının ekonomik önemi tam olarak anlaşılamazsa, bu hastalık ile ilgili çalışmalar ve araştırmalar, üretime yönelik değer taşımaktan ve ekonomik bir katkıda bulunmaktan yoksun olabilir.

Taşıdığı öneme karşın nohut, fungal hastalıkları hem üretim miktarını hem de ürünün pazar değerini düşürmektedir. Literatürden, nohuttun tüm gelişim aşamalarında fungal patojenlerin istilası ile karşılaştığı bilinmektedir. Toprak kökenli patojen fungus ya da benzeri etmenlerler arasında, Fusarium *oxysporum*'un sebep olduğu Fusarium solgunluğu, Verticillium solgunluğu (*Verticillium dahliae*), kuru kök çürüklüğü (*Rhizoctonia bataticola* Syn: *Macrophomina phaseolina*), kök çürüklüğü (*Rhizoctonia solani*), kök boğazı çürüklüğü (*Sclerotium rolfsii*), siyah kök çürüklüğü (*F. solani, F. moniliforme*) ve *Sclerotinia sclerotiorum*' un sebep olduğu gövde çürüklüğü hastalıkları yer almaktadır (Nene vd. 2012; Azevedo vd. 2017).

Hastalık etmeni olan Fusarium türleri, Kutuplardan Ekvator'a kadar organik materyal içeren her tip toprakta yaşayabilen oldukça yaygın funguslardır. Bitki türü ve organına göre *Fusarium* simptomları farklılık göstermesine rağmen, genellikle bitkide kök çürüklüğü ve solgunluğa neden olmaktadır (Özer ve Soran, 1991). Nohut'ta solgunluğa ve kök çürüklüğüne neden olan *Fusarium* türleri: *F. oxysporum, F. moniliforme, F. solani, F. avenaceum, F. equiseti, F. eumartii, F. proliferatum, F. semitectum, F. acuminatum, F. sambucinum* ve *F. redolens*'dir. (Trapero-Casas ve Jiménez-Díaz 1985; Maden 1987; Dolar 1996; Demirci 1999; Maruz vd. 2002; Landa vd. 2004; Jiménez-Díaz vd. 2015; Azevedo vd. 2017; Jendoubi vd. 2017; Yimer vd. 2018). Diğer taraftan, toprak kökenli *Rhizoctonia solani* ve *R. bataticola* etmenlerinin neden olduğu kök çürüklüğü İran, Lübnan, Meksika, Suriye, ABD, Brezilya, Avustralya, Etiyopya, Pakistan, Polanya, Hindistan ve ülkemizde gözlenmiştir (Kaiser 1981; Mazur vd. 2002; Güllü 2003; Lande vd. 2004; Aghakhani ve Dubey 2009; Dubey vd. 2014; Azevedo vd. 2017; Yimer vd. 2018). Türkiye'de *R. solani* ve *R. bataticola*'nın nohutlarda kök boğazında koyu kahverengi kök çürüklüğüne ve üst kısımlarında sararma ve solgunluğa neden olduğu Dolar (1996) ve Demirci vd. (1999) tarafından bildirilmiştir. Mevcut literatürde, nohutta, nadiren de olsa kök ve gövde çürümesine neden olan etmenler arasında *Sclerotinia sclerotiorum* ve *S. rolfsii*'nin de bulunabileceği belirtilmektedir (Maruz vd. 2002; Shahjahan vd. 2016; Mandal ve Dubey 2011). *S.rolfsii*'ye karşı, nohut bitkilerinin fide döneminin daha hassas (Sreekar vd. 2003), ancak ileriki dönemlerde *S. sclerotiorum* daha önemli hale geldiği bilinmektedir (Lindbeck vd. 2009).

Fusarium solgunluğu dünya çapında nohutu etkileyen en önemli hastalıklardan biridir. Bu hastalık ilk olarak 1918 yılında Hindistan'da rapor edilmiştir. Şu anda Asya, Afrika, Güney Avrupa ve Amerika'da nohut yetiştirilen bölgelerin çoğunda yaygındır. Fusarium solgunluğu Akdeniz Havzası, Hindistan alt kıtası ve Kaliforniya'da nohut üretimini sınırlayan önemli bir faktör haline gelmiştir.(Haware, 1990; Jalali ve Chand, 1992; Nene ve Reddy, 1987;Trapero-Casas ve Jimenez-Díaz, 1985; Westerlund ve ark., 1974). Patojenlerin doğru tanımlanması ve hızlı karakterizasyonu, etkili bitki hastalıkları yönetimi için çok önemlidir. *Fusarium oxysporum* Schlechtend.:Fr. tarımsal ürünlerde vasküler çürüklük hastalıklarına neden olan anamorfik toprak kökenli bir fungustur. Konukçu spesifikliğine ve konukçu çeşitler arasındaki virülans varyasyonuna dayalı olarak formae speciales olarak sınıflandırılır (Trapero-Casas ve Jiménez-Díaz 1985). Fusarium solgunluğunun bir etmeni olan nohuttaki Fusarium solgunluğu, patojenite testlerinde hastalık sendromu ile ayırt edilen sararma ve solma olmak üzere iki patotip ile büyük çeşitlilik gösterir (Yimer vd. 2018). Sararma, ilerleyici yaprak sararması, damar renk değişikliği ve 40 gün içinde bitki ölümüne neden olurken, solgunluk şiddetli kloroz ve sarkıklığa neden olur (Trapero-Casas ve Jiménez-Díaz 1985). *F. oxysporum* f. sp. *ciceris*'nin sekiz ırkı mevcuttur (0, 1A, 1B/C, 2, 3, 4, 5, ve 6). Irkların tamamı sararma sendromuna neden olurken, 1A, 2, 3, 4, 5 ve 6 ırkları solgunluk sendromuna neden olur. Irk 2, 3 ve 4 sadece Hindistan'da rapor edilirken, ırk 0, 1B/C, 5 ve 6 çoğunlukla Akdeniz bölgesinde ve Amerika Birleşik Devletleri'nde bulunur. Türkiye'de ise 0, 2 ve 3 nolu ırkların yaygın olduğu Bayraktar ve Dolar (2012) tarafından yapılan çalışma ile saptanmıştır. Fusarium solgunluğunun 7 bölgede ve 37 ilde yetiştirlen nohutlarda yaygın olarak görüldüğü ise Kocalar vd. (2020) tarafından yapılan geniş kapsamlı çalışma ile bildirilmiştir.

4. NOHUT SOLGUNLUK/KÖK ÇÜRÜKLÜĞÜNÜN SİMPTOMATOLOJİSİ, EKOLOJİSİ VE EPİDEMİYOLOJİSİ

Kök çürüklüğü/solgunluk hastalığın belirtileri nohut vejetasyonunun her evresinde gözlene bilmektedir. Hastalıktan etkilenen bitkiler, kök ve kök boğazı çürüklüklerinden dolayı öbek öbek sararmakta ve ilerleyen süreçte bu bitkilerde kurumalara bağlı olarak bitki ölümleri gerçekleşmektedir (Haware vd. 1990). Hastalığa hasas çeşitlerde, ekimden sonra 25 gün içerisinde (Erken Solgunluk), solgun, mat yeşil renk ve kuruma gösteren yapraklar, bitkinin tamamen çökmesine neden olmaktadır (Landa vd. 2004). Ancak hastalık belirtileri (Geç Solgunluk), ekimden 6 – 8 hafta sonra, çiçeklenme döneminin başlangıcında, genelde daha çok göze çarpmaktadır (Azevedo vd. 2017; Jendoubi vd. 2017; Yimer vd. 2018). Geç solgunluk görülen bitkilerde, köklerin kabuk ve odun dokusunda ıslak ya da kuru siyahımsı ya da kahverengi renkli lezyonlar, yaprak ve yaprak saplarında sararma veya açık kahverngi renkli nekrotik lezyonlar ve bitki tüm üst aksamında tamen çökme gözlenmektedir (Jiménez-Díaz vd. 2015; Jendoubi vd. 2017).

F. oxysporum f. sp. *ciceris* bitki dokularının iç veya dış yüzeylerinde klamidosporlar yoluyla toprakta inaktif olarak hayatta kalan, eşeysiz üreyen ve kökte yaşayan fakültatif parazit bir fungustur (Yimer vd. 2018). İn vitro misel büyümesi için sıcaklık ve pH koşullar, izolatlara bağlı olarak sırasıyla 7,5 ila 35°C ve 5,1 ila 5,9'dur (Landa vd. 2004). Klamidosporlar eski misellerde ve enfekte nohut dokularında oluşur ve hiflerde düz, kaba duvarlı, terminal veya interkalar olabilir (Jalali ve Chand, 1992). Enfekte toprak, nohutta Fusarium solgunluğu epidemilerinin gelişimi için ana inokulum kaynağıdır. Enfekte tohumlar da hastalığın birincil inokulum kaynağıdır. Enfekte tohumlardan yetiştirilen bitkiler, enfekte toprağa ekilen sağlıklı tohumlardan yetiştirilen bitkilere göre daha hızlı solmaktadır (Jiménez-Díaz vd. 2015). Topraktaki klamidosporlar, nohutta Fusarium solgunluğu için birincil inokulumdur ve çimlenme, konukçuların ve konukçu olmayanların tohum ve kök eksüdatları tarafından uyarılır. Patojen, istila edilmiş toprakta ekimden hemen sonra çimlenen tohumlarda ve büyüyen fidelerde giriş kazanır (Jalali ve Chand 1992; Landa vd. 2004). Patojen istila esas olarak kotiledonlar ve epikotil ile hipokotilin kotiledonlarla birleştiği veya kotiledonlara yakın bölgelerinden ve daha az oranda da kök uzama ve olgunlaşma bölgesinden gerçekleşir (Landa vd. 2004). Patojenin epikotil ve gövde ksilemini kolonize etme hızı ve yoğunluğu, *F. oxysporum* f. sp. *ciceris* ırk/nohut genotip kombinasyonunun uyumluluk derecesiyle doğrudan ilişkilidir. Şiddetli semptomlar geliştikçe ve bitki yaşlandıkça enfekte dokularda bol miktarda klamidospor oluşur (Jiménez-Díaz vd. 2015). Bu klamidosporlar, fungusun organik kalıntılar ve kök eksüdaları tarafından desteklenen sınırlı saprofitik büyümesinin yanı sıra konukçuların ve konukçu olmayanların geçici enfeksiyonları ile yaşam döngülerinden geçebilir (Haware vd. 1990).

Nohutta Fusarium solgunluğu, patojen ırkların saldırganlığı, topraktaki inokulum yoğunluğu, çevre koşulları ve çeşit duyarlılığı gibi çeşitli faktörlerden etkilenmektedir (Haware vd. 1990; Jiménez-Díaz vd. 2015). Hastalığın toprak matriks potansiyelinin azalmasıyla arttığı ve 500 ve 1000 propagül g^{-1} toprak inokulum yoğunluğu ile 25 ve 30°C'de şiddetli bir şekilde geliştiği, ancak 15 ve 20°C'de gelişmediği bildirilmiştir (Jendoubi vd. 2017). İnokulum yoğunluğu 5000 propagül g^{-1} toprak olsa bile 10°C'de hastalık gelişmemiştir (Landa vd. 2004). Toprak sıcaklığı ve *F. oxysporum* f. sp. *ciceris* 0 ve 5 ırklarının inokulum yoğunluğu arasındaki ilişkiyi

belirlemek için kantitatif doğrusal olmayan modeller kullanılmıştır. Modeller, Fusarium solgunluğunda sıcaklık×ırk saldırganlığı etkileşimini göstermiştir. P-2245 ve cv. hatlarının enfeksiyonu için en uygun toprak sıcaklığı PV-61'in 5. ırk tarafından enfeksiyonu için en uygun toprak sıcaklığı sırasıyla 22 ila 26°C olarak tahmin edilmiştir (Haware vd. 1990; Jiménez-Díaz vd. 2015)).

5. NOHUT SOLGUNLUK/KÖK ÇÜRÜKLÜĞÜ İLE MÜCADE

Nohuttaki Fusarium solgunluğu, patojenin birincil inokulumu ile karakterize edilen monosiklik bir hastalıktır. Hastalık ile mücadele etmek için patojeni eradike ve ilk inokulumu azaltmak hedeflenmelidir. Kontrol önlemleri arasında patojen içermeyen tohumların kullanılması, yüksek riskli topraklar için yer seçimi, inokulumun azaltılması veya ortadan kaldırılması, dirençli çeşitlerin kullanılması, sağlıklı tohumların fungisitler veya biyokontrol ajanları ile korunması ve patojen enfeksiyonunu önlemek için ekim nöbeti uygulamalarının seçilmesi yer alır. Bu önlemler entegre bir yönetim stratejisi dahilinde birleştirilmelidir.

5.1. Patojenin Eradikasyonu

Nohutta Fusarium solgunluğunun yönetimi, etkili karantina ve sertifikalı patojen içermeyen tohum kullanımını gerektirir. Patojenin tohum yoluyla yayılmasını önlemek için patojen içermeyen alanlarda sağlıklı tohum üretilmelidir (Pande vd. 2007). *F. oxysporum* f. sp. *ciceris* DNA'sını toprakta ve enfekte asemptomatik nohut bitkilerinin kök ve gövdelerinde 1 pg'ye kadar ölçmek için gerçek zamanlı bir kantitatif polimeraz zincir reaksiyonu (q-PCR) protokolü geliştirilmiştir; bu protokol sertifikasyon programlarında, bitki sağlığı denetimlerinde ve karantina mevzuatında tespit ve tanımlama için kullanılabilir (Jimenez-Fernandez vd. 2011).

Tohum kaynaklı inokulum, 1,5 g kg^{-1} Benlate® T ile tohum sosu yapılarak yok edilebilir (Haware vd. 1978). Sertifikalı veya fungisitle muamele edilmiş tohum, düşük hastalık riskli toprak ve biyokontrol ajanlarıyla tohum işlemleriyle birlikte kullanılmalıdır. Topraktaki *F. oxysporum* f. sp. *ciceris* inokulumu sanitasyon, toprak solarizasyonu ve organik değişikliklerle azaltılabilir. Bu hastalık kontrol önlemleri maliyetli olabilir ve hastalık tahminine ve ürün hasat ekonomisine göre değerlendirilmelidir (Blok vd. 2000; Kirkegaard 2009). Bununla birlikte, toprak solarizasyonu ve organik değişiklikler, toprak kaynaklı fungal patojenlerin ve bitki paraziti nematodların inokulumu üzerinde spesifik olmayan bir etkiye sahip olabilir. Etkilenen mahsullerden döküntüleri çıkarmak ve bunları yakmak veya alevlendirmek gibi sanitasyon, sonraki mahsulde hastalık riskini azaltabilir (Arora vd. 1996). Nisan-Mayıs aylarında yapılan toprak solarizasyonu, Fusarium solgunluğunu başarılı bir şekilde kontrol eder ve Akdeniz iklimine sahip bölgelerde nohut bitkisinin büyümesini ve verimini artırır. *F. oxysporum* f. sp. *ciceris* ile enfekte olmuş toprağın ilaçlanması, yüksek N içeren ürünlerle yapılan toprak işleme ile de sağlanabilir (Bailey ve Lazarovits 2003; Lazarovits 2004).

5.2. Dayanıklılık Mekanizması ve Fizyolojisi

Nohutta Fusarium solgunluğuna karşı direnç, pratik ve uygun maliyetli bir bireysel hastalık kontrol önlemidir. *F. oxysporum* f. sp. *ciceris* ırklarına karşı direnç esas olarak desi germplasmında ve daha az ölçüde kabuli nohutlarında ve yabani *Cicer* spp'de tanımlanmıştır. 0 ve 5 ırklarına karşı kombine direnç *C. bijugum, C. cuneatum, C. judaicum* türlerinde

tanımlanırken, *C. canariense* ve *C. chorassanicum* türleri 0 ırkına dirençli ancak 5 ırkına duyarlıdır. Test edilen tüm *C. pinnatifidum* türü 5. ırka karşı duyarlı iken bazıları 0. ırka karşı dirençlidir (Kaiser vd. 1994). ICRISAT'ta 13.500'den fazla desi germplazm aksesyonunun direnç taraması 165 direnç kaynağı tanımlarken, ICARDA'da Fusarium solgunluğu direnci için taranan 5174 kabuli germplazm aksesyonu arasında 110 dirençli hat tanımlanmıştır. Birkaç kabuli hattı bir veya birkaç *F. oxysporum* f. sp. *ciceris* ırkına karşı direnç taşımaktadır ve desi hattı L-1186'dan aktarılan altı sonraki çeşitteki direnç 0, 1A, 1B/C, 5 ve 6 ırklarına karşı etkilidir (Haware vd. 1990; van Rhenen vd. 1992).

F. oxysporum f. sp. *ciceris*'in belirli ırklarına karşı direnç, ırka veya direnç kaynağına bağlı olarak monojenik veya oligojenik olarak tanımlanmaktadır (Sharma vd. 2005; Sharma ve Muehlbauer 2007). ICRISAT'ta 1A ırkına karşı direnç üzerine yapılan ilk çalışmalarda, geç solma fenotipinin h1, h2 ve H3 olmak üzere üç bağımsız gen tarafından kontrol edildiği varsayılmıştır. İki ya da üç bağımsız gene dayanan benzer bir genetik sistemin, solgunluk hasta parsel taramasında ırk 2'ye direnç kazandırdığı bulunmuştur (Gumber vd. 1995; Kumar 1998); bu da geç solma ya da tam direnç ve homozigot resesif durumu içermiştir. Daha sonra Sharma ve arkadaşları (2005) yapay inokulasyonda ırk 2'ye direncin tek bir resesif gen tarafından yönetildiğini göstermiştir. Nohut genetik haritasının 2. bağlantı grubunda iki kümede yer alan altı tek, resesif direnç geni (foc-01, -02, -2, -3, -4 ve -5) tanımlanmıştır (Halila vd. 2009; 2010).

Irk 0'a karşı direnç, bağımsız olarak ayrılan iki gen tarafından kontrol edilir: JG-62 katılımında bulunan foc-01 ve CA-1938, CA-2139 ve WR-315 hatlarında bulunan foc-02 (Sharma vd. 2005). Her iki gen de ayrı ayrı patojenin 0. ırkına karşı tam direnç sağlamaktadır. Irk 4'e karşı direnç bazı hatlarda monogenik resesif iken, 'Surutato-77'de digenik resesiftir (Tullu vd. 1999).

Nohutta Fusarium solgunluğunda ırka özgü yavaş solma reaksiyonu ilk olarak Sharma ve arkadaşları (2005) tarafından 2. ve 3. ırklarla inoküle edilen bazı nohut hatlarında gözlemlenmiş ve daha sonra solgunluk gösteren bir parselde 0. ırka karşı rapor edilmiştir. Yavaş solma reaksiyonunun genetiği henüz çalışılmamıştır, ancak minör genler tarafından kontrol edildiği öne sürülmüştür.

Tam dirençli fenotip, lokalize hücre ölümü gelişmeden histolojik ifadede değişiklik gösterebilir. Irk 5 ile enfeksiyon, duyarlı 'JG-62' ile karşılaştırıldığında 'WR-315' köklerinde lipid peroksidasyonu, katalaz (CAT) ve süperoksit dismutaz (SOD) aktivitelerinde daha erken bir artış belirlemiştir (García-Limones vd. 2002). Kök ekstraktlarının daha ileri analizleri, araştırmacıları, gövdelerde artmış diamin oksidaz (DAO) aktivitesinin ve köklerde lipid peroksidasyonu ile CAT ve SOD aktivitelerinin daha erken artışlarının, 'WR-315'te ırk 5'e dirençle ilişkilendirilebileceği sonucuna götürmüştür (García-Limones vd. 2002; 2009).

5.3. Fusarium Solgunluğuna Karşı Dayanıklılığı Etkileyen Abiyotik ve Biyotik Faktörler

Nohut çeşitlerinin *F. oxysporum* f. sp. *ciceris* ırkları tarafından enfeksiyona karşı ırka özgü direnç tepkisi, hem sıcaklıktan hem de bitki paraziti nematodlarla birlikte enfeksiyondan önemli ölçüde etkilenebilir (Landa vd. 2006; Castillo vd. 2003). Yapay aşılama deneyleri, inkübasyon sıcaklığındaki 3°C'lik bir artışın kabuli cv. Ayala ve PV-1 aksesyonunun ırk 1A'ya tepkisinin sabit 24°C'de orta veya yüksek derecede dirençli iken 27°C'de yüksek derecede duyarlı hale gelmesi için yeterli olduğunu göstermiştir (Landa vd. 2006). Bu sıcaklık etkisi, İsrail'deki tarla

deneylerinde gösterildiği gibi, nohutta Fusarium solgunluğunu yönetmek için kültürel uygulamaların kullanımı üzerinde bir etkiye sahiptir. Topraktaki *F. oxysporum* f. sp. *ciceris* inokulumu, bitki paraziti nematodlarınki ile çakışmaktadır ve bitkinin iki patojen tarafından enfeksiyonu, fungusa karşı değerli direnci riske atabilir ve duyarlı çeşitlerde hastalık şiddetini artırabilir. Kök-düğüm (*Meloidogyne* spp.) ve kök-lesion (*Pratylenchus* spp.) nematodları nohuda zarar veren en önemli nematodlar arasındadır ve birkaç çalışma *F. oxysporum* f. sp. *ciceris* ile ortak enfeksiyonların bitkinin mantara tepkisi üzerindeki etkisini ele almıştır (Castillo vd. 1998; 2003; Krishna Rao and Krishnappa 1996; Mani and Sethi, 1987; Navas Cortes vd. 2008). Hindistan'da yapılan çalışmalar, solmaya dirençli nohutun *Meloidogyne incognita* veya *Meloidogyne javanica* ile birlikte enfeksiyonlarının, tanımlanamayan bir *F. oxysporum* f. sp. *ciceris* ırkına karşı direncin kırılmasına yol açabileceğini göstermiştir (Krishna Rao ve Krishnappa 1996; Mani ve Sethi 1987; Uma Maheswari vd. 1995; 1997). İspanya'daki çalışmalar, Akdeniz Havzası'nda nohutlara saldırdığı bildirilen tek nematod olan tahıl ve baklagil kök-ur nematodu *Meloidogyne artiellia* ile etkileşimlere odaklanmıştır (Castillo vd. 2008; Di Vito ve Greco, 1988). F. oxysporum f. sp. ciceris ırk 5'e karşı *M. artiellia* kaynaklı direncin kırılmasının altında yatan mekanizmalar, CA-336.14.3.0 ve ICC-14216 hatlarında proteomik bir yaklaşımla daha ayrıntılı olarak araştırılmıştır (Navas-Cortes et al., 2008). Kök proteomlarının karşılaştırmaları, *M. artiellia* ile birlikte enfeksiyonu takiben ırk 5'e verilen farklı tepkilerin, enfekte olmuş bitkilerdeki kurucu protein seviyelerindeki farklılıkları içermediğini göstermiştir. 'CA-336.14.3.0' nohutlarının 'ICC-14216 K' ile karşılaştırıldığında daha yüksek yanıt verebilirliği, nematod tarafından enfeksiyon sırasında eski hatta daha güçlü bir metabolik yeniden programlama ile ilgili olabilir (Castillo vd. 2003; Palomares-Rius vd. 2011).

5.4. Ekim Tarihi ve Biyolojik Mücadele

Ekim tarihi, nohut mahsulünün verimini belirlemede çok önemli bir faktördür ve Akdeniz bölgesinde geleneksel olarak ilkbaharda ekim yapılır. Bununla birlikte, sezon ilerledikçe, ürün artan sıcaklıklar ve artan toprak nemi stresiyle karşılaşır, bu da vejetatif ve üreme dönemlerini kısaltır ve verimi düşürür. Fusarium solgunluğu görülme sıklığı ve şiddeti, ilkbaharda ekilen ürünlerde ortaya çıkan sıcak ve kuru topraklar tarafından artırılır. Buna karşılık, kış ekimi, mahsulün büyüme aşamalarının optimum çevre koşullarıyla eşleşmesini sağlar ve topraktaki mevcut suyun daha iyi kullanılmasıyla verimi artırır. Nohut ekim zamanı, Fusarium solgunluğunun yönetimi için tavsiye edilmiştir ve Hindistan'da yapılan çalışmalar, Ekim ortasına kadar yapılan ekimlerde Fusarium solgunluğu yoğunluğunun azaldığını ve nohut tohum veriminin arttığını göstermiştir. Güney İspanya'da yapılan 3 yıllık bir çalışmada, ekim tarihinin erken ilkbahardan erken kışa alınmasının salgın başlangıcını önemli ölçüde geciktirdiği, salgın gelişimini yavaşlattığı ve nihai hastalık görülme sıklığını, şiddetini ve verim kaybını azalttığı bulunmuştur. Bununla birlikte, nohut ekiminin ilerletilmesinin Fusarium solgunluğunun kontrolü üzerindeki net etkileri, çeşidin duyarlılığına ve *F. oxysporum* f. sp. *ciceris* ırkının virülansına göre değişmiştir. Tohum verimi kaybı öncelikle *F. oxysporum* f. sp. *ciceris* ırkının virülansı ve daha az ölçüde nohut çeşidinin duyarlılığı tarafından belirlenmiştir.

Nohutta Fusarium solgunluğunun yönetimi için ekim tarihi seçimini bir hastalık kontrol stratejisi olarak kullanırken, seçilen ekim tarihlerinde hakim olan sıcaklıklardan kaynaklanan biyolojik kontrol uygulamalarının etkileri üzerinde olumsuz bir etkiden kaçınmak için dikkatli

olunmalıdır. Nohutta Fusarium solgunluğu, farklı bakteriyel veya fungal biyokontrol ajanlarıyla (örneğin, *Bacillus* spp., patojenik olmayan *F. oxysporum, Pseudomonas* spp. ve *Trichoderma harzianum*) tedavi edilerek kontrol edilebilir. Bununla birlikte, bu mikrobiyal ajanlar tarafından hastalığın baskılanmasının aşağıdakilerden etkilendiği gösterilmiştir:

i) patojenin inokulum yoğunluğu,
ii) patojenin ırkı, suşu veya izolatı ve
iii) biyokontrol faaliyetinin çalışması gereken çevresel koşullar.

6. SONUÇ

Fusarium solgunluğu, patojenin henüz rapor edilmediği Avustralya dışında, dünya çapında nohut üretimi için önemli bir sorundur. Hastalık, patojenin toprakta uzun süre hayatta kalması ve popülasyonlarında en az sekiz patojenik ırkın varlığı ile tercih edilmektedir. Bu ırklar, inokulum miktarı ve şiddetli hastalık için gerekli çevresel koşullardan etkilenen duyarlı çeşitler üzerinde virülans ve saldırganlık açısından farklılık gösterir. Hastalık görülme sıklığı ve şiddeti, patojen inokulum yoğunluğu, sıcak toprak sıcaklığı ve nohut çeşidinin duyarlılığından etkilenir. Fusarium solgunluğunun etkili yönetimi, patojenin ve patojenik ırklarının doğru ve hızlı bir şekilde teşhis edilmesini gerektirir. Bu sürece yardımcı olmak için moleküler protokoller geliştirilmiştir. Yaygın patojen ırk(lar)ına dirençli, yüksek verimli, iyi adapte olmuş nohut çeşitleri en pratik ve uygun maliyetli bireysel hastalık kontrol önlemidir. Bununla birlikte, mevcut *F. oxysporum* f. sp. *ciceris* ırk(lar)ının moleküler protokoller kullanılarak ekim öncesi teşhisi, riskli topraklardan kaçınmaya yardımcı olacaktır. Yavaş solma direncinin diğer ekim öncesi hastalık kontrol önlemleriyle birleştirilmesi, entegre hastalık yönetiminde verimliliği artıracaktır.

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COMPARATIVE ANTIFUNGAL ACTIVITY OF METHANOL AND HEXANE EXTRACTS OF *Pteridium aquilinum* AGAINST *Monilinia fructigena*

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ABSTRACT

In this study, the antifungal activity of methanol and hexane extracts obtained from the aerial parts of *Pteridium aquilinum* (bracken fern) was evaluated against the major plant pathogen *Monilinia fructigena*. The plant extracts were applied at concentrations of 0 (control), 0.5, 1, and 2 mg/mL. A negative control and a commercial fungicide containing 80% Thiram were used as reference treatments to assess the effectiveness of the extracts.

According to the results, the methanol extract inhibited the mycelial growth of *M. fructigena* by 19.40%, 26.16%, and 50.85% at doses of 0.5, 1, and 2 mg/mL, respectively. The hexane extract, on the other hand, inhibited fungal growth by 12.89%, 19.05%, and 28.68% at the same concentrations. These findings indicate that the methanol extract exhibited stronger antifungal activity compared to the hexane extract.

In conclusion, plant-derived natural antifungal compounds show promise as eco-friendly and cost-effective alternatives for the control of plant pathogens and could contribute to the development of biopesticides in sustainable agriculture.

Key words: Antifungal activity, Plant extracts, *Pteridium aquilinum, Monilinia fructigena*

1. INTRODUCTION

With the rapid increase in global population, the need to obtain higher yields and better-quality products from limited agricultural land has intensified. To meet this demand, various strategies have been developed to combat harmful organisms, among which chemical control remains the most widely adopted and effective approach. However, cultural and biological control methods are also considered important alternatives (Türküsay & Onoğur, 1996). In recent years, concerns about environmental pollution and disruptions to ecological balance have been increasingly associated with the excessive and improper use of synthetic pesticides.

The antifungal properties of plants are primarily attributed to the volatile oils and phenolic compounds naturally present in their structures. A significant relationship has been established between the chemical composition of these volatile oils and their antifungal efficacy (Cooner & Beuchat, 1984). Plant-derived pesticides are suggested to be more economical than synthetic ones, as they can be cultivated and applied by growers themselves and are considered environmentally friendly, making them suitable for use in integrated pest management programs (Lovang & Wildt-Persson, 1998).

Among the major fungal pathogens affecting fruit production worldwide are species of *Monilinia*, which are well-known for causing brown rot. Of particular importance are *Monilinia fructigena*, *M. fructicola*, and *M. laxa*, which are responsible for blossom blight, twig blight, and brown fruit rot in fruit trees and ornamental plants (Petróczy et al., 2012). *Monilinia fructigena* specifically leads to considerable losses in fruit yield and quality. While chemical fungicides are commonly used for the control of this pathogen, the adverse effects of synthetic chemicals on human health and the environment have prompted the search for alternative and more sustainable control methods. One such method involves the use of plant extracts.

Pteridium aquilinum (bracken fern) is a perennial plant with a wide global distribution. It is a non-flowering species commonly found along the coastal regions of Anatolia and in forest clearings (Özkara et al., 2003; Eslava-Silva et al., 2023). This plant contains various phenolic acids and exhibits antimicrobial activity against several important plant pathogens, including *Fusarium oxysporum* f.sp. *lycopersici*, *Sclerotinia sclerotiorum*, *Botrytis cinerea*, *Rhizoctonia solani*, *Pythium* spp., *Corynebacterium* spp., and *Erwinia* spp. (Francisco & Cooper-Driver, 1984; Yılar et al., 2019). Moreover, aqueous leaf extracts of bracken fern have been reported to inhibit seed germination, hypocotyl elongation, and root growth in several vegetable species (Wang et al., 2011).

The aim of this study is to evaluate the contact antifungal activity of methanol and hexane extracts derived from the aerial parts of *Pteridium aquilinum* against *Monilinia fructigena*, a major pathogen responsible for significant yield and quality losses in fruit production.

2. MATERIALS AND METHODS

Plant Material

The plant material used in this study, *Pteridium aquilinum*, was collected from Tokat (Turkey) during its vegetative growth period. The harvested plant samples were dried in a shaded

environment and subsequently ground into a fine powder. The powdered plant material was stored in airtight containers until extraction.

Preparation of Plant Extracts

A total of 100 grams of powdered plant material was placed into separate 1-liter Erlenmeyer flasks. Methanol was added to each flask in sufficient quantity to cover the plant material completely. The mixtures were shaken on an orbital shaker at 120 rpm for 72 hours at room temperature. The resulting solutions were filtered through Whatman filter paper, and the methanol solvent was evaporated using a rotary evaporator at 40 °C. The residual dry extracts were dissolved in 50% aqueous acetone and adjusted to final concentrations of 0.5, 1, and 2 mg/mL for further bioassay applications.

In Vitro Antifungal Activity Assay

Potato Dextrose Agar (PDA) was prepared and sterilized by autoclaving, then cooled to 40 °C. The prepared plant extracts were incorporated into the sterile PDA to yield final concentrations of 0.5, 1, and 2 mg/mL. The medium was poured into 60 mm diameter Petri dishes to a uniform depth of approximately 10 mm. Mycelial discs (5 mm in diameter), excised from 7-day-old cultures of the test fungus (Monilinia fructigena), were placed at the center of each plate. The inoculated plates were incubated at 25 ± 2 °C for 7 days. Fungal growth was measured daily, and mycelial diameters were recorded for each treatment . The percentage inhibition of mycelial growth was calculated using the formula described by Pandey et al. (1982):

$I = 100 \times (dc - dt) / dc$

I = Percentage inhibition of mycelial growth

dc = Mycelial growth in control

dt = Mycelial growth in treatment

A commercial fungicide containing 80% Thiram was used as a positive control. The experiment was conducted using a completely randomized design with three replications and two repetitions per treatment.

3. RESULTS AND DISCUSSION

In this study, the antifungal effects of methanol and hexane extracts of *Pteridium aquilinum* against *Monilinia fructigena* were evaluated under in vitro conditions, and the results are presented in Table 1. A significant correlation was observed between the applied concentrations and the inhibition rates of mycelial growth. The data indicate that both extracts inhibited the mycelial growth of *M. fructigena* in a dose-dependent manner. The methanol extract exhibited inhibition rates of 12.89%, 19.05%, and 28.68% at concentrations of 0.5, 1, and 2 mg/mL, respectively. In comparison, the hexane extract demonstrated a stronger antifungal activity, resulting in inhibition rates of 19.40%, 26.16%, and 50.85% at the same concentrations.

Table 1. Inhibition rates (%) of *Pteridium aquilinum* methanol and hexane extracts on *Monilinia fructigena* mycelial growth

Concentration (mg/mL)	Hexane Extract (%)	Methanol Extract (%)
C− (Negative Control)	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}
C+ (Positive Control, 80% Thiram)	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
0.5	19.40 ± 1.55^{d}	12.89 ± 2.81^{cd}
1.0	26.16 ± 0.46^{c}	19.05 ± 2.04^{bc}
2.0	50.85 ± 1.01^{b}	28.68 ± 2.15^{b}

Values followed by different letters within the same column indicate statistically significant differences ($p < 0.05$).

These findings suggest that while both extracts possess antifungal activity against *M. fructigena*, the hexane extract is notably more effective, especially at higher concentrations. This may be attributed to the differential solubility and extraction of bioactive compounds in non-polar versus polar solvents, with hexane possibly extracting more potent lipophilic antifungal compounds from *P. aquilinum*. These results highlight the potential of plant-based extracts, particularly from ferns such as *P. aquilinum*, as environmentally friendly alternatives to synthetic fungicides in the management of brown rot in fruit production systems.

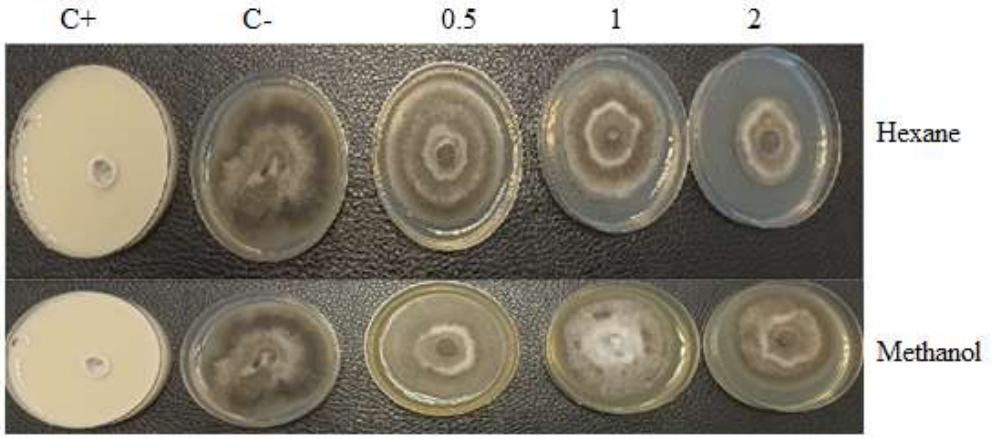

Figure 1. Effect of *Pteridium aquilinum* methanol and hexane extracts on *Monilinia fructigena* mycelial growth

The results demonstrated that the hexane extract exhibited significantly higher antifungal activity compared to the methanol extract, with nearly twice the inhibitory effect at the 2 mg/mL

concentration. This suggests that the non-polar compounds present in the hexane extract are more effective in suppressing *M. fructigena* mycelial development.

The antifungal activity observed in *P. aquilinum* extracts is likely attributed to the presence of secondary metabolites, particularly phenolic compounds known for their antimicrobial properties. These bioactive constituents, including phenolics, flavonoids, and other phytochemicals, play a critical role in the plant's defense mechanisms against pathogens. Furthermore, the plant also exerts allelopathic effects by inhibiting seed germination and the growth of neighboring plant species, thereby playing a significant ecological role (Glassman & Muller, 1978; Francisco & Cooper-Driver, 1984).

P. aquilinum has been shown to exert strong inhibitory effects on other crops, which are believed to be associated with allelochemicals such as selligueain (Jatoba et al., 2016). Previous research has reported that hexane, chloroform, and aqueous extracts of *P. aquilinum* variably inhibited the mycelial growth of *Puccinia arachidis* and *Phaeoisariopsis personata* (Sahayaraj et al., 2009). Additionally, methanol and hexane extracts of *P. aquilinum* have demonstrated antifungal activity against *Fusarium oxysporum* f.sp. *lycopersici* and *Sclerotinia sclerotiorum*, with inhibition rates ranging between 64.22% and 79.48% for *S. sclerotiorum*. For *F. oxysporum* f.sp. *lycopersici*, methanol and hexane extracts inhibited mycelial growth by 73.58% and 83.92%, respectively (Yılar et al., 2019).

In light of these findings, the hexane extract of *Pteridium aquilinum* represents a promising natural source of bioactive antifungal agents against plant pathogens. Considering the growing demand for environmentally friendly and cost-effective alternatives to synthetic pesticides, the integration of such natural compounds in biopesticide development efforts is strongly recommended.

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COMPARATIVE EVALUATION OF LEAF, FLOWER AND SEED EXTRACTS OF VIXTEX AGNUS-CASTUS FOR THEIR ANTIFUNGAL ACTIVITY AGAINST FUSARIUM OXYSPORUM SPECIES

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ABSTRACT

This study aimed to evaluate the antifungal effects of methanol extracts obtained from the leaves, seeds, and flowers of *Vitex agnus-castus* against important plant pathogens: *Fusarium oxysporum* f. sp. *melonis* (Fom), *F. oxysporum* f. sp. *cucumerinum* (Foc), and *F. oxysporum* f. sp. *lycopersici* (Fol). The plant extracts were applied at concentrations of 0.5, 1, and 2 mg/mL, and their effects were compared with a negative control and a commercial fungicide containing 80% Thiram as a positive control.

According to the findings, the seed extract exhibited the highest antifungal activity across all tested pathogens. It inhibited mycelial growth of Foc, Fol, and Fom by 59.27%, 59.80%, and 62.81%, respectively. The leaf extract showed moderate antifungal activity, suppressing the mycelial development of Foc, Fol, and Fom by 36.28%, 50.95%, and 39.06%, respectively. The flower extract also demonstrated notable inhibition rates: 50.61% for Foc, 38.14% for Fom, and 52.98% for Fol.

Overall, the results indicate that antifungal activity increased in a dose-dependent manner, with the seed extract being the most effective among the plant parts tested. These findings suggest

that *V. agnus-castus* contains bioactive compounds with antifungal potential and could serve as a promising source of eco-friendly and sustainable biopesticides for the management of plant diseases.

Keywords: *Vitex agnus-castus*, *Fusarium oxysporum* spp. Antifungal activity, Plant extracts

VİTEX AGNUS-CASTUS'UN YAPRAK, ÇİÇEK VE TOHUM EKSTRAKTLARININ *FUSARİUM OXYSPORUM* TÜRLERİNE KARŞI ANTİFUNGAL AKTİVİTE AÇISINDAN KARŞILAŞTIRMALI DEĞERLENDİRİLMESİ

ÖZET

Bu çalışma, *Vitex agnus-castus* bitkisinin yaprak, tohum ve çiçek organlarından elde edilen metanol ekstraktlarının önemli bitki patojenlerinden *Fusarium oxysporum* f. sp. *melonis* (Fom), *F. oxysporum* f. sp. *cucumerinum* (Foc) ve *F. oxysporum* f. sp. *lycopersici* (Fol) üzerindeki antifungal etkilerini belirlemeyi amaçlamaktadır. Bitki ekstraktları, 0.5, 1 ve 2 mg/mL konsantrasyonlarında uygulanmış; değerlendirmelerde negatif kontrol ve %80 Thiram içeren ticari bir fungisit pozitif kontrol olarak kullanılmıştır.

Araştırma bulgularına göre, tohum ekstraktı tüm patojen türlerine karşı en yüksek antifungal etkiyi göstermiştir. Foc, Fol ve Fom'un miselyum gelişimi tohum ekstraktı ile sırasıyla %59,27, %59,80 ve %62,81 oranlarında inhibe edilmiştir. Yaprak ekstraktı ise orta düzeyde etki göstererek Foc, Fol ve Fom'un miselyal gelişimini sırasıyla %36,28, %50,95 ve %39,06 oranlarında baskılamıştır. Çiçek ekstraktı da dikkate değer bir antifungal etki sergilemiş; bu etki Foc için %50,61, Fom için %38,14 ve Fol için %52,98 olarak ölçülmüştür.

Elde edilen veriler, antifungal etkinin uygulanan doza bağlı olarak arttığını ve özellikle tohum ekstraktının *Fusarium oxysporum* patojenlerine karşı diğer bitki kısımlarından elde edilen ekstraktlara kıyasla daha güçlü bir inhibitör etki gösterdiğini ortaya koymuştur. Bu sonuçlar, *V. agnus-castus* bitkisinin doğal antifungal bileşikler bakımından zengin bir kaynak olabileceğini ve bitki hastalıklarıyla mücadelede çevre dostu biyopestisitlerin geliştirilmesinde potansiyel bir aday olduğunu göstermektedir.

Anahtar Kelimeler: *Vitex agnus-castus, Fusarium oxysporum* spp. Antifungal aktivite, Bitki ekstraktı

1.GİRİŞ

Tarımsal alanlarda ürünleri bozan hastalıklar, zararlılar ve yabani otlar önemli kayıplara neden olmaktadır. Patojenik mantarlar, bitkilerde hasat sonrası da dahil olmak üzere gelişim aşamalarında değişikliklere neden olan ana enfeksiyon etkenleridir. Meyve ve sebzelerde, görünüş, besin değeri, organoleptik özellikler ve sınırlı raf ömrü ile ilgili kalite sorunlarına neden olan çok çeşitli mantar cinsleri vardır (Agrios, 2004). Buna ek olarak, bazı durumlarda mantarlar mikotoksin veya alerjen üretimi nedeniyle tüketiciler arasında alerjik veya toksik bozukluklardan dolaylı olarak sorumludur. Genellikle fitopatojen funguslar sentetik fungisitlerle kontrol edilmektedir (Harris, vd., 2001). Ancak bugüne kadar yapılan çalışmalar, artan pestisit kullanımının çeşitli sorunlara neden olduğunu ortaya koymuştur. Pestisitlerin insan sağlığı ve çevre üzerindeki zararlı etkileri nedeniyle bunların kullanımı giderek kısıtlanmaktadır (Harris, vd., 2001). Bunun yanında; artan üretim talebi ve tarımsal kimyasalların kullanımına ilişkin düzenlemeler ve kullanılan kimyasallara dirençli patojenlerin ortaya çıkması, yeni aktif moleküllerin ve yeni kontrol stratejilerinin araştırılmasını ve uygulanmasını gerekli kılmaktadır. Antik çağlardan bu yana, bitkiler alemi analjezikler, anti-enflamatuarlar, astım ilaçları ve diğerleri gibi bilinen terapötik özelliklere sahip çeşitli bileşikler sağlamıştır. Son yıllarda, bitki özlerinin antimikrobiyal özellikleri dünyanın farklı bölgelerinden artan sıklıkta rapor edilmektedir (Cowan, 1999). Bitki metabolitleri ve bitki bazlı ilaçların sentetik pestisitlere kıyasla insan sağlığına ve çevreye daha az zararlı olduğu düşünülmekte ve bu yönde çalışmalar yapılmaktadır (Kordali ve ark., 2007). Bu nedenle çeşitli bitki ekstraktlarının ve uçucu yağların bitki hastalıkları üzerindeki etkileri üzerine yapılan çalışmalar ön plana çıkmıştır. Türkiye coğrafi konumuna bağlı olarak Akdeniz, İran-Turan ve Avrupa-Sibirya bölgesi olmak üzere 3 temel fitocoğrafik bölgeye ayrılır (Doğan ve Mert, 1998). Bu nedenle bitki çeşitliliği ve endemizm açısından oldukça zengindir. Akdeniz lemur vejetasyonunun tipik bir elemanı olan Vitex agnus-castus L, Verbenaceae familyasından çok yıllık bir bitkidir (Anonim, 2015). Ancak son sınıflandırmada Lamiaceae familyasına dahil edilmiştir (Asdadi ve ark., 2014). Hayıt, acı ayıt, hayıd, beş parmak otu gibi çeşitli isimlerle anılan Vitex agnus-castus, kıyılarda ve kayalık arazilerde yetişen çalı, nadiren küçük ağaç formunda bitkilerdir (Anonim, 2015). Vitex agnus-castus bitkisinin tıpta yaraların ve basurların iyileştirilmesinde kullanıldığına dair bilgilerin geçmişi en az yıllar öncesine kadar uzanmasına rağmen (Chantaranothai, 2011), günümüzde farklı kısımları adet söktürücü, spazmodik dismenore, menopasual durumlar, yetersiz emzirme ve akne gibi bazı rahatsızlıkların iyileştirilmesinde kullanılmaktadır (Maltaş ve ark., 2010). Ayrıca, Vitex agnus-castus'un uçucu yağ ve bitki ekstraktlarının antioksidan, antimikrobiyal ve antifungal aktiviteleri bildirilmiştir. Ayrıca Vitex agnus-castus tohumlarından elde edilen uçucu yağın Candida türleri üzerinde güçlü bir antifungal aktivite gösterdiği (Asdadi vd., 2014) ve yedi bakteri türünü içeren Vitex agnus-castus metanol ekstraktlarının Candida albicans mantarına karşı antimikrobiyal etkiye sahip olduğu bildirilmiştir (Maltaş vd., 2010). Bitki methanol ekstraktının önemli bitki patojeni funguslar olan *Alternaria. solani, Rhizoctonia solani, Sclerotinia sclerotiorum* türleri üzerine antifungal aktiviteleri rapor edilmiştir (Yılar ve ark., 2015). Bu çalışma ile Türkiye'de normal olarak yetişen Vitex agnus-castus bitkisinin metanol ekstraktlarının, tarımsal üretimde önemli kayıplara yol açan Foc, Fom ve Fol bitki patojenleri üzerindeki antifungal aktivitesi ortaya konmuştur.

2. MATERYAL VE METOD

2.1. Bitki Materyali

Denemelerde kullanılan *Vitex agnus-castus* bitki materyali Antalya ilinden toplanmıştır. Toplanan bitkiler Kırşehir Ahi Evran Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü Laboratuvarında oda sıcaklığında kurutulmuş ve elektrikli değirmende öğütülmüşlerdir. Öğütülen bitki materyalleri denemeler kuruluncaya kadar oda sıcaklığında gölgede kağıt torbalar içerisinde muhafaza edilmişlerdir.

2.2. Bitki methanol ekstraktının Hazırlanması

100 g öğütülmüş bitki materyali 1L Erlenmeyere konmuş ve üzerine 600 mL metanol ilave edilmiştir. Bu çözeltiler oda sıcaklığında 24 saat boyunca orbital çalkalayıcıda tutulmuştur. Bu süre sonunda filtre kağıdından süzülen ekstrakt katı hale gelene kadar 32°C'de evaporatör methanol uzaklaştırılmıştır. Kalan katı madde DMSO çözeltisi ile çözülerek farklı konsantrasyonda dozlar elde edilmiştir (Kadıoğlu ve Yanar, 2004).

2.3. Fungus kültürlerinin hazırlanması

Bitki patojeni funguslar, Kırşehir Ahi Evran Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü Fitopatoloji laboratuvarında bulunan stoklardan elde edilmiştir. Bu stok kültürlerden elde edilen funguslar 7 gün boyunca 25±2ºC'de, 90 mm'lik petri kaplarında geliştirilmiştir. Denemelerde bu son gelişen taze kültürler kullanılmıştır.

2.4. İn vitro koşullarda bitki methanol ekstraktının antifungal aktivitesi: Methanol ekstraktından elde edilen özüt DMSO-su karışımıyla çözülerek elde edilen stok çözeltiler son konsantrasyon 100, 200 ve 400 ppm olacak şekilde 45-50 ºC'ye kadar soğutulan PDA ortamlarına ilave edilmiştir (Onaran and Yılar, 2012). Kontrol olarak, funguslar sadece PDA içeren petri kaplarına ekimi yapılmıştır. Ayrıca denemelerde pozitif kontrol olarak Thiram etkili maddeli bir fungusit kullanılmıştır. Farklı dozlardaki bu PDA ortamları 60 mm çaplı petri kaplarına 10 ml olacak şekilde dökülmüştür. Denemelerden 7-10 günlük önce geliştirilmiş bitki patojeni kültürlerinde alınan 5 mm çaplı miselyum diskleri ekstrakt ilaveli PDA ortamı içeren petri kaplarına ekimi yapılmıştır. Fungus kültürleri inokulasyondan sonra gelişme kabininde 25±1ºC'de7 gün boyunca inkubasyona bırakılmıştır (Yılar ve ark., 2020, Yılar ve ark., 2023). Bu çalışma 4 tekerrürlü olarak 2 defa tekrarlanmıştır. Petri kaplarındaki gelişen miselyum çapları digital Caliper aleti ile ölçülmüştür. Ekstraktların miselyum gelişmesi engelleme yüzdesi aşağıdaki formüle göre hesaplanmıştır:

I:100x(dc-dt)/dc

I:Yüzde miselyum gelişimi engelleme oranı

dc: Kontroldeki miselyum gelişimi

dt: Uygulamadaki miselyum gelişimi(Pandey et al., 1982)

3. BULGULAR ve TARTIŞMA

Vitex agnus-castus bitki methanol ekstraktının önemli bitki patojeni *Fusarium* türleri üzerine antifungal aktivite sonuçları Çizelge ve grafiklerle verilmiştir. Buna göre bitki methanol ekstraktları uygulanan doza, bitki kısmına ve *Fusarium* türlerine bağlı olarak değişen oranlarda antifungal aktivite sergilemiştir. Bitki çiçek methanol ekstraktı en yüksek konsantrasyonda(400ppm) ey yüksek engelleyici etkiyi Fol miselyum gelişimi üzerine göstermiş olup, bunu Foc ve Fom izlemiştir (Çizelge 1, Grafik 1). Benzer sonuçlar Bitki yaprak ve tohum ekstraktlarında da görülmüştür. Nitekim, bitki yaprak ekstraktı kontrole kıyasla %50,95 engelleme oranı ile en yüksek etkiyi Fol üzerine göstermiş, bunu Fom ve Foc takip etmiştir (Çizelge 2, Grafik 2). Bitki tohum ekstraktı diğer ekstraktlara göre fungusların miselyum gelişimi üzerine daha etkili olduğu belirlenmiştir. Buna göre tohum ekstraktı %62,81 engelleme ile en yüksek etkiyi Fom üzerine göstermiş, bunu %59,80 ile Fol ve %59,27 engelleme oranı ile Foc izlemiştir (Çizelge 3, Grafik 3).

Çizelge 1. *Vitex agnus-castus* çiçek methanol ekstraktının *Fusarium* türlerinin miselyum gelişimi üzerine engelleme oranı (%)

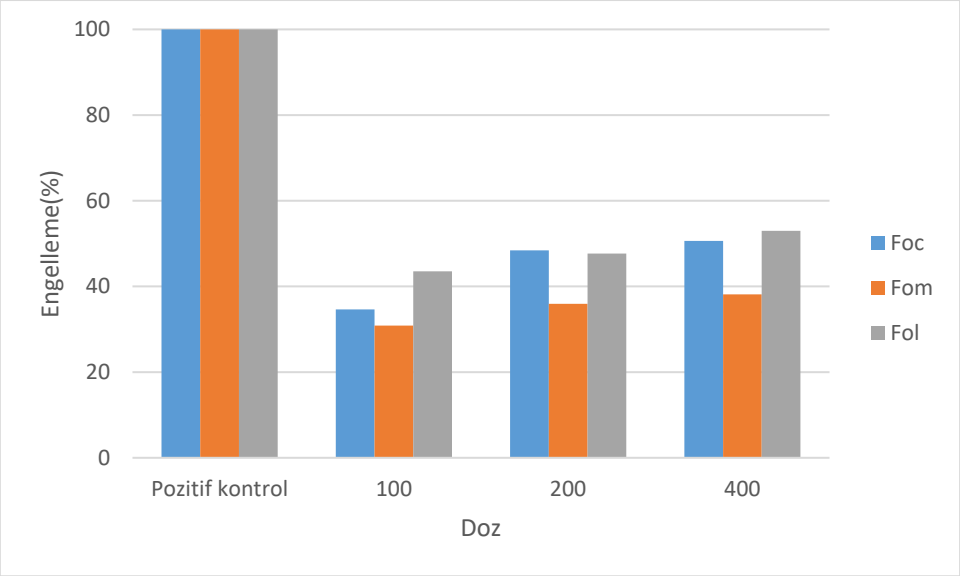
Doz	Foc	Fom	Fol
Pozitif kontrol	100,0a±0,0	100,0a±0,0	100,0a±0,0
Kontrol	0,0 d±0,0	0,0d±0,0	0,0d±0,0
100	34,62c±0,2	30,87c±0,6	43,53c±0,9
200	48,42b±0,3	35,96b±1,0	47,67c±2,2
400	50,61b±1,5	38,14b±2,2	52,98b±1,7

Çizelge 2. *Vitex agnus-castus* yaprak methanol ekstraktının *Fusarium* türlerinin miselyum gelişimi üzerine engelleme oranı (%)

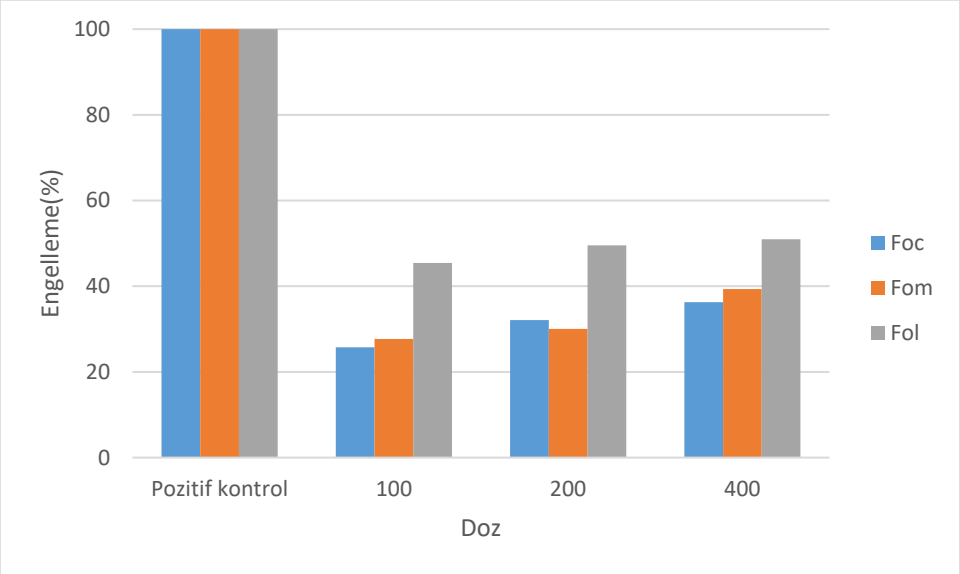
Doz	Foc	Fom	Fol
Pozitif kontrol	100,0a±0,0	100,0a±0,0	100,0a±0,0
Kontrol	0,0e±0,0	0,0e±0,0	0,0d±0,0,0
100	25,73d±0,5	27,69d±0,7	45,45c±0,5
200	32,08c±0,7	30,03c±0,1	49,55c±0,4
400	36,28b±0,5	39,35b±1,0	50,95b±0,4

Çizelge 3. *Vitex agnus-castus* tohum methanol ekstraktının *Fusarium* türlerinin miselyum gelişimi üzerine engelleme oranı (%)

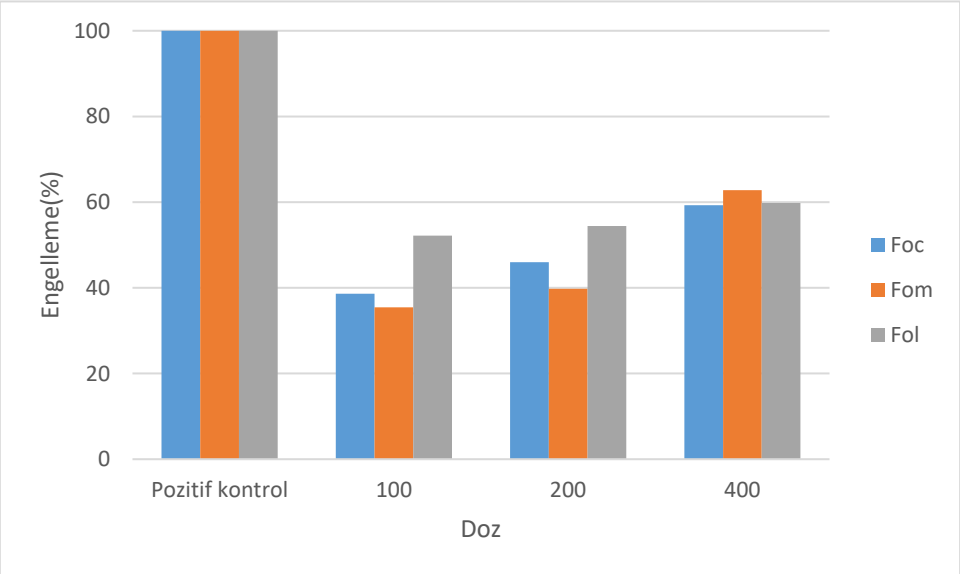
Doz	Foc	Fom	Fol
Pozitif kontrol	100,0a±0,0	100,0a±0,0	100,0a±0,0
Kontrol	0,0e±0,0	0,0d±0,0	0,0d±0,0
100	38,62d±0,3	35,45c±0,6	52,19c±0,6
200	46,00c±0,4	39,78c±0,7	54,41c±1,0
400	59,27b±3,4	62,81b±1,5	59,80b±2,3



Grafik 1. *Vitex agnus-castus* çiçek methanol ekstraktının *Fusarium* türlerinin miselyum gelişimi üzerine engelleme oranı (%)



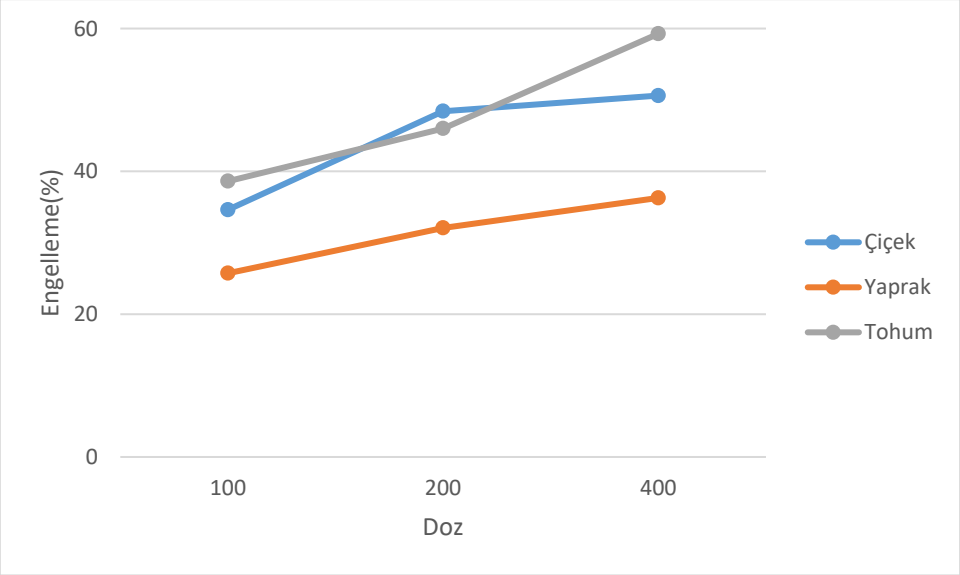
Grafik 2.*Vitex agnus-castus* yaprak methanol ekstraktının *Fusarium* türlerinin miselyum gelişimi üzerine engelleme oranı (%)



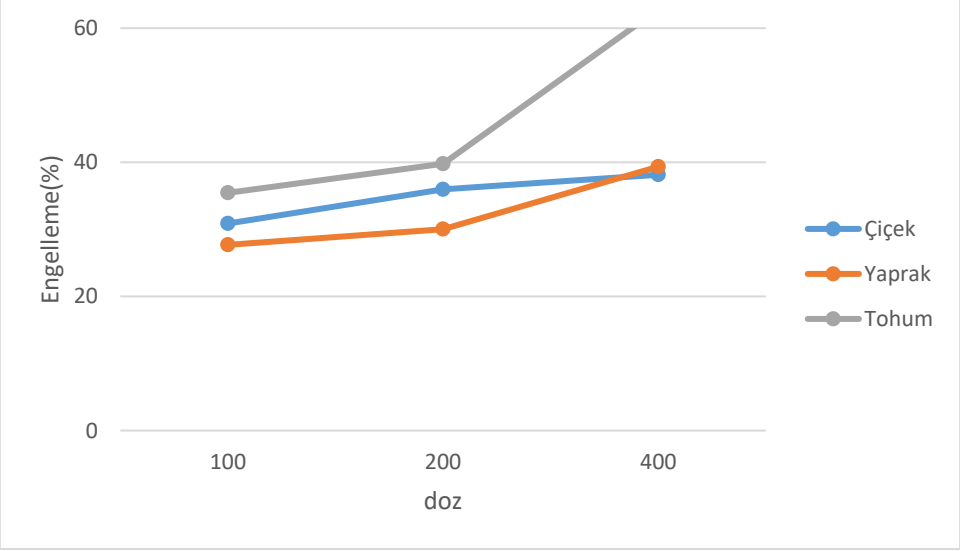
Grafik 3. *Vitex agnus-castus* tohum methanol ekstraktının *Fusarium* türlerinin miselyum gelişimi üzerine engelleme oranı (%)

Hastalık etmeni üzerinden bir değerlendirme yapılacak olursa; Foc miselyum gelişimi üzerine tohum ekstraktı en yüksek engelleme etkisi göstermiştir. Tohum ekstraktının 400 ppm dozu Foc miselyum gelişimini kontrole kıyasla %59,27 inhibe etmiştir. Bunu %50,61 ile çiçek ve %36,28 ile yaprak ekstraktı takip etmiştir (Grafik 4). Diğer *Fusarium* türleri üzerine

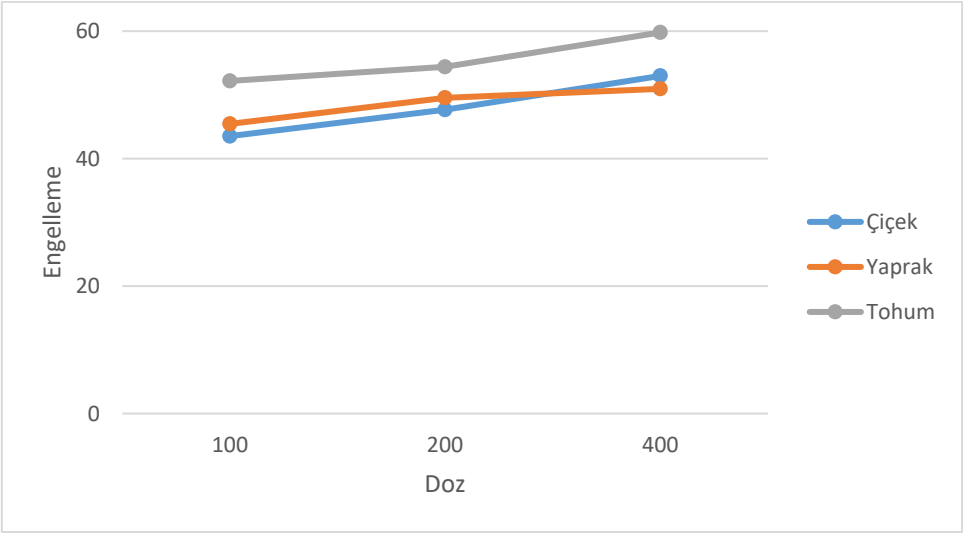
ekstraktların 400ppm dozunda; engelleme oranlarında farklılık olmakla beraber yine tohum ekstraktı en yüksek engelleyici etkiyi sergilemiştir (Grafik 5, Grafik 6).



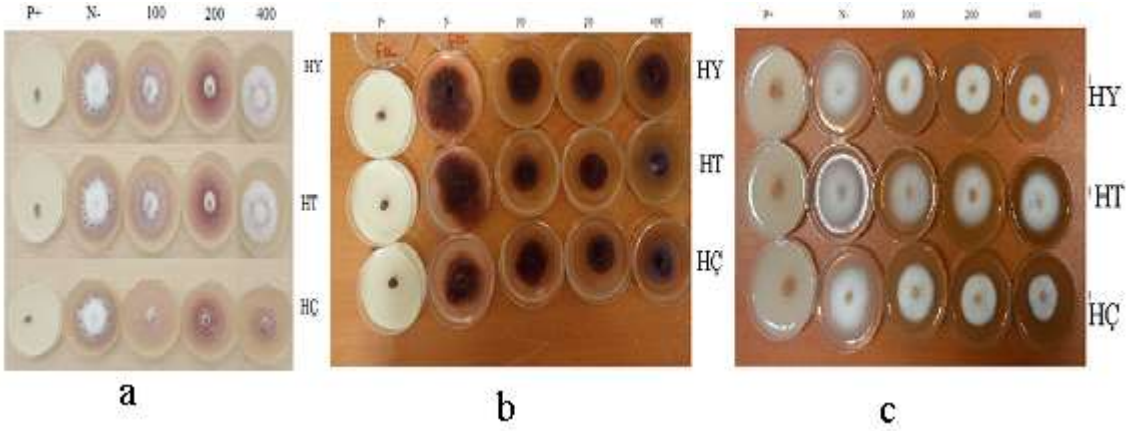
Grafik 4. *Vitex agnus-castus* bitki methanol ekstraktının Foc miselyum gelişimi üzerine engelleme oranı (%)



Grafik 5. *Vitex agnus-castus* bitki methanol ekstraktının Fom miselyum gelişimi üzerine engelleme oranı (%)



Grafik 5. *Vitex agnus-castus* bitki methanol ekstraktının Fol miselyum gelişimi üzerine engelleme oranı (%)



Şekil 1. *Vitex agnus-castus* bitki methanol ekstraktının Fom(a), Fol(b) ve Foc(c) patojeni fungusların miselyum gelişim üzerine etkisi

V. agnus-castus yaprak, çiçek ve meyveleri fenolik asitler ve türevleri, flavonoidler, tanenler, iridoitler, diterpenoidler ve uçucu yağ bileşimi bakımından zengindir (Sağlam vd., 2007; Hajdú vd., 2007; Proestos vd., 2006; Cabral vd., 2008; Stojković vd., 2011; Latovi vd., 2012; Fakir vd., 2014). Başka bir çalışmada, V. agnus castus'un yaprak ve meyvelerinin önemli düzeyde vitexin bileşiği içerdiği belirlenmiştir. Vitexin, antioksidan, antimikrobiyal, anti-inflamatuar, hepatoprotektif, spazmolitik, antiviral, antitiroid ve antiglikasyon gibi birçok biyolojik özelliğe sahip olduğu bildirilmiştir (Gökbulut ve ark., 2010; Peng ve ark., 2008; Zielińska ve Zieliński, 2011). Bu nedenledir ki *Vitex agnus-castus* bitkisinin farklı kısımlarımdan elde edilen ekstrakt ve uçucu yağlarının biyolojik aktivitesi üzerine çalışmalar yürütülmüş ve yürütülmeyede devam

etmektedir. Bitki tohumlarından elde edilen uçucu yağın *Candida* türleri üzerinde güçlü bir antifungal aktivite sergilediği (Asdadi vd., 2014) rapor edilmiştir. Önceki çalışmalarda, bazı *Vitex* türleri Gram-pozitif bakterilere (0.02-8.00 mg ml^{-1}) karşı iyi büyüme inhibisyonu gösterirken, Gram-negatif bakterilere ve mayalara (0.50-8.00 mg ml^{-1}) karşı daha düşük aktivite göstermiştir (Nyiligira ve ark., 2008). Vitex trifolia yapraklarının antimikrobiyal aktivitesi daha önce araştırılmıştır. Tüm ekstraktlar gram-pozitif ve gram-negatif türlerin büyümesini inhibe etmiştir. Sadece DCM yaprak ekstresi 5 mg ml-1 dozunda *Candida albicans*'a karşı inhibisyona neden olmuştur (Hernandez ve ark., 1999). Disk difüzyon deneyi, *Vitex trifolia*'nın petrol ekstresi ve eta-nolik ekstresi ile gerçekleştirilmiştir. Petrol eteri fraksiyonunun etanolik olandan daha aktif olduğu bulunmuştur (Hossain ve ark., 2001). Maltaş ve ark.(2010) yürüttükleri çalışmada *Vitex agnus castus*'un sadece metanolik ekstresinin antifungal aktivite gösterdiği belirtilmektedir. Başka bir çalışmada; antioksidant aktivite testlerinde, EtOAc ekstraktının özellikle DPPH-serbest radikal testinde (IC50 = 15.68 ± 1.51 µg/mL) dikkate değer bir etkiye sahip olduğunu, enzimatik analizlerde de diklorometan ekstraktının bütirilkolinesterazı orta derecede inhibe ettiği rapor edilmiştir (IC50 = 133,54 ± 1,45 µg/mL)(Bramki ve ark., 2025). Bitki methanol ve su ekstraktları *C. Albicans* klinik izolasyonlarına karşı antifungal aktivite sergilemiştir (Keikha ve ark., 2018). Vitex ekstraktı disk füzyon yöntemi kullanılarak yürütülen çalışmada, 50 mm'lik büyüme inhibisyon zonu ile Staphylococcus aureus'a karşı antifungal etki göstermiştir (Ghannadi ve ark., 2012). Vitex agnus castus'tan izole edilen agnusid maddesinin E. floccosum (31.25 µg/ml), T. simii (62.5 µg/ml), C. lunata (250 µg/ml), T. rubrum (62.5µg/ml), C. albicans (125 µg/ml) ve Scopulariopsis sp'ye (500 µg/ml) karşı güçlü antifungal aktivite aktivite göstermiştir (Mohandass ve ark., 2010).

Mevcut çalışmada ise *Vitex agnus-castus* methanol ekstraktının önemli toprak patojeni olan Fusarium türler üzerine antifungal etkiye sahip olduğu ortaya konmuştur.

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BIOEFFICACY AND CHEMICAL PROFILING OF TWO ESSENTIAL OILS AGAINST *SITOPHILUS GRANARIUS* L. (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT

Sitophilus granarius L. (Coleoptera: Curculionidae) is a widespread pest of stored cereals, causing substantial quantitative and qualitative losses, particularly in wheat, barley, oats, and rye. In this study, the essential oils (EOs) of *Lavandula angustifolia* Mil. (Lamiaceae) and *Eucalyptus globulus* Labill. (Myrtaceae) EOs were evaluated under laboratory conditions for their contact toxicity, repellency, and fumigant effects against *S. granarius*. Chemical compositions of the oils were identified using gas chromatography-mass spectrometry (GC-MS) and gas chromatography-flame ionization detection (GC-FID). Jaccard similarity analysis was used to assess compositional similarity, while t-SNE Clustering Analysis classified compounds based on structural relationships. In contact toxicity assays, the highest mortality (92.6%) was observed at 35% *L. angustifolia* oil concentration on day two. The most potent effect (97.9% mortality) was achieved with a mixture of 20% *L. angustifolia* and 50% *E. globulus* oil. Maximum repellency occurred at 0.25% (class IV) and 1% (class V) *L. angustifolia* concentrations, and the strongest fumigation effect was observed at 1.5 µl/ml air concentration. Major compounds identified were linalool, linalyl acetate, and 1,8-cineole in *L. angustifolia*, and 1,8-cineole, cymene, and alpha-pinene in *E. globulus*. The oils showed 30.7% overall compositional similarity; linalool and linalyl acetate had the highest pairwise similarity (52%). t-SNE analysis revealed three molecular clusters, separating the oils based on their dominant compounds. These results suggest that both essential oils, due to their multi-modal actions and eco-friendly nature, hold promise as alternative or complementary agents in integrated pest management (IPM) strategies for stored grain protection.

Keywords: Botanical fumigation, chemical composition, environmentally friendly control, principle component analysis

SITOPHILUS GRANARIUS L. (COLEOPTERA: CURCULIONIDAE) ÜZERİNDE İKİ UÇUCU YAĞIN BİYOETKİNLİĞİ VE KİMYASAL PROFİLLEMESİ

ÖZET

Sitophilus granarius L. (Coleoptera: Curculionidae) depolanmış tahıllarda yaygın bir zararlı olup, özellikle buğday, arpa, yulaf ve çavdarda önemli nicel ve nitel kayıplara neden olmaktadır. Bu çalışmada, *Lavandula angustifolia* Mil. (Lamiaceae) ve *Eucalyptus globulus* Labill. (Myrtaceae) uçucu yağları, *S. granarius*'a karşı temas toksisitesi, kovuculuk ve fumigant etkileri açısından laboratuvar koşullarında değerlendirilmiştir. Yağların kimyasal bileşimleri gaz kromatografisi-kütle spektrometresi (GC-MS) ve gaz kromatografisi-alev iyonizasyon tespiti (GC-FID) kullanılarak tanımlanmıştır. Bileşimsel benzerliği değerlendirmek için Jaccard benzerlik analizi kullanılırken, t-SNE Kümeleme Analizi yapısal ilişkilere dayalı olarak bileşikleri sınıflandırmıştır. Temas toksisitesi deneylerinde, en yüksek ölüm oranı (%92.6) ikinci günde %35 *L. angustifolia* yağı konsantrasyonunda gözlenmiştir. En güçlü etki (%97.9 ölüm) %20 *L. angustifolia* ve %50 *E. globulus* yağı karışımı ile elde edilmiştir. Maksimum kovuculuk %0.25 (sınıf IV) ve %1 (sınıf V) *L. angustifolia* konsantrasyonlarında meydana gelmiş ve en güçlü fümigasyon etkisi 1.5 µl/ml hava konsantrasyonunda gözlenmiştir. Tanımlanan başlıca bileşikler *L. angustifolia*'da linalool, linalil asetat ve 1,8-cineole, *E. globulus*'ta ise 1,8-cineole, cymene ve alpha-pinene olmuştur. Yağlar %30.7 genel bileşimsel benzerlik göstermiştir; linalool ve linalil asetat en yüksek ikili benzerliğe (%52) sahiptir. t-SNE analizi, yağları baskın bileşiklerine göre ayıran üç moleküler küme ortaya çıkarmıştır. Bu sonuçlar, çok modlu etkileri ve çevre dostu doğaları nedeniyle her iki uçucu yağın da depolanmış tahılların korunmasına yönelik entegre zararlı yönetimi (IPM) stratejilerinde alternatif veya tamamlayıcı maddeler olarak umut vaat ettiğini göstermektedir.

Anahtar Kelimeler: Bitkisel fümigasyon, kimyasal bileşim, çevre dostu mücadele, temel bileşen analizi

1. INTRODUCTION

The granary weevil, *Sitophilus granarius* L., 1758 (Coleoptera: Curculionidae), is widely distributed throughout Türkiye and causes significant damage and economic losses by feeding on various stored grains (Bağcı et al., 2014; Koçak et al., 2018). For decades, control of this pest has relied primarily on synthetic insecticides. However, repeated applications have led to the development of resistance in pest populations, necessitating the use of higher doses. This, in turn, increases risks to human and environmental health and raises concerns regarding pesticide residues in food products (Alpkent et al., 2023).

As a result of these drawbacks, there has been a growing demand for natural compounds that rapidly degrade into harmless metabolites. Among these, essential oils (EOs) have attracted attention as environmentally benign alternatives that can be integrated into pest management programs. Notably, biopesticides are considered safe for human health (Generally Recognized as Safe, GRAS) and offer substantial benefits due to their minimal residue potential and low impact on non-target organisms (Essiedu et al., 2020; Alpkent et al., 2024).

The biological activity of EOs can vary significantly depending on the plant's chemical profile, cultivation conditions, and harvest timing (Verma et al., 2010). *Lavandula angustifolia* essential oil, rich in monoterpenes such as linalool and linalyl acetate, has been shown to possess antimicrobial, antioxidant, and anti-inflammatory properties. Moreover, it exhibits promising insecticidal activity, including both direct toxicity and repellent effects on agricultural pests. In addition to these, larvicidal and ovicidal properties have also been reported (Prusinowska & Śmigielski, 2014; Chiffelle et al., 2019; Valizadeh et al., 2021). Some studies have further suggested that Eos of *L. angustifolia*, when used in combination with conventional synthetic insecticides, can enhance their toxic effects through synergistic interactions (Faraone et al., 2015). Such synergy may reduce the likelihood of resistance development and strengthen environmentally friendly integrated pest management (IPM) strategies.

Similarly, *E. globulus* represents another promising natural alternative for pest control in agriculture. Its essential oil, particularly rich in the active component 1,8-cineole, has demonstrated strong insecticidal properties against various insect species (Aziz et al., 2019). Research has shown that *E. globulus* exhibits repellent effects, especially against pests like *S. zeamais*, providing effective protection against infestation (Mossi et al., 2010). Additionally, the plant's inherent disease resistance and its positive contribution to ecosystem health further support its integration into sustainable plant protection approaches. The use of *Eucalyptus* species in crop protection is increasingly recognized as a valuable component of IPM programs (Puig et al., 2018).

Essential oils are considered effective and environmentally sound alternatives to synthetic insecticides due to their rich chemical composition and diverse biological activities. Their integration into sustainable agriculture and pest management practices holds great promise for reducing reliance on synthetic chemicals (Chiffelle et al., 2019; Faraone et al., 2015). Therefore, this study aims to investigate the insecticidal activity of *L. angustifolia* and *E. globulus* EOs against *S. granarius*.

2. MATERIALS AND METHODS

Insect Rearing

Sitophilus granarius adults used in this study were obtained from stock cultures maintained at Ankara University, Faculty of Agriculture, Department of Plant Protection. Rearing conditions were maintained at 25 ± 1 °C and 55 ± 5% relative humidity (RH) in climate-controlled chambers. Clean wheat grains, previously stored at low temperatures, were conditioned 24 hours before use. Adult insects (500–1000 individuals, mixed sexes) were introduced into 1 L glass jars containing 300–500 g of wheat. Adults were transferred to new containers every three days via sieving. As begin to appear dates of new adults were recorded, and individuals aged 7–14 days were selected for bioassays.

Plant Material and Chemical Composition Analysis

Essential oils of *L. angustifolia* and *E. globulus* were supplied by Biomesi Ar-Ge company (Türkiye). These oils were obtained via cold-press extraction and distillation methods. Their chemical compositions were determined using Gas Chromatography-Mass Spectrometry (GC-MS) and Gas Chromatography-Flame Ionization Detection (GC-FID), following the analytical protocol described by Özek et al. (2010).

Briefly, samples were diluted at a 1:100 ratio using hexane and analyzed using a GC-MS/FID system (Agilent 7890A GC, Agilent 5975C MS detector), equipped with an HP InnowaxCapillary column. Helium was used as the carrier gas at a constant flow rate of 0.8 mL/min. A 1 µL aliquot of each sample was injected in split mode (40:1). The injector temperature was set at 250 °C. The oven temperature program was as follows: initial hold at 60 °C, ramped to 220 °C at 4 °C/min, followed by a 10-minute hold at 220 °C. The total run time was 60 minutes. Mass spectra were recorded in the 35–450 m/z range using electron impact ionization at 70 eV. Compound identification was conducted by comparison with WILEY7 and OIL ADAMS spectral libraries.

Contact Toxicity Bioassay

Lavandula angustifolia essential oil was diluted to different concentrations of 10 - 35%, using a buffer solution consisting of 1% dimethyl sulfoxide (DMSO) and 0.02% Triton X-100 in double-distilled water. Each treatment group consisted of 30 insects and placed in 90 mm Petri dishes. The control group received only the DMSO/Tx-100 buffer. For the evaluation of the potential effects of increasing the insecticidal mortality rate, diluted *E. globulus* essential oil (50%) was applied in combination with varying concentrations of *L. angustifolia* oil. Treated insects were placed in Petri dishes containing 1 g of wheat and incubated in dark chambers at 25 ± 1 °C and 55 ± 5% RH. Mortality was assessed at 24, 48, and 72 hours post-treatment. Insects were considered dead if unresponsive to soft forceps or warm air stimulation. Individuals showing movement were further observed for 24 hours to confirm survival. A completely randomized design (CRD) were conducted for the experiments. Five concentrations were chosen, except for the control. All concentrations were established in four replicates.

Repellency Bioassay

Five sub-lethal concentrations of *L. angustifolia* essential oil were tested for repellency at five different times. For this purpose, 90 mm Whatman No. 1 filter paper was used. One half was treated with the test solution (essential oil + buffer), while the other half received the control solution (1% DMSO + 0.02% Tx-100). Solutions were applied at a defined volume per surface area (µL/cm²) using a micropipette. Papers were air-dried under a fume hood for 15 minutes. Twenty mixed-sex adult *S. granarius* were placed in the center of each the Petri dish. The dishes were sealed with Parafilm and incubated at 25 ± 1 °C and 55 ± 5% RH. Each treatment was replicated four times in a completely randomized design (CRD). At predetermined time intervals, the number of insects on each half of the paper was recorded.

Repellency percentage (PR) was calculated using the formula: $PR = \frac{N_c - N_t}{N_c + N_t} \times 100$

Where; N_c is the number of insects on the control side, and N_t is the number on the treated side (McDonald et al., 1970). Repellency classes were defined according to Juliana and Su (1983):

Class 1 = 0.1–20%, **Class 2** = 20.1–40%, **Class 3** = 40.1–60%, **Class 4** = 60.1–80%, **Class 5** = 80.1–100%.

Fumigant Activity Bioassay

Fumigant toxicity of *L. angustifolia* (70%) oil was assessed using 230 cc airtight glass jars. A small amount of wheat was placed in 20 cc pin- punctured PVC containers containing 30 adult beetles.. These cups were fixed inside the larger jars. Essential oils were applied onto Whatman No. 1 filter paper strips using micropipettes, and the jars were immediately sealed. Experiments were incubated at 25 ± 1 °C and 55 ± 5% RH. Mortality was assessed at 24, 48, and 72 hours. Suspected dead insects were transferred to clean Petri dishes and observed for 24 hours. Individuals that failed to respond to gentle brushing were recorded as dead. Each treatment included four replicates, and the experiment followed a CRD.

Molecular Similarity and Dimensionality Reduction

To evaluate molecular similarity between the components of *L. angustifolia* and *E. globulus* oils, SMILES (Simplified Molecular Input Line Entry System) strings were converted into Morgan fingerprints using the RDKit toolkit (Landrum, 2013). Pairwise molecular similarity was quantified using the Tanimoto coefficient. A two-dimensional projection of the high-dimensional (Principal component analysis) fingerprint data was generated using t-Distributed Stochastic Neighbor Embedding (t-SNE) for visualization of molecular clusters and patterns. The resulting similarity matrix was displayed as a heatmap, with individual cell values representing Tanimoto coefficients (Babicki et al., 2016; Wilkinson and Friendly, 2009).

Statistical Analysis

Mortality data from contact and fumigant toxicity assays were arcsine transformed prior to analysis. One-way Analysis of Variance (ANOVA) was performed, and means were separated using Tukey's HSD test. Statistical significance was considered at $\alpha = 0.05$. Analyses were performed using MINITAB 18 (Release 18.1). The efficacy of each essential oil was evaluated across different concentrations and time intervals.

3. RESULTS

Chemical Composition of Essential Oils

Gas chromatographic analysis identified a total of 19 constituents in *L. angustifolia* essential oil and 8 constituents in *E. globulus* oil. The dominant components of *L. angustifolia* oil were linalool (42.55%) and linalyl acetate (31.47%), whereas *E. globulus* oil was primarily composed of 1,8-cineole (82.23%) and limonene (7.79%) (Table 1).

Table 1. Essential oils component of *Lavandula angustifolia* and *Eucalyptus globulus*

Compounds	***Lavandula angustifolia***		***Eucalyptus globulus***	
	Retention Time	**(%)**	**Retention Time**	**(%)**
α-pinene			12.94	3.11
myrcene	19.07	2.03		
β- myrcene			19.07	0.52
phellandrene			19.26	0.51
α -terpinene			19.92	0.56
Limonene	21.27	0.89	20.87	**7.79**
1,8-Cineole	21.74	3.77	21.47	**82.23**
γ-terpinene			22.81	1.30
beta-ocimene	22.97	2.94		
3-octanone	23.13	0.95		
hexyl acetate	23.79	0.86		
cymene			23.91	3.99
hexyl isobutyrate	23.35	1.15		
Camphor	33.32	3.40		
Linalool	33.72	**42.55**		
linalyl acetate	34.25	**31.47**		
lavandulyl acetate	35.62	1.33		
β -Caryophyllene	35.90	1.17		

hexyl tiglate	36.19	0.31		
β -farnesene	37.45	0.66		
α -terpineol	38.44	0.52		
borneol	38.67	3.51		
geranyl acetate	40.03	1.79		
geraniol	42.34	0.24		
α -bisabolol	51.81	0.48		

Contact Toxicity

The contact toxicity of varying concentrations of *L. angustifolia* essential oil against *S. granarius* adults, as well as its binary mixtures with a constant 50% concentration of *E. globulus* oil, was assessed (Tables 2 and 3). *Lavandula angustifolia* alone at 10% and 17.5% concentrations exhibited the lowest mortality rates across three time points, with no significant time-dependent differences ($F = 0.03$; df = 2, 11; $P > 0.05$; $F = 0.01$; df = 2, 11; $P > 0.05$). At 35% concentration, mortality reached 87–92.64% but remained statistically unchanged over time ($F = 0.4$; df = 2, 11; $P > 0.05$). Daily evaluation of mortality across concentrations revealed significant differences, ranging from 1.69% to 87% ($F = 48.59$; df = 5, 23; $P < 0.05$). However, third-day results did not differ significantly from day one ($F = 35.47$; df = 5, 23; $P < 0.05$).

In mixture treatments, the addition of 50% *E. globulus* oil enhanced mortality at all *L. angustifolia* concentrations (Table 3). For instance, the 5% + 50% mixture showed no significant day-to-day variation, though mortality began at 17% on day one ($F = 0.01$; df = 2, 11; $P > 0.05$). The highest mortality was observed in the 20% + 50% mixture, with 88% mortality on day one and 99.78% on day three ($F = 6.9$; df = 2, 11; $P < 0.05$). Across days, mortality rates in both 5% + 50% and 20% + 50% mixtures ranged from 18% to 98.78%, showing significant variation ($F = 67.13$; df = 5, 23; $P < 0.05$).

Table 2. Contact toxicity of different concentrations of *Lavandula angustifolia* essential oil against *Sitophilus granarius*

Plant	**Concentration (%)**	**Time**		
		1 DAT*	**2 DAT**	**3 DAT**
Lavandula angustifolia	10.0	1.69±2.25A†c	2.50±3.53Ac	2.50±3.53Ac
	17.5	2.50±3.53Ac	3.24±4.97Ac	3.24±4.97Ac
	25.0	36.06±4.61Ab	36.06±4.61Ab	37.98±3.83Ab
	30.0	60.05±0.30Ab	65.35±1.21Aab	65.35±1.21Aab
	35.0	87.05±0.68Aa	92.64±3.98Aa	92.64±3.98Aa
	Control	0Ac	0Ac	0Ac

*DAT: day after treatment
† Uppercase letters in the same column indicate the difference between concentrations; lowercase letters in the same row indicate the statistical differences between treatment times.

Table 3. Contact toxicity of different concentrations of *Lavandula angustifolia* and fixed concentration of *Eucalyptus globulus* essential oils against *Sitophilus granarius*

Plant	**Binary Concentration (%)**	**Time**		
		1 DAT*	**2 DAT**	**3 DAT**
Lavandula angustifolia + *Eucalyptus globulus* (50%)	5%+50%	17.26±2.22A†c	18.03±2.35Ac	18.03±2.35Ac
	10%+50%	22.66±4.24Ac	24.57±3.72Acd	24.57±3.72Ac
	15%+50%	54.51±2.52Ab	55.34±2.30Abc	55.34±2.30Ab
	17.5%+50%	77.01±0.80Aab	78.74±0.95Ab	78.74±0.95Ab
	20%+50%	88.52±0.31Ba	97.89±2.86ABa	99.78±0.84Aa
	Control	0Ad	0Ae	0Ad

*DAT: day after treatment,
† Uppercase letters in the same column indicate the difference between binary concentrations; lowercase letters in the same row indicate the statistical differences between treatment times.

Repellency Activity

Lavandula angustifolia essential oil exhibited concentration- and time-dependent repellency against *S. granarius* (Table 4). Two hours after application, repellency rates for 0.25%, 0.5%, 1%, 2%, and 5% concentrations were 65%, 45%, 75%, 90%, and 100%, respectively. At 48 hours, 2% oil maintained a repellency of 95%. Notably, even at 1% concentration, repellency reached the highest rating (Class 5: 80.1–100%) by the end of 48 hours, indicating sustained repellent activity.

Table 4. Repellent activity of lavender essential oil against *Sitophilus granarius*

Concentration (%)	**Time (h)**					**Mean repellency (%) / Class**
	2	**4**	**8**	**24**	**48**	
0.25	65	75	75	75	65	71/**4**
0.50	45	80	85	80	65	71/**4**
1	75	90	90	80	85	84/**5**
2	90	100	95	90	95	94/**5**
5	100	100	100	100	100	100/**5**

Fumigant Toxicity

Varying doses of 70% *L. angustifolia* essential oil were evaluated for fumigant activity (Table 5). After one day, the lowest dose (1 µL/mL air) resulted in 9.74% mortality ($F = 2.56$; $df = 2, 11$; $P > 0.05$), while the highest mortality (97%) was observed at 1.625 µL/mL ($F = 1.82$; $df = 2, 11$; $P > 0.05$). A dose of 1.5 µL/mL achieved >90% mortality in the shortest time.

Daily comparisons revealed a dose-dependent linear increase in mortality. However, no statistically significant difference was observed between the results on the second and third days, indicating a plateau in fumigant activity.

Table 5. Fumigation effect of lavender essential oil against *Sitophilus granarius* at different times after treatment

Dose (µl/ml air)	**Time**		
	1 DAT*	**2 DAT**	**3 DAT**
1	9.74±0.42A†c	13.24±0.16Ad	15.64±0.36Ad
1.25	21.64±0.05Bc	22.48±0.04ABd	25.81±0.03Ad
1.375	55.03±0.48Ab	57.56±0.49Ac	63.41±0.40Ac
1.5	83.33±1.64Aa	91.45±0.99Ab	95.87±2.45Ab
1.625	97.12±4.23Aa	99.78±0.84Aa	100±0Aa
Control	0.21±0.84Ad	0.21±0.84Ae	0.21±0.84Ae

* DAT: day after treatment,
† Uppercase letters in the same column indicate the difference between doses; lowercase letters in the same row indicate the statistical differences between treatment times.

Molecular Similarity Analysis

Molecular similarity analysis using the Jaccard Similarity Index indicated an overall similarity of 30.7% between the complete molecular profiles of *L. angustifolia* and *E. globulus* oils (Niwattanakul et al., 2013). At the individual component level, the main constituents of *L. angustifolia*—linalool and linalyl acetate—shared a high similarity score of 52%. In contrast, 1,8-cineole showed negligible similarity (0.05%) with the major lavender constituents, suggesting distinct molecular structures. Within *E. globulus*, 1,8-cineole showed 20% similarity with cymene and alpha-pinene (Figure 1, Figure 2).

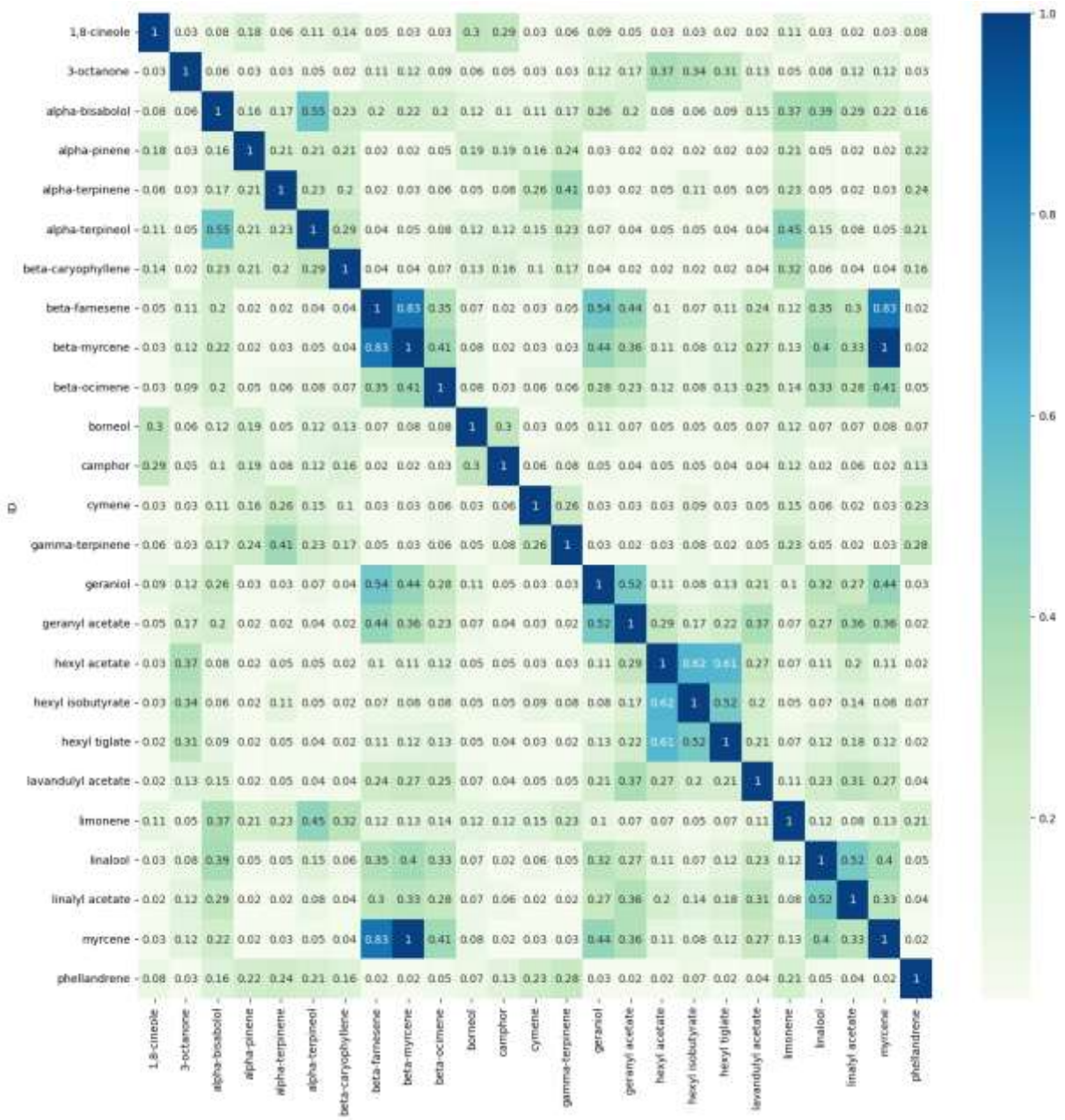

Fig. 1. Molecular clustering analysis. The SMILES strings of each molecule were converted to Morgan fingerprints using RDKit. Similarity between molecules was quantified using the Tanimoto coefficient. Similarity matrix was visualized as a heatmap, with each cell displaying the Tanimoto coefficient.

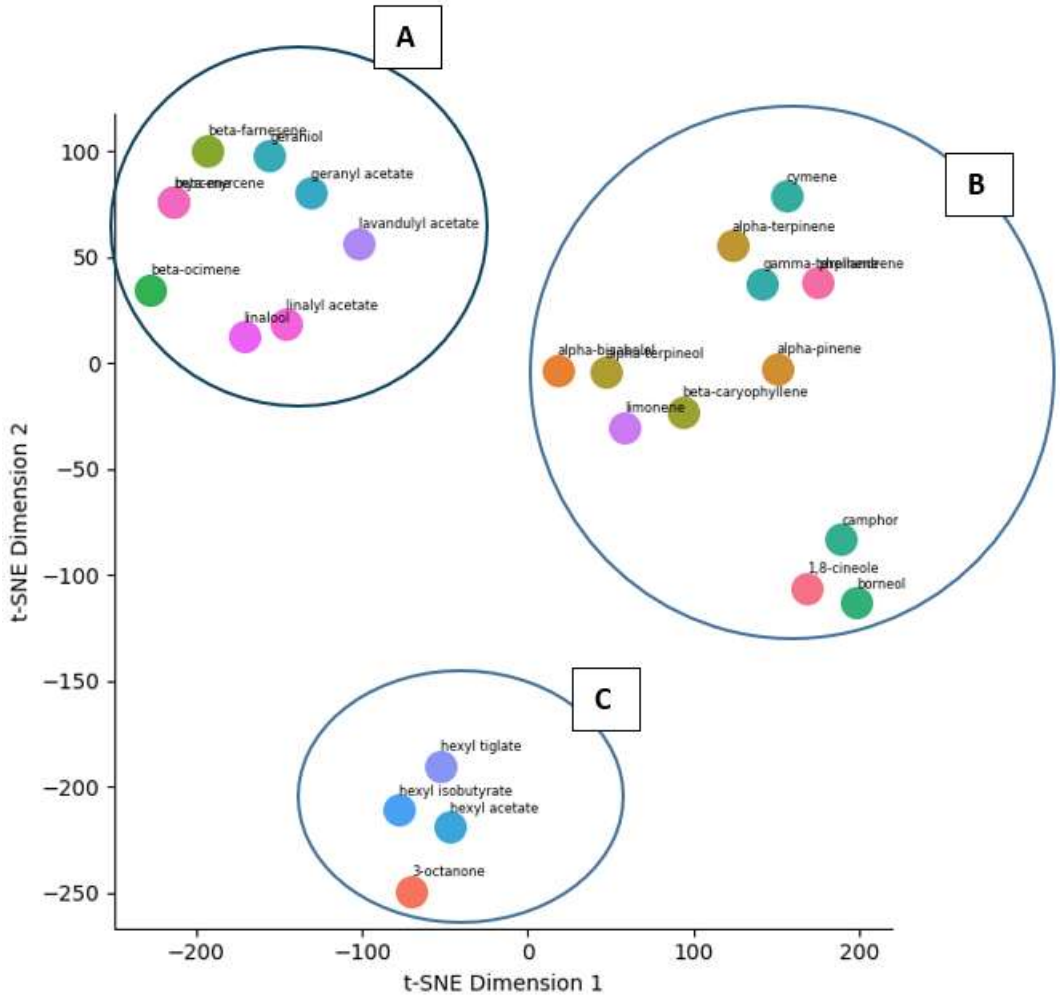

Fig. 2. T-distributed stochastic neighbor embedding (t-SNE) was used to visualize fingerprint similarities in a scatter plot, where each dot represents a unique hit compound.

According to the t-SNE analysis, three distinct molecular clusters were observed (Fig. 2), indicating major structural divergence between key active compounds. The principal compounds in *L. angustifolia* (linalool 42.55% and linalyl acetate 31.47%) grouped within cluster A, while the dominant components of *E. globulus* (1,8-cineole 82.23%, cymene 3.99%, and alpha-pinene 3.11%) were placed in cluster B.

4. DISCUSSION

Present study provides detailed insights into the insecticidal efficacy and chemical profiles of *L. angustifolia* and *E. globulus* EOs against the stored-product pest *Sitophilus granarius* under controlled laboratory conditions. These findings not only align with previously documented

insecticidal effects of these EOs but also offer novel contributions, particularly regarding their binary combinations and molecular similarity analysis.

Chemical profiling through GC-MS and GC-FID revealed that *L. angustifolia* EO consisted primarily of linalool (42.55%) and linalyl acetate (31.47%), while *E. globulus* EO was dominated by 1,8-cineole (82.23%) and limonene (7.79%). These results corroborate earlier findings on the phytochemical composition of these oils (Prusinowska & Śmigielski, 2014; Batish et al., 2008; Soković et al., 2010). The presence of linalool and 1,8-cineole as major constituents is particularly relevant, given their well-established insecticidal and repellent properties against various Coleopteran pests (Alkan et al., 2021; Isman & Grieneisen, 2014; Nerio et al., 2009).

One of the distinctive aspects of this study lies in the integration of chemical similarity analysis using Jaccard similarity coefficients and Tanimoto-based molecular clustering. The two oils shared an overall compositional similarity of 30.7%, with linalool and linalyl acetate showing the highest individual similarity (52%). Based on these preliminary results, it is possible that the results not only highlight the structural difference between the two oils but also provide an intermolecular rationale for the bioactivities of the essential oils, which may account for their increased mortality at low concentration on the pest when used in combination. The low structural similarity between 1,8-cineole and lavender constituents (e.g., similarity score of 0.05) supports the hypothesis that their insecticidal mechanisms or mode of action may involve complementary or non-overlapping modes of action, increasing the probability of synergism (Cherkasov et al., 2014). According to the t-SNE analysis, three distinct molecular clusters were observed (Fig. 2), indicating major structural divergence between key active compounds. The principal compounds in *L. angustifolia* (linalool 42.55% and linalyl acetate 31.47%) grouped within cluster A, while the dominant components of *E. globulus* (1,8-cineole 82.23%, cymene 3.99%, and alpha-pinene 3.11%) were placed in cluster B. These clustering results underscore the molecular dissimilarity between linalool and 1,8-cineole, suggesting they interact with different physiological targets within the pest organism. This supports the notion that distinct bioactivity mechanisms may be at play. Previous studies have shown that the major constituents of EOs often mirror their overall biophysical and biological properties (Ipek et al., 2005), although the effects may vary depending on concentration or whether compounds are applied individually or as part of a complex mixture. As such, synergistic interactions among multiple constituents in an essential oil may yield effects that cannot be explained by the activity of the dominant compounds alone. Additionally, the activity of major components may be modulated by minor ones (Hoet et al., 2006; Bakkali et al., 2008). Therefore, for biological applications, examining the entire oil composition is more informative than focusing solely on selected constituents, as the concept of synergy becomes more meaningful in a whole-oil context.

The contact toxicity assays demonstrated that *L. angustifolia* alone at 35% concentration caused high mortality (92.6%) in *S. granarius* adults by the second day, comparable to prior research on lavender EO effects against *S. oryzae* and *T. castaneum* (Benelli et al., 2018; Pavela, 2015). However, the combined application of *L. angustifolia* (20%) with *E. globulus* (50%) significantly enhanced efficacy, achieving 99.78% mortality within three days. This synergy highlights the potential of EO blends to overcome the moderate efficacy observed at lower individual concentrations and to potentially delay resistance development, as suggested in

earlier studies (Faraone et al., 2015). The increased mortality observed in the binary treatments also supports the hypothesis that structurally divergent yet bioactive constituents may exert multi-target toxic effects on insects, possibly affecting the nervous system, respiratory activity, or cellular membranes concurrently (Regnault-Roger et al., 2012).

Repellency results indicated that *L. angustifolia* EO exhibited strong and persistent deterrent activity against *S. granarius*, with concentrations as low as 1% resulting in repellency rates over 80% for up to 48 hours. These findings echo those of Nerio et al. (2009), who reported high repellent activity of monoterpene-rich EOs against storage pests. The results also demonstrate time- and dose-dependent repellency, consistent with the volatization and diffusion characteristics of EO components (Pavela & Benelli, 2016). The high repellency observed even at low doses makes *L. angustifolia* a promising candidate for push-pull strategies or for integration into packaging materials for stored grain protection.

Fumigant assays showed that *L. angustifolia* EO had potent vapor-phase toxicity, with over 90% mortality at 1.5 µL/mL air concentration. The maximum effect (100% mortality) was achieved at 1.625 µL/mL. These results are consistent with the fumigant activity of lavender and other monoterpene-rich oils documented in the literature (Lee et al., 2003; Tripathi et al., 2009). The dose-dependent mortality trend, followed by a plateau between days two and three, suggests rapid action followed by saturation of the toxic effect, a phenomenon also reported by Huang et al. (2021) for other volatile bioinsecticides.

Overall, the findings strongly support the potential of both *L. angustifolia* and *E. globulus* EOs as components of an eco-friendly Integrated Pest Management (IPM) framework targeting stored-product pests. The observed synergistic effects of the binary EO treatments are particularly noteworthy, indicating a promising approach for enhancing efficacy while potentially lowering the required concentrations. The additional use of cheminformatics tools to analyze molecular similarity and clustering adds a mechanistic dimension to EO-based pest management research, opening new avenues for rational EO formulation based on chemical complementarity.

5. CONCLUSION

This study comprehensively demonstrated the bioefficacy of *L. angustifolia* and *E. globulus* EOs against *S. granarius* through contact toxicity, repellency, and fumigant assays. The results highlighted that both oils exhibit substantial insecticidal activity, with *L. angustifolia* at 35% concentration achieving over 90% mortality, and the binary mixture of 20% *L. angustifolia* + 50% *E. globulus* yielding nearly complete mortality. Furthermore, strong repellency was achieved at relatively low concentrations, indicating these oils' potential for use as both lethal and behavioral control agents in pest management systems.

The GC-MS and GC-FID analyses revealed distinct yet partially overlapping chemical profiles, with linalool and linalyl acetate dominating *L. angustifolia*, and 1,8-cineole being the main compound in *E. globulus*. The limited structural similarity (30.7%) between the two oils, combined with the pronounced enhancement of efficacy in binary treatments, points toward complementary modes of action. The integration of molecular similarity analyses and clustering

using cheminformatics tools provides a mechanistic rationale for their synergism and offers a data-driven foundation for future EO blend formulations.

Taken together, these findings support the incorporation of both essential oils—either individually or in synergistic combinations—into eco-friendly Integrated Pest Management (IPM) frameworks for stored grain protection. Their rapid action, sustained efficacy, and low environmental footprint make them promising alternatives or adjuncts to conventional synthetic insecticides. Future studies should focus on field validation, formulation stability, and potential impacts on non-target organisms to further facilitate their adoption in sustainable agricultural practices.

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EVALUATION OF THE EFFECTS OF INSECT NETS USED IN VENTILATION OPENINGS IN GREENHOUSES ON VENTILATION

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ABSTRACT

The study was conducted to evaluate the effects of insect nets on the air exchange coefficient in a block greenhouse covered with polyethylene cover material with a base area of 1000 m^2 (2x500 m^2), which is widely used in Kırşehir province. For this purpose, calculations were made for the long-term wind speeds of the province and six different ventilation openings (10%, 15%, 20%, 25%, 30%, 35%). In the calculations, firstly, the air exchange numbers that will occur in the greenhouse in case of using insect net without insect net and using insect net with 3 different porosity coefficients (0.50, 0.40 and 0.25) in the ventilation opening were calculated. Then, depending on the number of air changes, the internal and external temperature differences reached in the greenhouse interior were calculated when the shading net was used and not used. According to the results obtained, it was determined by the calculation that there was no good ventilation opportunity in the greenhouse with the applications in case the ventilation opening was 10%, 15% and 20%. According to the average wind speeds in the province, for good ventilation, insect nets should not be used in the ventilation opening and the ventilation opening ratio should be at least 25%. It has been determined that in the use of insect nets, the ventilation opening should be 30% and insect nets with a porosity of 0.50 should be used. In addition, while the $\Delta T_{(in-out)}$ temperature difference in the greenhouse where shading nets were used at 25% ventilation opening between March and September varied between 0.7-1.9 °C, the $\Delta T_{(in-out)}$ temperature difference in the greenhouse where shading nets were not used varied between 1.5-3.8 °C. It has been shown that insect nets stretched over ventilation openings in greenhouses reduce the number of air exchanges and increase the indoor-outdoor temperature difference due to decreasing porosity coefficients. For this reason, it has been determined that paying attention to the planning of ventilation openings in greenhouses where insect nets are used is important for proper ventilation.

Keywords: Greenhouse, air exchange number, porosity coefficient, shading net

SERALARDA HAVALANDIRMA AÇIKLIKLARINDA KULLANILAN BÖCEK TÜLLERİNİN HAVALANDIRMA ÜZERİNDEKİ ETKİLERİNİN DEĞERLENDİRİLMESİ

ÖZET

Çalışma, Kırşehir ilinde yaygın olarak kullanılan taban alanı 1008 m^2 (2x504 m^2) olan polietilen örtü malzemesi ile kaplı blok serada böcek tüllerinin hava değişim katsayısı üzerindeki etkilerinin değerlendirilmesi amacıyla yürütülmüştür. Bu amaçla, ili ait uzun yıllık rüzgar hızları ve altı farklı havalandırma açıklıkları (%10, %15, %20, %25, %30, %35) için hesaplamalar yapılmıştır. Hesaplamalarda ilk olarak böcek tülü kullanılmayan ve havalandırma açıklığında 3 farklı porozite katsayısına sahip (0.50, 0.40 ve 0.25) böcek tülü kullanılması durumunda serada ortaya çıkacak hava değişim sayıları hesaplanmıştır. Daha sonra hava değişim sayısına bağlı olarak gölgeleme tülü kullanılması ve kullanılmaması durumunda sera iç ortamında ulaşılan iç ve dış sıcaklık farklılıkları hesaplanmıştır. Elde edilen sonuçlara göre, havalandırma açıklığının %10, %15 ve %20 olması durumunda uygulamalar ile serada iyi bir havalandırma imkanı olmadığı yapılan hesaplama ile belirlenmiştir. İlde ortalama rüzgar hızlarına göre iyi bir havalandırma için havalandırma açıklığında böcek tülü kullanılmaması ve havalandırma açıklık oranın en az %25 olması gerekmektedir. Böcek tülü kullanımında ise havalandırma açıklığının %30 olması ve porozitesi 0.50 olan böcek tülü kullanılması gerektiği belirlenmiştir. Ayrıca, Mart-Eylül ayları arasında %25 havalandırma açıklığında gölgeleme tülü kullanılan serada $\Delta T_{(iç-dış)}$ sıcaklık farkı 0.7-1.9 °C arasında değişirken gölgeleme tülü kullanılmayan serada $\Delta T_{(iç-dış)}$ sıcaklık farkı 1.5-3.8 °C arasında değişmektedir. Seralarda havalandırma açıklıklarına gerilen böcek tülleri azalan porozite katsayılarına bağlı olarak hava değişim sayısını azalttığı ve iç-dış sıcaklık farkını arttırdığı ortaya konulmuştur. Bu nedenle böcek tüllerinin kullanıldığı seralarda havalandırma açıklıklarının planlanmasına dikkat edilmesinin uygun bir havalandırma için önemli olduğu belirlenmiştir.

Anahtar Kelimeler: Sera, hava değişim sayisi, porozite katsayisi, gölgeleme tülü

1. GİRİŞ

Havalandırma, sera iklimini kontrol etmek için en önemli araçlardan biridir. Bir seranın içi ve dışı arasındaki hava değişimi, ürünün gelişimini ve üretimini etkileyen sıcaklık, nem ve karbondioksit konsantrasyonu gibi çevresel koşulları etkiler. Kış aylarında yapılan havalandırma, iç ortamda artan yüksek nemi gidermeli ve seranın içinde iyi bir atmosfer sağlamalıdır. Yaz aylarında yapılan havalandırma ise iç koşullara bağlı olarak soğutma sağlamalı ve nemi gidermelidir. Bu nedenle, iç çevre koşullarının iyi bir şekilde kontrol edilmesi ve yüksek kaliteli üründen oluşan iyi bir ürün verimi sağlamak için bir seranın havalandırma özelliklerini bilmek gerekir (Baptista ve ark., 1999).

Akdeniz ülkelerinin çoğunda sera soğutması genellikle rüzgar ve sıcaklık etkisiyle doğal havalandırma ile gerçekleştirilir. Genellikle çok basit ve düşük verimlilikle çalışan bu sistemler iç ortam iklimini bitki yetiştiriciliğine uygun hale getirmekte yetersiz kalabilmektedir (Baille, 2001; Luo ve ark, 2005). Ayrıca, bu seraların çoğunun düşük yükseklik ve hacim, düz çatı ve küçük havalandırma yüzey alanı ile karakterize edilen yapısı ve şekli bölgelenin iklim koşullarına göre tasarlanmadığını göstermektedir. Bu nedenle iç ortamda gerekli soğutmayı sağlamaz. Sonuç olarak, ortaya çıkan mikro iklim yılın büyük bir bölümünde ürün büyümesi için yeterli olmaktan uzaktır (Castilla ve Lopez Galvez, 1994). Perez Parra ve ark. (2004) herhangi bir rüzgar hızında en yüksek havalandırma oranının hem çatı hem de yan açıklıkların aynı anda açıldığında elde edildiğini bildirmişlerdir. Araştırmacılar iyi bir havalandırma için seralarda havalandırma açıklığı alanının taban alanına oranını %20-%25 olması gerektiğini bildirmişlerdir (Nicolaus 1990; Baytorun ve ark., 1994). Ayrıca, seralarda iyi bir havalandırma için hava değişim katsayısının 30 1/h olması durumunda iyi ve 50 1/h olması durumunda ise çok iyi havalandırma olarak sınıflandırılmıştır (Baytorun, 1986). Son yıllarda, sera zararlılarının pestisitlere karşı direnç geliştirmesi, pestisit kullanımına bağlı çevresel sorunları azaltma zorunluluğu ve tüketicilerin kalıntı bırakmayan ürünlere olan talepleri, havalandırma açıklıklarına böcek tüllerinin kullanımını arttırmıştır (Teitel ve ark., 2005). Tüller, böceklerin bitkilere ulaşmasını önleyen mekanik bir bariyer görevi görür ve böylece doğrudan ürün hasarı ve böcek yoluyla bulaşan virüs hastalıklarının görülme sıklığını azalması neticesinde pestisit uygulamasına olan ihtiyaç azalır (Teitel ve ark., 2007). Aslında Akdeniz havzasındaki pek çok yetiştirici, bitkileri aşırı sıcaktan korumaktan ziyade böceklerden korumayı daha önemli görür. Ancak, böcek tülleri hava hareketine karşı ekstra bir bariyer görevi gördüklerinden havalandırma oranını önemli ölçüde azaltabilir ve Akdeniz seralarında sıklıkla görülen yetersiz havalandırmadan kaynaklanan yüksek iç hava sıcaklıkları sorununu daha da kötü hale getirir (Soni ve ark., 2005).

Yapılan bu çalışmada Kırşehir ilinin uzun yıllık ortalama rüzgar hızlarında, farklı havalandırma açıklığı ve farklı poroziteye sahip böcek tülü kullanılması durumunda serada ortaya çıkacak hava değişim sayılarının belirlenmesi ve belirlenen hava değişim sayılarına bağlı olarak gölgeleme tülü kullanılması ve kullanılmaması durumunda ulaşılan sıcaklık farkının hesaplanması amaçlanmıştır.

2. MATERYAL VE METOT

Çalışmada hesaplamalar Kırşehir ilinde yaygın olarak kullanılan taban alanı 1008 m^2 olan seralar için yapılmıştır. Hesaplama yapılan seranın boyutsal özellikleri Çizelge 1'de, Kırşehir iline ait aylık ortalama rüzgar hızı değerleri ise Çizelge 2'de verilmiştir.

Çizelge 1. Hesaplama yapılan seraya ait boyutsal özellikler

Parametreler	Boyutlar	Parametreler	Boyutlar
Bölme sayısı	2 adet	Çatı yüksekliği	2.10 m
Bölme uzunluğu	63.0 m	Çatı eğim açısı	35°
Bölme genişliği	8 m	Taban alanı	1008 m^2
Yan duvar yüksekliği	3.5 m	Sera hacmi	4939.2 m^3

Çizelge 2. Kırşehir iline ait aylık ortalama rüzgar hızı

Rasat süresi (yıl)	Ocak	Şubat	Mart	Nisan	Mayıs	Haziran	Temmuz	Ağustos	Eylül	Ekim	Kasım	Aralık
92	1.8	2.1	2.3	2.3	2.1	2.5	3.3	3.1	2.5	1.9	1.7	1.7

Seralarda enerji dengesi yöntemine göre istenen sıcaklık farkına bağlı gereksinilen hava değişim sayısı Eşitlik 1'de verilmiştir (Bailey, 1998; ANSI/ASAE EP 406.4, 2003; Boulard, 2006; Von Zabeltitz, 2011).

$$V_A = \frac{\tau . I_o . (1 - E . f)}{cp . \rho . \Delta T} - \frac{U . A_C}{cp . \rho . A_G} \quad (1)$$

Eşitlikte; τ= Kullanılan örtü malzemesinin geçirgenliği (-), I_o= Güneş ışınımı şiddeti (W/m^2), cp= Havanın özgül ısısı (Wh/kg°C), ρ= Havanın yoğunluğu (kg/m^3), ΔT= İç ve dış sıcaklık farkı (°C), U= Örtü malzemesine ait ısı iletim katsayısı (W/m^2°C), A_C= Örtü yüzey alanı (m^2), E= Seraya ulaşan güneş ışınımının buharlaşmada kullanılan oranı (bitkiyle tamamen kaplı serada için 0.9 alınmıştır), f= Bitki örtü faktörü (toprakta doğrudan üretimin yapıldığı sera için 0.8 alınmıştır).

Seranın havalandırmasında ortaya çıkan hava akış debisi Eşitlik 2'de verilmiştir.

$$V_V = \frac{A_V}{2} . C_d . v_w . \sqrt{C_w} \quad (2)$$

Eşitlikte; V_v= Hava akış debisi (m^3/s) A_V= Havalandırma açıklık alanı (m^2), C_w= Rüzgar basınç katsayısı (-),Vw= Rüzgar hızı (m/s), Cd= Deşarj katsayısı (-).

Havalandırma açıklıklarında böcek tülünün kullanılması durumunda tülün porozite katsayısına bağlı olarak ortaya çıkan hava akış debisi Eşitlik 3'te verilmiştir.

$$V_{VS} = V_V.\left(\varepsilon.(2-\varepsilon)\right) \quad (3)$$

Eşitlikte; ε= Böcek tülünün porozite katsayısı

Serada birim alan için hava değişim sayısı (V_A) Eşitlik 4'te gerekli olan deşarj katsayısı Eşitlik 5'te verilmiştir.

$$V_A = \frac{A_V}{2.A_G}.C_d.vw.\sqrt{C_w}.(\varepsilon.(2-\varepsilon)) \quad (4)$$

$$C_d = \frac{1}{\sqrt{1.9+0.7exp[-L_o/(32.5.H_o.Sin\alpha)]}} \quad (5)$$

Eşitlikte; A_G= Sera taban alanı (m^2), L_o= Havalandırma açıklığının uzunluğu (m), H_o= Havalandırma açıklığının genişliği (m), α= Havalandırma kapaklarının açıklık açısı

3. BULGULAR VE TARTIŞMA

Çalışmada, Kırşehir iline ait uzun yıllık ortalama rüzgar hızlarında aylara bağlı ortaya çıkan hava değişim sayıları Çizelge 3'te verilmiştir.

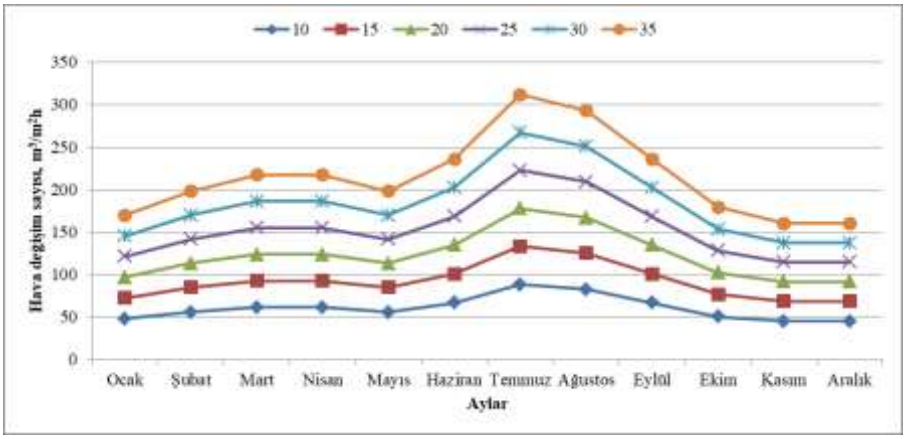
Çizelge 3. Serada farklı havalandırma açıklığında ortaya çıkan hava değişim sayıları

Rüzgar hızı,	**Havalandırma açıklık oranı, %**					
m/s	**10**	**15**	**20**	**25**	**30**	**35**
Ocak	48.3	73.0	97.3	121.6	145.9	170.3
Şubat	56.3	85.1	113.5	141.9	170.3	198.6
Mart	61.7	93.2	124.3	155.4	186.5	217.6
Nisan	61.7	93.2	124.3	155.4	186.5	217.6
Mayıs	56.3	85.1	113.5	141.9	170.3	198.6
Haziran	67.0	101.3	135.1	168.9	202.7	236.5
Temmuz	88.5	133.8	178.4	223.0	267.6	312.2
Ağustos	83.1	125.7	167.6	209.5	251.3	293.2
Eylül	67.0	101.3	135.1	168.9	202.7	236.5
Ekim	50.9	77.0	102.7	128.4	154.1	179.7
Kasım	45.6	68.9	91.9	114.9	137.8	160.8
Aralık	45.6	68.9	91.9	114.9	137.8	160.8

Serada aylara bağlı olarak ortaya çıkabilecek hava değişim sayıları en düşük %10 havalandırma açıklık oranında Kasım ve Aralık ayında 45.6 m^3/m^2h iken en yüksek hava değişim sayısı %35 havalandırma açıklığında Temmuz ayında 312.2 m^3/m^2h olarak hesaplanmıştır (Çizelge 3). Kırşehir ilinde Temmuz ayında ortaya çıkan 3.3 m/s lik ortalama rüzgar hızı değeri nedeniyle serada hava değişim sayısı hesaplanan tüm hava oranlarında en yüksek değerlere sahip

olmuştur. Ancak seralarda sıcaklıkların yükselmeye başladığı Temmuz ve Ağustos aylarında ortaya çıkan 3 m/s ve daha yüksek hızlarda esen rüzgâr iç ortamın soğutulmasına katkı sağlarken, özellikle PE örtülü seralar için meydana gelebilecek şişme ve yırtılmalar bakımından bir dezavantaj oluşturabileceği bildirilmiştir (Boyacı, 2018).

Uzun yıllık ortalama rüzgâr hızına bağlı olarak serada hesaplanan hava değişim sayılarının grafiksel gösterimi Şekil 1'de verilmiştir.



Şekil 1. Serada aylara bağlı rüzgâr hızlarında ortaya çıkan hava değişim sayıları

Şekil 1'de görüldüğü üzere hava değişim sayısı aylara göre değişen hava hızlarında farklılıklar göstermiştir. Buna göre artan hava hızları ve havalandırma açıklık oranlarında hava değişim sayısı artış göstermiştir. Bu nedenle doğal havalandırma açıklıklarının belirlenmesinde bölgeye uygun seraların tasarlanması ve esen rüzgarın yönü ile hızlarının dikkate alınması doğal havalandırmanın etkili çalışması bakımından önemlidir.

Serada aylara bağlı olarak farklı havalandırma açıklığı oranı ve poroziteye sahip böcek tüllerinin kullanılması durumunda, ulaşılacak hava değişim sayısı ve hava değişim katsayısı değerleri Çizelge 4'te verilmiştir.

Çizelge 4. Farklı havalandırma oranları ve porozitenin hava değişim sayısına etkisi

AV/AG (%)	Havalandırma açıklığında	Hava değişim sayısı ve katsayısı	O	Ş	M	N	M	H	T	A	E	E	K	A
10	Böcek tülü yok	VA	48.3	56.3	61.7	61.7	56.3	67.0	88.5	83.1	67.0	50.9	45.6	45.6
		N (1/h)	9.8	11.5	12.6	12.6	11.5	13.7	18.1	17.0	13.7	10.4	9.3	9.3
	Ɛ= 0.50	VA	36.2	42.2	46.3	46.3	42.2	50.3	66.4	62.3	50.3	38.2	34.2	34.2
		N (1/h)	7.4	8.6	9.4	9.4	8.6	10.3	13.5	12.7	10.3	7.8	7.0	7.0
	Ɛ= 0.40	VA	30.9	36.0	39.5	39.5	36.0	42.9	56.6	53.2	42.9	32.6	29.2	29.2
		N (1/h)	6.3	7.4	8.1	8.1	7.4	8.8	11.6	10.9	8.8	6.7	6.0	6.0
	Ɛ= 0.25	VA	21.1	24.6	27.0	27.0	24.6	29.3	38.7	36.4	29.3	22.3	19.9	19.9
		N (1/h)	4.3	5.0	5.5	5.5	5.0	6.0	7.9	7.4	6.0	4.5	4.1	4.1
15	Böcek tülü yok	VA	73.0	85.1	93.2	93.2	85.1	101.3	133.8	125.7	101.3	77.0	68.9	68.9
		N (1/h)	14.9	17.4	19.0	19.0	17.4	20.7	27.3	25.6	20.7	15.7	14.1	14.1
	Ɛ= 0.50	VA	54.7	63.9	69.9	69.9	63.9	76.0	100.3	94.3	76.0	57.8	51.7	51.7
		N (1/h)	11.2	13.0	14.3	14.3	13.0	15.5	20.5	19.2	15.5	11.8	10.5	10.5
	Ɛ= 0.40	VA	46.7	54.5	59.7	59.7	54.5	64.9	85.6	80.4	64.9	49.3	44.1	44.1
		N (1/h)	9.5	11.1	12.2	12.2	11.1	13.2	17.5	16.4	13.2	10.1	9.0	9.0
	Ɛ= 0.25	VA	31.9	37.2	40.8	40.8	37.2	44.3	58.5	55.0	44.3	33.7	30.2	30.2
		N (1/h)	6.5	7.6	8.3	8.3	7.6	9.0	11.9	11.2	9.0	6.9	6.2	6.2
20	Böcek tülü yok	VA	97.3	113.5	124.3	124.3	113.5	135.1	178.4	167.6	135.1	102.7	91.9	91.9
		N (1/h)	19.9	23.2	25.4	25.4	23.2	27.6	***36.4***	***34.2***	27.6	21.0	18.8	18.8
	Ɛ= 0.50	VA	73.0	85.1	93.2	93.2	85.1	101.3	133.8	125.7	101.3	77.0	68.9	68.9
		N (1/h)	14.9	17.4	19.0	19.0	17.4	20.7	27.3	25.6	20.7	15.7	14.1	14.1
	Ɛ= 0.40	VA	62.3	72.6	79.6	79.6	72.6	86.5	114.2	107.2	86.5	65.7	58.8	58.8
		N (1/h)	12.7	14.8	16.2	16.2	14.8	17.7	23.3	21.9	17.7	13.4	12.0	12.0
	Ɛ= 0.25	VA	42.6	49.7	54.4	54.4	49.7	59.1	78.0	73.3	59.1	44.9	40.2	40.2
		N (1/h)	8.7	10.1	11.1	11.1	10.1	12.1	15.9	15.0	12.1	9.2	8.2	8.2
25	Böcek tülü yok	VA	121.6	141.9	155.4	155.4	141.9	168.9	223.0	209.5	168.9	128.4	114.9	114.9
		N (1/h)	24.8	***29.0***	***31.7***	***31.7***	***29.0***	***34.5***	***45.5***	***42.7***	***34.5***	26.2	23.4	23.4
	Ɛ= 0.50	VA	91.2	106.4	116.6	116.6	106.4	126.7	167.2	157.1	126.7	96.3	86.1	86.1
		N (1/h)	18.6	21.7	23.8	23.8	21.7	25.9	***34.1***	***32.1***	25.9	19.6	17.6	17.6

	Ɛ= 0.40	VA	77.8	90.8	99.5	99.5	90.8	108.1	142.7	134.1	108.1	82.2	73.5	73.5
		N (1/h)	15.9	18.5	20.3	20.3	18.5	22.1	29.1	27.4	22.1	16.8	15.0	15.0
	Ɛ= 0.25	VA	53.2	62.1	68.0	68.0	62.1	73.9	97.5	91.6	73.9	56.2	50.3	50.3
		N (1/h)	10.9	12.7	13.9	13.9	12.7	15.1	19.9	18.7	15.1	11.5	10.3	10.3
30	Böcek tülü yok	VA	145.9	170.3	186.5	186.5	170.3	202.7	267.6	251.3	202.7	154.1	137.8	137.8
		N (1/h)	29.8	*34.7*	*38.1*	*38.1*	*34.7*	*41.4*	*54.6*	*51.3*	*41.4*	*31.4*	28.1	28.1
	Ɛ= 0.50	VA	109.5	127.7	139.9	139.9	127.7	152.0	200.7	188.5	152.0	115.5	103.4	103.4
		N (1/h)	22.3	26.1	28.5	28.5	26.1	*31.0*	*41.0*	*38.5*	*31.0*	23.6	21.1	21.1
	Ɛ= 0.40	VA	93.4	109.0	119.3	119.3	109.0	129.7	171.2	160.9	129.7	98.6	88.2	88.2
		N (1/h)	19.1	22.2	24.4	24.4	22.2	26.5	34.9	32.8	26.5	20.1	18.0	18.0
	Ɛ= 0.25	VA	63.9	74.5	81.6	81.6	74.5	88.7	117.1	110.0	88.7	67.4	60.3	60.3
		N (1/h)	13.0	15.2	16.7	16.7	15.2	18.1	23.9	22.4	18.1	13.8	12.3	12.3
35	Böcek tülü yok	VA	170.3	198.6	217.6	217.6	198.6	236.5	312.2	293.2	236.5	179.7	160.8	160.8
		N (1/h)	***34.7***	***40.5***	***44.4***	***44.4***	***40.5***	***48.3***	***63.7***	***59.8***	***48.3***	***36.7***	***32.8***	***32.8***
	Ɛ= 0.50	VA	127.7	149.0	163.2	163.2	149.0	177.4	234.1	219.9	177.4	134.8	120.6	120.6
		N (1/h)	26.1	***30.4***	***33.3***	***33.3***	***30.4***	***36.2***	***47.8***	***44.9***	***36.2***	27.5	24.6	24.6
	Ɛ= 0.40	VA	109.0	127.1	139.2	139.2	127.1	151.3	199.8	187.7	151.3	115.0	102.9	102.9
		N (1/h)	22.2	25.9	28.4	28.4	25.9	***30.9***	***40.8***	***38.3***	***30.9***	23.5	21.0	21.0
	Ɛ= 0.25	VA	74.5	86.9	95.2	95.2	86.9	103.5	136.6	128.3	103.5	78.6	70.4	70.4
		N (1/h)	15.2	17.7	19.4	19.4	17.7	21.1	27.9	26.2	21.1	16.0	14.4	14.4

Çizelgeye bakıldığında seralarda böcek tüllerinin kullanılmaması durumunda hava değişim sayısı ve katsayısı değerlerinin havalandırma açıklık oranlarının artışı ile arttığı görülmektedir. Bunun yanında azalan porozite katsayılarında ise hava değişim sayıları ve katsayıları azalmıştır. Araştırmacıların yapmış oldukları çalışmalarında, Baytorun, (1986) seralarda iyi bir havalandırma için hava değişim katsayısının 30 1/h ve 50 1/h olması durumunda ise çok iyi havalandırma olarak sınıflandırılmıştır. Öztürk ve Başçetinçelik, (2002) ise hava değişim sayısının dakikada 0.75 olması durumunda, sera iç ortamında sıcaklık artışı yaklaşık 6 ºC, dakikada 1 olması durumunda ise yaklaşık 5 ºC olacağını belirtmişlerdir. Ayrıca, Soni ve ark., (2005) ise böcek tüllerinin hava hareketine karşı ekstra bir bariyer görevi görmesi nedeniyle havalandırma oranını önemli ölçüde azaltabileceğini ve bu durumda yetersiz havalandırmadan kaynaklanan yüksek iç hava sıcaklıklarının artacağını belirtmişlerdir. Buna göre çalışmada %25

havalandırma açıklık oranında böcek tülü kullanılmaması durumunda iyi bir havalandırma etkinliği sağlanırken bu aylarda rüzgar hızı ve böcek tülü porozitelerine bağlı olaraktan iyi bir havalandırma etkinliği sağlanamayacağı belirlenmiştir. Havalandırma açıklık oranının %30 ve %35 olması durumunda ise böcek tülü kullanılmadığı takdirde iyi bir havalandırma etkinliği sağlanabilecektir. Ancak bu havalandırma açıklık oranlarında böcek tülü kullanılması durumunda ise en fazla porozitesi Ɛ= 0.50 olan böcek tülleri kullanılmalıdır. Havalandırma açıklık oranı %35 olan ve Ɛ= 0.40 poroziteye sahip böcek tüllerinin kullanılması durumunda Haziran-Eylül ayları arasında iyi bir havalandırma mümkün olmaktadır. Ancak karasal iklime sahip bölgelerde soğuk dönemlerde ortaya çıkan düşük sıcaklık değerleri ve havalandırma açıklıklarındaki infiltrasyon kayıpları düşünüldüğünde bu açıklık alanlarının artırılması yanında bu açıklıklarda mümkün olan en iyi şekilde açıklıkların azaltılmasının önemli olduğu da dikkate alınmalıdır.

Çalışmada, dış ortamdaki ışınımın 900 W/m^2 olması ve porozite katsayıları farklı böcek tülünün kullanılması durumunda %50 gölgeleme tülü kullanılan ve kullanılmayan serada Mart- Eylül ayları arasında ulaşılan hava değişim sayısı, hava değişim katsayısı ve iç-dış sıcaklık farkı Çizelge 5'te verilmiştir.

Çizelge 5. Farklı havalandırma açıklığı, rüzgâr hızları ve porozite katsayılarına sahip böcek tülünün kullanılması durumunda serada ulaşılan sıcaklık farkları

AV/AG (%)	Vw (m/s)	Havalandırma açıklığında	VA (m^3/m^{2}h)	N (1/h)	ΔT Gölgeli (°C)	ΔT Gölgesiz (°C)
25	Mart	Böcek tülü yok	155.4	31.7	1.0	2.0
		Ɛ=0.5	116.6	23.8	1.2	2.5
		Ɛ= 0.4	99.5	20.3	1.4	2.8
		Ɛ= 0.25	68.0	13.9	1.8	3.6
	Nisan	Böcek tülü yok	155.4	31.7	1.0	2.0
		Ɛ=0.5	116.6	23.8	1.2	2.5
		Ɛ= 0.4	99.5	20.3	1.4	2.8
		Ɛ= 0.25	68.0	13.9	1.8	3.6
	Mayıs	Böcek tülü yok	141.9	29.0	1.1	2.1
		Ɛ=0.5	106.4	21.7	1.3	2.6
		Ɛ= 0.4	90.8	18.5	1.5	3.0
		Ɛ= 0.25	62.1	12.7	1.9	3.8
	Haziran	Böcek tülü yok	168.9	34.5	0.9	1.8
		Ɛ=0.5	126.7	25.9	1.2	2.3
		Ɛ= 0.4	108.1	22.1	1.3	2.6
		Ɛ= 0.25	73.9	15.1	1.7	3.4

Çizelge 5. Farklı havalandırma açıklığı, rüzgâr hızları ve porozite katsayılarına sahip böcek tülünün kullanılması durumunda serada ulaşılan sıcaklık farkları (Çizelge 5 in devamı)

AV/AG (%)	Vw (m/s)	Havalandırma açıklığında	VA (m^3/m^2h)	N (1/h)	ΔT Gölgeli (°C)	ΔT Gölgesiz (°C)
25	Temmuz	Böcek tülü yok	223.0	45.5	0.7	1.5
		Ɛ=0.5	167.2	34.1	0.9	1.9
		Ɛ= 0.4	142.7	29.1	1.1	2.1
		Ɛ= 0.25	97.5	19.9	1.4	2.8
	Ağustos	Böcek tülü yok	209.5	42.7	0.8	1.5
		Ɛ=0.5	157.1	32.1	1.0	1.9
		Ɛ= 0.4	134.1	27.4	1.1	2.2
		Ɛ= 0.25	91.6	18.7	1.5	2.9
	Eylül	Böcek tülü yok	168.9	34.5	0.9	1.8
		Ɛ=0.5	126.7	25.9	1.2	2.3
		Ɛ= 0.4	108.1	22.1	1.3	2.6
		Ɛ= 0.25	73.9	15.1	1.7	3.4

Çizelge 5 te görüldüğü üzere Mart ve Nisan aylarında havalandırma açıklıklarında böcek tülü kullanılmaması durumunda havalandırma katsayısı değerleri serada iyi bir havalandırma için yeterli olurken bu aylarda düşük rüzgar hızları ve porozite katsayılarının artması nedeniyle havalandırma sayısı azalmıştır. Mayıs ayında düşük rüzgar hızları nedeniyle ise iyi bir havalandırma oluşmayacağı görülmektedir. Bunun yanında Haziran ve Eylül ayları arasında havalandırma açıklıklarında böcek tülü kullanılmaması durumunda iyi bir havalandırma yapılabilecek iken Temmuz ve Ağustos aylarında ise Ɛ= 0.50 porozitede de iyi bir havalandırma yapabilme imkanı ortaya çıkmaktadır. Porozite katsayılarının azalması ise iyi bir havalandırmaya engel olmuştur. Ayrıca azalan havalandırma katsayılarının iç ortam sıcaklıklarını arttırdığı belirlenmiştir. Bu aylarda seraya ulaşan güneş radyasyonun azaltılması amacıyla yaygın olarak kullanılan gölgeleme tüllerinin iç ortama etkisi incelendiğinde, serada havalandırma açıklık oranın %25 olması durumunda Mart–Eylül ayları arasında havalandırma açıklıklarında böcek tülü kullanılmaması ve kullanılması durumunda serada gölgeleme tülü kullanılarak gelen radyasyonun %50 sinin azaltılması ile ulaşılan iç-dış sıcaklık farkı 0.7–1.9 °C arasında ortalama 1.3 °C arasında olarak hesaplanmıştır. Aynı durumda gölgeleme tülü kullanılmaması durumunda ise bu değerler 1.5–3.8 °C arasında ortalama 2.5°C olarak hesaplanmıştır. Fatnassi ve ark. (2003) tarafından yapılan çalışmada, anti-trips (Ɛ= 0.19) ve anti-afit (Ɛ= 0.56) tüllerinin havalandırma açıklıklarına konulmasıyla sıcaklık ve nemde önemli artışlar olduğunu belirtmişlerdir. Serada havalandırma açıklıklarında böcek tüllerinin kullanılmaması durumunda iç ve dış sıcaklık farkı 3.58 °C iken tüllerin kullanımı ile sera içi (kanopi yüksekliğinde) ve dışı arasındaki sıcaklık farkı sırasıyla 18.0 °C ve 12.8 °C'lik maksimum sıcaklık farklarına neden olmuştur. Ayrıca, tül olmadan havanın maksimum nem

oranı değeri yaklaşık 3.5 g/kg iken anti-trips ve anti-afit tüllerinin kullanılmasıyla sırasıyla 29 ve 19 g/kg'a yükselmiştir. Boyacı ve Başpınar (2022) iç ortamda yüksek sıcaklıkların azaltılabilmesi için doğal havalandırma ile birlikte hava sirkülasyonunu engellemeyecek şekilde gölgeleme tüllerinin kullanılması serada iç ve dış sıcaklık farkının azaltılmasına katkı sağlayacağını bildirmişlerdir. Çalışmada'da araştırmacıların belirttiği gibi böcek tülleri havalandırma açıklıklarında bariyer görevi gördüğünden iç sıcaklıkları arttırmıştır. Bu sıcaklıkların azaltılmasına katkı sağlaması için gölgeleme tüllerinin kullanılması ise iç ortama ulaşan radyasyon değerlerini azaltması nedeniyle ulaşılan iç ve dış sıcaklık farkını azaltmıştır.

4. SONUÇ VE ÖNERİLER

Seralarda havalandırma açıklıklarında kullanılan böcek tüllerinin havalandırma üzerindeki etkilerinin değerlendirildiği çalışma sonucunda,

- Sera tasarımının bölge iklimine uygun olması ve havalandırma açıklık oranlarının bölgenin iklim özelliklerine göre planlanmasının doğal havalandırma yönteminden daha yüksek verimin alınmasını sağlayacaktır.

- Havalandırma açıklıklarında kullanılan böcek tüllerinin bariyer etkisi yapması nedeniyle serada hava değişim sayısını azalttığı ve bunun iç ortam sıcaklık değerlerini arttıracağı belirlenmiştir.

- Sera iç ortam sıcaklıklarının azaltılması amacıyla kullanılan gölgeleme tülleri ise gölgeleme oranına bağlı olarak iç ortama ulaşan radyasyon değerlerini azaltarak sıcaklıkların azaltılmasına katkı sağlayacaktır.

Çalışma sonucunda, seralarda kullanılan böcek tüllerinin porozite katsayının azaltılması seraya giren böceklerin azaltılmasına katkı sağlarken havalandırmayı azaltacağı ve bunun bitki yetiştiriciliğine olumsuz etkide bulunacağı belirlenmiştir. Buna göre havalandırma açıklık oranlarının bölgenin iklim özellikleri dikkate alınarak planlanması doğal havalandırmanın daha etkin kullanılması bakımından önemli olacaktır.

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EVALUATION OF THE EFFECT OF NATURAL VENTILATION AND COOLING APPLICATIONS ON INDOOR CLIMATE IN A HIGH TUNNEL GREENHOUSE

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ABSTRACT

In order to make the indoor temperature, which increases due to the solar radiation reaching the greenhouse during periods of increasing temperatures, suitable for plant cultivation, greenhouses need to be air-conditioned. For this purpose, it was aimed to determine the effect of natural ventilation and cooling applications on the indoor climate in the high tunnel greenhouse. In the study, four different applications (natural ventilation, natural ventilation+external shading net, commercial cellulose pad, commercial cellulose pad+external shading net) were applied in the high tunnel greenhouse in order to make the indoor climate parameters suitable for plant cultivation. According to the results obtained, in natural ventilation and natural ventilation+external shading net applications, the temperature measured in the interior environment was 10.4 °C and 9.3 °C higher than the exterior environment, and the relative humidity values were 14% and 11% lower than the exterior environment, respectively. In cooling applications, the cooling effect measured in front of the pad in commercial cellulose pad and commercial cellulose pad+external shading net applications was determined as 5.2 °C and 7.2 °C lower than the external environment, and the relative humidity values were determined as 31.7% and 34.8% higher than the external environment, respectively. The cooling efficiencies of the applications were calculated as 49.0% and 58.6%, cooling capacities were 2.5 kW and 3.4 kW, and the system coefficient of performance values were 9.9 and 13.5, respectively. Water consumption values were measured as 3.4 L/h and 3.5 L/h, respectively. As a result of the study, commercial pads made positive contributions in reducing indoor temperatures and increasing relative humidity values during periods when temperatures increased. However, it was concluded that it is important to pay attention to the amount of water consumed in businesses with water restrictions and electricity consumed in the use of cooling applications.

Keywords: High tunnel greenhouse, temperature, relative humidity, cooling efficiency, cooling capacity

YÜKSEK TÜNEL SERADA DOĞAL HAVALANDIRMA VE SERİNLETME UYGULAMALARININ İÇ ORTAM İKLİMİ ÜZERİNDEKİ ETKİSİNİN DEĞERLENDİRİLMESİ

ÖZET

Sıcaklıkların arttığı dönemlerde seraya ulaşan güneş ışınımına bağlı olarak artan iç ortam sıcaklığın bitki yetiştiriciliğine uygun hale getirilebilmesi için seraların iklimlendirilmesi gereklidir. Bu amaçla yüksek tünel serada doğal havalandırma ve serinletme uygulamalarının iç ortam iklimi üzerindeki etkisinin belirlenmesi amaçlanmıştır. Çalışmada, iç ortam iklim parametrelerinin bitki yetiştiriciliğine uygun hale getirilebilmesi amacıyla yüksek tünel serada dört farklı uygulama (doğal havalandırma, doğal havalandırma+dıştan gölgeleme tülü, ticari selüloz ped, ticari selüloz ped+dıştan gölgeleme tülü) yapılmıştır. Elde edilen sonuçlara göre doğal havalandırma ve doğal havalandırma+dıştan gölgeleme tülü uygulamalarında iç ortamda ölçülen sıcaklık dış ortamdan sırasıyla 10.4 °C ve 9.3 °C daha yüksek, oransal nem değerleri ise dış ortamdan sırasıyla %14 ve %11 daha düşük olarak ölçülmüştür. Serinletme uygulamalarında ise ticari selüloz ped ve ticari selüloz ped+dıştan gölgeleme tülü uygulamalarında soğutma etkisi dış ortamdan sırasıyla 5.2 °C ve 7.2 °C düşük, oransal nem değerleri ise dış ortamdan sırasıyla %31.7, %34.8 yüksek olarak belirlenmiştir. Uygulamaların soğutma verimleri sırasıyla %49.0 ve %58.6, soğutma kapasiteleri 2.5 kW ve 3.4 kW ve sistemin performans katsayısı değerleri ise 9.9 ve 13.5 olarak hesaplanmıştır. Saatlik olarak tüketilen su miktarı sırasıyla 3.4 L/h ve 3.5 L/h olarak ölçülmüştür. Çalışma sonucunda sıcaklıkların arttığı dönemlerde ticari pedler iç ortam sıcaklıkların azaltılması ve oransal nem değerlerinin arttırılmasında olumlu katkılar sağlamıştır. Ancak serinletme uygulamalarının kullanımında tüketilen elektrik enerjisi ve su kısıtı bulunan işletmelerde tüketilen su miktarına dikkat edilmesinin önemli olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Sera, sıcaklık, oransal nem, serinletme etkinliği, soğutma kapasitesi

1. GİRİŞ

Seralar, içerisinde yetiştirilen ürünleri olumsuz hava koşullarından korumak ve ürün kalitesini artırmak için inşa edilen yapılardır (Debhi ve ark., 2017). Sıcak iklimlerde, seralar yılın soğuk ve ılıman dönemlerinde tarımsal üretime özel olarak tasarlanmıştır. Ancak, yüksek yaz sıcaklıkları yetiştirilen ürünlerin gelişimini olumsuz etkiler (Callejón-Ferre ve ark., 2009). Kurak ve yarı kurak bölgelerde, yaz sıcaklıkları, gündüzleri 40 °C'yi aşabilen sıcaklıklar ve %30'un altındaki bağıl nem seviyeleri ile karakterize edilir (Al-Helal ve ark., 2004). Bu nedenle, yılın en sıcak zamanları için seranın içindeki hava sıcaklığını düşürmeyi amaçlayan stratejiler geliştirilmiştir (Cámara-Zapata ve ark., 2020).

Yarı kurak iklimlerdeki seralarda, düşük ekonomik maliyetleri nedeniyle en yaygın kullanılan soğutma sistemleri doğal havalandırma ve gölgelemedir (Muñoz ve ark., 1999; Kittas ve ark., 2002). İlk yatırım maliyetlerinin daha ucuz ve işletilmesinin daha kolay olması nedeniyle doğal havalandırma uygulaması yaygın olarak kullanılsa da bu yöntem çoğu zaman güneşli yaz günlerinde içerideki aşırı enerjinin dışarı atılmasında yeterli olamamaktadır (Baille, 1999). Gölgeleme tülleri ise seranın içine kurulurlarsa havalandırma oranlarını düşürür sera dışına kurulması durumunda ise hareketli gölgeleme tüllerinin kurulumu için ortaya çıkan yüksek maliyet ve sera yapısının üzerindeki artan yükler gibi dezavantajları vardır (González-Real ve ark., 2006; Montero ve ark., 2013).

Bu sorunların üstesinden gelmek için, aralarında buharlaştırıcı soğutma tekniklerinin de bulunduğu çok sayıda soğutma sistemi tasarlanmıştır. Doğrudan buharlaştırıcı soğutma grubu, fan-ped ve sisleme sistemlerini içerir (Misra ve Ghosh, 2018). Bu sistemler havadaki duyulur ısıyı gizli ısıya dönüştürerek ısı yükünü azaltır ve bitki gelişimi için uygun sera içi ortamı sağlar (Mutwiwa ve ark., 2007). Fan-ped sistemi, daha iyi hava doygunluk verimliliği nedeniyle daha fazla sıcaklık düşüşüne izin verir (López ve ark., 2012; Misra ve Ghosh, 2018). Bu sistemlerdeki temel sorunlar, daha fazla ekonomik yatırım gerektiren ve daha yüksek kalitede su gerektiren su ve enerji tüketimidir (sisleme sisteminde daha yüksektir) (Rabbi ve ark., 2019). Fan-ped sisteminin çalışmasını optimize etmek için yapılan uygulamalar arasında gölgelendirme perdeleriyle kullanılması iç ortam sıcaklıklarını azaltmak için iyi sonuçlar vermiştir (Ghosal ve ark., 2003). Farklı soğutma sistemlerinin (buharlaştırıcı soğutma, doğal havalandırma ve gölgeleme) birleştirilmesi sera enerjisi gereksinimlerini azaltabilir ve sıcak iklimlerde örtü altında bitki üretimi için optimum koşulları sağlayabilir (Xu ve ark., 2015; Ghoulem ve ark., 2019). Bu nedenle, bir fan-ped sistemini saha koşullarında karakterize etmek, diğer sistemlerin pedin çalışma parametreleri üzerindeki etkisini analiz etmeyi ve kombinasyonlarının ve/veya uyumsuzlukların varlığını belirlemeyi gerektirir (Cámara-Zapata ve ark., 2020). Sethi ve Sharma (2007), mevcut teknolojilerin hiçbirinin mükemmel olarak kabul edilemeyeceği sonucuna vardı, çünkü hiçbiri seraların ve iç mekan bitkilerinin tüm soğutma gereksinimlerini karşılamıyor. Bir soğutma sisteminin seçimi ve işletimi, iklim türü, yetiştirilecek bitki, maliyet, bakım, işletim kolaylığı, güvenilirlik, sistemin ömrü, elektriğe bağımlılık vb. gibi çeşitli parametrelere dayanmaktadır. Bu nedenle, sera soğutması için en uygun teknolojinin, çiftçinin maksimum getiri elde etmek için sezon dışı bitkileri yetiştirmek için istediği koşulların çoğunu karşılayan teknoloji olduğu söylenebilir.

Bu amaçla çalışmada, sıcaklıkların bitki yetiştiriciliğine olanak tanımadığı dönemlerde iç ortam sıcaklıkların azaltılması için farklı soğutma uygulamalarının bazı performans parametreleri ve iç ortam iklimine etkisini araştırmaktır.

2. MATERYAL VE METOT

Doğal havalandırma ve soğutma uygulamaları yapılan yüksek tünel seranın boyutları 3x5 m olup taban alanı 15 m^2 dir. Havalandırma açıklığı olarak ön cephe duvarındaki kapı boyutları 180 cm x 80 cm ve arka cephe duvarından bulunan pencere boyutları 50 cm x 50 cm olup havalandırma açıklık alanının taban alanına oranı %11.3'tür. Örtü malzemesi ise 36 aylık UV+IR katkılı PE plastik ile örtülüdür.

Yüksek tünel serada kullanılan doğrudan evaporatif soğutucunun havalandırma debisi 1500 m^3/h ve akan su miktarı saatte 216 L'dir. Evaporatif soğutucu içerisinde yaygın olarak kullanılan ticari selüloz ped kullanılmış ve ped kalınlığı 3 cm dir. Sistem günlük olarak 09:00-18:00 saatleri arasında çalıştırılmış ve tüketilen saatlik enerji miktarı 0.250 W'tir. Sistemin çalıştığı saatler arasında ortalama elektrik tüketimi 2.25 kWh'tir.

Çalışmada iç ve dış ortamda ölçülen iklim verileri Onset HOBO U12 sıcaklık ve oransal nem ölçer ile kayıt altına alınmıştır. Veri kaydediciler 30 dakikalık aralıklar ile verileri kayıt altına alınmıştır. Evaporatif soğutucunun elektrik tüketimi TT Technic PMG-1 ile kayıt altına alınarak ölçülmüştür.

Yüksek tünel serada, (1) Doğal havalandırma (DH), (2) Doğal havalandırma + dıştan gölgeleme tülü (DH+DGT), (3) ticari selüloz ped (CP) ve (4) Selüloz ped + dıştan gölgeleme tülü (CP+DGT) olmak üzere dört farklı uygulama yapılmıştır.

Evaporatif soğutma sisteminin performansının belirlenmesi amacıyla hesaplamalarda kullanılan eşitlikler aşağıda verilmiştir. Uygulamalarda, iç ve dış sıcaklık farkı olan uygulamaların soğutma etkisi Eşitlik 1 yardımıyla hesaplanmıştır (Almaneea ve ark., 2022).

$$\Delta T = T_i - T_d \qquad (1)$$

Eşitlikte; ΔT= uygulamaların soğutma etkisi (°C), Ti= İç ortam hava sıcaklığı (°C), Td= Dış ortam hava sıcaklığı (°C).

Evaporatif sistemin serinletme etkinliği Eşitlik 2 ile hesaplanmıştır (Maurya ve ark., 2014).

$$\eta = \frac{[td - ti]}{[td - twb]} x100 \qquad (2)$$

Eşitlikte; η= Soğutma sisteminin etkinliği (%), td= Dış ortam hava sıcaklığı (°C), ti= İç ortam hava sıcaklığı (°C), twb= Dış havanın ıslak termometre sıcaklığı (°C), dır.

Evaporatif serinletme pedinin soğutma kapasitesi Eşitlik 3 ile hesaplanmıştır (Maurya ve ark., 2014).

$$Qc = Ma \times Cpa \times [td - ti] \times 3.6 \quad (3)$$

Eşitlikte; Qc= Soğutma kapasitesi (kJ/h), Ma=Havanın kütlesel akış hızı (kg/s), Cpa= Havanın özgül ısısı (J/kg°C)

Su tüketim oranı Eşitlik 4 ile hesaplanmıştır (Maurya ve ark., 2014).

$$Q\omega = Ma\ [\omega o - \omega i]\ x\ 3600 \quad (4)$$

Eşitlikte; Qω= Su tüketim oranı (kg/sa), ωi= Dış ortam havasının pede girmeden önceki özgül nemi (kg/kg), ωo= Dış ortam havasının pedden çıktıktan sonraki özgül nemi (kg/kg)

Soğutma sisteminin performans katsayısı Eşitlik 5 ile hesaplanmıştır (Abohorlu Doğramacı ve ark., 2019).

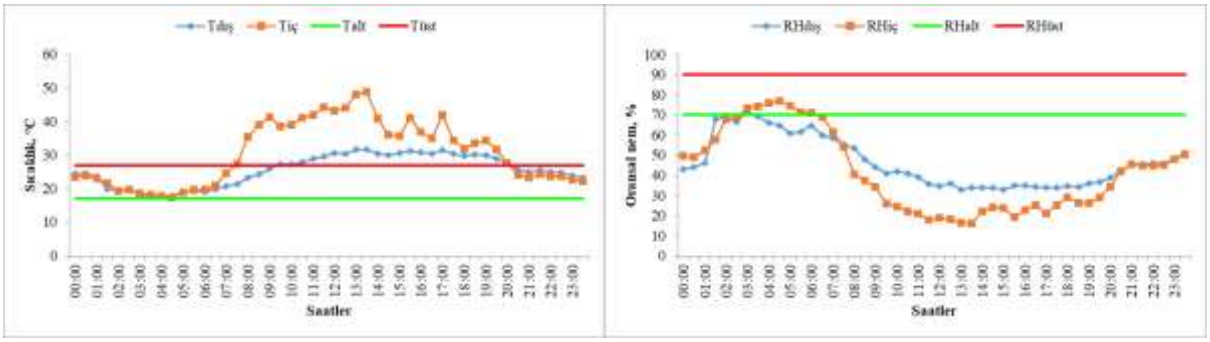
$$COP = \frac{Q_C}{W_{fan}+W_{pompa}} \quad (5)$$

Eşitlikte; Wfan ve Wpompa= soğutma sisteminde kullanılan fan ve pompanın elektrik tüketimi (kWh)

3. BULGULAR VE TARTIŞMA

3.1. Doğal Havalandırma Uygulamaları

İlk yatırım ve işletim maliyetlerinin düşük olması nedeniyle yaygın olarak kullanılan doğal havalandırma (DH) uygulamalarında ölçülen iç ve dış ortam sıcaklık ve oransal nem değerlerinin zamana bağlı değişimleri Şekil 1'de verilmiştir.

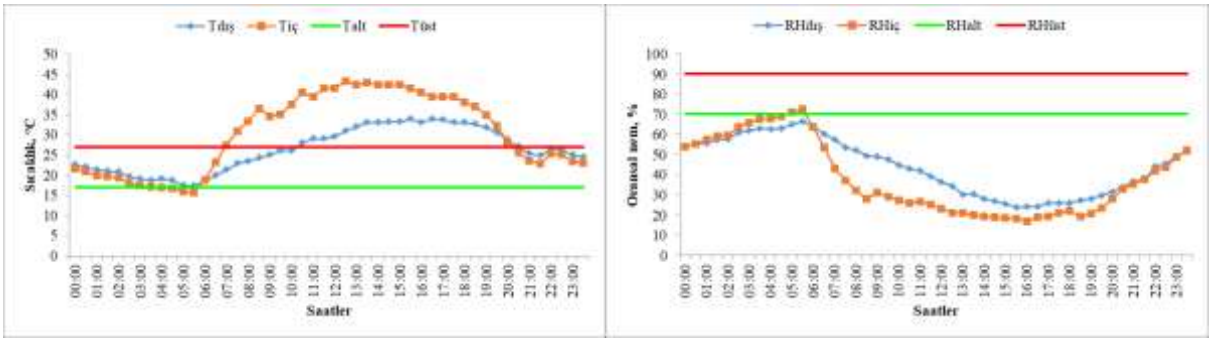


Şekil 1. DH uygulamasında ölçülen sıcaklık ve oransal nem değerlerinin zamana bağlı değişimleri

Gün içerisinde dış ortamda artan sıcaklık değerleri, iç ortamda sıcaklıkların artmasına neden olmuştur. Ayrıca artan sıcaklık değerlerinin etkisi ile iç ortamda bağıl nem değerleri azalmıştır. Doğal havalandırma uygulaması yapılan günde dış ortam sıcaklık değerleri 26.1-31.7 °C ve oransal nemin %33.0-44.0 arasında değişim göstermiştir. İç ortamda ölçülen sıcaklık 32.0-49.0 °C ve oransal nem %16.0-34.2 arasında ölçülmüştür. Yüksek tünel dışında ölçülen sıcaklık ve oransal neminin ortalama 29.8 °C ve %36.2 ölçüldüğü günde iç ortamda ölçülen sıcaklık ve oransal nem değerleri 40.3 °C ve %22.4 olarak belirlenmiştir. Bu durumda iç ortam sıcaklığı dış ortamdan 10.5 °C yüksek, oransal nem ise %13.8 daha düşük olduğu belirlenmiştir. DH uygulamasında örtü malzemesi nedeniyle iç ortama ulaşan güneş radyasyonu %30 azalmıştır. Artan güneş radyasyonuna bağlı olarak iç ortam sıcaklık değerlerinin arttığı bu dönemlerde yüksek tünel sera içine ulaşan yüksek radyasyon değerlerinin azaltılması amacıyla örtü altı yetiştiriciliğine yaygın olarak kullanılan dıştan gölgeleme tülü uygulaması doğal havalandırmaya katkı sağlayacaktır.

3.2. Doğal Havalandırma ve Dıştan Gölgeleme Tülü Uygulamaları

Güneş radyasyon değerlerinin yüksek yoğunluğuna sahip olduğu bölgelerde, yüksek havalandırma oranları her zaman sera iç ortam sıcaklıklarını azaltmada yeterli olamamaktadır. Bu durumda yüksek güneş yoğunluğu bitkilerde ısı stresine neden olur. Bunu azaltmak içinse seralarda gölgeleme tülü kullanılır (Holcman ve Sentelhas, 2012). Doğal havalandırma + Dıştan gölgeleme tülü (DH+DGT) uygulamasında ölçülen iç ve dış ortam sıcaklık ve oransal nem değerlerinin zamana bağlı değişimleri Şekil 2'de verilmiştir.



Şekil 2. DH +DGT uygulamasında sıcaklık ve oransal nem değerlerinin değişimi

Çalışmada DH+DGT uygulamasına benzer olarak dış ortamda artan sıcaklık değerleri iç ortam sıcaklıklarını arttırması oransal nem değerlerini ise azaltmıştır (Şekil 2). Gün içerisinde dış ortamda ölçülen sıcaklık 25.0-34.0 °C ve oransal nem %23.8-49.0 arasında değişmiştir. İç ortamda ise ölçülen sıcaklık 34.6-43.3 °C ve oransal nem %16.9-31.2 arasında ölçülmüştür. Dış ortamda ölçülen sıcaklık ve oransal nemin ortalama 31.0 °C ve %33.0 olduğu günde iç ortam sıcaklık ve oransal nem değeri 40.3 °C ve %22.2 olarak belirlenmiştir. Bu durumda iç ortam sıcaklığı dış ortamdan 9.3 °C yüksek, oransal nem ise %10.8 düşük ölçülmüştür. DH+DGT uygulamasında dış ortama göre iç ortama ulaşan güneş radyasyonu %55 azalmıştır.

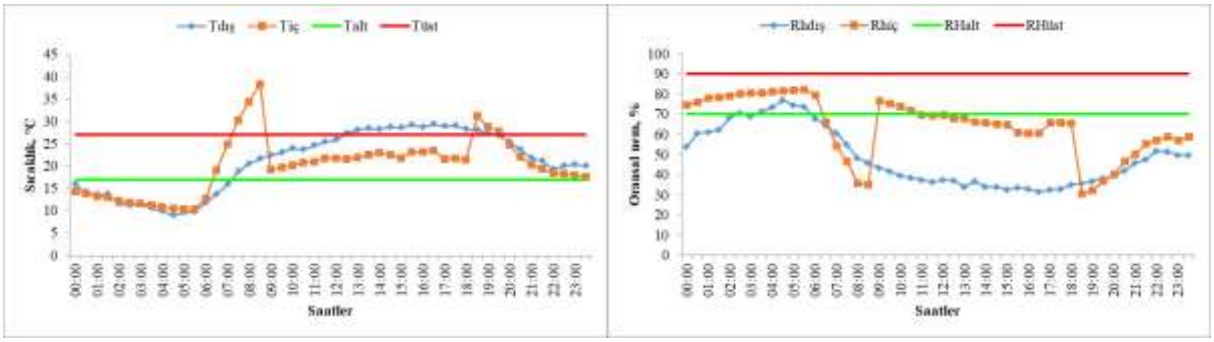
Serada yetiştiriciliği yapılan bitkiler için iç ortam sıcaklık değerlerinin 17–27 °C ve oransal nem değerlerinin %80 düzeyinde olması istenir (von Zabeltitz, 1994). Yapılan ölçümlerde DH uygulamasında (40.3 °C ve %22.4) bitki yetiştiriciliği bakımından yüksek sıcaklık, düşük oransal nem değerlerindedir. İç ortam sıcaklıklarını azaltmak ve oransal nem değerlerini yükseltmek için dıştan gölgeleme tülü uygulaması ile sera iç ortamına ulaşan güneş radyasyonu değerlerini azaltıp iç ortam iklimini bitki yetiştiriciliğine uygun hale getirmek iyi bir yöntem olabilmektedir. Fakat DH+DGT uygulamasında da (40.3 °C ve %22.2) ölçülen yüksek iç ortam sıcaklığı ve düşük oransal nem değerleri göstermiştir ki yaz aylarında gölgeleme tülü uygulaması da DH uygulamasına benzer olarak iç ortam iklimini bitki yetiştiriciliğine uygun hale getirmekten uzak olduğu görülmüştür (Şekil 1 ve Şekil 2).

Seralarda kullanılan doğal havalandırma uygulamasının etkinliği düşük dış hava hızlarında sınırlı olmaktadır. Kullanılan gölgeleme tülleri kullanılan tekniğe ve gelen güneş radyasyonunu azaltma oranına bağlı olarak serada yapılan üretimi ve yetiştiriciliği yapılan ürünün kalite özelliklerini olumsuz etkileyebilir (Aroca-Delgado ve ark., 2018; McCartney ve ark., 2018). Abbouda ve Almuhanna (2012) serada 200 µm kalınlığında UV katkılı polietilen örtü malzemesi ve %60 oranında gölgeleme tülü kullanılması durumunda, sera dış ve iç ortamında ölçülen solar radyasyon değerini sırasıyla 555.7 W/m^2 ve 298.7 W/m^2 olarak ölçülmüş ve örtü malzemesinin etkin geçirgenliğini ortalama %53.8 olduğunu bildirmişlerdir. Yürütülen çalışmada kullanılan örtü malzemesinin yansıtma özelliği ve dıştan kullanılan gölgeleme tülünün etkisiyle iç ortama ulaşan güneş radyasyonu DH uygulamasında %30, DH+DGT uygulamasında %55 oranında azalmıştır.

Yapılan çalışmada, DH uygulaması yapılan bir gündeki benzer sıcaklık değerlerine göre iç ortamda 1.5 °C lik bir sıcaklık farkı oluşmuştur. Gölgeleme tülü nedeniyle her nekadar iç ortama ulaşan güneş radyasyonu değeri azalsa da sıcaklıkları 40°C ve üzerine çıktığı günlerde iç ortamda biriken ısı enerjisinin dış ortama atılması mümkün olmamıştır. Bunun neticesinde yapılan her iki uygulamadan da iç ortam sıcaklık ve oransal nem değerleri iç ortam iklimini bitki yetiştiriciliği için gerekli olan optimum değerlere getirememiştir. Bu durumda birim alandan daha fazla verim alınmasına olanak sağlayan seralarda yüksek sıcaklık ve düşük oransal nem değerleri bitkilerin çiçek bağlaması, gelişim ve verim parametrelerini olumsuz etkileyecektir. Dış ortam sıcaklık değerlerinin yükseldiği bu dönemlerde yetiştiricilik için iç ortam sıcaklık değerini düşüren ve oransal nem değerlerini yükselten evaporatif serinletme uygulamalarının gerekliliği ortaya çıkmaktadır.

3.3. Selüloz ped uygulaması

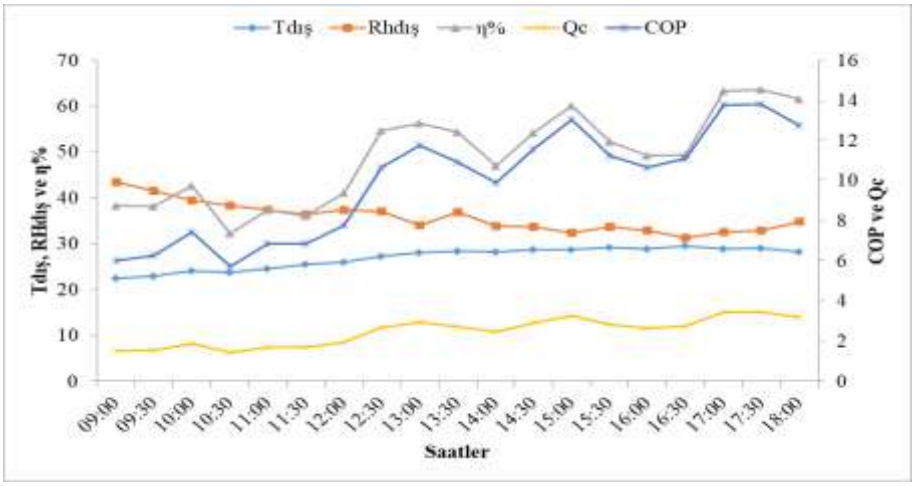
Çalışmada, CP uygulamasında ölçülen sıcaklık ve oransal nem değerlerinin zamana bağlı değişimleri Şekil 3' te verilmiştir.



Şekil 3. CP uygulamasında ölçülen sıcaklık ve oransal nem değerleri

CP uygulamasında sistemin çalışmadığı gece saatlerinde iç sıcaklıklarının düşük olmasına karşın güneşin doğuşu ile birlikte güneş radyasyonu etkisini göstererek iç ortam sıcaklıklarını arttırmıştır. İç ortamda artan sıcaklık değerleri ise oransal nem değerlerini azaltmıştır (Şekil 3). Soğutma sisteminin çalıştığı 09:00-18:00 saatleri arasında ölçülen dış sıcaklık değerleri 22.4 °C - 29.4 °C arasında ortalama 27 °C ölçülmüştür. Bu saatler arasında iç ortam sıcaklıkları 19.3 °C - 23.5 °C arasında ortalama 21.7 °C ölçülmüştür. Buna göre soğutma etkisi 3 °C - 7.4 °C arasında ortalama 5.2 °C olarak hesaplanmıştır. Dış bağıl nem değerleri ise %31.3 - %43.4 arasında ortalama %35.8 olarak ölçülmüştür. İç ortam bağıl nem değerleri ise %60.5 - %76.6 arasında ortalama %67.5 olarak ölçülmüştür. Buharlaştırmalı soğutma sistemi ile iç ortamda oransal nem dış ortama göre %31.7 artmıştır.

CP uygulamasında ölçülen ve hesaplanan performans parametrelerinin zamana bağlı değişimi Şekil 4'te verilmiştir.

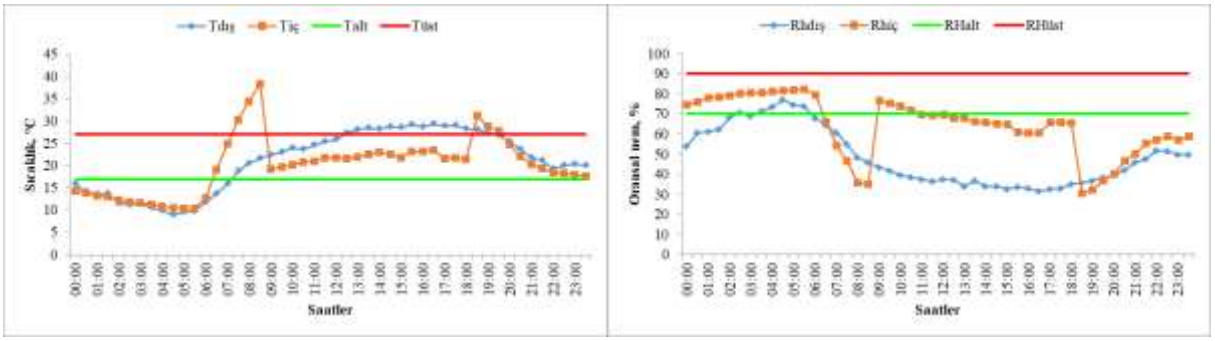


Şekil 4. CP uygulamasında performans parametrelerinin zamana bağlı değişimleri

Çalışmada CP uygulamasında soğutma verimi %32.3 - %63.6 arasında ortalama %49 olarak hesaplanmıştır. Sistemin soğutma kapasitesi 1.4 kW - 3.5 kW arasında ortalama 2.5 kW, COP değeri 5.7 - 13.8 arasında ortalama 9.9 olarak hesaplanmıştır (Şekil 4). Su tüketimi 1.6 L/h - 5.3 L/h arasında ortalama 3.4 L/h ve günlük su tüketimi ortalama 63.9 L olarak hesaplanmıştır.

3.4. Selüloz ped ve Dıştan gölgeleme uygulaması

Çalışmada, ticari selüloz ped+ dıştan gölgeleme tülü uygulamasında ölçülen sıcaklık ve oransal nem değerlerinin değişimi Şekil 5' te verilmiştir.

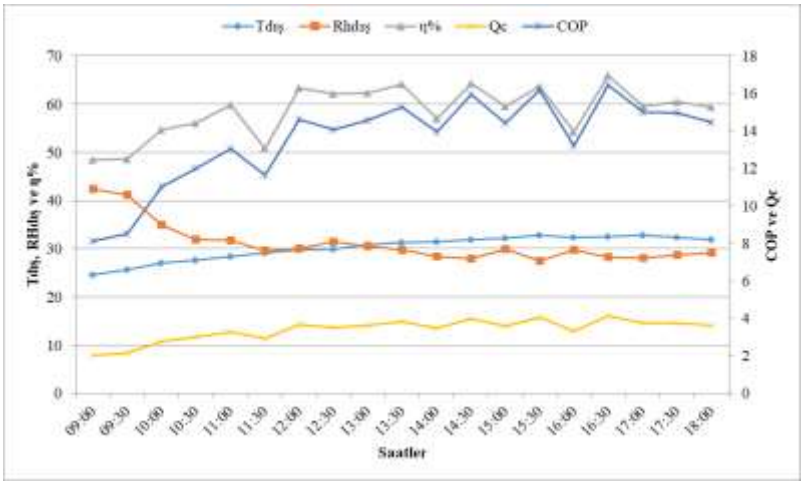


Şekil 5. CP+DGT uygulamasında ölçülen sıcaklık ve oransal nem değerleri

Çalışmada, CP+DGT uygulamasında CP uygulamasına benzer olarak günün erken saatlerinde artan iç ortam sıcaklıkları oransal nem değerlerini azaltmıştır. Soğutma sisteminin çalıştığı 09:00-18:00 saatleri arasında ölçülen dış sıcaklık değerleri 24.6 °C - 32.7 °C arasında ortalama 30.2 °C ölçülmüştür. Bu saatler arasında iç ortam sıcaklıkları 20.3 °C - 25.2 °C arasında

ortalama 23 °C olarak ölçülmüştür. Yüksek tünel serada ölçüm yapılan saatler arasında soğutma etkisi 4.3 °C - 8.9 °C arasında ortalama 7.2 °C olarak hesaplanmıştır. Dış bağıl nem değerleri ise %27.4 - %42.3 arasında ortalama %31.1 olarak ölçülmüştür. İç ortam bağıl nem değerleri ise %60-%74.2 arasında %65.9 olarak ölçülmüştür. Buna göre buharlaştırmalı soğutma sistemi ile iç ortamda oransal nem %34.8 artmıştır.

CP+DGT uygulamasında ölçülen ve hesaplanan performans parametrelerinin zamana bağlı değişimi Şekil 6'da verilmiştir.



Şekil 6. CP+DGT uygulamasında performans parametrelerinin zamana bağlı değişimleri

CP+DGT uygulamasında soğutma verimi %48.4 - %65.9 arasında ortalama %58.6 olarak hesaplanmıştır. Sistemin soğutma kapasitesi 2 kW - 4.1 kW arasında ortalama 3.4 kW, COP değeri 8.1 - 16.4 arasında ortalama 13.5, su tüketimi 2.6 L/h - 5.4 L/h arasında ortalama 3.5 L/h ve günlük su tüketimi ortalama 65.8 L olarak hesaplanmıştır.

Çalışmada, soğutma etkisi değerlerine bakıldığında iç ortamda ölçülen sıcaklıklar dış ortamdan CP uygulamasında 5.2 °C ve CP+DGT uygulamasında 7.2 °C daha düşük olarak hesaplanmıştır. Araştırmacıların evaporatif uygulamalar üzerine yapmış oldukları çalışmalarda soğutma etkisini, Jakubowski ve ark. (2024) tarafından CP ve CP+DGT uygulamasında sırasıyla 5.5 °C ve 6.6 °C, Gunhan ve ark. (2007) CP uygulamasında farklı hava hızları için 3.91- 4.97 °C arasında ve Shivpuje ve ark. (2018) CP uygulamasında pede giren ve ped den çıkan sıcaklıkları arasındaki farkın 5-7 °C arasında olduğunu belirlemişlerdir. Bu sonuçlar araştırmacıların çalışmaları ile uyumlu bulunmuştur. Çalışmada elde edilen sonuçlara gör CP ve CP+DGT uygulamalarının her iki uygulamada iç ortamdaki sıcaklık değerlerini bitki yetiştiriciliğine uygun koşullara getirilebilecektir. Evaporatif sistem ile duyulur ısı gizli ısıya dönüştürülerek iç ortamdaki sıcaklık değerlerini azaltıp oransal nem değerlerini arttırması nedeniyle bu sistemlerin soğutma etkisi DH ve DH+DGT uygulamalarına göre oldukça yüksek olmuştur. Aynı zamanda, CP+DGT uygulamasında kullanılan dıştan gölgeleme tülünün iç

ortama ulaşan güneş radyasyonu azaltılması nedeniyle soğutma etkisi CP uygulamasından fazla olduğu belirlenmiştir.

Yüksek tünel sera içerisinde ölçülen oransal nem değerleri dış ortama göre CP uygulamasında yaklaşık %31.7 ve CP+DGT uygulamasında %34.8 daha yüksek ölçülmüştür. Gunhan ve ark. (2007) CP uygulamasında farklı hava hızları için bağıl nem değerlerini %27.4-%37.2 arasında ve Shivpuje ve ark. (2018) pede giren havanın ortalama bağıl neminin %23.3-%26.6 arasında arttığını bildirmişlerdir. Çalışmada elde edilen sonuçlar araştırmacıların çalışmaları ile benzer özellikler göstermiştir. Dış ortamda artan sıcaklık değerleri oransal nem değerlerini azaltmıştır. Böylece, dış ortamdan soğutma pedinin içine giren kuru hava daha fazla nem almış ve iç ortamdaki bağıl nem değerlerinin artmasını sağlamıştır. Her iki uygulamada da iç ortam iklim koşulları bitki yetiştiriciliğine uygun hale getirilse de CP+DGT uygulamasında dıştan gölgeleme tülü kullanılması iç ortamı CP uygulamasına göre daha uygun hale getirmiştir.

Soğutma verimliliği bakımından CP uygulaması ortalama %49.0, CP+DGT uygulaması ortalama %58.6 olarak hesaplanmıştır. Çalışmada kullanılan dıştan gölgeleme tülü soğutma verimliliğini olumlu yönde etkilemiştir. Gunhan ve ark. (2007) CP uygulaması için soğutma verimliliğini %46.1, ve Vala ve ark. (2016) CP uygulamasında %57.14–%90.70 belirlemişlerdir. Elde edilen sonuçlar araştırmacıların yapmış oldukları çalışmalar ile farklılıklar göstermiştir. Bu farklılıklar uygulamalarda kullanılan ped kalınlığına ve dış ortam kuru havasına bağlı olarak değişim göstermiştir.

Soğutma kapasitesi CP uygulaması için ortalama 2.5 kW ve COP değeri 9.9 iken CP+DGT uygulaması için ortalama 3.4 kW ve COP değeri 13.5 olarak hesaplanmıştır. Çalışmada CP+DGT uygulamasının CP uygulamasına göre soğutma etkisinin fazla olması soğutma kapasitesini (Qc) ve COP'u arttırmıştır (Şekil 4 ve Şekil 6). Chaomuang ve ark. (2023) CP için soğutma kapasitesinin 0.3-0.6 kW ve COP değerinin yaklaşık 2.2–4.5 arasında ve soğutma kapasitesinin sadece sıcaklık düşüşüyle değil bunun yanında su akış hızıyla da ilişkili olduğunu bildirmişlerdir. Çalışmada, soğutma sisteminin 2 m/s lik yüksek hava akış hızında olması sistemin soğutma kapasitesi ve COP değerlerini arttırmıştır.

Çalışmada, tüketilen su tüketimi karşılaştırıldığında SP uygulamasında 63.9 L/gün iken SP+DGT uygulamasında 65.8 L/gün olarak hesaplanmıştır. Dış ortamdaki düşük oransal nem, evaporatif soğutucuya giren kuru havanın daha fazla nem almasına ve dolayısıyla daha fazla su tüketilmesine neden olur. Nikolaou ve ark. (2018) hıyar yetiştirilen bir serada fan-ped sistemi için sera birim taban alanına 3 L/m^2' suyun tüketildiğini bildirmişlerdir. Franco ve ark. (2014) CP için tüketilen suyun 1.8–2.62 L/h arasında değiştiğini belirtmişlerdir. Yürütülen çalışmada, birim alan için tüketilen su miktarı CP uygulamasında 4.3 L/m^2, CP+DGT uygulamasında 4.4 L/m^2 su tüketilmiştir. Birim alan için su tüketimindeki farklılıklar iklim koşulları, ped kalınlıkları gibi farklılıklardan kaynaklanmıştır. İklim değişikliği ve yağış rejimlerindeki düzensizlikler nedeniyle su kullanımının öneminin her geçen gün arttığı günümüzde seraların soğutulması kadar soğutma amaçlı kullanılan su miktarının bilinmesinin de önemli olduğu görülmektedir. Çünkü su kısıtının olduğu bölgelerde evaporatif (buharlaştırmalı) soğutma uygulamalarında tüketilen su miktarının fazlalığı sistemin uygulanabilirliğini de etkileyecektir.

Soğutma sisteminin elektrik tüketimine bakıldığında saatlik enerji tüketimi 0.250 W ölçülmüştür. Gün içerisinde sistemin çalıştığı saatler arasında toplam tüketim ortalama 2.25

kWh olarak ölçülmüştür. Sıcaklıkların yükseldiği Haziran-Ağustos ayları arasında soğutma yapılacak saatler ve yetiştiricilik süreside dikkate alınarak elektrik tüketimi için yapılan harcamalara dikkat edilmesi gerekmektedir. Çünkü bu aylarda açık tarla koşullarında yetiştirilen ürünlerin piyasa çıkması da soğutma için karar vermede önemli bir kriter olarak ortaya çıkmaktadır.

4. SONUÇ VE ÖNERİLER

Yüksek tünel serada doğal havalandırma ve serinletme uygulamalarının iç ortam iklimi üzerindeki etkisinin değerlendirildiği çalışmada,

Yüksek sıcaklıkların bitki yetiştiriciliğine imkan vermediği veya yetiştiriciliği sınırlandırdığı koşullar altında doğal havalandırma ve doğal havalandırma+dıştan gölgeleme tülü uygulamalarının iç ortam sıcaklığını bitki yetiştiriciliğine uygun hale getiremediği bu yöntemlerin daha çok ilkbahar ve sonbahar mevsimlerinde kullanılmasının uygun olduğu belirlenmiştir. Bu dönemlerde yetiştiricilik yapılabilmesi için evaporatif soğutma sistemlerinin kullanımı yetiştiricilikte bitki gelişim ve verim parametreleri üzerinde etkili olacaktır.

Bu amaçla kullanılan fan-ped sisteminin verimliliği dış ortamda artan hava sıcaklığı ve azalan oransal nem ile birlikte arttığından sistemin kullanıldığı bölgenin iklimine dikkat edilmesi gerekmektedir. Aynı zamanda elde edilen sonuçlar, fan-ped sistemi çalışmasının gölgelendirme ile birleştirildiğinde daha uygun iç ortam iklimi sağladığı belirlenmiştir.

Fan ped sistemi için kullanılan su miktarı ve elektrik enerjisinin fiyatlarının üretim maliyetleri içindeki payının belirlenmesi ve ürün satış fiyatı arasındaki ekonomik dengenin işletmeler tarafından belirlenmesi karlı bir üretim açısından önemlidir.

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KNOWLEDGE AND ATTITUDE LEVELS OF FEMALE CONSUMERS IN NEVŞEHİR PROVINCE ABOUT THE STORAGE OF BEE PRODUCTS

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ABSTRACT

This study aims to measure the knowledge, attitudes and behaviors of bee product consumers in Nevşehir province regarding the preservation of bee products. Bee products are natural products known for their many health benefits, primarily honey, propolis, royal jelly, pollen and bee venom. They have an important place in child nutrition, especially due to their immune system-supporting effects. However, there is not enough scientific data on how much mothers know about these products, their usage habits and the storage conditions for these products. In this context, a survey was conducted among women living in Nevşehir. The survey aims to measure the level of knowledge of mothers about the preservation of bee products. The findings of the study will help determine the level of awareness in society about the preservation methods of bee products. In line with the data obtained, training programs and informative campaigns can be organized to raise awareness of mothers. When the age of the participants in the study is examined, it was determined that 41.5% (111 people) were women between the ages of 36-45, 46% (122 people) of the participants had a bachelor's degree and 58.2% (153 people) were public personnel. According to the results of the research, the rate of those who store honey in closed containers outside was 77.5% (207 people), and the rate of those who store pollen and perga in a dry and cool place was 32.4% (85 people). Finally, it was determined that 51.3% (135 people) of the participants had no information about the storage of royal jelly. As a result, this research aims to contribute to the widespread use of bee products and the development of more conscious consumption habits. It is expected that the data obtained will shed light on public health policies and nutritional guidelines.

Keywords: Apitherapy, mother, child.

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NEVŞEHİR İLİNDEKİ KADIN TÜKETİCİLERİN ARI ÜRÜNLERİNİN MUHAFAZASI KONUSUNDAKİ BİLGİ VE TUTUM DÜZEYLERİ

ÖZET

Bu çalışma, Nevşehir ilindeki arı ürünleri tüketicilerinin arı ürünlerinin muhafazası konusundaki bilgi, tutum ve davranışlarını ölçmeyi amaçlamaktadır. Arı ürünleri, başta bal, propolis, arı sütü, polen ve arı zehri olmak üzere birçok sağlık yararı ile bilinen doğal ürünlerdir. Özellikle bağışıklık sistemini destekleyici etkileri nedeniyle çocuk beslenmesinde önemli bir yere sahiptir. Ancak annelerin bu ürünler hakkında ne kadar bilgi sahibi olduğu, kullanım alışkanlıkları ve bu ürünlere yönelik muhafaza şartları konusunda yeterli bilimsel veri bulunmamaktadır. Bu kapsamda, Nevşehir'de yaşayan kadınlara anket çalışması yapılmıştır. Anket ile annelerin arı ürünlerinin muhafazası hakkındaki bilgi düzeylerini ölçmek amaçlanmaktadır. Çalışmanın bulguları, toplumda arı ürünlerinin muhafaza yöntemleri hakkındaki bilinç düzeylerini belirlemeye yardımcı olacaktır. Elde edilen veriler doğrultusunda, annelerin bilinçlendirilmesine yönelik eğitim programları ve bilgilendirici kampanyalar düzenlenebilir. Araştırmaya katılanların yaşlarına bakıldığında en çok 36-45 yaş aralığındaki kadınlardan oluştuğu %41,5 (111 kişi), katılımcıların %46'sinin (122 kişi) lisans düzeyinde eğitime sahip oldukları, %58,2'sinin (153 kişi) kamu personeli olduğu belirlenmiştir. Araştırma sonuçlarına göre balı kapalı kapta dışarıda muhafaza edenlerin oranı % 77,5 (207 kişi), polen ve pergayı kuru ve serin yerde muhafaza edenlerin oranı % 32,4 (85 kişi) olarak gerçekleşmiştir. Son olarak arı sütünün muhafazası ile ilgili ise katılımcıların %51,3'ünün (135 kişi) hiçbir bilgilerinin olmadığı belirlenmiştir. Sonuç olarak, bu araştırma, arı ürünleri kullanımının yaygınlaştırılması ve daha bilinçli tüketim alışkanlıklarının geliştirilmesine katkı sağlamayı amaçlamaktadır. Elde edilen verilerin, halk sağlığı politikalarına ve beslenme rehberlerine ışık tutması beklenmektedir.

Anahtar kelimeler: Apiterapi, anne, çocuk.

GİRİŞ

Arı ürünleri, insanlık tarihi boyunca beslenme ve sağlık alanında önemli bir role sahip olmuştur. Bal, propolis, arı sütü, polen ve arı zehri gibi ürünler, zengin besin içerikleri ve terapötik özellikleri nedeniyle giderek artan bir ilgi görmektedir (Pasupuleti vd., 2017). Bu ürünlerin bağışıklık sistemini güçlendirme, antioksidan etki gösterme ve antimikrobiyal özellikler sergileme gibi çeşitli sağlık yararları bilimsel çalışmalarla desteklenmektedir (Eteraf-Oskouei ve Najafi, 2013). Özellikle çocuk beslenmesinde önemli bir yere sahip olan arı ürünlerinin etkinliği, büyük ölçüde doğru muhafaza edilmelerine bağlıdır (Bogdanov vd., 2008). Ancak, tüketicilerin bu ürünlerin uygun saklama koşulları hakkındaki bilgi düzeyleri ve uygulamaları konusunda sınırlı veri bulunmaktadır. Bu bağlamda, özellikle annelerin arı ürünlerinin muhafazası konusundaki bilgi, tutum ve davranışlarının incelenmesi, halk sağlığı açısından kritik öneme sahiptir. Bu çalışma, Nevşehir ilindeki kadın tüketicilerin arı ürünlerinin muhafazası konusundaki bilgi düzeylerini, tutumlarını ve uygulamalarını değerlendirmeyi amaçlamaktadır. Elde edilecek bulgular, toplumda arı ürünlerinin doğru kullanımı ve saklanması konusundaki bilinç düzeyinin artırılmasına yönelik stratejilerin geliştirilmesine katkı sağlayacaktır. Apiterapi ürünleri, arı ve arı ürünlerinin sağlık amaçlı kullanımını içeren doğal tedavi yöntemlerinde kullanılan ürünlerdir. Başlıca apiterapi ürünleri şunlardır:

1. **Bal:**

Bal, nektar ve bitki salgılarının arılar tarafından toplanıp, vücutlarında değişikliğe uğratılarak petek gözlerine depo edilmesi sonucu oluşan tatlı bir gıdadır. Antibakteriyel, antioksidan ve anti-inflamatuar özelliklere sahiptir. Yapılan çalışmalar, balın yara iyileşmesini hızlandırdığını, üst solunum yolu enfeksiyonlarında semptomları hafiflettiğini ve sindirim sistemi rahatsızlıklarında faydalı olabileceğini göstermiştir (Eteraf-Oskouei & Najafi, 2013).

2. **Polen:**

Polen, çiçekli bitkilerin erkek üreme hücrelerini içeren tozlardır. Arılar tarafından toplanıp, nektar ve tükürük salgılarıyla karıştırılarak oluşturulur. Yüksek protein, vitamin ve mineral içeriğiyle besleyici bir gıda takviyesidir. Araştırmalar, polenin bağışıklık sistemini güçlendirdiğini, antioksidan etkiye sahip olduğunu ve prostat sorunlarında faydalı olabileceğini göstermiştir (Komosinska-Vassev et al., 2015).

3. **Propolis:**

Propolis, arıların bitki tomurcukları ve reçinelerinden topladığı, kovan içinde dezenfektan ve yapı malzemesi olarak kullandığı bir maddedir. Güçlü antimikrobiyal, antioksidan ve anti-inflamatuar özelliklere sahiptir. Bilimsel çalışmalar, propolisin ağız ve diş sağlığını korumada, yara iyileşmesinde ve bazı kanser türlerine karşı koruyucu etkisinin olabileceğini göstermiştir (Sforcin, 2016).

4. **ArıSütü:**

Arı sütü, işçi arıların hypopharyngeal ve mandibular bezlerinden salgılanan, kraliçe arı ve larvaların beslenmesinde kullanılan besin değeri yüksek bir maddedir. İçerdiği proteinler, vitaminler ve mineraller sayesinde bağışıklık sistemini güçlendirici ve yaşlanma karşıtı etkilere sahiptir. Yapılan araştırmalar, arı sütünün kolesterol düzeylerini düşürmede, menopoz semptomlarını hafifletmede ve cilt sağlığını iyileştirmede etkili olabileceğini göstermiştir (Ramadan & Al-Ghamdi, 2012).

5. ArıZehri:

Arı zehri, bal arılarının savunma mekanizması olarak kullandıkları, iğnelerinden salgılanan bir maddedir. Anti-inflamatuar ve analjezik özelliklere sahiptir. Klinik çalışmalar, arı zehrinin romatoid artrit, multiple skleroz ve kronik ağrı gibi rahatsızlıklarda semptomları hafifletmede etkili olabileceğini göstermiştir. Ancak alerjik reaksiyon riski nedeniyle kullanımı dikkat gerektirir (Lee et al., 2005).

6. Balmumu:

Balmumu, işçi arıların karın bölgelerindeki bezlerden salgıladıkları, petek yapımında kullandıkları bir maddedir. Kozmetik ve tıbbi ürünlerde yaygın olarak kullanılır. Araştırmalar, balmumunun cilt bakımında nemlendirici ve koruyucu etkilerinin yanı sıra, bazı cilt rahatsızlıklarının tedavisinde de faydalı olabileceğini göstermiştir (Fratini et al., 2016).

Materyal ve Yöntem

Bu araştırma, Nevşehir ilinde yaşayan kadın tüketicilerin arı ürünlerinin muhafazası konusundaki bilgi ve tutum düzeylerini belirlemek amacıyla yapılmıştır. Araştırmanın evrenini Nevşehir ilinde yaşayan 18 yaş ve üzeri kadın tüketiciler oluşturmaktadır. Örneklem seçiminde basit tesadüfi örnekleme yöntemi kullanılmış ve toplam 269 kadın tüketici araştırmaya dahil edilmiştir. Veriler, yüz yüze görüşme tekniği kullanılarak toplanmıştır. Veri toplama süreci Kasım-Aralık 2024 tarihleri arasında gerçekleştirilmiştir. Elde edilen veriler, SPSS 25.0 istatistik programı kullanılarak analiz edilmiştir. Verilerin analizinde tanımlayıcı istatistiklerden frekans, yüzde yöntemi kullanılmıştır.

BULGULAR

Tablo 1. Katılımcıların yaş düzeyleri

Yaş Aralığı	% Oranı	Kişi Sayısı
45 Üzeri	28,5	76
36 - 45	41,5	111
26 - 35	22,3	59
18 - 25	7,5	20

Bu çalışmaya katılan 266 kişiden %7,5'i (20 kişi) 18-25 yaş aralığında, %22,3'i (59 kişi) 26-35 yaş aralığında, %41,5'i (111 kişi) 36-45 yaş aralığında , %28,5'i (76 kişi) ise 46 yaş ve üzeri yaşta olduğunu belirtmiştir.

Tablo 2. Katılımcıların eğitim düzeyleri

Eğitim Kategorileri	% Oranı	Kişi Sayısı
Lisans Üstü	14,3	38
Lisans	46	122
Ön lisans	17,4	46
Ortaöğretim	14,3	38
İlköğretim	7,9	21

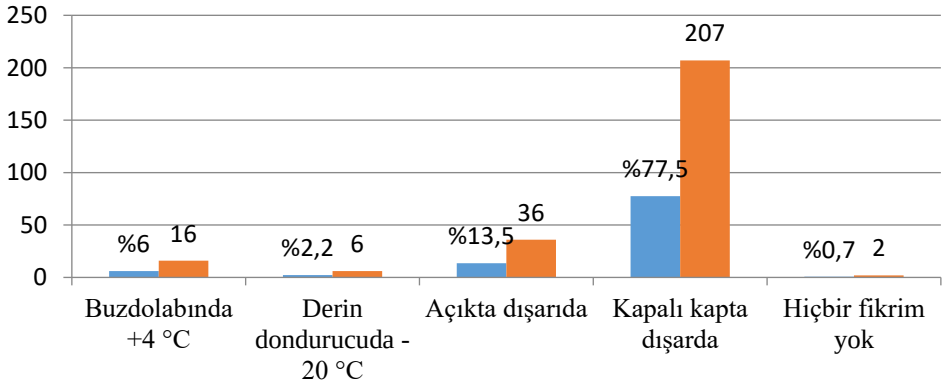
Katılımcıların eğitim durumuna bakıldığında %7,9'unun (21 kişi) ilköğretim düzeyinde, %14,3'ünün (38 kişi) ortaöğretim düzeyinde, % 17,4'ünün (46 kişi) önlisans düzeyinde, % 46'sının (122 kişi) lisans düzeyinde, son olarak %14,3'ünün ise; (38 kişi) ise lisansüstü eğitim aldığı görülmüştür.

Tablo 3. Katılımcıların meslek grupları

Meslek Grupları	% Oran	Kişi Sayısı
Ev Hanımı	16	42
Serbest	13,7	36
İşçi	12,2	32
Memur	58,2	153

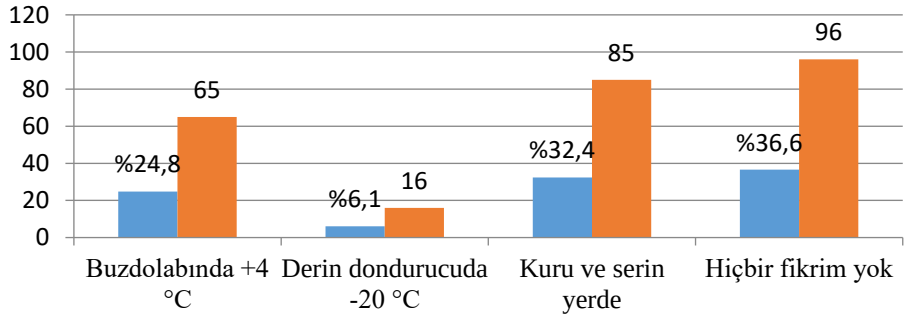
Ankete katılan kadınların iş hayatı ve çalışma durumunlarına bakıldığında ise %58,2'sinin (153 kişi) memur, %12,2'sinin (32 kişi) işçi, %13,7'sinin (36 kişi) serbest ve %16'sının (42 kişi) ise ev hanımı olduğu görülmüştür.

Tablo 4. Katılımcıların balı nasıl muhafaza ettikleri



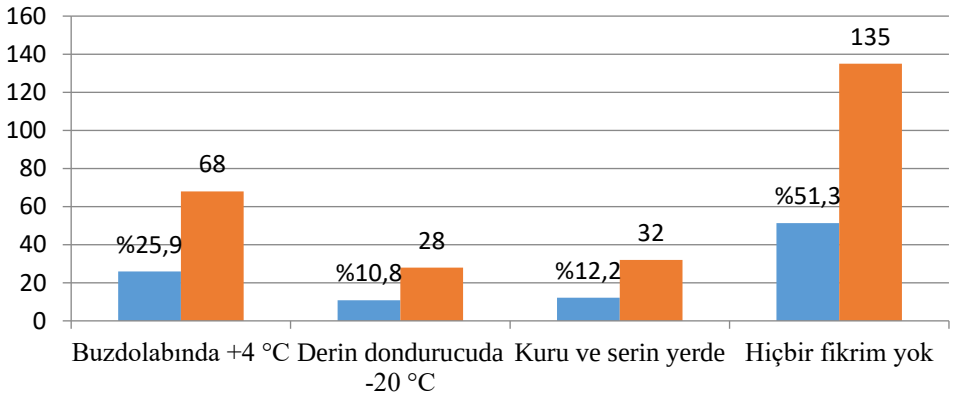
Katılımcılara balı nasıl muhafaza ettikleri sorulmuş; % 6'sının (16 kişi) buzdolabında (+4 °C) muhafaza ettikleri, % 2,2'sinin (6 kişi) derin dondurucuda (-20 °C) muhafaza ettikleri, % 13,5'inin (36 kişi) açıkta dışarıda muhafaza ettikleri, % 77,5'inin (207 kişi) kapalı kapta dışarıda muhafaza ettikleri belirlenmiştir. Araştırmaya katılanların % 0,7'sinin (2 kişi) ise hiç bir fikirlerinin olmadığını belirlenmiştir.

Tablo 5. Katılımcıların polen ve pergayı nasıl muhafaza ettikleri



Polen ve perga'nın saklanması hakkında katılımcıların % 24,8'i (65 kişi) buzdolabında (+4 °C), % 6,1'i (16 kişi) derin dondurucuda (-20 °C), % 32,4'ü (85 kişi) kuru ve serin yerde muhafaza ederim derken; % 36,6'sı ise (96 kişi) hiçbir fikirlerinin olmadığını belirtmiştir.

Tablo 6. Katılımcıların arı sütünü nasıl muhafaza ettikleri



Arı sütünün nasıl saklanacağı konusunda katılımcıların % 25,9'unun (68 kişi) buzdolabında (+4 °C), %10,6'sının (28 kişi) derin dondurucuda (-20 °C), %12,2'sinin (32 kişi) kuru ve serin yerde muhafaza ettikleri belirlenmiştir. Katılımcıların yarısından fazlası olan %51,3'ünün ise; (135 kişi) arı sütünü nasıl muhafaza edecekleri hakkında hiç bir fikirlerinin olmadığını belirlenmiştir.

SONUÇ VE ÖNERİLER

Bu çalışma, Nevşehir ilindeki kadın tüketicilerin arı ürünlerinin muhafazası konusundaki bilgi, tutum ve davranışlarına ışık tutmuştur. Araştırma sonuçları, katılımcıların özellikle bal muhafazası konusunda nispeten iyi bir bilgi düzeyine sahip olduklarını göstermiştir; %77,5'i balı kapalı kapta dışarıda muhafaza ettiğini belirtmiştir. Ancak, diğer arı ürünlerinin muhafazası konusunda bilgi eksikliği olduğu gözlemlenmiştir. Örneğin, polen ve perganın doğru muhafazası konusunda yalnızca %32,4'ünün bilgi sahibi olduğu, arı sütünün muhafazası konusunda ise katılımcıların yarısından fazlasının (%51,3) hiçbir bilgiye sahip olmadığı tespit edilmiştir. Bu bulgular, arı ürünlerinin muhafazası konusunda toplumda genel bir bilgi eksikliği olduğunu ve özellikle bal dışındaki ürünler için farkındalık artırıcı çalışmalara ihtiyaç duyulduğunu göstermektedir. Katılımcıların demografik özellikleri göz önüne alındığında, eğitim düzeyi yüksek ve çoğunlukla kamu personeli olan bir örneklem grubunda bile bu bilgi eksikliğinin gözlemlenmesi, konunun önemini vurgulamaktadır. Bu doğrultuda, arı ürünlerinin doğru muhafazası konusunda kapsamlı eğitim programları düzenlenmesi, bilgilendirici kampanyalar yürütülmesi ve özellikle annelere yönelik bilinçlendirme çalışmaları yapılması önerilmektedir. Ayrıca, arı ürünlerinin etiketlerinde muhafaza koşullarına dair daha detaylı bilgilerin yer alması, tüketicilerin bu konudaki farkındalığını artırabilir. Gelecekte yapılacak çalışmalarda, farklı bölgelerdeki tüketicilerin bilgi düzeylerinin karşılaştırılması ve arı ürünlerinin muhafazası ile sağlık etkileri arasındaki ilişkinin incelenmesi, konuya daha geniş bir perspektif kazandırabilir. Sonuç olarak, bu araştırma, arı ürünlerinin daha bilinçli tüketimi ve doğru muhafazası konusunda toplumsal farkındalığın artırılması gerekliliğini ortaya koymuştur. Elde edilen bulgular, halk sağlığı politikalarının geliştirilmesine ve beslenme rehberlerinin güncellenmesine katkı sağlayabilir. Bu öneriler doğrultusunda yapılacak çalışmaların, Nevşehir ilindeki kadın tüketicilerin arı ürünlerinin muhafazası konusundaki bilgi ve tutum düzeylerini artıracağı ve dolayısıyla arı ürünlerinden elde edilecek faydayı maksimize edeceği düşünülmektedir. Bu apiterapi ürünleri, geleneksel ve tamamlayıcı tıp uygulamalarında giderek daha fazla ilgi görmektedir. Ancak, her doğal ürün gibi, bu ürünlerin de potansiyel yan etkileri ve etkileşimleri olabileceği unutulmamalı ve kullanımları konusunda bir sağlık profesyoneline danışılmalıdır. Benzer şekilde Özdemir (2025) de yaptığı çalışmada tıbbi aromatik bitkilerin de aynı apiterapi ürünlerinde olduğu gibi sağlık profesyonellerince önerilen dozda kullanılması gerektiğine vurgu yapmıştır. Bu sonuçlar Nevşehir ili örnekleminde yapılmış kesitsel bir çalışmadır. Farklı örneklem grubunda farklı tarihlerde yapılacak çalışmada farklı sonuçlar elde edilebilir.

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HEAT STRESS IN COTTON

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ABSTRACT

The optimum temperatures for cotton are between 20 and 30 °C. Cotton yield and quality are significantly reduced, especially when daily maximum temperatures are above 35 ºC. Heat stress causes an increase in the production of hydrogen peroxide, superoxide radical, and hydroxyl radical reactive oxygen species. Photosynthesis is suppressed while respiration increases and, as a result, the quantity and distribution of assimilates that support boll development are disturbed. The suppression of assimilate synthesis reduces root depth and volume. Although cotton is sensitive to temperature during the growing period, the anthesis period following flowering is particularly sensitive to high temperatures. The formation of male and female gametes in the flower and the viscosity of the stigma are disrupted. As a result, the square, flower, and especially the young bolls may fall off and the number of seeds in the boll may decrease. Fiber length may be reduced, while fibers may coarsen. The negative effects are exacerbated when high temperatures are combined with water stress.

Keywords: Boll Retention, Fiber Quality, Heat Stress, Photosynthesis, Yield

PAMUKTA YÜKSEK SICAKLIK STRESİ

ÖZET

Pamuk için optimum sıcaklıklar 20 ila 30 °C arasındadır. Pamukta verim ve kalite özellikle günlük maksimum sıcaklıklar 35 ºC'nin üzerinde gerçekleştiğinde önemli ölçüde azalmaktadır. Yüksek sıcaklık stresi hidrojen peroksit, süper oksit radikal ve hidroksil radikal gibi reaktif oksijen türlerinin üretiminde artışa neden olmaktadır. Verim ve kalitenin azalışında fotosentezin yavaşlaması buna karşı solunumun artması sonucu koza gelişimini destekleyen asimilatların miktarının ve paylaşımının bozulması etkilidir. Asimilat sentezinin baskılanması kök derinliği ve hacmini azaltmaktadır. Pamuk, gelişme periyodunda sıcaklığa karşı hassas olmasına karşın çiçeklenmeyi izleyen anthesis dönemi yüksek sıcaklığa özellikle duyarlıdır. Çiçekte erkek ve dişi gamet oluşumu ve dişicik tepesi vizkozitesi bozulmaktadır. Sonuçta tarak, çiçek ve özellikle genç kozaların dökülmesi ve kozada tohum sayısının azalması görülebilir. Lif uzunluğu azabilir buna karşın lifler kabalaşabilir. Yüksek sıcaklıklar su stresi ile birleştiğinde olumsuz etkiler daha da ağırlaşmaktadır.

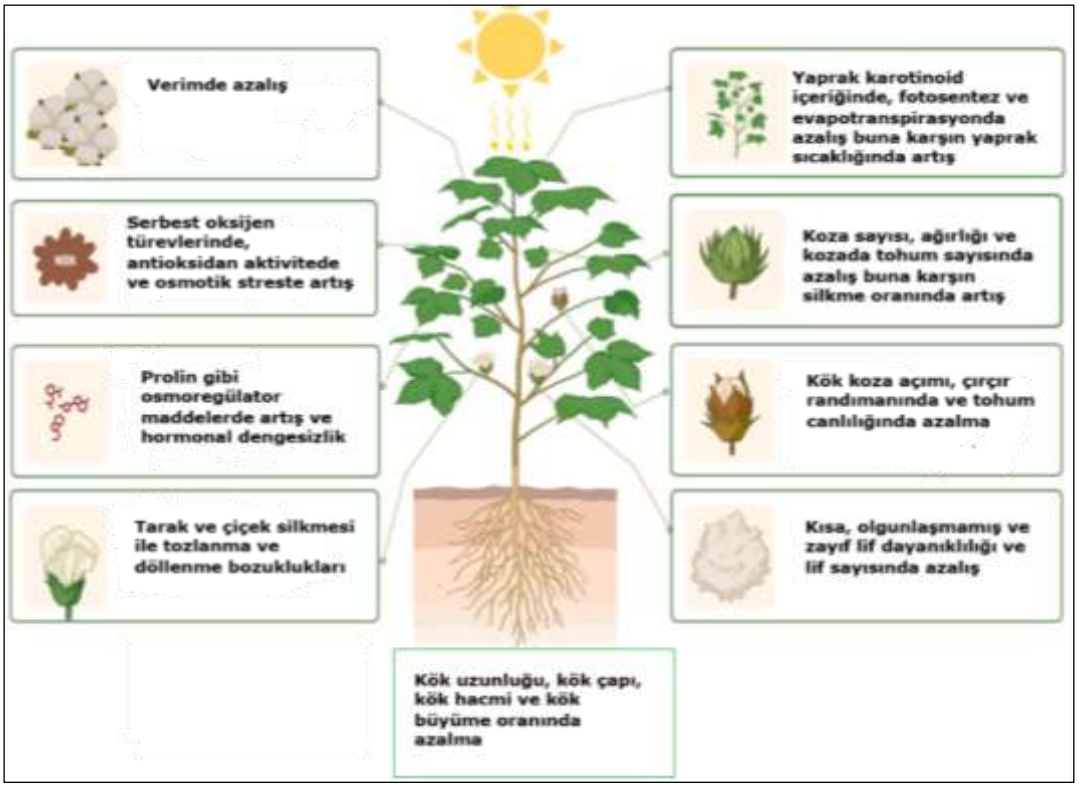
Anahtar Kelimeler: Fotosentez, Koza Bağlama, Lif Kalitesi, Yüksek Sıcaklık Stresi, Verim

1. GİRİŞ

Küresel iklim değişikliğinin bir sonucu olarak sıcaklıklar arttıkça yüksek sıcaklık stresi (HS) oluşumlarının sıklığı, süresi ve yoğunluğu artmaktadır (Iqbal vd., 2023). Fotoperiyoda duyarlı olamayan pamuk çiçeklenme periyodunda sıcaklığa karşı oldukça hassastır (Ünay ve Başal, 2005). Pamukta verim yönünden görülen farklılık %70 oranda sıcaklık dalgalanmalarından kaynaklanmakta ve yüksek sıcaklık çoğu kez kuraklık ile etkileşim halindedir (Rahman, 2006; Farooq vd., 2015; Luo vd., 2014; Nasim vd., 2016; Rahman vd., 2017). Pamukta maksimum büyüme ve gelişme 33 °C'de gerçekleşse de 36 °C'nin üzerinde silkme nedeniyle koza tutumunda önemli bir düşüşler meydana gelmektedir (Luo, 2011; Nasim vd., 2016; Singh vd., 2007).

Erken büyüme aşamaları, çiçeklenme ve koza gelişimi özellikle tozlanma ve döllenme aşamalarında yüksek sıcaklığın yol açtığı olumsuzluklar görülmektedir (Li vd., 2018). Şekil 1'de görüldüğü gibi fotosentez kapasitesi, oksidatif denge, protein sentezi, stoma davranışları, membran bütünlüğü, lipit oksidasyonu ve karbonhidrat üretimi gibi çeşitli biyokimyasal ve fizyolojik reaksiyonlar HS'ye oldukça hassastır (Karumannil vd., 2023; Yang vd., 2022). Pamukta yüksek sıcaklık ile birlikte reaktif oksijen türevlerinde ve beraberinde süperoksit dismutaz (SOD), katalaz (CAT), peroksidaz (POX) ve askorbat peroksidaz (APX) gibi enzimatik antioksidanların aktivitesinde de önemli artışlar gerçekleşmektedir (Sekmen vd., 2014; Sarwar vd., 2018).

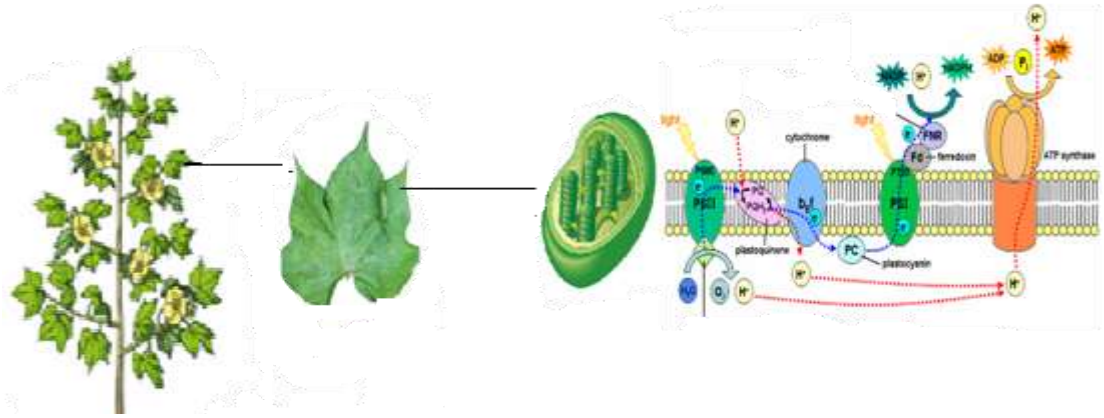
Gece/gündüz şeklinde 32/40 °C'nin üzerindeki sıcaklık, köklerin dağılımını ve büyümesini bozduğu için daha kısa ve bodur kökler görülmektedir (Reddy vd., 1997). Bununla birlikte HS tohum, kök ve yaprak hücrelerinde membranlardaki yağ asidi bileşimini etkilemekte ve hücre işlevlerini olumsuz yönde etkilemektedir (Tsvetkova vd., 2002).



Şekil 1. Pamuk yüksek sıcaklık stresinin etkileri (Dev vd., 2024'den değiştirilerek)

2. FOTOSENTEZ ÜZERİNE ETKİSİ

Pamukta HS artışı ile birlikte yaprak alanı (Abro vd., 2023) ve klorofil sentezinin engellenmesi (Tewari ve Tripathy, 1998) ile birlikte klorofil içeriği (Reddy vd., 2004, Hejnák vd., 2015) azaltmaktadır. Son olarak ise klorofil parçalayıcı enzimlerin aktivitesinde artış görülmektedir (Wang vd., 2018; Hu vd., 2020). Klorofil a klorofil b ye göre olumsuzluklardan daha fazla etkilenmektedir (Thompson vd., 2022). HS sünger mezofil ve palisat tabakası ile birlikte yaprak kalınlığını, hemiselülozik fraksiyonları ve hücre sertliğini artırmaktadır (Muñoz vd., 1993). Şekil 2'de özetlendiği gibi, kloroplastlarda yüksek sıcaklığa en duyarlı bölüm ışık reaksiyonunun gerçekleştiği tilakoid membranlardır (Berry ve Bjorkman, 1980; Demirel, 2008) ve tilakoid membranda düzensizlik ve bozulmalar görülmektedir (Havaux vd., 1996, Sharkey, 2005, Ristic vd., 2007, Herritt ve Fritschi 2020). Kloroplastta yer alan ısı şoku proteini fotosistem II deki elektron taşınma olaylarını korumaktadır (Heckathorn, 1998). Ayrıca, HS mezofil kloroplastlarında grana boyutunu artırmakta, tilakoid membranları bozmakta ve amiloplast birikimini artırmaktadır (Anderson vd., 2021; Zhang vd., 2022). Tilakoid membranlardaki düzensizlik öncelikle fotosistem II'yi etkilemektedir ve fotosentetik fosforilizasyonun engellenmesi ile ATP ve NADPH sentezi azalmaktadır (Haque vd., 2014). RubisCO'nun karboksilasyon yerine oksilasyon kapasitesinin artışı ile birlikte fotorespirasyon artmakta ve net fotosentez azalmaktadır.

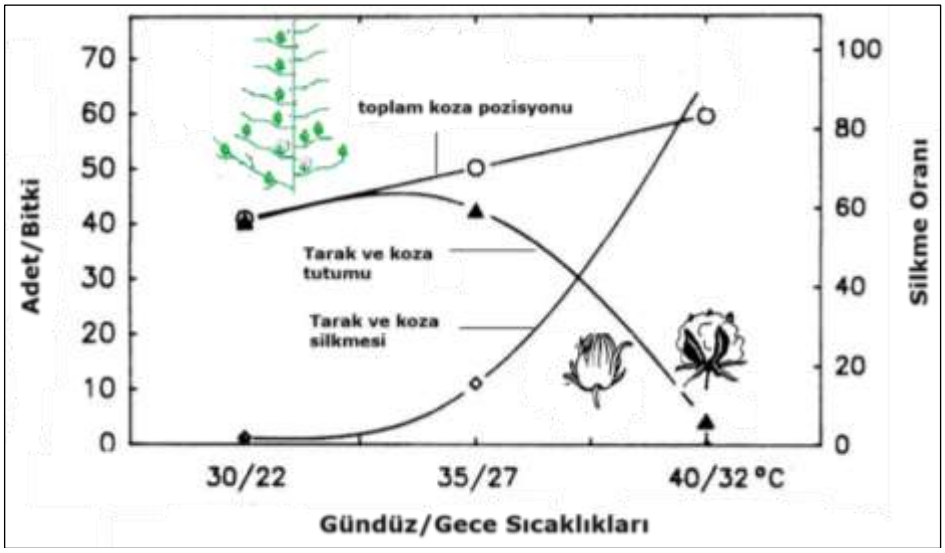


Yaprak alanı	-	Fotosentez	-	Fotosistem II	-
Yaprak dökülmesi	+	Solunum	+	Tilakoid akışkanlığı	+
		Fotorespirasyon	+	Rubisko	-
				Şok proteini	+

Şekil 2. Bitki, yaprak ve kloroplastlarda olan değişimler

3. ÇİÇEKLENME, TOZLANMA-DÖLLENME VE KOZA OLUŞUMUNA ETKİSİ

Döllenmenin gerçekleşmesi için tüm üreme sürecinde senkronizasyon gereklidir. Erkek ve dişi gamet oluşumu, polen çimlenmesi ve polen tüpü gelişimi içerisinde yüksek sıcaklık stresine en duyarlı süreç tozlanma ve döllenmeyi sınırlandırmaktadır (Hedhly vd., 2009; Zinn vd., 2010; Masoomi-Aladizgeh vd., 2022). Polen çimlenmesi optimum değeri 28 °C'dir (Burke vd., 2004), buna karşın 28 °C üzerindeki sıcaklıklarda azalır ve 37 °C'nin üzerindeki sıcaklıklarda ani bir şekilde düşme göstermektedir. Şekil 3'den izlenebildiği gibi, 30 °C'den 40 °C'ye sıcaklık artışı koza pozisyon sayısını artırsa da çiçeklenme aşamasındaki 30 °C'yi aşan yüksek sıcaklıklar tarak ve çiçek silkmesine neden olur (Hemberger vd., 2023) ve 35 °C'de koza tutumu önemli ölçüde azalır ve sıcaklıklar 40 °C'yi aştığında neredeyse durmaktadır (Ahmad vd., 2020).



Şekil 3. Farklı gündüz/gece sıcaklıklarının koza tutumu ve silkme oranlarına etkisi (Hodges vd., 1993'den değiştirilerek).

4. VERİME ETKİSİ

Gece ve gündüz sıcaklıkları, pamuk verim potansiyelinin belirlenmesinde önemli bir rol oynasa da yüksek gece sıcaklığının verimi azaltıcı etkisi daha yüksektir (Khan vd., 2020). Pamukta verim kapasitesinin artması için güçlü bir fide gelişimini takip eden hızlı bir vejetatif gelişme istenmektedir. Optimum sıcaklıkların 2-3 °C üzerindeki sıcaklıklarda biyokütlede %10'luk bir azalış beraberinde %40'lık bir verim azalışı (Majeed vd., 2021) veya her 1 °C sıcaklık artışında 11 kg da^{-1} verim azalışı bildirilmiştir (Singh vd., 2007). Vejetatif büyüme sırasında yüksek sıcaklıklar bodurlaşmaya ve beraberinde koza sayısında azalmaya neden olmaktadır (Schuster ve Monson, 1990). Yüksek sıcaklığın etkisi ile küçük, biçimsiz kozalar (Şekil 4) ve daha az lif miktarı görülmektedir (Khan vd., 2024). Solunum artışına eşlik eden aşırı karbonhidrat kullanımı nedeniyle koza sayısı ve ağırlığındaki azalışa paralel bir şekilde verim düşmektedir (Salman vd., 2019; Xu vd., 2020; Li vd., 2020; Yousaf vd., 2023).

Şekil 4. Yüksek sıcaklıklar nedeniyle kozada meydana gelen şekil bozuklukları (Dodds, 2018)

5. LİF KALİTESİ ÜZERİNE ETKİSİ

Pamukta en önemli lif kalite özellikleri lif inceliği, uzunluğu ve dayanıklılığıdır. Solunumu artıran ve böylelikle karbonhidrat kapasitesini azaltan özellikle gece sıcaklıklarındaki artış koza ve tohumda lif sayısının azalmasına neden olmaktadır (Soliz vd., 2008; Loka and Oosterhuis, 2010). Yüksek sıcaklıklar fotosentetik aktiviteyi, selüloz birikimini, fosfor ve çözünür protein sentezini engellediği için lif uzunluğu ve dayanıklılığı olumsuz etkilenir (Li vd., 2020; Jamil vd., 2020; Aluko vd., 2021). Öte yandan yüksek sıcaklığın en önemli etkilerinden birisi kaba lif oluşumudur (van der Sluijs ve Roth, 2021; Correia vd., 2020). Bazı araştırıcılar ise yüksek sıcaklık ile ortaya çıkan kaba lifliliğin olgun ve daha dayanıklı liflere neden olduğunu belirtmiştir (Ahmad vd., 2020). Aşırı sıcaklıklar kuraklık ile birleştiğinde özellikle lif uzunluğunu olumsuz yönde etkilemektedir (Gao vd., 2021).

6. SONUÇ VE HEDEFLER

Pamuk gelişme dönemlerinin her evresinde yüksek sıcaklıkların olumsuz etkisi görülse de en hassas dönem çiçeklenme ve koza tutumu dönemleridir. Özellikle erkek ve dişi gamet oluşumu, tozlanma ve döllenme fizyolojisinin bozulması kozada tohum sayısı başta olmak üzere tüm koza komponentlerini etkilemektedir. Bu dönemde yapılacak hormon, amino asit ve bitki besin maddelerinin yapraktan uygulanması zararı hafifletebilir. Temmuz ve Ağustos aşırı sıcaklıklarından kaçmak için mümkün olduğunca erken ekim tercih edilmelidir. Yüksek sıcaklıklara toleranslı çeşit geliştirmek için germplazmın değerlendirilmesi ve yabani akrabaların anaç olarak kullanılabilmesi bir ön koşuldur. Bunun için kontrollü koşullarda veya ekim zamanı değişikliği önemli test yöntemleridir. Diploid türlerden tetraploid türlere gen aktarımı çok sayıda sorunla karşılaşsa da ileri ıslah teknikleri bu sorunu çözme konusunda olanak sağlamaktadır. Yabani türler içerisinde *Gossypium robinsonii* buna karşın kültürü yapılan türler içerisinde *Gossypium barbadense* melezleri ümitvar sonuçlar vermiştir.

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GREEN ENERGY, SWEET RESULTS: THE IMPACT OF WIND FARMS ON HONEY PRODUCTION

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ABSTRACT

Wind energy, recognized as one of the most vital sources of renewable energy, has emerged as a significant alternative to meet the growing global demand for power. However, the rapid expansion of wind farms has raised ecological concerns due to their potential negative impacts on pollinators-particularly bees. Unlike most existing studies that primarily focus on the behavioral effects of wind farms on bees, this research adopts a novel approach by investigating the relationship between the presence of wind farms and honey production, utilizing data collected from six provinces in Turkey's Aegean Region. The primary objective of this study is to identify and quantify the key factors influencing honey production by employing advanced machine learning techniques, which have gained increasing prominence in recent years. Comparative analyses, including t-tests, reveal that multiple factors significantly affect honey yields. Furthermore, this research integrates traditional statistical methods with cutting-edge machine learning (ML) approaches to conduct a comprehensive evaluation of the impact of wind farms on honey production. The findings indicate that beekeepers operating near wind farms produce, on average, 866 kg more honey per season compared to those in areas without wind farms. Furthermore, higher levels of honey production are significantly associated with beekeepers who are younger, possess lower levels of formal education, learned the profession through family tradition, own a vehicle, are registered farmers, and are members of cooperatives. Other positively correlated factors include practicing migratory beekeeping, holding agricultural insurance, regularly feeding hives (weekly), owning a greater number of hives, having more experience, and receiving government support. Supporting apicultural activities around wind farms is of great significance for both economic development and environmental sustainability. This research highlights the potential for synergistic collaborations between the wind energy and beekeeping sectors, aiming to enhance both

ecological and economic benefits. Additionally, incorporating bee-friendly vegetation into wind farm projects emerges as an effective strategy for maximizing the ecological and economic advantages of apiculture in these areas.

Keywords: Beekeeping, Honey Production, Energy, Machine Learning, Wind Farms, Turkiye

YEŞİL ENERJİ, TATLI SONUÇLAR: RÜZGÂR ÇİFTLİKLERİNİN BAL ÜRETİMİNE ETKİSİ

ÖZET

1. Yeşil enerji kaynakları arasında kritik bir öneme sahip olan rüzgâr enerjisi, küresel ölçekte artan enerji taleplerini karşılamak amacıyla enerji üretiminde önemli bir alternatif olarak dikkat çekmektedir. Ancak, rüzgâr enerjisinin hızla yayılması, polinatörler üzerinde, özellikle de arılar üzerinde oluşturabileceği olumsuz etkiler nedeniyle ekolojik endişelere yol açmıştır. Çoğunlukla rüzgâr çiftlikleri ile arı davranışları üzerine yapılan araştırmaların aksine, bu çalışma, Türkiye'nin Ege Bölgesi'ndeki altı ilde toplanan 300 veri kullanılarak, rüzgâr çiftlikleri ile bal üretimi arasındaki ilişkiyi ilk defa incelemektedir. Bu çalışmanın amacı, son yıllarda önem düzeyi artan makine öğrenim teknikleri kullanarak bal üretim miktarında etkili olan faktörlerin önem derecelerini belirlemektir. Yapılan karşılaştırmalar sonucunda, t-testi analizine göre birden fazla faktörün bal üretimini etkilediği tespit edilmiştir. Ayrıca bu çalışma, rüzgâr çiftliklerinin bal üretim miktarı üzerindeki etkilerini kapsamlı bir şekilde analiz etmek amacıyla geleneksel istatistiksel yöntemler ile son teknoloji makine öğrenimi (ML) tekniklerinin birleşimini kullanmaktadır. Elde edilen bulgulara göre rüzgâr çiftliği bölgesinde arıcılık yapan bir arıcının rüzgâr çiftliği olmayan bölgelere göre bir sezonda ortalama 866 kg daha fazla bal üretmektedir. Ayrıca, genç yaşta, düşük eğitim seviyesine sahip, mesleği aileden öğrenmiş, araca sahip, çiftlik kaydı bulunan ve kooperatif üyesi olan; göçebe arıcılık yapan, tarım sigortası bulunan, kovanlarını düzenli olarak (haftalık) besleyen, daha fazla kovana sahip, deneyimli ve devlet desteğinden yararlanan arıcıların bal üretim düzeylerinin anlamlı biçimde daha yüksek olduğu tespit edilmiştir. Rüzgâr çiftlikleri çevresinde gerçekleştirilen arıcılık faaliyetlerinin desteklenmesi hem ekonomik hem de çevresel sürdürülebilirlik açısından büyük önem arz etmektedir. Bu araştırma, rüzgâr enerjisi ile arıcılık sektörleri arasında ekonomik ve çevresel faydaları artırabilecek potansiyel iş birliklerinin keşfedilmesine olanak tanımaktadır. Ayrıca, rüzgâr çiftliği projelerinde arı dostu bitki örtüsünün desteklenmesi, arıcılığın hem ekolojik hem de ekonomik avantajlarını somut bir şekilde artırabilecek etkili bir yaklaşım olarak dikkat çekmektedir.

Anahtar Kelimeler: Arıcılık, Bal Üretimi, Enerji, Makine Öğrenimi, Rüzgar Santralleri, Türkiye

1. GİRİŞ

Enerji, temel insan ihtiyaçlarını karşılamanın yanı sıra gıda zincirinden çeşitli ekonomik faaliyetlerin yürütülmesine kadar geniş bir yelpazede kritik bir faktör olarak öne çıkmaktadır. Nüfus artışındaki hızlı yükseliş, ekonomik ve teknolojik gelişmeler, kentleşme dinamikleri ve iklim değişikliği gibi unsurlar, küresel enerji talebinde dikkate değer bir artışa yol açmaktadır (IEA, 2010). Uluslararası Enerji Ajansı'nın (IEA) 2010 yılı raporuna göre, dünya genelinde enerji talebinin 2035 yılına kadar %50 oranında artması öngörülmektedir (IEA, 2010). Bu artan enerji talebi, günlük yaşamın neredeyse her alanında yaygın olarak kullanılan ve tükenme riski taşıyan kömür, petrol ve doğal gaz gibi geleneksel fosil yakıtlardan karşılanmaktadır (Shi vd., 2021). Ancak, enerji ve elektrik üretiminde yenilenemeyen fosil kaynakların kullanımı, çevresel kirliliğe sebep olmakta ve bu durum insan sağlığı üzerinde ciddi olumsuz etkiler doğurmaktadır (Bridges vd., 2015; Hirschberg vd., 2016; Kim vd., 2020). Bunun yanısıra yeşilenerji olarak ta nitelendirilen yenilebilir enerji kaynakları tükenme riski taşımadığı gibi, temiz enerji üreterek kirliliği ve iklim değişikliğine neden olan sera gazı emisyonlarını azaltır; bu durum düşük emisyon seviyeleri sayesinde kirlilik ve buna bağlı sağlık sorunlarının azalmasına katkı sağlar (Silva vd., 2021; Olabi ve Abdelkareem, 2022; Olabi vd., 2022). Bu nedenle, birçok gelişmiş ve gelişmekte olan ülkeler, fosil yakıtların yerine geçebilecek ve çevre dostu olan yenilenebilir enerji kaynaklarına yönelmektedir (Ahmad ve Zhang, 2020; Opeyemi, 2021**).** Yenilenebilir enerji kaynakları içerisinde yer alan rüzgar enerjisi, modern teknolojisi, güvenilir altyapısı ve düşük maliyeti sayesinde diğer yenilenebilir enerji kaynaklarına kıyasla avantaj sağlamaktadır (Barra vd., 2021). Bu yönüyle rüzgâr enerjisi, dünyada yenilenebilir enerji kaynakları arasında en hızlı büyüyen, en yaygın kullanılan ve en fazla yatırım yapılan enerji türü olarak öne çıkmaktadır (Ahmad ve Zhang, 2020; Simla ve Stanek, 2020). Elektrik sektöründe yenilenebilir enerji payının 2023'te %30 seviyesindeyken, 2030 yılına gelindiğinde %46'ya ulaşması öngörülmektedir. Bu da büyük ölçüde güneş ve rüzgâr enerjisinden kaynaklanması beklenmektedir. On yılın sonunda ise rüzgâr enerjisinin, hidroelektrik enerjisini geride bırakarak güneş enerjisinin ardından küresel yenilenebilir elektrik üretiminde ikinci en büyük kaynak olması öngörülmektedir (IEA, 2024).

Rüzgâr enerjisi, elektrik üretimi sırasında çevreye zarar vermediği ve kirlilik yaratmadığı için sürdürülebilir ve çevre dostu bir enerji kaynağıdır (Olabi vd., 2023). Aynı zamanda yenilenebilir enerjinin temel bir unsuru olup düşük maliyetli ve güvenilir olmasıyla da öne çıkmaktadır (Sadorsky, 2021). Elektrik üretiminde kullanımı, diğer enerji santrallerine kıyasla daha az çevresel etkiye sebep olmaktadır (Sayed vd., 2021; Sadorsky, 2021). Yakıt yakılmadığı için rüzgâr çiftlikleri (RÇ) hava ve su kirliliğine neden olmaz (Gomaa vd., 2019; Ghenai vd., 2020). Atmosfere sera gazı salmadığı için temiz bir enerji kaynağı olan rüzgâr enerjisi, enerji güvenliğini artırırken emisyonları da azaltır (Mendecka ve Lombardi, 2019; Olabi vd., 2023). Ayrıca, istihdama ve ekonomik büyümeye katkıda bulunmasının yanı sıra, diğer enerji kaynaklarına kıyasla daha ekonomik ve sürdürülebilir olması nedeniyle de uygun yenilenebilir enerji seçeneklerinden biri olarak değerlendirilmektedir (Chien vd., 2021; Olabi vd., 2023). Bu nedenle, dünya genelindeki birçok ülke, fosil yakıtların yerini almayı ve ulusal enerji şebekelerine daha fazla temiz enerji entegre etmeyi hedefleyerek rüzgâr enerjisi santralleri inşa etmektedir (Nguyen vd., 2021). Rüzgâr çiftliklerinin birçok avantajı bulunmasına rağmen, planlama aşamalarına özen gösterilmeden yapılan kurulumlar, bazı olumsuz sonuçlara yol

açabilmektedir (Leroux vd., 2022). Örneğin, göçmen kuşlar, yarasalar ve arı kolonileri gibi hayvanlar üzerinde olumsuz etkilere yol açarak doğal dengeyi bozmakta; ayrıca orman kaybı, arazi erozyonu ve bitki örtüsüne zarar gibi çevresel sorunlara neden olmaktadır (Smallwood, 2013; Hayes, 2013; Marques vd., 2014; Nazir vd., 2020; Gürbüz vd., 2021; Guest vd., 2022; Leroux vd., 2022). Buna ek olarak, gölgeleme, ışık yansıması, çarpışmalar ve türbin kanatlarının titreşimlerinin arıların yön bulmasını zorlaştırabileceği, ayrıca kanat sesleri ve kaçak voltajın arılar üzerinde başka olumsuz etkilere yol açabileceği konusunda endişeler mevcuttur (Voigt, 2021; Guest vd., 2022; Leroux vd., 2022; Fourrier vd., 2023). Bu kapsamda rüzgar elektrik santrallerinin arıcılık üzerine olan olası negatif etkilerinin belirlenmesi için yapılan bu çalışma, arı kovanlarının uygun uzaklıklara yerleştirilmesi, bu uzaklığın bal üretimine olan etkisi, alanda kısıtlı olan bilgilerin derinleştirilmesi ve arıcılığın sürdürülebilirliği açısından büyük önem arzettiği düşünülmektedir.

Bu çalışma, makine öğrenimi metotunu kullanarak rüzgâr santrallerinin diğer önemli faktörlerle birlikte arı kolonileri ve özellikle bal üretim tahminini nasıl şekillendirdiği araştırılmıştır. Bulgular, rüzgâr santrallerine yakın bölgelerdeki arıcıların, daha uzak bölgelerdeki meslektaşlarına göre belirgin şekilde daha fazla bal elde ettiğini göstermektedir. Araştırma, yenilenebilir enerji ile tarım arasındaki etkileşimlere dikkat çekmektedir. Rüzgâr çiftlikleri ve arıların davranışları üzerine yapılan önceki çalışmalardan (Pustkowiak vd., 2018; Marques vd., 2020; Voigt, 2021; Guest vd., 2022; Leroux vd., 2022; Fourrier vd., 2023) farklı olarak, bu araştırma, diğer temel belirleyicilerle birlikte rüzgâr çiftliklerinin bal üretim miktarıyla olan ilişkisini ilk kez incelenmesi açısından oldukça önemlidir. Çalışmada, Türkiye'nin Ege Bölgesi'nde bulunan altı ilden (Çanakkale, İzmir, Muğla, Balıkesir, Aydın, Manisa) toplanan veriler kullanılmıştır. Bu çalışmanın amacı, makine öğrenimini kullanarak bal üretim miktarında etkili olan faktörlerin önem derecelerini belirlemektir. Yapılan karşılaştırmalar sonucunda, t-testi analizine göre birden fazla faktörün bal üretimini etkilediği tespit edilmiştir. Ayrıca bu çalışma, rüzgâr çiftliklerinin bal üretim miktarı üzerindeki etkilerini kapsamlı bir şekilde analiz etmek amacıyla geleneksel istatistiksel yöntemler ile son teknoloji makine öğrenimi (ML) tekniklerinin birleşimini kullanılmıştır. XGBoost gibi algoritmalar, özellik seçimini kolaylaştırmakla kalmayıp geleneksel yöntemlerin zorluklarını aşarak sağlam ve güvenilir sonuçlar sunmaktadır. Makine öğrenimi, sağlık, sosyal bilimler, ekonomi ve çevre gibi alanlarda önemli bir araç haline gelmiştir. Değişkenlerin önemini otomatik değerlendirme ve karmaşık etkileşimleri yakalama yeteneği, tahminleyebilir (prediktif) modellemeyi yeniden şekillendirmiştir. Boruta ve SHAP gibi yöntemler, etkili yordayıcıları belirlerken model şeffaflığını korur ve hassasiyet ile yorumlanabilirlik arasında denge sağlamaktadır. Bu çalışma, makine öğrenimi yöntemi ile elde edilen veriler ışığında, rüzgâr enerjisi ile arıcılık sektörleri arasında ekonomik ve çevresel faydaları artırabilecek potansiyel iş birliklerinin keşfedilmesine olanak tanımaktadır. Ayrıca, rüzgâr çiftliği projelerinde arı dostu bitki örtüsünün desteklenmesi, arıcılığın hem ekolojik hem de ekonomik avantajlarını somut bir şekilde artırabilecek etkili bir yaklaşım olarak dikkat çekmektedir.

2. MATERYAL VE METOT

2.1. Materyal

Bu çalışmaya ait veriler, Türkiye'nin Ege Bölgesi'nde yürütülen kapsamlı bir anket çalışmasına dayanmaktadır. Bölge, ülkenin toplam rüzgâr enerjisi üretim kapasitesinin yaklaşık %55'ini ve arıcılık faaliyetlerinin yaklaşık %20'sini barındırması açısından stratejik öneme sahiptir. Araştırma kapsamında yer alan Aydın, Balıkesir, Manisa, Çanakkale, İzmir ve Muğla illerindeki arıcılık işletmeleri incelenmiştir. Öncelikle tabakalı örnekleme yöntemi kullanılmak istenmiş, ancak Türkiye İstatistik Kurumu (TÜİK) ve Tarım ve Orman Bakanlığı'nın yalnızca illere ait toplam kovan sayılarını sağlamaması nedeniyle işletme düzeyinde yeterli veri elde edilememiştir. Bu nedenle, örnekleme sürecinde orantılı örnekleme yöntemi tercih edilmiştir. %10'luk bir hata payı gözetilerek örnek hacmi yaklaşık 150 olarak belirlenmiş ve bu sayı iller arasında eşit olarak dağıtılmıştır. Anketler, rüzgâr enerjisi santrallerine (RES) 10 km mesafede faaliyet gösteren sabit arıcılara uygulanmıştır. Aynı işletmenin eş zamanlı olarak hem RES etkisindeki hem de dışında kalan bölgelerde faaliyet göstermesinin mümkün olmaması nedeniyle, karşılaştırmalı analizlerde benzer yapısal özelliklere sahip ancak RES etkisinden uzak konumlanan arıcılık işletmeleri de araştırmaya dâhil edilmiştir. Literatürde (Baidya vd., 2004; Trieb, 2018; Danook vd., 2019) rüzgâr santrallerinin etkili olduğu alan genellikle 10–20 km yarıçap içinde tanımlandığından, bu çalışmada 10 km yarıçaplı bölge "RES bölgesi" olarak kabul edilmiştir. Bu çerçevede, her ilde RES içi ve dışı bölgelerden 25'er anket olmak üzere toplamda 300 anket gerçekleştirilmiştir. Veri toplama süreci, bal hasadının yoğunlaştığı Eylül ve Ekim aylarını kapsamaktadır.

2.2. Metot

Bu çalışmada, denetimli makine öğrenmesi algoritmalarından biri olan Extreme Gradient Boosting (XGBoost) modeli kullanılmıştır. XGBoost, karmaşık veri yapılarında değişkenler arasındaki doğrusal olmayan ilişkileri yüksek hassasiyetle modelleyebilmesiyle öne çıkmaktadır. Bu sayede hem sınıflandırma hem de regresyon problemlerinde yaygın olarak tercih edilir ve değişken önem analizlerinde etkili sonuçlar sunmaktadır. Modelin esnek yapısı, farklı türdeki değişkenlerin birlikte analiz edilmesine ve etkileşimlerin hiyerarşik olarak incelenebilmesine olanak tanımaktadır. Bu özellikleri nedeniyle, çok boyutlu ve heterojen bir yapıya sahip olan arıcılık sektöründe üretim çıktılarının belirleyicilerini analiz etmek için ideal bir yöntem olarak benimsenmiştir.

Araştırmada hedef değişken olarak bal üretim düzeyi belirlenmiştir. Bu değişken, arıcılık faaliyetlerinin nihai sonucunu nicel olarak yansıtmaktadır. Bağımsız değişkenler ise arıcılıkla doğrudan veya dolaylı bağlantılı biyofiziksel, ekonomik, sosyodemografik ve davranışsal göstergelerden oluşmaktadır. Bu göstergeler, arıcıların fiziksel özelliklerinden ekipman kullanım oranına, üretim ölçeğinden coğrafi konuma kadar geniş bir yelpazeyi kapsamaktadır. Veri seti, nicel ve nitel verilerin entegre edilmesiyle çok katmanlı bir yapıda tasarlanmıştır. Bu kapsamda, arıcılara uygulanan yapılandırılmış anketlerden elde edilen bireysel ve işletme düzeyindeki bilgiler ile bölgesel çevresel ve mekânsal veriler bir araya getirilmiştir. Anket verileri, arıcıların demografik özelliklerini, üretim pratiklerini, yönetim

stratejilerini ve bilgi kaynaklarını içerirken; çevresel veriler ise flora çeşitliliği, iklim koşulları, arazi kullanımı ve ulaşım altyapısı gibi dışsal faktörleri yansıtmaktadır. Model eğitildikten sonra, değişken önem analizi yapılarak bal üretimini en çok etkileyen ilk 10 değişken detaylıca incelenmiş ve tartışılmıştır. Bu analiz, yalnızca hangi faktörlerin üretim üzerinde daha belirleyici olduğunu göstermekle kalmamış, aynı zamanda arıcılığın çok boyutlu doğasını ortaya koyan yapısal ilişkileri de açığa çıkarmıştır. Elde edilen bulgular, üretim performansının sadece biyofiziksel koşullara değil, sosyoekonomik ve davranışsal faktörlere de bağlı olduğunu kanıtlayarak, arıcılık politikalarının bütüncül bir yaklaşımla geliştirilmesi gerektiğini desteklemektedir.

3. BULGULAR VE TARTIŞMA

Tablo 1, araştırmada kullanılan bağımlı ve bağımsız değişkenlerin ortalamalarını göstermektedir. Çalışma kapsamında, İzmir, Aydın, Muğla, Manisa, Balıkesir ve Çanakkale illerinden eşit sayıda katılımcı yer almakta olup, her il toplam katılımcıların %16,7'sini temsil etmektedir. Bir sezonda bir arıcılık işletmesi ortalama olarak yaklaşık 3680 kg bal elde etmiştir. Katılımcı arıcıların demografik profili incelendiğinde, %31,7'sinin 1965 yılı öncesinde, %62,3'ünün 1965-1980 yılları arasında ve %6'sının ise 1980 sonrası doğduğu görülmektedir. Eğitim düzeyine bakıldığında, katılımcıların %51,3'ü ilkokul mezunu iken, %16,3'ü yükseköğrenim düzeyine sahiptir. Sosyoekonomik göstergelere göre, arıcıların %91,3'ü evli, %83'ünün kişisel aracı bulunmaktadır. Ayrıca, %41,7'si Çiftçi Kayıt Sistemi'ne (ÇKS) kayıtlıyken, %94,3'ü bir arıcılık kooperatifine üyedir. Arıcıların %77,7'si arıcılığın yanı sıra başka bir mesleği de sürdürmektedir. Katılımcıların %49,3'ü arıcılıkla birlikte bitkisel ve hayvansal üretimle de ilgilenmektedir. %85,3'ü göçebe arıcılık yaparken, %85,7'si bal dışında farklı arıcılık ürünleri de üretmektedir. Ayrıca, %48'i arıcılığı temel geçim kaynağı olarak belirtmiş ve %43'ü arılarını tarımsal sigorta ile güvence altına almıştır.

Tablo 1. Bağımlı ve bağımsız değişkenlerin betimleyici istatistikleri

Değişkenler	İngilizce değişken isimleri	Tanımlayıcı	Ortalama	VİF
Bağımlı Değişkenler	**Dependent variable**			
Bal Üretimi	Honey production	Bir sezonda elde edilen bal miktarı (kg)	3679,82	-
Kukla değişkenler	**Dummy variables**			
İzmir	Izmir	İzmir'de arıcılık yapılıyorsa 1, yapılmıyorsa 0	0.167	2.363
Aydın	Aydin	Aydın'da arıcılık yapılıyorsa 1, yapılmıyorsa 0	0.167	2.372
Muğla	Mugla	Muğla'da arıcılık yapılıyorsa 1, yapılmıyorsa 0	0.167	2.877
Manisa	Manisa	Manisa'da arıcılık yapılıyorsa 1, yapılmıyorsa 0	0.167	2.354
Balıkesir	Balikesir	Balıkesir'de arıcılık yapılıyorsa 1, yapılmıyorsa 0 (referans grubu)	0.167	-
Çanakkale		Çanakkale'de arıcılık yapılıyorsa 1,yapılmıyorsa 0	0.167	2.052
Yaş Grubu < 1965	Age cohort < 1965	Birey 1965'ten önce doğmuşsa 1, değilse 0 (referans grubu)	0.317	-
Yaş Grubu 1965-1980	Age cohort 1965-1980	Birey 1965 - 1980 yaş grubundaysa 1, değilse 0	0.623	1.418
Yaş Grubu (Age cohort) >1980	Age cohort >1980	Birey 1980'den sonra doğmuşsa 1, değilse 0	0.060	1.696
İlkolkul	Elementary school	Birey ilkokul mezunu ya da hiç resmi eğitim almamış ise 1, diğer durumlar için 0 (referans grup)		-
Ortaokul	Secondary school	Birey ortaokul mezunu ise 1, değilse 0	0.127	1.309
Lise	High school	Birey lise mezunu ise 1, değilse 0	0.197	1.517
Üniversite	College	Birey üniversite diplomasına sahipse, yüksek lisans ve doktora dahil, 1; değilse 0	0.163	1.782
Dul/boşanmış	Widow/divorced	İşletmeci dul veya boşanmış ise 1, aksi takdirde 0 (referans grubu)		-
Evli (Married)	Married	Birey evli ise 1, değilse 0	0.913	2.372
Hiç	Never Married	Birey hiç evlenmemişse 1, değilse 0	0.047	2.532
Başkaları tarafından öğrenme	Learning by others	Arıcılık başka yöntemlerle öğreniliyorsa 1, aksi takdirde 0 (referans)	0.240	

Babadan öğrenme	Learning by father	Arıcılık babadan miras kaldıysa 1, değilse 0	0.490	2.039
Kurslar aracılığıyla öğrenme	Learning by courses	Arıcılık kurslar aracılığıyla öğrenildiyse 1, değilse 0	0.270	1.757
Araba	Car	Kişinin arabası varsa 1, değilse 0	0.830	1.172
Özel kayıt	Private registration	Arıcılık işletmesine ilişkin faaliyetlere kayıtlı ise 1, kayıtlı değilse 0	0.223	1.253
Çiftlik kaydı	Farm registration	İşletme çiftçi kayıt sistemine dahil ise 1, değilse 0	0.417	1.646
Kooperatif üyesi	Cooperative member	Arıcılık faaliyeti ile ilgili kooperatif/birlik üyeliği varsa 1, değilse 0	0.943	1.389
Arıcılık dışı işi	Out of beekeeping job	İşletmecinin arıcılık dışında bir işi varsa 1, yoksa 0	0.777	1.622
Bitkisel ve hayvansal üretim	Plant & animal production	Arıcılık dışında bitkisel ve hayvansal üretimle ilgili bir faaliyet varsa 1, yoksa 0	0.493	1.895
Göçebe	Nomad	Eğer birey göçebe ise 1, değilse 0	0.853	1.892
Sigorta	Insurance	Arılara yönelik tarım sigortası varsa 1, yoksa 0	0.430	1.617
Kredi bazlı borç	Credit-based debt	Tarımsal krediye dayalı borç varsa 1, değilse 0	0.377	1.516
Diğer arı ürünleri üretimi	Other bee production	Bal üretimi dışında arıcılık ürünleri üretimi varsa 1, yoksa 0	0.857	1.218
Geçim kaynağı	Livelihood	Arıcılık geçim kaynağıysa 1, değilse 0	0.480	2.212
Diğer kraliçe ırkı	Other queen breed	Kraliçe ırkı Kafkas, Karniyol, İtalyan veya Muğla dışındaysa 1, değilse 0	0.360	2.146
Diğer çalışan ırk	Other working breed	İşçi ve damızlık arı ırkı Kafkas, Karniyol, İtalyan veya Muğla ırklarından farklıysa 1, değilse 0	0.440	2.383
Kraliçe değişimi	Queen replacement	Kolonilerde ana arı değişimi yapılıyorsa 1, aksi takdirde 0	0.107	1.119
Haftalık besleme	Weekly feeding	Koloniler haftalık olarak beslenirse 1, aksi halde 0	0.423	1.351
Beslenme	Nutrition	Koloniler hem kek hem de şekerle besleniyorsa 1, aksi takdirde 0	0.777	1.210
Rüzgar çiftliği bölgesi	Wind farm region	Kovanların rüzgar çiftliği bölgesinde ise 1 , aksi taktirde 0	0.50	1.206
Sürekli değişkenler	**Continuous variables**			

Vücut kitle indeksi	Body mass index	Arıcının vücut kitle indeksi (ağırlığın boyun karesine bölümü)	26.710	1.212
Mesafe	Distance	Kovanların bulunduğu yerin ana yola uzaklığı (km)	2.910	1.227
Deneyim oranı	Experience proportion	Girişimcinin deneyim yaşının oranı	0.393	1.647
Çalışma oranı	Working proportion	Ailede çalışan birey sayısının toplam aile büyüklüğüne oranı	0.452	1.159
Sübvansiyon miktarı	Subsidy amount	Yıl boyunca arıcılık faaliyetleri için devlet destek miktarı (Türk Lirası)/10.000	6.971	11.268
Kovan sayısı	Hive count	Arıcının sahip olduğı kovan sayısı	232	12.744
Malzeme oranı	Materials proportion	İşletmede kovan başına kullanılan toplam malzeme sayısı	0.127	2.446
Sağım numarası	Milking number	Bir yıldaki toplam sağım sayısı	2.477	1.638
Toplam gözlem sayısı			300	

Önemli bir bulgu olarak, arıcılıkla uğraşan katılımcıların %49'u bu mesleği babalarından öğrenmiş, %27'si arıcılıkla ilgili kurslara katılarak bilgi edinmiş, kalan %24'ü ise çeşitli diğer yollarla arıcılığı öğrenmiştir. Koloni bakım uygulamalarına bakıldığında ise, arıcıların %42,3'ü kovanlarını haftalık olarak beslemektedir. Besleme yöntemlerinde ise %77,7'si hem arı keki hem de şeker kullanarak kolonilerini desteklemektedir. Diğer değişkenlerin istatistiksel değerleri Tablo 1'de detaylı olarak sunulmuştur.

Tablo 2, modele dâhil edilen ikili ve çok düzeyli kategorik değişkenler için ortalama bal üretim miktarı ve ortalama bal üretim farkını ve ilgili istatistikleri ele almaktadır. Eğer kategorik değişken iki düzeyden yüksek ise bir düzeyini referans alıp diğer değişkenlerin bal üretim miktarını bu referans düzeyin sahip olduğu bal üretim miktarı ile karşılaştırılmış ve ilgili istatistikler bu verilerden türetilmiştir. Ayrıca eğer değişkenler sürekli bir yapıda ise bu değişkenlerle bölgedeki bal üretim miktarı ile olan ikili korelasyon katsayılarını istatistiki düzeyi ile birlikte hesaplanıp Tablo 2'de sunulmuştur. İllere göre yapılan değerlendirmelerde, sezonluk ortalama bal üretimi bakımından en yüksek verime sahip ilin Muğla olduğu belirlenmiştir. Muğla ilinde faaliyet gösteren arıcılar, bir sezonda ortalama 5.258 kg bal üretmekte olup, bu değer diğer illerle kıyaslandığında oldukça yüksek bir seviyededir. Muğla'yı sırasıyla 4.098 kg ile Manisa ve 4.063 kg ile İzmir illeri takip etmektedir. Buna karşılık, Balıkesir ili, 2.356 kg ile arıcı başına sezonluk ortalama bal üretiminin en düşük olduğu il konumundadır. Veriler incelendiğinde, Muğla'daki bir arıcının, Balıkesir'deki bir arıcıya göre sezonda ortalama 2.902 kg daha fazla bal ürettiği görülmektedir. Bu fark istatistiksel olarak anlamlı bulunmuş olup ($p < 0.05$), iller arasında bal üretim kapasitesine etki eden belirgin farklılıkların varlığını göstermektedir. Balıkesir ili ile yapılan karşılaştırmalarda, Çanakkale hariç diğer dört ilin tamamında istatistiksel olarak anlamlı üretim farkları saptanmıştır. Bu durum, bal üretimindeki farklılıkların yalnızca bireysel ya da işletmeye özgü değişkenlerden

değil; aynı zamanda coğrafi yapı, iklim özellikleri, flora zenginliği ve bitki örtüsündeki çeşitlilik gibi çevresel faktörlerden de kaynaklandığını düşündürmektedir. Özellikle Muğla'nın yüksek üretim kapasitesi, ilin zengin bitki örtüsü, uzun bal üretim sezonu ve uygun iklim koşullarıyla ilişkilendirilebilir. Buna karşın Balıkesir'deki görece düşük üretim miktarı, bölgedeki floristik çeşitliliğin sınırlı olması ya da iklimin arıcılık faaliyetlerine elverişliliğinin düşük olmasından kaynaklanıyor olabilir. Bu bağlamda, arıcılık faaliyetlerinin planlanmasında ve bölgesel desteklerin düzenlenmesinde, söz konusu çevresel faktörlerin dikkate alınması önem arz etmektedir.

Tablo 2. Her kategorik değişken için ortalama bal üretimi ve istatistiksel test

Değişken	Ortalama bal üretim miktarı	Standart sapma	Ortalama bal üretim farkı	Standart sapma	p-değeri	Alt limit GA	Üst limit GA
Kategorik Değişkenler:							
Şehirler							
İzmir	4062.8	3316.2	1706.5	2.900 ***	0.005	728.7	2684.3
Aydın	3231.4	2609.4	875.1	1.708 *	0.091	24.4	1725.9
Muğla	5258.3	4306.7	2902.0	4.115 ***	0.000	1728.4	4075.7
Manisa	4097.6	3703.6	1741.3	2.751 ***	0.007	688.9	2793.7
Çanakkale	3072.4	3.193.8	716.1	1.246	0.216	-238.7	1670.9
Balıkesir (referans)	2356.3	2512.9	-	-	-	-	-
Yaş grupları							
Yaş grubu 1965-1980	3982.2	3330.1	1179.4	3.302 ***	0.001	589.7	1769.1
Yaş grubu > 1980	5166.7	6496.4	2363.8	1.522	0.145	-329.7	5057.4
Yaş grubu < 1965(referans)	2802.8	2546.1	-	-	-	-	-
Eğitim seviyeleri							
Ortaokul	4332.2	3668.1	134.2	0.203	0.840	-971.4	1239.8
Lise	3156.3	3118.6	-1041.7	-2.093 **	0.038	-1866.7	-216.7
Üniversite	2175.9	2588.8	-2022.1	-4.315***	0.000	-2799.3	-1244.8
İlkokul (referans)	4197.9	3571.2	-	-	-	-	-
Medeni hal							
Evli	3684.6	3449.5	437.1	0.602	0.557	-847.7	1721.9
Hiç evlenmemiş	3957.1	3959.9	79.6	0.560	0.581	-1465.4	2884.7
Dul/Boşanmış(referans)	3247.5	2408.3	-	-	-	-	-
Öğrenme türleri							

Babadan öğrenme	4648.9	4012.3	1500.8	3.354 ***	0.001	761.5	2240.1
Kurslar aracılığıyla öğrenme	2393.8	2272.8	-754.3	-1.920 *	0.057	-1404.9	-103.7
Başkaları tarafından öğrenme (referans)	3148.1	2554.9	-	-	-	-	-
İkili (kukla) Değişkenler:							
Araba							
Evet	3867.8	3638.3	1105.6	3.119 ***	0.002	518.6	1692.7
Hayır (referans)	2762.2	1922.6	-	-	-	-	-
Özel kayıt							
Evet	3738.3	3651.6	75.27	0.151	0.880	-751.2	901.8
Hayır (referans)	3663.0	3372.8	-	-	-	-	-
Çiftlik kaydı							
Evet	4478.4	4077.5	1368.9	3.26 ***	0.001	674.9	2063.0
Hayır (referans)	3109.4	2755.5	-	-	-	-	-
Kooperatif üyesi							
Evet	3779.5	3460.8	1758.8	2.846 ***	0.009	693.4	2824.2
Hayır (referans)	2020.7	2402.9	-	-	-	-	-
Arıcılık dışında işi olan							
Evet	3488.9	3463.9	-854.9	-1.869 *	0.064	-1613.7	-96.31
Hayır (referans)	4343.9	3251.2	-	-	-	-	-
Bitkisel ve hayvansal üretim							
Evet	4358.0	3944.1	1338.6	3.423 ***	0.001	692.9	1984.2
Hayır (referans)	3019.5	2697.1	-	-	-	-	-
Göçer							
Evet	4189.0	3463.3	3471.8	15.337***	0.000	3098.2	3845.3
Hayır (referans)	717.3	439.4	-	-	-	-	-
Sigorta							
Evet	4649.7	3945.2	1701.6	4.178 ***	0.000	1028.9	2374.4
Hayır (referans)	2948.1	2780.5	-	-	-	-	-
Kredi bazlı borç							
Evet	4779.9	3957.6	1764.8	4.125 ***	0.000	1057.5	2472.1
Hayır (referans)	3015.1	2882.9	-	-	-	-	-
Diğer arı ürünleri üretimi							
Evet	3782.5	3495.8	716.7	1.423	0.160	-123.9	1557.3

Hayır (referans)	3065.9	2976.1	-	-	-	-	-
Geçim kaynağı							
Evet	5412.3	3850.2	3331.7	9.369 ***	0.000	2744.1	3919.2
Hayır (referans)	2080.6	1914.9	-	-	-	-	-
Diğer kraliçe ırkı							
Evet	2923.5	3031.3	-1181.8	-3.035***	0.003	-1824.6	-538.9
Hayır (referans)	4105.3	3573.9	-	-	-	-	-
Diğer çalışan ırk							
Evet	3505.1	3977.9	-311.9	-0.754	0.452	-995.2	371.3
Hayır (referans)	3817.1	2935.8	-	-	-	-	-
Kraliçe arı değişimi							
Evet	4245.0	3840.7	632.7	0.892	0.378	-564.6	1829.9
Hayır (referans)	3612.3	3380.2	-	-	-	-	-
Haftalık besleme							
Evet	4479.3	3945.4	1386.4	3.360 ***	0.000	704.9	2067.8
Hayır (referans)	3092.9	2870.7	-	-	-	-	-
Beslenme							
Evet	3570.9	3124.5	-487.6	-0.858	0.393	-1432.2	457.1
Hayır (referans)	4058.5	4338.3	-	-	-	-	-
Rüzgar çiftliği bölgesi							
Evet	4112.7	3956.4	865.7	2.199 **	0.029	215.9	1515.5
Hayır (referans)	3246.9	2754.9	-	-	-	-	-
Üretim miktarı ile olan korelasyonlar:							
Vücut kitle indeksi	-	-	-	0.045	0.441	-0.05	0.14
Mesafe	-	-	-	-0.049	0.393	-0.14	0.05
Deneyim oranı	-	-	-	0.314***	0.000	0.23	0.40
Çalışma oranı	-	-	-	0.071	0.219	-0.02	0.17
Sübvansiyon miktarı	-	-	-	0.774***	0.000	0.73	0.81
Kovan sayısı	-	-	-	0.818***	0.000	0.78	0.85
Malzeme oranı	-	-	-	-0.456***	0.000	-0.53	-0.38
Sağım numarası	-	-	-	0.434***	0.000	0.35	0.51
Bal üretimi miktarı	3679.8	3430.9	-	-	-	-	-

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. GA güven aralığını ifade eder.

Yaş gruplarına göre yapılan analizler, bal üretim miktarının yaşla birlikte değişkenlik gösterdiğini ortaya koymaktadır. 1980 sonrası doğan genç arıcılar, bir sezonda ortalama 5.167 kg bal üretimiyle en yüksek verime sahip grup olarak öne çıkmaktadır. Bu grubu, sezonda ortalama 3.982 kg bal üreten 1965–1980 doğumlu orta yaş grubundaki arıcılar takip etmekte; 1965 yılı öncesinde doğan yaşlı arıcılar ise ortalama 2.803 kg ile en düşük üretim düzeyine sahip grubu oluşturmaktadır. Veriler, orta yaş grubundaki arıcıların yaşlı arıcılara kıyasla sezonda ortalama 1.179 kg daha fazla bal ürettiğini göstermektedir. Öte yandan, genç ve yaşlı arıcılar arasındaki üretim farkı daha belirgin olmasına rağmen, bu fark istatistiksel olarak anlamlı bulunmamıştır. Bu durum, genç arıcılar grubunda gözlenen yüksek iç grup varyansı ve buna bağlı olarak yüksek standart sapma ile açıklanmaktadır. Genç arıcılardan bazıları oldukça yüksek üretim rakamlarına ulaşırken, bazı bireylerin düşük üretim seviyelerinde kalması, ortalamanın istatistiksel anlamlılığını gölgede bırakmıştır. Bu bulgular, yaş faktörünün deneyimle birlikte üretime etkili olabileceği kadar, fiziksel kapasite, yeniliklere açıklık ve teknolojiyi kullanma becerileri gibi etkenlerle de ilişkili olabileceğini düşündürtmektedir. Özellikle genç arıcıların daha modern yöntemleri benimsemeye yatkın olmaları, verimlilikteki artışa katkı sağlıyor olabilir. Buna karşılık, yaşlı arıcıların daha geleneksel yöntemlerle üretim yapmaları ve fiziksel sınırlılıkların etkisiyle üretimde düşük seviyelerde kalmaları muhtemeldir. Sonuç olarak, yaş grupları arasında gözlemlenen üretim farklılıkları yalnızca deneyim süresiyle değil, çağdaş tarım teknolojilerinin benimsenme düzeyi ve fiziksel iş gücü kapasitesi gibi çok boyutlu faktörlerle birlikte değerlendirilmelidir.

Eğitim düzeyine göre yapılan karşılaştırmalarda, ilkokul mezunu arıcıların sezonluk bal üretiminin diğer gruplara kıyasla daha yüksek olduğu gözlemlenmiştir. Buna göre, ilkokul mezunu bir arıcı bir sezonda ortalama 4.198 kg bal üretirken, üniversite mezunu bir arıcının ortalama üretimi 2.176 kg ile sınırlı kalmaktadır. Bu sonuçlara göre, üniversite mezunu bir arıcının, ilkokul mezunu bir arıcıya kıyasla sezonda ortalama 2.022 kg daha az bal ürettiği anlaşılmaktadır. Ayrıca lise mezunu bir arıcının da ilkokul mezunu bir arıcıya göre ortalama 1.042 kg daha az üretmektedir. Bulgularımızla paralel olarak, Uzundumlu vd. (2011), ilköğretim mezunu arıcıların daha yüksek eğitim düzeyine sahip meslektaşlarına kıyasla daha fazla bal ürettikleri rapor edilmiştir. Öte yandan, Tadesse vd. (2021), elde ettiğimiz sonuçların aksine, eğitim seviyesi arttıkça bal üretiminin de arttığını belirlemişlerdir. Bu farklılık, çalışma yapılan bölgelerdeki üretim pratikleri, teknoloji kullanımı ve bilgiye erişim düzeylerindeki değişikliklerden kaynaklanıyor olabilir.

Benzer şekilde, arıcılık mesleğinin edinilme yöntemi de bal üretim miktarı üzerinde belirleyici bir faktör olarak öne çıkmaktadır. Arıcılık becerilerini informal yollarla edinen arıcılar, formal eğitim ve öğretim yoluyla mesleği edinenlere kıyasla daha yüksek seviyede bal üretimi gerçekleştirmektedir. Özellikle mesleği babasından öğrenen arıcılar, sezonda ortalama 4.649 kg bal üretimiyle diğer gruplardan belirgin şekilde istatistiksel önemli düzeyde ayrılmaktadır ($p < 0.05$). Bu grubun, referans grubuna kıyasla ortalama 1.501 kg daha fazla bal ürettiği tespit edilmiştir. Bu durum, deneyime dayalı uygulamalı öğrenmenin ve kuşaktan kuşağa aktarılan bilgi birikiminin, arıcılık faaliyetlerinde daha verimli üretim süreçleri geliştirilmesine olanak sağlamasından kaynaklanmaktadır. Geleneksel bilgi aktarımı, arıcılıkta çevresel koşullara uyum sağlama, sorunlara pratik çözümler üretme ve üretim süreçlerini daha etkin yönetme konusunda önemli avantajlar sunmaktadır.

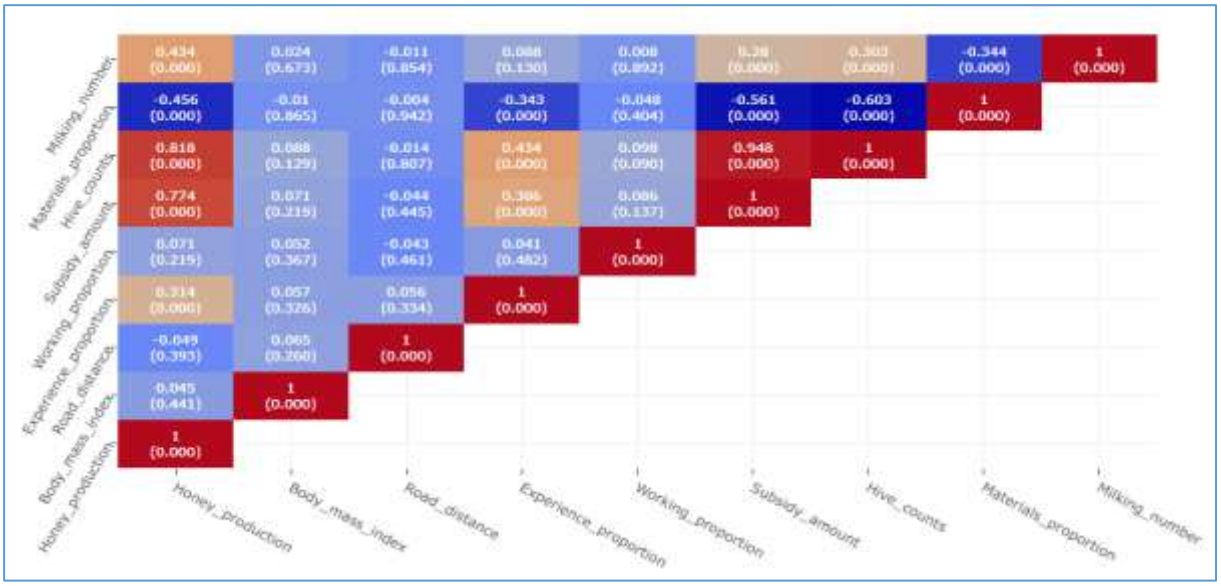
Bal üretim miktarı ile kukla değişkeni arasındaki ilişkiler incelenmiş ve bu analiz sonucunda istatistiki açıdan önemli bulgular elde edilmiştir. Örneğin araba sahibi olan bir arıcının araba sahibi olmayan bir arıcıya kıyasla sezonda ortalama 1.106 kg daha fazla bal üretmektedir. Aynı şekilde arıcıların çiftçi kayıt sistemine kayıtlı olması ve bir arıcılık kooperatifine üye bulunmaları, bal üretim düzeyine anlamlı ve olumlu katkılar sağlamaktadır. Örneğin, çiftlik kaydı bulunan arıcıların yıllık ortalama bal üretimi 4.478 kg iken, kaydı olmayan arıcıların üretimi ortalama 3.109 kg düzeyindedir. Bu fark, çiftlik kaydı bulunan bir arıcının yılda ortalama 1.369 kg daha fazla bal ürettiğini göstermektedir. Benzer şekilde, bir kooperatife üye olan arıcılar da üretim açısından avantajlı konumdadır. Kooperatif üyeleri, üye olmayanlara kıyasla yıllık ortalama 1.759 kg daha fazla bal üretmektedir. Bu bulgular, kurumsal destek mekanizmalarına erişimin ve örgütlü yapılar içinde yer almanın, arıcılık faaliyetlerinin verimliliğini artırıcı bir etkiye sahip olduğunu ortaya koymaktadır. Kooperatife üye olmanın bal verimine pozitif etki olduğu gözlenmiştir (Uzundumlu vd., 2011).

Öte yandan, arıcılık dışında başka bir işle meşgul olan arıcıların bal üretim düzeyleri, yalnızca arıcılıkla uğraşanlara kıyasla daha düşük kalmaktadır. Verilere göre, ek bir işle uğraşan arıcılar, sadece arıcılık yapan arıcılara göre sezonda ortalama 855 kg daha az bal üretmektedir. Bu durum, arıcılığa ayrılan zaman, emek ve kaynakların bölünmesinin, üretim miktarı üzerinde olumsuz bir etki yarattığını göstermektedir. Dolayısıyla, tam zamanlı arıcılık yapan üreticiler, faaliyetlerini daha verimli bir şekilde yürüterek daha yüksek üretim düzeylerine ulaşabilmektedir. Arıcılık faaliyetlerinin yanı sıra bitkisel ve hayvansal üretimle de uğraşan arıcılar, bu faaliyetlerde bulunmayanlara kıyasla sezonda ortalama 1.339 kg daha fazla bal üretmektedir. Bu durum, tarımsal faaliyetlerin birbirini desteklemesi ve arıcılık için uygun çevresel koşulların sağlanmasına katkıda bulunmasından kaynaklanabilir. Göçebe arıcılık yapan arıcılar, sabit arıcılık yapanlara göre sezonda ortalama 3.472 kg daha fazla bal üretmektedir. Bu fark, göçebe arıcılığın bitki örtüsü zengin bölgelerde nektar akımına göre hareket etme olanağı sunmasından ileri gelebilmektedir. Arıcılar, bal üretimini artırmak amacıyla daha kapsamlı göçebe arıcılık uygulamalarına yönelme eğilimi göstermektedir (Grillot, 2020). Arıcının göçebe olması bal verimini pozitif yönde etkilemektedir (Uzundumlu vd., 2011). Ayrıca Tarım sigortası yaptıran, tarımsal kredi kullanan ve arıcılığı ana geçim kaynağı olarak benimseyen arıcılar, sırasıyla ortalama 1.702 kg, 1.765 kg ve 3.332 kg daha fazla bal üretmektedir. Bu durum, söz konusu grupların riski azaltarak üretime daha fazla yatırım yapmaları ve arıcılığa daha fazla kaynak ayırmalarıyla açıklanabilir.

Ege Bölgesi'nde gerçekleştirilen çalışmada, kullanılan kraliçe arı ırkının bal verimi üzerindeki etkisi dikkat çekici düzeyde ortaya konmuştur. Özellikle Kafkas, Karniyol, İtalyan ve Muğla ırkı kraliçe arılarla çalışan arıcıların, diğer ırkları tercih edenlere kıyasla anlamlı düzeyde daha yüksek bal üretimi gerçekleştirdiği belirlenmiştir. Bu bulgu, arı ırkının genetik yapısı ve fizyolojik özelliklerinin, üretim verimliliği üzerinde kritik bir rol oynadığını göstermektedir. Bal üretimini etkileyen temel faktörler arasında yalnızca arı ırkı değil; aynı zamanda iklim koşulları, parazit ve hastalık baskısı, arıcılıkta uygulanan yönetim stratejileri ve çevresel flora çeşitliliği de önemli yer tutmaktadır (Karadaş ve Birinci, 2018; Çelik ve Yılmaz, 2019). Özellikle koloni yönetiminde besleme sıklığı öne çıkan bir değişkendir. Araştırma bulgularına göre, kovanlarını haftalık olarak besleyen arıcılar, daha seyrek besleme yapanlara kıyasla

sezonda ortalama 1.386 kg daha fazla bal üretmektedir. Bu fark, düzenli beslemenin koloni gelişimini hızlandırarak arı sağlığını desteklemesiyle açıklanabilir.

Dikkat çeken bir diğer sonuç ise, kovanların konumlandırıldığı çevresel koşulların bal verimi üzerindeki etkisidir. Rüzgar enerji santrali (RES) bölgelerinde faaliyet gösteren arıcıların, RES dışı bölgelerdeki meslektaşlarına kıyasla sezonda ortalama 866 kg daha fazla bal ürettiği belirlenmiştir ve bu fark istatistiksel olarak anlamlı bulunmuştur ($p < 0.05$). Bu durum, RES bölgelerinde kimyasal tarım ilaçlamalarının daha sınırlı olması, çevresel stres faktörlerinin düşük düzeyde seyretmesi ya da flora çeşitliliğinin daha iyi korunmuş olmasıyla ilişkilendirilebilir. Bu bulgular, bal üretimini artırmaya yönelik stratejilerin yalnızca biyolojik faktörlerle değil; aynı zamanda yönetsel ve çevresel unsurlarla bütüncül bir şekilde ele alınması gerektiğini göstermektedir. Arı ırkı seçimi, besleme sıklığı ve kovan yerleşimi gibi kararlar, üretim verimliliğinde belirleyici olmaktadır ve bu nedenle arıcılık faaliyetlerinde bilimsel temelli uygulamaların önemi giderek artmaktadır.



Şekil 1. Bal üretim miktarı ile sürekli değişkenler arasındaki korelasyon analizi

Model kapsamında gerçekleştirilen korelasyon analizi (Şekil 1), sürekli değişkenler ile bal üretimi arasındaki ilişkileri ortaya koyarak bazı dikkat çekici sonuçlar sunmaktadır. Analiz sonuçlarına göre, bal üretim miktarı ile kovan sayısı ve sübvansiyon miktarı arasında yüksek düzeyde pozitif korelasyon tespit edilmiş ve bu ilişki düzeyi istatistiksel olarak önemli bulunmuştur. Bu bulgular, özellikle üretim kapasitesini doğrudan etkileyen kovan sayısının ve sağlanan ekonomik desteklerin bal üretimi üzerinde belirleyici bir rol oynadığını göstermektedir. Kovan sayısı, doğal olarak üretim potansiyelini yansıtan bir unsur olarak öne çıkmakta; sübvansiyon desteği ise arıcının üretim faaliyetlerini genişletmesine, ekipman yatırımlarını artırmasına veya koloni sağlığını iyileştirmesine olanak tanımaktadır. Bal üretimi ile sağım sayısı arasında ise pozitif önemli ($p < 0.05$) istatistiksel bir ilişki bulunmuştur. Bu

durum, yıl içerisinde daha fazla sağım yapan arıcıların sezonda daha yüksek üretim elde ettiklerini ve kolonilerini daha etkin yönettiklerini göstermektedir.

Arıcılık deneyimi ile bal üretimi arasında zayıf düzeyde pozitif önemli ($p < 0.05$) istatistiksel bir ilişki gözlenmiştir Bu sonuç, deneyimin üretim sürecine belirli katkılar sağladığını, ancak tek başına üretkenliği artıran yeterli bir unsur olmadığını göstermektedir. Öte yandan, bal üretimi ile malzeme oranı arasında negatif bir ilişki saptanmıştır. Bu bulgu, üretime kıyasla daha fazla girdi kullanımının verimlilik üzerinde olumsuz bir etki yarattığını düşündürmektedir. Aşırı malzeme kullanımı, kaynakların etkin olmayan biçimde tüketildiğini göstermektedir. Bu durum aynı zamanda yüksek girdi maliyetlerinin üretim artışını sınırlayabileceğine işaret etmektedir. Sonuç olarak, model bulguları, bal üretimini artırmaya yönelik stratejiler geliştirilirken özellikle üretim kapasitesine yönelik değişkenler (kovan sayısı) ve ekonomik destek mekanizmalarının (sübvansiyonlar) öncelikli olarak ele alınması gerektiğini göstermektedir. Bunun yanında, sağım sıklığı gibi yönetimsel faktörlerin ve girdi kullanımındaki etkinliğin de üretkenlik açısından kritik olduğu anlaşılmaktadır.

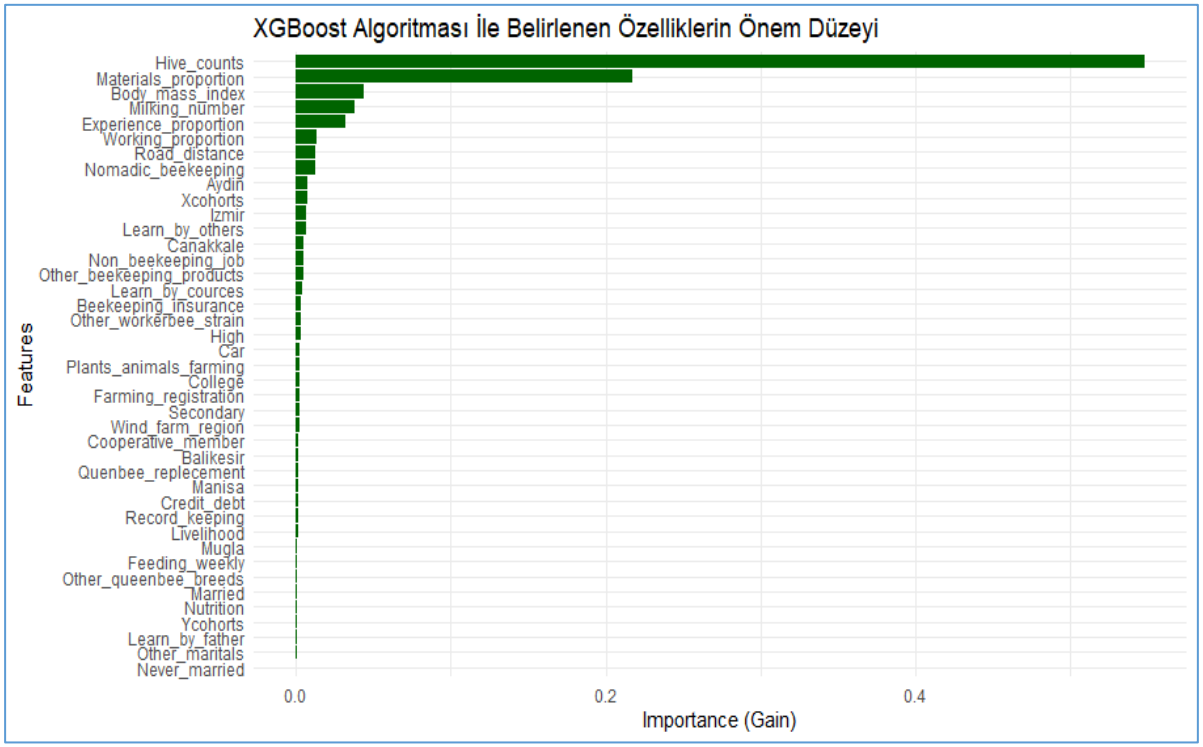
XGBoost modeli kullanılarak gerçekleştirilen analiz sonucunda, arıcılıkta bal üretim düzeyini etkileyen faktörlerin yalnızca biyofiziksel unsurlarla sınırlı olmadığını, aynı zamanda ekonomik, sosyodemografik ve davranışsal dinamiklerin de belirleyici bir rol oynadığını ortaya koymaktadır (Şekil 2-3). Model çıktıları, bal üretim düzeyinin şekillenmesinde çok boyutlu bir etkileşim ağının varlığını açıkça göstermektedir. Bu analiz, arıcılık sektörünün sürdürülebilir büyümesi için hangi faktörlere odaklanılması gerektiğini aydınlatmakta ve politika yapıcılara çok yönlü müdahale stratejileri geliştirme konusunda yol göstermektedir.

Modelin çıktılarına göre, bal üretim düzeyi üzerinde en yüksek etkiye sahip değişken, kovan sayısıdır. Bu, üretim hacminin en temel belirleyicisinin arıcının sahip olduğu kovan miktarı olduğunu göstermektedir. Kovan sayısı yalnızca bir niceliksel kapasite göstergesi değil, aynı zamanda üretim ölçeğini ve potansiyel girdi kullanım düzeyini de temsil etmektedir. İkinci sırada yer alan değişken bal üretim sürecinde kullanılan malzeme oranıdır. Bu bulgu, üretim ölçeği arttıkça daha sistemli ve donanımlı ekipman kullanımına ihtiyaç duyulduğunu göstermektedir. Malzeme kullanımındaki artış, aynı zamanda üretim kapasitesine paralel bir teknik altyapı ihtiyacını yansıtmaktadır. Bu nedenle, arıcıların daha verimli malzeme yönetimi konusunda desteklenmesi önem arz etmektedir.

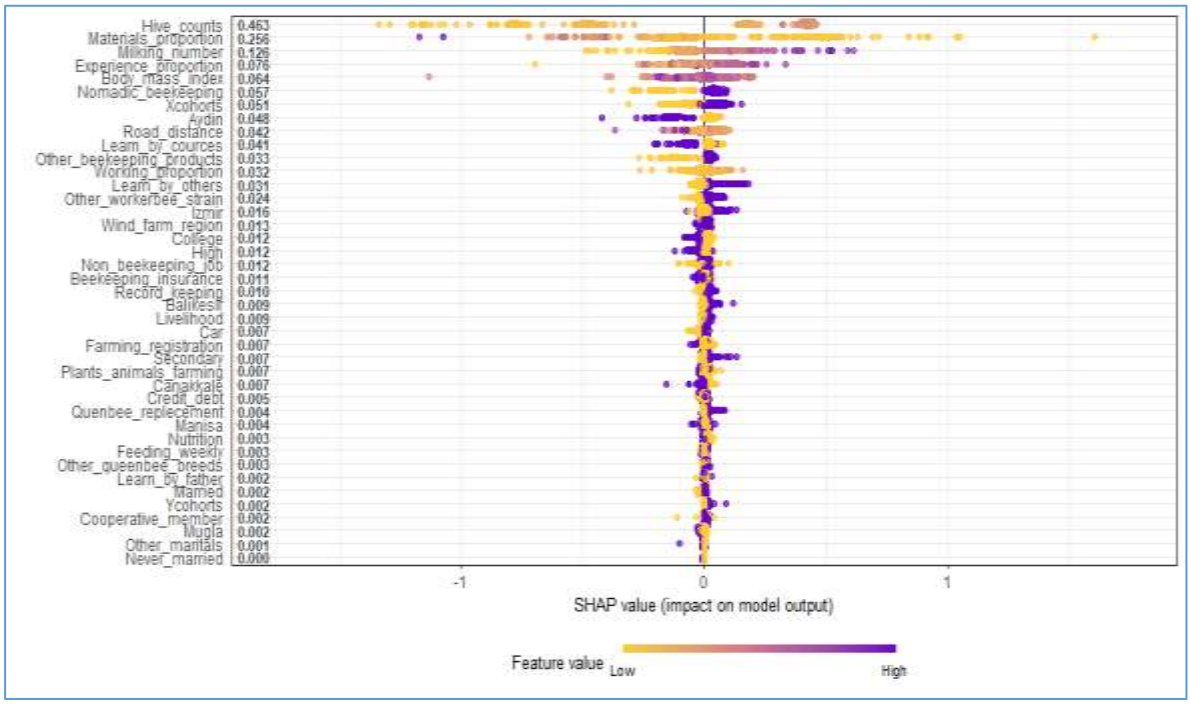
Üçüncü sıradaki vücut kitle indeksi (VKİ), arıcının fiziksel uygunluğunun dolaylı yoldan üretim verimliliği üzerinde etkili olduğunu göstermektedir. Fiziksel kapasite, özellikle üretim sürecinde hareketlilik gerektiren işlerde performansı belirleyici bir unsur haline gelmektedir. Bu durum, sektörde ergonomik çalışma koşullarının geliştirilmesi ve sağlık destek programlarının yaygınlaştırılması gereğini ortaya koymaktadır. Dördüncü sırada yer alan sağım sayısı, doğrudan arıcılık faaliyetiyle ile ilişkili olup çevresel koşullar, flora çeşitliliği ve göç rotaları gibi etmenlerle bağlıdır. Sağım sayısındaki farklılıklar, bal verimini dolaylı olarak etkileyebilecek mekânsal ve çevresel faktörlere işaret etmektedir. Bu bağlamda, arıcılık bölgelerinde ekolojik dengeyi koruyacak politikalar geliştirilmesi önem kazanmaktadır. Beşinci sıradaki deneyim oranı, arıcının bilgi ve tecrübe düzeyinin üretim sürecine olan katkısını ortaya koymaktadır. Daha deneyimli arıcıların teknik yeterlilikleri ve kriz yönetim becerileri daha gelişmiş olup, bu da üretim düzeyine doğrudan yansımaktadır. Ancak, deneyim

faktörü tek başına yeterli olmayıp, diğer değişkenlerle etkileşim içinde değerlendirildiğinde daha anlamlı hale gelmektedir. Altıncı sırada bulunan çalışma oranı, arıcılığın tam zamanlı bir meslek olarak icra edilip edilmediğini göstermektedir. Profesyonel düzeyde yapılan arıcılık faaliyetlerinin üretim düzeyine olumlu katkı sunduğu gözlemlenmektedir. Tam zamanlı çalışan arıcılar, zaman ve kaynaklarını daha etkili biçimde yönetebilmekte, dolayısıyla üretim kapasitesini artırabilmektedir. Yerleşim yerinin merkezî yollara uzaklığı, yedinci sırada yer almakta ve mekânsal erişilebilirliğin üretim kapasitesine olan etkisini yansıtmaktadır. Uzak bölgelerde faaliyet gösteren arıcıların, doğaya yakınlık ve düşük rekabet gibi avantajlara sahip olduğu; bu nedenle üretim düzeylerinin daha yüksek olabileceği anlaşılmaktadır. Bu durum, kırsal altyapının planlanmasında dikkate alınması gereken önemli bir faktördür. Sekizinci sıradaki göçebe arıcılık, farklı flora kaynaklarından faydalanma olanağı sunduğu için daha esnek ve verimli üretim biçimleri ile ilişkilidir. Göçebe üretim modeli, özellikle iklimsel ve çevresel çeşitliliğin yüksek olduğu bölgelerde bal verimliliğini artırıcı etki göstermektedir. Dokuzuncu sıradaki orta kuşak arıcılar, arıcılığı bir hobi değil geçim kaynağı olarak gören bir grup olarak, üretim düzeyine hem beşeri hem de fiziksel sermaye yoluyla katkı sağlamaktadır. Bu kuşakta yer alan bireylerin, daha fazla yatırım yapmaya ve verimliliği artırmaya istekli oldukları görülmektedir. Son olarak, başkalarından öğrenme değişkeni, geleneksel bilgi aktarım yollarının üretim performansına olan olumlu etkilerini ortaya koymaktadır. Aileden öğrenme, usta-çırak ilişkileri ve yöresel bilgi birikimi, modern tekniklerle entegre edildiğinde sektörel büyümeyi destekleyici bir potansiyel taşımaktadır.

Elde edilen tüm bu bulgular, arıcılık sektöründe üretim düzeyini etkileyen faktörlerin çok boyutlu ve iç içe geçmiş bir yapıya sahip olduğunu göstermektedir. Biyofiziksel kapasitenin (kovan sayısı, malzeme oranı) yanı sıra, bireysel özellikler (VKİ, deneyim, çalışma oranı), çevresel koşullar (yerleşim yeri, sağım sayısı) ve sosyo-kültürel etmenler (göçebe arıcılık, başkalarından öğrenme) üretim kapasitesi üzerinde belirleyici rol oynamaktadır. Bu bulgular, arıcılığa yönelik müdahalelerin yalnızca tarımsal üretim araçlarına değil, aynı zamanda eğitim, sağlık, çevre ve kırsal kalkınma gibi alanlara da yayılması gerektiğini göstermektedir. Genel olarak, XGBoost modelinin belirlediği bu ilk on değişken, arıcılıkta bal üretim düzeyini şekillendiren dinamiklerin biyolojik, ekonomik, çevresel ve sosyokültürel unsurlardan oluşan karmaşık bir yapıda olduğunu ortaya koymaktadır. Bu bulgular, arıcılığın sürdürülebilir gelişimi için çok boyutlu politika araçlarına ihtiyaç duyulduğunu göstermektedir.



Şekil 2. Bal üretim düzeyini belirleyen değişkenlerin önem düzeyine göre sıralanışı



Şekil 3. SHAP değerlerinin bal üretim düzeyi üzerindeki etkisi

4. SONUÇ VE ÖNERİLER

Rüzgâr enerjisi, çevreye duyarlı yapısı ve sürdürülebilir kalkınmaya katkısıyla, yenilenebilir enerji kaynakları arasında en hızlı büyüyen ve en fazla yatırım çeken alternatif olarak öne çıkmaktadır. Enerji üretiminde sunduğu avantajlara rağmen, rüzgâr çiftliklerinin plansız ve bilinçsiz şekilde kurulması, doğal habitatlar, ekosistem dengesi ve insan faaliyetleri üzerinde olumsuz etkiler yaratabilmektedir. Literatürde çoğunlukla rüzgâr türbinlerinin arıların yön bulma kabiliyetleri üzerindeki etkileri ve ekosistemlerdeki değişim incelenmiş olsa da, rüzgâr enerjisi altyapısının özellikle bal üretimi gibi tarımsal çıktılar üzerindeki doğrudan etkilerine ilişkin çalışmalar sınırlı kalmıştır. Bu çalışma, Türkiye'nin Ege Bölgesi'nde yer alan altı ili kapsayan kapsamlı bir saha araştırmasına dayanarak, arıcılık üretimi ile rüzgâr enerjisi santrallerine (RES) yakınlık arasındaki ilişkiyi incelemekte ve bu alandaki bilgi boşluğunu doldurmayı amaçlamaktadır. Araştırma bulgularına göre, kovanlarını RES bölgelerinde konumlandıran arıcılar, RES dışı bölgelerde faaliyet gösterenlere kıyasla sezonda ortalama 866 kg daha fazla bal üretmektedir. İl bazında değerlendirildiğinde ise, Muğla ilindeki arıcıların sezonda ortalama 5.258 kg, Balıkesir'dekilerin ise ortalama 2.356 kg bal ürettiği görülmektedir. Ayrıca, genç yaşta, düşük eğitim seviyesine sahip, mesleği aileden öğrenmiş, araca sahip, çiftlik kaydı bulunan ve kooperatif üyesi olan, göçebe arıcılık yapan, tarım sigortası bulunan, kovanlarını düzenli olarak (haftalık) besleyen, daha fazla kovana sahip, deneyimli ve devlet desteğinden yararlanan arıcıların bal üretim miktarlarının daha yüksek olduğu tespit edilmiştir. Bu doğrultuda bal üretimini artırmak amacıyla, deneyimli ve fazla sayıda kovana sahip arıcıların desteklenmesi, devlet desteklerine erişimin kolaylaştırılması, göçebe arıcılık faaliyetlerinin teşvik edilmesi, araç sahibi olmanın sağladığı lojistik avantajların artırılması, çiftlik kaydı ve kooperatif üyeliğinin yaygınlaştırılması, tarım sigortası kapsamının genişletilmesi ve düzenli koloni besleme uygulamalarına yönelik teşviklerin güçlendirilmesi gerekmektedir.

Rüzgâr çiftliklerinin çevresinde yapılan arıcılık faaliyetleri, bu alanlardaki zengin biyoçeşitlilik ve nektar kaynakları sayesinde bal üretimini artırmakta ve çevresel sürdürülebilirliğe katkı sağlamaktadır. Arıcılığı yaşam biçimi haline getiren ve deneyim kazanan üreticiler, verimliliklerini daha da artırmaktadır. Bu bulgular, yenilenebilir enerji projeleri ile tarımsal üretimin uyum içinde yürütülebileceğini göstermektedir. Bu doğrultuda, türbin çevresinde arı dostu bitkilerin teşviki ve rüzgâr santrallerinin arıcılık açısından yüksek potansiyelli alanlar olarak değerlendirilmesi, ekolojik ve ekonomik fayda sağlayabilir. Bu kapsamda önerilen "arıcılık uygunluk haritası", kırsal kalkınma politikalarının şekillendirilmesine katkı sunabilir. Bal üretimi ile rüzgâr santrallerine yakınlık arasında tespit edilen pozitif ilişki, tarımsal üretim, çevresel sürdürülebilirlik ve yenilenebilir enerji arasında uyumlu ve karşılıklı faydaya dayalı bir etkileşimin mümkün olduğunu göstermektedir. Bu durum, enerji, gıda ve ekosistem hizmetlerini birlikte ele alan bütüncül yaklaşımların önemini ortaya koymakta olup, rüzgâr enerjisi ile arıcılığın entegrasyonu, sürdürülebilir kalkınma hedeflerine katkı sağlayacak güçlü bir model olarak öne çıkmaktadır.

XGBoost modeliyle elde edilen bulgular, arıcılık sektörünün sürdürülebilir gelişimi için yalnızca üretim odaklı değil, aynı zamanda sosyal, çevresel ve kurumsal boyutları kapsayan çok boyutlu politika yaklaşımlarının gerekliliğini ortaya koymaktadır. Bu kapsamda, üretim sürecinde ihtiyaç duyulan donanım ve ekipmanlara erişimi kolaylaştırmak amacıyla

kooperatifleşme teşvik edilmeli, toplu alımlar yoluyla maliyetler azaltılmalıdır. Arıcıların fiziksel uygunluklarının üretim performansına olan etkisi dikkate alınarak, sağlık taramaları, ergonomi eğitimleri ve destekleyici sağlık programları hayata geçirilmelidir. Çevresel sürdürülebilirliği gözeten bir yaklaşımla, flora çeşitliliğini koruyacak projeler desteklenmeli, özellikle sağım faaliyetlerinin yoğunlaştığı alanlarda doğal dengeyi koruyucu önlemler güçlendirilmelidir. Bilgi aktarımında geleneksel sistemlerin hâlen önemli bir rol oynadığı arıcılıkta, bu bilgiyi modern tekniklerle harmanlayan hibrit eğitim modelleri geliştirilmeli ve yeni arıcıların deneyimli üreticilerle mentorluk ilişkileri kurmaları sağlanmalıdır. Kırsal bölgelerde üretimin pazara entegrasyonunu kolaylaştırmak amacıyla ulaşım, enerji ve iletişim altyapıları iyileştirilmeli; göçebe arıcılığın taşıdığı potansiyel göz önüne alınarak bu üretim biçimine yönelik geçici kamp alanları ve mevzuat kolaylıkları sunulmalıdır. Tüm bu bütüncül stratejiler, arıcılığın hem ekonomik kalkınmaya hem de ekolojik dengeye katkısını artırarak, sektörü daha dirençli ve sürdürülebilir bir yapıya kavuşturacaktır.

Çalışma, kapsam açısından yalnızca Ege Bölgesi ile sınırlı kalmış olup, bu durum bulguların genellenebilirliğini kısıtlayabilecek bir faktör olarak öne çıkmaktadır. Gelecek araştırmalarda, Türkiye'nin farklı arıcılık bölgelerini kapsayan daha geniş ölçekli çalışmalar yürütülerek bölgesel çeşitliliklerin ve dinamiklerin derinlemesine anlaşılması büyük önem taşımaktadır. Bu doğrultuda, coğrafi bilgi sistemleri (CBS) ve uzaktan algılama sistemleri (UAS) gibi ileri teknolojilerin kullanımı, RES gibi arıcılıkla bağlantılı çevresel, sosyoekonomik ve mekânsal faktörlerin çok boyutlu ve karşılaştırmalı bir şekilde analiz edilmesini mümkün kılacaktır. Söz konusu bütüncül yaklaşımlar, arıcılık sektörüne özgü, yerel koşullara duyarlı ve daha etkili politika önerilerinin geliştirilmesine değerli katkılar sunabilir.

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THE EFFECT OF FERTILISER AND BACTERIA APPLICATIONS ON NITROGEN AND PROTEIN RATIOS IN GRASS PEA

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ABSTRACT

Grass pea, which is used in many areas around the world and mostly grown as a fodder plant in our country, is not cultivated much, although it has the opportunity to grow in every region. Considering the possible climate change scenarios and drought factors that may arise in the future, the importance of the plant becomes more important. When we consider the roughage costs in animal husbandry, the high nutritional value of the plant makes it advantageous again. It is also an important plant in terms of improving the soil and preventing unnecessary fertilizer use by being used as green fertilizer thanks to bacteria that can bind nitrogen in the air specific to legumes. Each plant has its own bacterial strain for effective nitrogen fixation and adequate nodule formation. In this study, the effects of different bacterial strains on the grass pea plant were examined to determine the most effective strain, and since it is desired to have a small amount of nitrogen in the environment for the bacteria to work better, the experiment was carried out using different doses of DAP fertilizer, which also contains phosphorus, as a nitrogen source. was carried out to investigate the effects of isolated rhizobium bacteria on grass pea and also to determine the most appropriate dose of DAP fertilizer. In the study conducted as a pot experiment, control (samples without bacterial inoculation), alfalfa, vetch, soybean and pea bacterial strains inoculated with grass pea seeds; 0, 4 and 10 kg/da DAP fertilizer doses were applied and sown in the medium. Above-ground nitrogen and protein values and below-ground nitrogen and protein values were measured at 50% flowering. According to the results of analysis of variance, for above-ground nitrogen and protein values, bacteria application was found significant at 1% level, while fertilizer doses application was found significant at 5% level. For below-soil nitrogen and protein values, both treatments were found to be significant at 1% level. Above-ground nitrogen values ranged between 3.75-5.91% and protein values ranged between 23.45-36.95%. Subsoil nitrogen values varied between 0.14-2.17% and protein values varied between 0.87-13.58%. The highest results for above-ground plant nitrogen and protein values were obtained in the control group and 4 kg/da DAP fertilizer dose, while the lowest results were determined at 4 and 10 kg/da doses of soybean bacterial strain. For below-ground nitrogen and protein values, the highest values were obtained from soybean bacterial strain and 10 kg/da DAP fertilizer dose, while the lowest values were obtained from alfalfa bacterial strain and 0 kg/da fertilizer dose in the control group. When the results were evaluated,

it was observed that increasing fertilizer doses had positive effects on subsoil nitrogen and protein values, while they did not have much effect on above-soil nitrogen and protein values. It was observed that the bacterial strains used gave better results on above-ground nitrogen and protein values than the uninoculated groups. It is thought that the measurement time may also have a significant effect on the values and it would be appropriate to conduct field trials at different measurement times.

Keywords: Grass pea, Rhizobium, Nitrogen, Protein,

MÜRDÜMÜKTE GÜBRE VE BAKTERİ UYGULAMALARININ AZOT VE PROTEİN ORANLARI ÜZERİNE ETKİSİ

ÖZET

Dünya genelinde birçok alanda kullanılan, ülkemizde çoğunlukla yem bitkisi olarak yetiştirilen mürdümük, her bölgede yetişme imkânı olmasına rağmen tarımı fazla yapılmamaktadır. Gelecekte karşılaşılabilecek olası iklim değişikliği senaryoları ve ortaya çıkacak kuraklık etmenleri göz önüne alındığında bitkinin önemi daha fazla ortaya çıkmaktadır. Hayvancılıktaki kaba yem maliyetlerini düşündüğümüzde de besin değerlerinin yüksek olması bitkiyi yine avantajlı konuma getirmektedir. Baklagillere özgü havada bulunan azotu toprağa bağlayabilen bakteriler sayesinde yeşil gübre olarak kullanılıp, toprağı iyileştirmesi ve gereksiz gübre kullanımının önüne geçilmesi yönünden de önemli bir bitkidir. Azot fiksasyonunun etkili olabilmesi ve yeterli nodül oluşumu için her bitkinin kendine özgü bakteri suşu bulunmaktadır. Çalışmada farklı bakteri suşlarının mürdümük bitkisinde etkileri incelenerek en etkili suşu belirlemek, ayrıca bakterilerin daha iyi çalışabilmesi için ortamda az miktarda da olsa azot bulunması istendiğinden, azot kaynağı olarak, içeriğinde fosfor da bulunan DAP gübresin farklı dozları kullanılarak deneme yürütülmüştür. izole edilen rhizobium bakterilerinin mürdümük üzerinde etkilerini araştırmak ve ayrıca en uygun DAP gübre dozunu ortaya koymak amacıyla gerçekleştirilmiştir. Saksı denemesi şeklinde gerçekleştirilen çalışmada kontrol (bakteri aşılaması yapılmayan örnekler), yonca, fiğ, soya ve bezelye bakteri suşları ile aşılanan mürdümük tohumları; 0, 4 ve 10 kg/da DAP gübre dozlarının uygulandığı ortama ekilerek denemeye alınmıştır. %50 çiçeklenme döneminde yapılan ölçümlerde toprak üstü azot ve protein değerleri ile toprak altı azot ve protein değerleri ölçülmüştür. Varyans analizi sonuçlarına göre toprak üstü azot ve protein değerleri için bakteri uygulaması %1 seviyesinde önemli bulunurken, gübre dozları uygulaması %5 seviyesinde önemli bulunmuştur. Toprak altı azot ve protein değerlerinde ise her iki uyulama da %1 seviyesinde önemli olduğu saptanmıştır. Toprak üstü azot değerleri %3.75-5.91, protein değerleri %23.45-36.95 aralığında değişmiştir. Toprak altı azot değerlerinin %0.14-2.17, protein değerlerinin ise %0.87-13.58 aralığında değiştiği görülmüştür. Elde edilen bulgular incelendiğinde toprak üstü bitki azot ve protein değerleri için en yüksek sonuçlar kontrol grubu ve 4 kg/da DAP gübre dozunda elde edilirken, en düşük sonuçlar soya bakteri suşunun 4 ve 10 kg/da dozlarında tespit edilmiştir. Toprak altı azot ve protein değerleri için ise en yüksek veriler soya bakteri suşu ve 10 kg/da DAP gübre dozundan elde edilirken, en düşük değerler yonca bakteri susu ile kontrol grubunda 0 kg/da gübre dozunda elde edilmiştir. Ortaya çıkan sonuçlar değerlendirildiğinde artan gübre dozlarının toprak altı azot ve protein değerlerine olumlu etkileri gözlenirken, toprak üstü azot ve protein değerlerine fazla etkisi görülmemiştir. Kullanılan bakteri suşlarının toprak üstü azot ve protein değerleri üzerine aşısız gruplardan daha iyi sonuçlar verdiği görülmüştür. Ölçüm zamanının da değerler üzerinde önemli bir etkisinin olabileceği ve farklı ölçüm zamanlarında tarla denemesi de yapılmasının uygun olacağı düşünülmektedir.

Anahtar Kelimeler: Mürdümük, Rhizobium, Azot, Protein,

1.GİRİŞ

Artan dünya nüfusu ile birlikte besin ihtiyacı da paralel olarak artış göstermektedir. Hayvanların kaba yem ihtiyacının karşılanamaması elde edilen verimin azalmasına neden olmakta, bunun sonucunda ise insanların hayvansal protein yönünden eksik kaldığı görülmektedir (Arslan ve Çakmakçı 2011). Baklagiller de insan beslemesinde doğrudan ve dolaylı olarak büyük bir öneme sahiptir. Dünya genelinde özellikle insanların protein ihtiyacının karşılanabilmesi için yüksek protein içerikli bitkilerin yetiştirilmesi öncelikler altına alınmış olup, yapılan çalışmalarla bu bitkilerdeki verimliliğin de üst seviyeye çıkarılması amaçlanmaktadır (Eşiyok, 2016). Ancak üretimi arttırmak için kullanılan gübreler toprağa zarar vermekte ve maliyet açısından sorun oluşturmaktadır. Özellikle münavebe kültürünün yaygınlaşmaması ve aynı ürünlerin yıllar boyunca ekilmesinden dolayı topraklarda belli elementler azalarak, verimin düşmesine sebep olmaktadır. Verimi arttırmak için uygulanan kimyasal gübreler hem maliyetli olmakta hem de insan ve hayvan sağlığı için tehdit oluşturmaktadır (Açıkgöz, 2001). Bunun yanında toprak ıslahında da ön plana çıkan baklagiller toprağın iyileştirilmesinde ve sürdürülebilirliğinde etkin rol oynamaktadır.

Baklagil türleri arasında mürdümük hastalık ve zararlılara olan direnci ile ön plana çıkmaktadır (Vaz Patto vd. 2006). Mürdümük ülkemizin neredeyse her bölgesinde yetiştirilebilme olanağına sahip olan bir baklagil yem bitkisidir. Gelişmiş kök sistemi ile kuraklığa karşı dayanıklı olmasıyla birlikte, yetişme ortamına bakıldığında birçok toprak tipinde başarılı sonuçlar elde edilebilmektedir (Rybinski, 2003). Bu durumlar da tercih edilme sebepleri arasında yer almaktadır. Mürdümük bitkisi kullanım alanları incelendiğinde, insan ve hayvan beslenmesi yanında, toprak ıslahı amacıyla yeşil gübrelemede kullanıldığı da görülmektedir (Karadağ, 2009). Ülkemizde mürdümüğün daha çok hayvan beslemesinde ön plana çıktığı bilinmektedir. Mürdümük bitkisi, kendinden sonra tarımı yapılacak farklı bitkilere de fayda sağlamakta, toprağı azot yönünden iyileştirmektedir (Kumar vd. 2011).

Bakteri aşılaması ile baklagillerin köklerinde nodül oluşumu sağlanarak, havadaki azot bağlanır ve azot ihtiyacı karşılanır. Toprakta doğal olarak bulunan bakteriler az miktarda olduğundan ya da etkileri zayıf olduğundan aşılama işlemi yapılmadığında istenilen nodül oluşumu yeterli düzeyde sağlanamaz (Gök ve Onaç, 1995). Rhizobium bakterilerinin sağladığı azot fiksasyonu ile köklerde oluşacak nodüller vasıtasıyla bitkinin ihtiyacı olan azot karşılanabilir böylece aşırı gübrelemeye ihtiyaç kalmaz. Kimyasal gübrelerin kullanımının sınırlandırılması ile ekonomik olarak avantaj sağlacak olup, ayrıca toprakta oluşabilecek verimsizliğin önüne geçilmesine de sağlayacaktır (Kılıç, 2014). Özellikle baklagillerde bulunan rhizobium bakterileri sayesinde köklerde bağlanan azot daha temiz içerikli bir azot kaynağı olup, bitkisel aksamları da yeşil gübreleme ile toprağa faydalı olmaktadır.

DAP gübresi içeriğinde azot ve fosfor bulunduran bir gübredir. Yağış yüksek olduğunda ya da fazla sulama yapıldığında topraktan hemen yıkanmaz. Bitkiler için en etkili olduğu dönem özellikle ilk gelişme dönemleridir. Bu dönemde fosfor kökün gelişebilmesi için önem arz etmektedir. Baklagillerde sıklıkla kullanılıp, taban gübresi olarak değerlendirilmektedir.

Farklı bitkilerden izole edilmiş Rhizobium bakterilerinin aşılaması ve bünyesinde azot ile fosfor bulunan DAP gübre dozlarının mürdümük bitkisinin toprak altı ve toprak üstü aksamındaki azot ve protein oranlarını belirlemek, bitki gelişimine katkı sağlayarak kullanılabilirliğini arttırmak

ve kullanım alanlarını genişletmek, yeşil gübrelemeye uygunluğunu tespit ve teşvik ederek gübre zararlarını azaltmak projemizin amaçları arasında yer almaktadır.

2.MATERYAL VE METOT

2.1. Materyal

Kocaeli ilinde sera koşullarında saksı denemesi şeklinde yürütülen çalışmada materyal olarak; piyasadan temin edilen DAP gübresi, Toprak, Gübre ve Su Kaynakları Merkez Araştırma Enstitüsü Müdürlüğü'nden temin edilen farklı bitkilerden izole edilmiş bakteri suşları ve Batı Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğünden temin edilen mürdümük tohumları kullanılmıştır.

2.2. Metot

Denemede kullanılan tohumlar dezenfeksiyon edilmek amacıyla %3 lük Sodyum Hipoklorit çözeltisinde 5 dakika bekletilmiş, ardından yıkanmış ve kurutularak işleme uygun hale getirilmiştir (Baltepe ve Mert, 1972). Toprak ise otoklavda 121 ºC de 1 saat süre ile sterilize edilerek kullanılmıştır (Alef ve Nannipleri, 1995). Çalışma 3 tekerrürlü olacak şekilde planlanmıştır. Çalışmada kullanılan toprak karışımı 2/4 tarla toprağı, 1/4 kum ve 1/4 torf şeklindedir. Saksıların derinliği 13 cm, genişliği ise 15 cm'dir. DAP gübresinin (0, 4, 10 kg/da) farklı dozları ortama ilave edilmiş olup, tohumlar ekim öncesi yonca, fiğ, bezelye ve soya bitkilerinden izole edilen bakteri suşu ile muamele edilerek ekilmiştir. Kontrol grubunda hiçbir suş kullanılmamıştır. Saksılara ekilen tohumlardan çıkış sonrası her saksıda 3 adet bitki kalacak şekilde seyreltme yapılmıştır.

Tablo 1. Çalışmada kullanılan toprak karışımının fiziksel ve kimyasal özellikleri

pH	Ec (mS/cm)	Tekstür	Kireç (%)	Organik madde (%)	Azot (%)
7.31	0.193	Kumlu Balçık	5.78	2.46	0.0822

Tablo 1. incelendiğinde çalışmada kullanılan toprak karışımının hafif alkali, tuzsuz, orta kireçli, organik madde içeriği yüksek ve azot içeriği düşük olduğu görülmektedir.

2.3. Analiz Yöntemleri

Toprak üstü bitki azot ve protein içeriğinin tespiti için bitki gövde kısmından alınan örnekler Kjhelldal yöntemine göre analiz edilmiş, ve azot değerleri elde edilmiştir (Kacar, 1972). Elde edilen azot değerlerinin 6,25 katsayısı ile çarpımı neticesinde ise protein değerleri tespit edilmiştir (Bremner, 1965). Toprak altı azot ve protein içeriği tespiti için aynı işlemler uygulanmış ve kök kısmından alınan örnekler kullanılmıştır.

Çalışmada elde edilen veriler JMP istatistik paket programı kullanılarak değerlendirilmiş, yapılan varyans analizi sonucunda ortalamalar arasındaki farklar LSD testi ile gruplandırılmıştır (Düzgüneş ve diğ, 1987).

3.BULGULAR VE TARTIŞMA

3.1. Mürdümükte Toprak Üstü Azot ve Protein İçerikleri

Yapılan ölçümler sonucunda elde edilen toprak üstü azot ve protein değerlerinin varyans analiz sonuçları Tablo 2. de verilmiştir. Değerler incelendiğinde Bakteri türü ve Bakteri türü*Gübre dozu interaksiyonu %1 düzeyinde önemli bulunurken, Gübre dozu %5 düzeyinde istatistiki açıdan önemli bulunmuştur.

Tablo 2. Araştırmada elde edilen toprak üstü bitki azot ve protein değerlerine ait varyans analiz tablosu

Varyasyon Kaynakları	SD	HKT	F
Bakteri türü	4	6.5141867	6.4319**
Gübre (DAP) dozu	2	1.9858800	3.9216*
Bakteri türü* Gübre (DAP) dozu	8	7.7560533	3.8290**
Hata	30	7.596000	
Genel	44	23.852120	

* :P <0. 05, **: P <0. 01, ö.d.: Önemli Değil

Toprak üstü bitki azot ve protein değerlerinin ortalamalarına ait sonuçlar Tablo 3. de verilmiştir.

Tablo 3. Araştırmada elde edilen toprak üstü azot ve protein içeriklerine ait ortalama değerler

Bakteri Suşu	DAP Dozu	Toprak Üstü Azot	Toprak Üstü Protein
Kontrol	0	5.03bd	31.45bd
	4	5.91a	36.95a
	10	4.73bd	29.60bd
Fiğ	0	5.29ac	33.06ac
	4	5.34ac	33.39ac
	10	4.59ce	28.68ce
Yonca	0	5.55ab	34.68ab
	4	4.52ce	28.25ce
	10	4.36de	27.25de
Soya	0	4.94bd	30.89bd
	4	3.80e	23.79e
	10	3.75e	23.45e
Bezelye	0	4.24de	26.52de
	4	4.29de	26.85de
	10	5.05bd	31.56bd
CV (%)		10,56	10.56
LSD		1,12	7.06
Önem		**	**

Çalışmada elde edilen veriler değerlendirildiğinde; en yüksek toprak üstü bitki azot (%5,91) ve protein (%36,95) değerlerinin kontrol grubunda 4 kg/da gübre dozunda elde edildiği belirlenmiştir. En düşük toprak altı azot değerleri soya bakteri suşuyla aşılanmış grupta 4 ve 10 kg/da gübre dozlarında sırasıyla %3.80 ve %3.75 olarak tespit edilmiştir. Protein değerleri ise %23.79 ve %23.45 olarak belirlenmiştir. Bakteri türü açısından kontrol edildiğinde Şekil 1. de görüldüğü gibi aşısız grup en yüksek ortalama değerleri vermiş olup, en yakın ortalama değerler fiğ grubuna ait bakteri suşundan elde edilmiştir. Soya bakteri suşu en düşük ortalamaların olduğu grup olarak görülmektedir. Tablo 3 de belirtilen ortalama değerler tablosu incelendiğinde kullanılan gübre dozları ile farklı bakteri suşlarının etkilerinin değiştiği belirlenmiştir. Toprak üstü azot ve protein değerleri yüksek gübre dozları ile bakteri suşu aşılı suşlarda pozitif yönde artış göstermemiştir.

Yağmur ve Engin (2005) yapmış oldukları aşılama çalışmasında nohut bitkisinde toprak üstü bitki aksamında protein oranlarının değişmediğini belirlemişlerdir. Doğan ve diğ. (2007) çalışmalarında farklı demir dozları ile bakteri aşılmasını denedikleri yerfıstığında protein değerlerinin istatistiki açıdan değişmediğini belirlemişlerdir. Karadağ ve diğ. (2008) farklı illerde yürütmüş oldukları çalışmalarında ekimle birlikte azot ve fosfor gübreleri kullanmış

mürdümükte protein değerlerini % 17.89-26.70 oranlarında belirlemişlerdir. Sarıoğlu (2017) yürütmüş olduğu çalışmada soyada aşılama yapılmayan örneklerde daha yüksek azot değerleri olduğunu belirtmiştir. İşler ve Coşkan (2019) değişik bakteri aşılama yöntemleri ile soya bitkisi üzerinde yürttükleri çalışmalarında aşısız gruplarda azot değerlerinin daha yüksek olduğunu belirtmişlerdir. Tufan (2019) Mürdümük bitkisi ile yaptığı çalışmasında ortalama protein içeriklerini %23.93-27.23 değer aralığında belirlemiştir. Deniz (2020) Çalışmasında mürdümük bitkisinde ortalama toprak üstü protein oranlarını %12.52-16.28 aralığında tespit etmiştir. Deniz ve diğ. (2020) yapmış oldukları çalışmada mürdümük bitkisine ekimle birlikte azot uygulaması yapmış ve toprak üstü protein değerlerini % 11.90-20.23 olarak belirlemişlerdir. Güleç Şen (2021) mürdümükte tuzluluk oranlarının yükseldikçe toprak üstü protein değerlerinin de artış gösterdiğini bildirmiştir. Küçükkaya (2022) mürdümük bitkisi ile yürütmüş olduğu çalışmasında yozgat ilinde toprak üstü protein içeriklerini %27.71-28.88 aralığında belirlemiştir. Sezer (2024) Bilecik ilinde iki yıl süreyle devam ettiği çalışmasında mürdümükte protein değerlerini 2022 yılında ortalama %18.13, 2023 de ise %19.70 olarak belirlemiştir.

İncelenen kaynaklarda aşılama çalışmalarının etkisiz olduğu aşısız grupların daha yüksek ortalamalar verdiği tespit edilmiş, çalışmada da aynı sonuçlar elde edilmiştir. Ancak çalışmada gübre dozu*bakteri suşu interaksiyonunun da önemli olduğu tespit edilmiş ve uygun dozlarda uygun bakteri suşu kullanımında farklı değerler elde edilebileceği düşünülmektedir. Ayrıca incelenen kaynaklarda toprak üstü azot ve protein değerlerinin çalışmada eld edilen değerlerden genel olarak daha düşük olduğu tespit edilmiştir. Bu durumun varyans analiz tablosunda gübre dozu interaksiyonunun önemli bulunmasıyla bağlantılı olarak farklı gübre dozları kullanımı, yağış ve sulamada farklılıklar yada farklı çeşit ve popülasyonlarda bitki kullanımından kaynaklabileceği düşünülmektedir.

3.2. Mürdümükte Toprak Altı Azot ve Protein İçerikleri

Mürdümük bitkisi ile yapılan farklı DAP gübre dozları ve bakteri aşılama işlemi ile elde edilen toprak altı azot ve protein değerlerine ait varyans analiz sonuçları Tablo 4. de verilmiştir. Elde edilen değerler incelendiğinde Bakteri türü, Gübre dozu ve Bakteri türü*Gübre (DAP) dozu interaksiyonlarının %1 düzeyinde istatistiki olarak önemli tespit edilmiştir.

Tablo 4. Araştırmada elde edilen toprak altı bitki azot ve protein değerlerine ait varyans analiz tablosu

Varyasyon Kaynakları	SD	HKT	F
Bakteri türü	4	146.13837	60.7855**
Gübre (DAP) dozu	2	563.10122	468.4378**
Bakteri türü* Gübre (DAP) dozu	8	266.45955	55.4162**
Hata	30	18.03125	
Genel	44	993.73038	

* :P <0. 05, **: P <0. 01, ö.d.: Önemli Değil

Toprak altı bitki azot ve protein değerlerine ait ortalama değerler Tablo 5. de verilmiştir.

Tablo 5. Araştırmada elde edilen toprak altı azot ve protein içeriklerine ait ortalama değerler

Bakteri Suşu	DAP Dozu	Toprak Altı Azot	Toprak Altı Protein
Kontrol	0	0.16g	1.00g
	4	0.39f	2.47f
	10	1.67c	10.47c
Fiğ	0	0.24fg	1.50fg
	4	0.71e	4.45e
	10	0.22fg	1.39fg
Yonca	0	0.14g	0.87g
	4	1.50c	9.37c
	10	1.93b	12.06b
Soya	0	0.25fg	1.58fg
	4	0.34fg	2.16fg
	10	2.17a	13.58a
Bezelye	0	0.20fg	1.25fg
	4	1.26d	7.91d
	10	1.91b	11.97b
CV (%)		14,16	14.16
LSD		0,27	1.74
Önem		**	**

Çalışmada elde edilen ortalama değerler incelendiğinde, en yüksek toprak altı azot ve protein değerleri soya bakteri suşunda 10 kg/da gübre dozunda %2.17 ve %13.58 olarak tespit edilmiştir. En düşük ortalama toprak altı azot ve protein değerleri aşısız grupta ve yonca bakteri suşu ile aşılanmış grupta, 0 kg/da gübre (DAP) dozunda elde edilmiştir. Bu değerler aşısız grupta %0.16 azot ve %1.00 protein, yonca bakteri aşılı grupta ise azot %0.14 ve protein %0.87 olarak tespit edilmiştir. Gübre dozu*bakteri türü interaksiyonu önemli çıkan çalışmada, gübre dozlarının bakteri suşlarına etkisi Tablo 5 de görüldüğü gibi en fazla 10 kg/da ortaya çıkmıştır. Ayrıca yüksek gübre dozlarında bakteri suşu aşılamanın azot ve protein değerleri üzerindeki önemi görülmüştür.

Doğan ve diğ. (2007) bakteri aşılaması yaptıkları çalışmalarında kök azot içeriklerini kontrol etmiş ve anlamlı farklılıklar olduğunu belirtmişlerdir. Coşkan ve diğ. (2009) farklı bakteri suşları ve gübre kullanarak yürüttükleri çalışmalarında soya kök azot değerlerinde farklılıkların olmadığını tespit etmişlerdir. İşler ve Coşkan (2009) soyada kök azot içeriklerini %2.18-2.87 değer aralığında belirlemiş ve en düşük ortalamaların aşısız grupta olduğunu tespit etmişlerdir.

Akkurt (2010) Bakteri aşılaması yapılan fasulye örneklerinde aşısız gruplara göre daha yüksek değerlerin tespit edildiğini bildirmiştir. Sarıoğlu (2017) soya bitkisiyle yapmış olduğu çalışmasında bakteri aşılaması yapılan topraklarda aşısız olanlara göre daha yüksek değerler tespit etmiştir. İncekara (2023) Çalışmasında farklı baklagillerde bakteri aşısız örneklerde düşük değerler elde ederken en iyi ortalamaları rhizobium*azotobakter kombine aşılama yönteminde tespit etmiştir. Literatürde incelenen kaynaklarda yapılan incelemede, çalışmamızda elde edilen sonuçların benzerlik gösterdiği tespit edilmiş ve bakteri aşısı yapılan çalışmaların yüksek değerler verdiği görülmüştür. Bununla birlikte farklı sonuçlar elde edilen çalışmaların da bulunduğu, bu durumun çalışmada elde edilen bakteri suşu*gübre dozu interaksiyonunun istatistiki olarak önemli olması ile bağlantılı olarak çalışmalarda kullanılan farklı dozlarda gübre miktarından ve toprak özelliklerinin farklılığından kaynaklandığı düşünülmektedir. Ayrıca kullanılan bakteri suşlarının farklı olmasından kaynaklı bu durumun ortaya çıkabileceği düşünülmektedir.

4.SONUÇ

Toprak üstü azot ve protein değerleri incelendiğinde yapılan çalışmalarla paralellik gösterdiği ve aşısız denemelerin daha iyi sonuçlar verdiği görülmüştür. DAP gübre dozu açısından ise gübresiz ortalamaların daha yüksek değerler verdiği tespit edilmiştir. Ancak çalışmada gübre dozu*bakteri suşu interaksiyonu %1 düzeyinde önemli bulunmuş kullanılan bakteri suşlarıyla uygulanan gübre dozlarının değerler üzerindeki etkisi görülmüş, bazı bakteri suşlarının farklı dozlardaki gübrelerde kontrol ve gübresiz ortalamalara göre daha yüksek değerler verdiği tespit edilmiştir. Örneğin aşısız grupta 4 kg/da gübre dozunda en yüksek değer elde edilirken yonca ve fiğ bakteri suşu ile aşılı grupların 0 kg/da gübre dozunda da sonraki yüksek değerlerin ortaya çıktığı tespit edilmiştir. Bunun sebebi ise toprakta yeterli miktarda azot ve fosfor bulunmasından kaynaklanabileceği düşünülmektedir. Bununla birlikte çalışmada elde edilen değerlerin literatürde belirtilen çalışmalardan daha yüksek olduğu görülmüştür. Bu durumun çalışmaların yapıldığı ekolojik koşullardan, kullanılan gübre miktarlarından, yağış yada sulama değerlerinin farklılıklarından, tohum genotiplerinin farklılıklarından yada vejetasyon döneminden kaynaklanabileceği düşünülmektedir. Toprak altı azot ve protein değerleri incelendiğinde yapılan çalışmaların büyük çoğunluğu ile benzerlik gösterdiği ve bakteri aşılamanın etkili olduğu görülmüş, aşısız denemeler daha düşük değerler vermiştir. Bu durumun bakterilerin fikse ettiği azotun köklere bağlanmasıyla bağlantılı olabileceği düşünülmektedir. DAP gübre dozları incelendiğinde ise en yüksek değerlerin 10 kg/da gübre dozunda elde edildiği ve bu durumun da artan azot ve fosfor oranlarının bakteri etkinliği üzerindeki etkisinden kaynaklandığı düşünülmektedir. Çalışmada gübre dozu*bakteri suşu interaksiyonu toprak altı azot ve protein değerleri içinde önemli bulunmuş gübre dozlarının farklı bakteri suşları ile etkileşiminin olduğu tespit edilmiştir. Örneğin en yüksek ortalama değer soya bakteri suşunun 10 kg/da gübre dozunda elde edilmiş olmasına rağmen gübre dozlarının tamamına göre en yüksek ortalamalar yonca ve bezelye bakteri suşunda tespit edilmiş, soya bakteri suşunun 0 ve 4 kg/da gübre dozları düşük değerler vermiştir. Genel olarak sonuçlar değerlendirildiğinde kullanılacak gübre miktarının ve bakteri türünün incelenen özelliklerde farklılık gösterdiği ve uygun dozda uygun bakteri suşunun etkili olabileceği, ayrıca

tarla denemesi olarak farklı ekim zamanlarında, hasat zamanı ölçümlerin ve birkaç yıllık denemelerin sonuçlarının incelenmesinin uygun olabileceği düşünülmektedir.

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PLANT PROTEIN REVOLUTION FOR SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT: OPPORTUNITIES AND CHALLENGES

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ABSTRACT

The growing global population and changing dietary habits are placing significant pressure on food systems worldwide. While this pressure sometimes promotes the production of fairer and healthier products, it can also lead to an increase in fast, cheap, and unhealthy production methods. The widespread consumption of fast food has increased the demand for animal food and therefore its production. However, traditional animal protein production has recently faced criticism for its environmental impact, including greenhouse gas emissions, land use issues, water consumption, and biodiversity loss. In this context, the production and adoption of plant-based proteins and foods have been gaining traction.

The aim of this study is to examine the global demand for plant-based proteins and their potential impacts on sustainable agricultural practices and rural development. The "plant-based protein revolution" offers significant opportunities such as enhancing environmental sustainability, ensuring food security, and revitalizing rural economies. However, it also faces various challenges, including productivity, infrastructure, market access, and consumer acceptance. This study will investigate these opportunities and challenges based on data obtained through an extensive literature review. Additionally, the benefits and possible processes of this transformative change in the global food system will be explored.

The plant-based protein revolution presents valuable opportunities to transform agriculture, promote rural development, and build a more sustainable and equitable food system. However, the development of these new protein production models will only be possible through investments in these models, as well as the establishment of policies and collaborations that promote sustainable practices.

The plant-based protein revolution is not merely a dietary trend; it represents a fundamental shift in how we produce and consume food. It is driven by a range of factors, including increasing awareness of the environmental and health impacts of food choices, advancements in food technology, and evolving consumer preferences. While the transition to a plant-based food system offers significant benefits, recognizing and addressing the associated challenges will further improve the process.

This transition is crucial for ensuring food security, mitigating climate change, conserving natural resources, and improving human health. Current food production trends suggest that the future will witness an increase in plant-based food production and consumption. Embracing the plant-based protein revolution is essential for developing innovative foods and constructing more sustainable production processes.

Keywords: Plant-based protein, sustainability, climate

SÜRDÜRÜLEBİLİR TARIM VE KIRSAL KALKINMA İÇİN BİTKİSEL PROTEİN DEVRİMİ: FIRSATLAR VE ZORLUKLAR

ÖZET

Büyüyen küresel nüfus ve değişen beslenme alışkanlıkları, dünya çapındaki gıda sistemleri üzerinde önemli bir baskı oluşturmaktadır. Bu baskı zaman zaman daha adil ve sağlıklı ürünlerin üretimini desteklerken bazen de hızlı, ucuz ve sağlıksız üretimi arttırmaktadır. Fast-food gıda tüketiminin yaygınlaşması ile artan gıda talebi özellikle hayvansal gıda üretimini arttırmıştır. Ancak geleneksel hayvansal protein üretimi, son günlerde sera gazı emisyonları, arazi problemleri, su tüketimi ve biyoçeşitlilik kaybı gibi çevresel sorunlar açısından da ele alınmaktadır. Bu bağlamda bitki bazlı protein üretimi ve bitki bazlı gıdaların yaygınlaştığı da görülmektedir.

Bu çalışmada amaç bitkisel proteinlere yönelik oluşan küresel talebi ve bu talebin sürdürülebilir tarım uygulamaları ve kırsal kalkınma üzerindeki potansiyel etkilerini incelemektir. "Bitkisel protein devrimi", çevresel sürdürülebilirliği artırma, gıda güvenliğini sağlama ve kırsal ekonomileri canlandırma gibi önemli fırsatlar sunmaktadır. Ancak, verimlilik, altyapı, pazar erişimi ve tüketici kabulü gibi çeşitli zorluklarla da karşı karşıyadır. Bu etmenler açısından derin literatür taraması ile elde edilen verilere dayanarak bu fırsatlar ve zorluklar araştırılacaktır. Aynı zamanda küresel gıda sistemindeki bu dönüşümsel değişimin faydaları ve olası süreçleri incelenecektir. Bitkisel protein devrimi, tarımı dönüştürmek, kırsal kalkınmayı teşvik etmek ve daha sürdürülebilir ve adil bir gıda sistemi inşa etmek için önemli fırsatlar sunmaktadır. Ancak bu yeni protein üretim modellerinin gelişimi, modellere yatırım yaparak, sürdürülebilir uygulamaları teşvik eden politikalar ve işbirlikleri geliştirmek ile mümkün olabilecektir.

Bitkisel protein devrimi, yalnızca bir beslenme trendi değil; gıda üretme ve tüketme şeklimizde temel bir değişimdir. Gıda seçimlerinin çevresel ve sağlık etkileri hakkında artan farkındalık, gıda teknolojisindeki gelişmeler ve gelişen tüketici tercihleri dâhil olmak üzere bir dizi faktör tarafından yönlendirilmektedir. Bitkisel merkezli bir gıda sistemine geçiş önemli faydalar sunarken, ilgili zorlukları kabul etmek ve ele almak da süreci iyileştirecektir.

Bu geçiş, gıda güvenliğini sağlamak, iklim değişikliğini azaltmak, doğal kaynakları korumak ve insan sağlığını iyileştirmek için de önem taşımaktadır. Mevcut gıda üretim trendleri, gelecekte daha fazla bitkisel bazlı gıda üretimi/tüketimi yaşanacağını düşündürmektedir. Bitkisel protein devrimini benimsemek, yenilikçi gıdaları üretmek ve daha sürdürülebilir üretim süreçleri inşa etmek için de önem teşkil etmektedir.

Anahtar Kelimeler: bitki bazlı protein, sürdürülebilirlik, iklim

1. INTRODUCTION

Global food systems are under increasing pressure at the intersection of growing world population and changing dietary habits. This situation causes hunger to emerge as a critical and urgent issue worldwide. Indeed, increasing population and consumption patterns create an unprecedented demand load on already limited agricultural and natural resources. One of the harsh realities we face today is that while approximately one billion people struggle with chronic malnutrition, our current agricultural systems simultaneously deplete soil and water resources, threaten biodiversity, and disrupt the climate on a global scale (Foley et al., 2011). In this complex picture, meat consumption, a significant component of the diet, is considered one of the main drivers of global environmental change due to its multifaceted dimensions such as greenhouse gas emissions, land and water use, animal welfare concerns, impacts on human health, and modern farming practices (van der Weele et al., 2019).

In addition to this significant harm caused by human activities to nature, the problem of hunger also maintains its place on the global agenda. The FAO (2020) report reveals that the number of people affected by hunger in the world has shown an alarming slow upward trend in recent years. According to the report, factors such as food insecurity exacerbated by climate change and increasing conflicts worldwide lie behind this increase. The same data paints a grim picture, forecasting that the number of globally undernourished people will exceed 840 million by 2030 (FAO, 2020).

From a nutritional habits perspective, the proliferation of diets high in animal and processed foods is seen to have played a significant role in the increase of non-communicable diseases and deepened the negative environmental health impacts of food production (Blanco-Gutierrez et al., 2020). However, contrasting this general trend, a different awareness is also developing in many countries. There is a not insignificant and growing consumer base that consciously reduces or completely abandons animal product consumption and orients towards more traditional dietary patterns (Derbyshire, 2016; Serra-Majem et al., 2004). Specifically, among consumers adopting models like the flexitarian and Mediterranean diets, factors such as health, ethical values, environmental concerns, and animal welfare come to the fore. With these motivations, it is observed that consumers are reducing meat consumption and increasingly turning towards plant-based options (Derbyshire, 2016). Parallel to this consumer trend, a significant transformation is also taking place in the industrial sphere; industrial efforts to develop healthier and sustainable alternatives to animal products continue unabated (van der Weele et al., 2019).

As a concrete indicator of this transformation, the demand for plant-based proteins in Europe has reached remarkable levels. In the 2016/2017 period, this demand reached approximately 27 million tons of crude protein, and it has been reported that the European Union imports approximately 17 million tons of crude protein annually, a significant portion of which (13 million tons) is soy-based (Commission, 2018). Market data also confirms this rising trend. According to the Vegan Food Market reports prepared by Antriksh (2023), the global market, the global vegan food market is growing rapidly (Antriksh, 2023). Consequently, this increase in plant-based food production is recognized not just as a consumer preference but as an important alternative for transitioning to a more sustainable and ethical production model

(Broad, 2019). In this context, this study aims to comprehensively examine the opportunities presented by, and the challenges faced by, the rapidly growing plant-based food market, driven by increasing consumer interest and diversifying production alternatives.

2. OPPORTUNITIES AND CHALLENGES

This growing interest in plant-based proteins and the consequent developments in production trigger a significant transformation that can be described as a "plant-based protein revolution," and this process brings both considerable opportunities and challenges that need to be overcome.

2.1. Opportunities

The proliferation of the plant-based protein revolution offers significant opportunities, particularly for sustainable agriculture, rural development, and the future of the overall food system. These opportunities can be summarized under the following headings:

1. **Environmental Sustainability:** The first and most prominent opportunity lies in environmental sustainability. Current scientific data consistently show that plant-based diets support both human health and the health of our planet. Reducing large-scale animal food production can offer considerable environmental benefits by significantly reducing greenhouse gas emissions caused by the entire livestock value chain, land-use change and degradation, and the use of water resources, especially those at risk of scarcity (Espinosa-Marrón et al., 2022). Indeed, studies show that high consumption of animal foods creates greater pressure on the environment, whereas high consumption of plant-based foods is associated with lower environmental impact. Significant evidence in this area indicates that plant-based nutrition requires less land use and can mitigate biodiversity loss. Generally evaluated, the current scientific evidence strongly supports the transition to plant-based diets to reduce the environmental footprint of human dietary practices, confirming that this transition will also provide significant benefits for human health (Carey et al., 2023).

2. **Environment and Human Health Interaction:** In addition to environmental benefits, strong health motivations also underlie the shift towards plant-based diets. It is clearly observed that consumers adopting models like flexitarian and Mediterranean diets are increasingly reducing meat consumption and turning more towards plant-based diets due to heightened awareness of issues such as health, ethical values, environmental sensitivity, and animal welfare (Derbyshire, 2016). In fact, plant-based foods offer a significant contribution by providing a wide spectrum of phytochemicals that play critical regulatory roles in human health (Briskin, 2000). Of course, nutrition is complex; while some human nutrient requirements can be met more effectively from plant sources, animal foods might be an easier source for others. This situation suggests

that plant-based and animal-based foods might have a complementary, even symbiotic interaction in terms of their potential to improve human health (van Vliet et al., 2020). However, one of the most dominant motivations for consumers turning to plant-based foods is the desire to protect environmental health. Indeed, the environmental burden of today's food and agricultural system is substantial; the system causes 17.3 billion metric tons of carbon dioxide emissions annually, and a large portion of this massive total, 57%, originates directly from animal food production (Suri & Ray, 2023). From the perspective of consumer perception, health benefits stand out among the main advantages associated with plant-based diets; factors such as reduced saturated fat intake (79% agreement), increased fiber intake (76%), and helping prevent various diseases (70%) are frequently mentioned. However, it has been observed that demographic differences such as age, gender, and education also play a role in the perception of these benefits, although gender differences might be more pronounced than other factors (Lea et al., 2006). From the viewpoint of food industry stakeholders, current market conditions and the global macro-environment are considered to offer a highly favorable ground for investing in plant-based food and protein trends, both now and in the foreseeable future (Aschemann-Witzel et al., 2021).

3. **Market Trends and Consumer Preferences:** This positive health and environmental perception is clearly reflected in concrete market trends. As previously mentioned, Antriksh (2023) reports project the global Vegan Food Market to grow from its USD 28.42 billion value in 2023 to USD 63.23 billion by 2031, showing a strong annual growth rate (CAGR) of 10.53% during this period. A key factor underlying this remarkable growth is the increasing health consciousness among consumers. As people become more aware of the strong link between nutrition and overall health, their preference for plant-based foods, accepted as healthier alternatives compared to animal products, naturally increases (Antriksh, 2023). This trend also serves the goal of sustainable food systems. A sustainable food system aims to provide sufficient and nutritious food for everyone within the framework of limited natural resources, and the food sector, among both consumers and producers, is increasingly focusing on these sustainability issues. At this point, plant-based foods and proteins are considered a new and rapidly growing trend aiming to make a significant contribution to this global challenge (Aschemann-Witzel et al., 2021). Comparative studies on consumer acceptance offer interesting findings. For example, compared to the US, countries like India and China have been found to have significantly higher acceptance of "clean" (lab-grown/cultured) meat and plant-based meat. However, the same study found that food neophobia (reluctance towards new foods) is higher in India and China compared to the US, while attachment to meat is lower. These findings highlight the significant impact of demographic factors and established cultural beliefs on consumer acceptance; notably, a higher level of familiarity has been linked to greater acceptance of plant-based and clean meat in all countries. These results underscore the importance for alternative protein producers to explore new markets and approach them with the right strategies, especially in developing countries where meat consumption continues to rise

(Bryant et al., 2019). Therefore, it is predicted that the PBM (plant-based meat) market will grow with increased awareness, familiarity, and knowledge in the coming period. It is critically important for companies aiming for success in this market to focus on potential benefit categories (health, environment, ethics, etc.) that will help consumers adopt PBM alternatives to win over their target audiences (Safdar et al., 2022).

4. **Revitalization of Rural Economies:** Market growth opens new doors not only for urban consumers and the food industry but also for rural economies. The production of plant-based foods holds the potential to be a significant stakeholder in the rural economy. Specifically, the cultivation of necessary raw materials (e.g., protein crops) for plant-based meat alternatives, the opportunity to transition to new, value-added sectors in agricultural production, and the creation of new market opportunities for these alternative products are considered potential contributions to the rural economy (Newton & Blaustein-Rejto, 2021). Although it is noted that net margins and profitability at the farm level may, in some cases, be lower compared to traditional animal production equivalents, the situation can differ at the processing stage. At this stage, it is stated that plant-based products may provide socio-economic gains, such as the potential to create lower unemployment rates (Varela-Ortega et al., 2021).

In summary, when these factors converge – namely, increasing societal awareness, the desire to protect the planet, efforts to prevent non-communicable diseases, the goal of enhancing food security, the aim of ensuring nutritional adequacy, and the drive to develop sustainable food production practices – they strengthen the call for a holistic food system transformation. It is an undeniable fact that plant-based foods possess immense future potential due to requiring fewer natural resources and causing less harm to the environment (Suri & Ray, 2023). Ultimately, considering the current limited agricultural land, water, and energy resources, plant-based meat and other alternatives offer a promising solution path for sustainably feeding the growing global population.

2.2. Challenges

However, realizing the full potential benefits offered by this plant-based protein revolution faces several serious challenges that must be overcome:

1. **Policy and Regulatory Hurdles:** Firstly, uncertainties in the legal and regulatory framework pose a significant obstacle. Both in Turkey and globally, specific legal regulations and codex work related to plant-based foods are still in development, and the lack of clearly defined, internationally accepted standards in this area creates market uncertainty. This uncertainty complicates the commercialization of plant-based foods in various aspects. The lack of sufficient and standardized information regarding the relative advantages and disadvantages of different plant-derived ingredients and production processes, potential safety concerns (e.g., allergenicity risks), varying regulatory approaches across countries, and supply chain management issues hinder

companies' entry into and growth in this market. Therefore, providing more scientific data and clarity on these issues will help companies enter the plant-based food market more safely and successfully (McClements & Grossmann, 2021). On the other hand, government interventions such as taxation policies, incentive mechanisms, and public education programs could facilitate consumers' shift towards more plant-based diets. However, the effective design and implementation of such policies require more comprehensive and reliable information about the multifaceted social, economic, environmental, and health impacts of replacing animal products with plant-based alternatives.

2. **Infrastructure, Processing, and Industrial Adaptation:** In addition to legislative and policy uncertainties, production infrastructure and processing technologies also present significant challenges. Currently, the plant-based meat industry may face challenges and competition from the established traditional meat industry, particularly concerning legal and regulatory classification issues (Li, 2020). This situation also brings threats such as potential income loss concerns for farmers engaged in traditional agriculture and animal husbandry, barriers preventing these actors from transitioning to alternative meat sectors, and the risk of exclusion from these new sectors (Newton & Blaustein-Rejto, 2021). From a technical standpoint, the successful production of plant-based foods is constrained by difficulties in sourcing adequate quantities of suitable plant-derived ingredients, especially high-quality proteins, in a sustainable manner, and the lack of efficient, large-scale production processes to convert these ingredients into the desired final products (meat, milk, cheese analogues, etc.) sought by consumers. Particularly, creating plant-based analogues of products with complex structural and sensory attributes, such as whole muscle meat, fish, yogurt, and cheese, remains technically challenging with current technology. Therefore, there is a strong need for more fundamental and applied research to understand more deeply the complex relationship between the structural and functional properties of plant-based ingredients and the ability to produce high-quality animal product analogues that consumers wish to consume (McClements & Grossmann, 2021). These technical challenges are coupled with consumer-side barriers. For business opportunities to materialize on a larger scale, technological advancements alone are not sufficient; there must also be a positive shift in consumer beliefs, perceptions, and general understanding. Additionally, a significant contradiction arises from consumers expecting health benefits and "clean labels" (few and understandable ingredients) on one hand, while harboring general skepticism towards processed foods on the other. Overcoming this contradiction requires the development of innovative plant-based foods that can meet both consumer expectations – for instance, having simple and understandable ingredient lists, not containing excessive amounts of ingredients perceived as unhealthy like sugar and salt, and avoiding artificial ingredients unfamiliar or viewed skeptically by consumers (Aschemann-Witzel et al., 2021).

3. **Consumer Acceptance and Dietary Habits:** Finally, perhaps one of the most fundamental challenges is the difficulty in achieving consumer acceptance and changing established dietary habits. It is observed that consumers' awareness level regarding the environmental impacts of meat production is surprisingly low, and this applies to consumers in various European countries as well. Parallel to this, the willingness of people to change their meat consumption behavior (i.e., reduce or substitute – e.g., eating insects or meat substitutes) is generally observed to be low. Unfortunately, insufficient research has yet been conducted on how to more effectively motivate people to reduce meat consumption. Specifically, there is an urgent need for further research focusing on strategies that can help promote pro-environmental meat consumption behavior (e.g., behavioral interventions known as 'nudging'), given the lack of experimental studies that could trigger behavior change. Furthermore, studies representing the general population are scarce, and there is a need for more in-depth and comprehensive research on the underlying factors that increase people's willingness to reduce or substitute meat consumption (Hartmann & Siegrist, 2017). At this point, greater effort is needed to educate consumers accurately and understandably about the potential benefits and possible disadvantages of consuming plant-based foods; only then can consumers make informed and knowledge-based choices (McClements & Grossmann, 2021). An important finding emerging from research is that the main perceived barrier to adopting a plant-based diet is the lack of information about these diets (42% agreement). Moreover, demographic factors such as gender, age, and education have been observed to play a role in the perception of this barrier. For example, non-university graduates and older individuals appear less willing to change their current eating patterns compared to university graduates and younger participants (Lea et al., 2006). As a general trend, it is also noted that consumers' personal benefits (such as health, taste, cost) often take precedence when the environmental impact of food is concerned, and this situation can lead to environmental motivations being overshadowed by other consumption motives (Siegrist et al., 2024).

3. CONCLUSION

This study examined the rapidly growing plant-based food market within the context of pressures on global food systems and changing consumer trends, identifying the significant opportunities it presents and the key challenges it faces. Based on the analyzed data and literature, the following main conclusions have been reached:

- **A High-Potential Environmental and Health Alternative:** Plant-based diets and foods possess the potential to play a critical role in the transition to a sustainable food system by offering environmental advantages such as lower greenhouse gas emissions, land, and water use compared to traditional animal production. Concurrently, driven by increasing health consciousness, they are a significant source of consumer motivation due to potential health benefits like reducing saturated fat intake, increasing fiber intake, and preventing certain diseases.

- **Strong Market Growth and Economic Opportunities:** The global plant-based food market exhibits double-digit growth rates, supported by increasing consumer awareness, health, and ethical concerns. This situation creates a significant area for innovation and investment for the food industry, while also offering new revitalization opportunities for rural economies through the production and processing of plant-based protein raw materials.
- **Importance of Policy and Regulatory Framework:** For the healthy and reliable development of the market, there is an urgent need for clear, harmonized legal regulations and standards at national and international levels. Supportive public policies such as taxation, incentives, and education programs can play a key role in accelerating this transition, but a better understanding of the social, economic, and environmental impacts of these policies is necessary.
- **Need for Technological and Infrastructural Development:** Technological innovation and the development of production infrastructure are needed for plant-based products to successfully mimic the taste, texture, and nutritional value of animal products, particularly meat, milk, and cheese. Strengthening raw material supply chains and scaling up processing technologies are critical for market growth.
- **Challenge of Consumer Acceptance and Behavior Change:** Low consumer awareness of the environmental impacts of meat consumption, established dietary habits, potential reservations about new foods (neophobia), and the lack of information about plant-based products are among the most significant barriers to market expansion. Educating consumers and ensuring products meet sensory expectations are fundamental requirements for increasing acceptance rates.

Ultimately, the full realization of the potential offered by the plant-based food revolution depends on capitalizing on these opportunities and overcoming the challenges. A strong collaboration and coordination established among policymakers, industry players, researchers, and consumers will be decisive in progressing towards a more sustainable, healthy, and ethical global food system.

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THE IMPACT OF GLOBAL WARMING AND CLIMATE CHANGE ON THE POULTRY INDUSTRY

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ABSTRACT

Although the world's climates have seemed stable throughout human history, the findings from the past to the present show that this is not the case and that they have undergone some changes, albeit slightly. While climates may change due to natural causes, there may also be some changes resulting from human-made effects. The pollutants released with the world's population growth and industrialization are at the forefront of the effects that cause global warming and are created by humans. These pollutants directly and indirectly negatively affect the world's atmosphere, as well as the seas, soil and living creatures on earth. The agricultural sector that is most affected by these negativities is the livestock sector, which uses 45% of the world's land area ((Sejian, Gaughan et al. 2015). These effects can be in the form of extreme temperatures, storms and excessive rainfall, which directly affect the welfare and productivity of animals, as well as in the form of a decrease in the production of plant products used in their nutrition and the vegetation cover in pastures, which are their natural feeding areas. In both cases, animal production causes an increase in prices in parallel with the increase in costs along with the decrease in productivity, and therefore a decrease in people's purchasing power. The poultry industry, where most of the production is carried out in closed shelters, is also negatively affected by global warming and climate change. Feed costs, which constitute a large part of production costs, increase feed raw material prices due to the decrease in plant production efficiency, which is one of the negative results of global warming and climate change, as well as increasing the amount of energy required to keep shelter conditions at appropriate levels, and also increases the feed conversion rate of animals. In order to be able to cope heat stress caused by global warming, it is inevitable to develop different strategies in the livestock sector while water use strategies and drought-resistant varieties are being developed in plant production.

Keywords: Global warming, poultry industry, animal welfare.

KÜRESEL ISINMA VE İKLİM DEĞİŞİKLİĞİNİN KANATLI SEKTÖRÜNE ETKİSİ

ÖZET

İnsanlık tarihi boyunca dünya iklimleri her ne kadar durağan gibi görünse de geçmişten günümüze dek elde edilen bulgular bunun böyle olmadığını, az da olsa bir değişime maruz kaldığını göstermektedir. İklimler doğal nedenlerle değişeceği gibi insanlar tarafından oluşturulan etkilerden kaynaklanan bazı değişimler de olabilmektedir. Küresel ısınmaya sebep olan ve insanlar tarafından oluşturulan etkilerin en başında, dünya nüfus artışı ve sanayileşme ile birlikte açığa çıkan kirleticiler yer almaktadır. Bu kirleticiler, dünya atmosferi ile birlikte denizleri, toprağı ve dünyada yaşayan canlıları da doğrudan ve dolaylı olumsuz olarak etkilemektedir. Bu olumsuzlukların en fazla etkilediği tarımsal sektörlerin başında dünya kara alanlarının %45'ini kullanan hayvancılık sektörü gelmektedir((Sejian, Gaughan et al. 2015). Bu etkiler aşırı sıcaklık, fırtınalar ve aşırı yağışlar şeklinde doğrudan hayvanlar üzerinde onların refah ve verimini olumsuz etkileyen durumlar oluşturduğu gibi, onların beslenmesinde kullanılan bitkisel ürünlerin üretiminin ve doğal beslenme alanları olan meralardaki bitki örtüsünün azalması şeklinde de olabilmektedir. Her iki durumda da hayvansal üretim de verim düşüklüğü ile birlikte maliyetlerin artmasına paralel olarak fiyatların artmasına ve dolayısı ile insanların alım güçlerinin düşmesine sebep olmaktadır. Üretimin büyük kısmının kapalı barınaklarda yapıldığı kanatlı sektörü de küresel ısınma ve iklim değişikliğinden olumsuz olarak etkilenmektedir. Üretim masraflarının büyük kısmını oluşturan yem masrafı küresel ısınma ve iklim değişikliğinin olumsuz sonuçlarından biri olan bitkisel üretim verim düşüklüğünden kaynaklı yem hammadde fiyatlarının artmasının yanında barınak şartlarının uygun seviyelerde tutulması için gereken enerji miktarını da arttırmakta, hayvanların yem dönüşüm oranını da yükseltmektedir. Küresel ısınmanın sebep olduğu sıcaklık stresi ile mücadele edebilmek amacı ile bitkisel üretimde su kullanım stratejileri, kuraklığa dayanıklı çeşitler geliştirilirken hayvancılık sektöründe de farklı stratejiler geliştirilmesi kaçınılmazdır.

Anahtar Kelimeler: Küresel ısınma, kanatlı sektörü, hayvan refahı,

1. GİRİŞ

İnsanlık tarihi boyunca dünya iklimleri her ne kadar durağan gibi görünse de geçmişten günümüze dek elde edilen bulgular bunun böyle olmadığını, az da olsa bir değişime maruz kaldığını göstermektedir. İklimler doğal nedenlerle değişeceği gibi, insanlar tarafından oluşturulan etkiler de bu değişimlere katkıda bulunabilmektedir. Küresel ısınmaya sebep olan ve insanlar tarafından oluşturulan etkilerin en başında, dünya nüfus artışı ve sanayileşme ile birlikte açığa çıkan kirleticiler yer almaktadır. Bu kirleticiler, dünya atmosferi ile birlikte denizleri, toprağı ve dünyada yaşayan canlıları da doğrudan ve dolaylı olumsuz olarak etkilemektedir. Bu olumsuzlukların en fazla etkilediği tarımsal sektörlerin başında dünya kara alanlarının %45'ini kullanan hayvancılık sektörü gelmektedir (Sejian, Gaughan et al. 2015). Bu etkiler aşırı sıcaklık, fırtınalar ve aşırı yağışlar şeklinde doğrudan hayvanlar üzerinde onların refah ve verimini olumsuz etkileyen durumlar oluşturduğu gibi, onların beslenmesinde kullanılan bitkisel ürünlerin üretiminin ve doğal beslenme alanları olan meralardaki bitki örtüsünün azalması şeklinde de olabilmektedir. Her iki durumda da hayvansal üretim de verim düşüklüğü ile birlikte maliyetlerin artmasına paralel olarak fiyatların artmasına ve dolayısı ile insanların alım güçlerinin düşmesine sebep olmaktadır. Üretimin büyük kısmının kapalı barınaklarda yapıldığı kanatlı sektörü de küresel ısınma ve iklim değişikliğinden olumsuz olarak etkilenmektedir. Üretim masraflarının büyük kısmını oluşturan yem masrafı küresel ısınma ve iklim değişikliğinin olumsuz sonuçlarından biri olan bitkisel üretim verim düşüklüğünden kaynaklı yem hammadde fiyatlarının artmasının yanında barınak şartlarının uygun seviyelerde tutulması için gereken enerji miktarını da arttırmakta, hayvanların yem dönüşüm oranını da yükseltmektedir. Küresel ısınmanın sebep olduğu sıcaklık stresi ile mücadele edebilmek amacı ile bitkisel üretimde su kullanım stratejileri, kuraklığa dayanıklı çeşitler geliştirilirken hayvancılık sektöründe de farklı stratejiler geliştirilmesi kaçınılmazdır.

2. KÜRESEL ISINMA

Yeryüzünde yaşayan tüm canlılar için vazgeçilmez olan atmosfer birçok gazın karışımından oluşmuştur. Atmosferi meydana getiren bu gazların her birinin ayrı fiziksel ve kimyasal özellikleri bulunmaktadır. Atmosferin bileşenleri durağan olmayıp, bazı zamanlarda bölgeden bölgeye küçük değişiklikler gösterebilir. Ancak bu bileşenler belirli standartlardaki miktarlarını korumak zorundadır, aksi halde atmosfer içerisindeki tüm canlı ve yapılar için tehlikeli bir durum oluşturur. Genel olarak dünya güneşten gelen ışınlardan çok dünya üzerine düşen güneş ışınlarının yansımasıyla ısınmaktadır. Başta karbondioksit, metan ve su buharı olmak üzere, bu ışınlar atmosferdeki gazlar tarafından tutularak dünya ısınmaktadır. Güneşten yeryüzüne gelip atmosfere doğru yansıyan güneş ışınlarından bilhassa enerji yüklü olan kızılötesi ışınların uzaya geri dönmesinin atmosferdeki gazlar tarafından engellenmesine sera etkisi adı verilmektedir. Sera gazlarının atmosferdeki miktarı arttıkça bunların sera etkisi de artmaktadır. Sera etkisi normalde doğal bir süreç olup, dünyada yaşamın sağlanabilmesi için gereken sıcaklığı sağlamaktadır. Atmosferin ısıyı tutma özelliği sayesinde yeryüzündeki suların sıcaklığı dengede kalarak, okyanus ve nehirlerin donması engellenmiş olur. Sera gazı oluşumunun iki farklı sebebi vardır. Bunlardan birincisi bitki ve hayvanların solunumu ile doğal yollardan oluşan gazlar, ikincisi ise insan aktiviteleri sonucu oluşan gazlardır. İnsanlardan kaynaklanan

gazlar büyük oranda, fosil yakıtların yakılması, orman alanlarının azalması, yoğun hayvansal üretim, sentetik gübre kullanımı ve endüstriyel süreçlerdir (Sejian, et al. 2015). Sanayi Devrimi ile artan insan aktivitesi, gelişen teknolojinin hızla yaygınlaşması ve yaşam standardının yükseltilmesi çabaları atmosferde sera etkisi yapan gazların miktarında gereğinden fazla artmaya neden olmuştur (Mikhaylov, et al. 2020).

Küresel ısınma, insan faaliyetleri, özellikle fosil yakıt yakımı nedeniyle, dünya atmosferindeki ısıyı hapseden sera gazı seviyelerini artıran, 1850 yılı sanayi öncesi dönemden bu yana dünya yüzeyinin uzun vadeli ısınmasıdır. Sanayi öncesi dönemden bu yana, insan faaliyetlerinin dünya'nın küresel ortalama sıcaklığını yaklaşık 1 santigrat derece artırdığı tahmin edilmektedir ve şu anda her on yılda 0,2 santigrat dereceden fazla artmaktadır. Mevcut ısınma eğilimi, 1950'lerden bu yana insan faaliyetlerinin açık bir sonucudur ve binlerce yıldır benzeri görülmemiş bir hızla ilerlemektedir.

Ortalama sıcaklıktaki artışa ek olarak, sıcak günlerin sayısı ve sıcak hava dalgalarının sayısı gibi aşırı olayların sıklığında da bir artış vardır. Sıcak hava dalgaları, hava sıcaklığının süresi ve yoğunluğunun birleşimidir ve insan faaliyetlerinin yanı sıra çiftlik hayvanlarının sağlığını ve üretkenliğini de güçlü bir şekilde etkileyebilir (Bernabucci, 2019).

3. TARIMSAL ÜRETİMDE SERA GAZI SALIMI

Tarımla ilişkili sera gazları üç çeşit olup, bunlar; Karbondioksit (CO2), metan (CH4) ve nitröz oksittir (N2O). Diğer önemli sera gazları arasında su buharı ve birçok halokarbon bileşiği bulunur, ancak bunların emisyonlarının tarımdan etkilendiği düşünülmemektedir. Nitröz oksit (N2O) ve metan (CH4) konsantrasyonlarının artması özellikle tehlikelidir çünkü her ikisi de diğerlerinden çok daha yüksek oksidasyona sahiptir (Podkówka etal, 2015). Metan gazı karbondioksitten 23 kat, azotoksit ise 296 kat daha fazla sera etkisine sahiptir. Fosil yakıt kullanımının insan kaynaklı CO2 emisyonlarının %75'inden fazlasından sorumlu olduğu düşünülmektedir. Başta ormansızlaştırma olmak üzere arazi kullanım değişikliği geri kalanından sorumludur. İnsan faaliyetlerinin son 25 yılda CH4 emisyon oranını iki katından fazla artırdığı düşünülmektedir (Synder ve diğerleri, 2009). Tarımla ilişkili üç sera gazı olan karbondioksit, metan ve azotoksitin (CO2, CH4 ve N2O) ısıyı hapsetme etkinlikleri ve atmosferdeki devir oranları bakımından farklılık göstermektedir. Bitkisel üretim faaliyetlerinde karbondioksit, metan ve azotoksit ile kıyaslandığında daha fazla üretilir. Bitkiler, fotosentez yoluyla büyük miktarlarda karbondioksit tüketmelerine karşın, bu bitkisel ürünler sonunda diğer canlılar tarafından tüketildiklerinde veya ayrıştıklarında tekrar karbondioksite dönüşürler. Tarımsal kaynaklı net karbondioksit salınımı, toplam karbondioksit salınımına kıyasla azdır ve çoğunlukla işletmelerde, tarımsal ürünlerin üretimi ve taşınmasında kullanılan enerjiden kaynaklanır. Metan gazı en çok, pirinç üretiminden ve geviş getiren hayvanlardan salınır. Sular altında kalan pirinç tarlalarındaki organik materyalin anaerobik ayrışması, büyüme mevsimi boyunca öncelikle pirinç bitkileri aracılığıyla difüzyonla atmosfere yayılan metan (CH4) üretir. Hayvan gübresi, dünya genelinde yaklaşık yedi milyar ton tarımda kullanılmaktadır. Hayvan gübresinin tarımsal toprakta organik gübre olarak kullanılması, yalnızca toprak sağlığını ve tarımsal verimliliği artırmakla kalmaz, aynı zamanda sera gazı emisyonları üzerinde de önemli bir etkiye sahiptir. Hayvansal gübredeki metan üretimi, anaerobik koşullar ve parçalanabilir

organik gübrenin birleşiminden kaynaklanır. Hayvan gübresi, toplam insan kaynaklı metan emisyonlarının yaklaşık % 6'sını oluşturur (Chataut etal, 2023). Azot oksit oluşumu toprak mikro organizmaları tarafından nitrifikasyon ve denitrifikasyon ile oluşur. Toprağa uygulanan azotlu gübreler azot oksit oluşumunun ana sebebidir. Oluşan azot oksit miktarı; kullanılan gübrenin türü, uygulama oranı, uygulama tekniği, uygulama zamanı, toprak işleme sistemi, diğer kimyasalların kullanımı, topraktaki mikroorganizma sayısı gibi pek çok faktörden etkilenebilir.

Ruminant hayvanlar çevreye, tek mideli hayvanlardan önemli ölçüde daha fazla miktarda gaz salarlar. Ruminantların sindirim sistemleri, selülolitik ve metanojenik mikroorganizmaların aktivitesi ile fermantasyon yoluyla yapısal karbonhidratları kullanmak üzere adapte olmuştur. Sindirim sürecinde, düşük molekül ağırlıklı uçucu yağ asitleri olarak sınıflandırılan metan ve metan olmayan uçucu organik bileşikler üretirler (Brade ve diğerleri, 2008) Metan ve metan olmayan uçucu organik bileşikler yalnızca sindirim sisteminde üretilmez. Gübre ve hayvanların vücutları, bunların önemli bir miktarını ve ek olarak azotlu maddeleri devamlı üretir. Dışkı ve idrarda bulunan sindirilmemiş organik madde ve su, metan üreten bakteriler için mükemmel bir kaynaktır; bunlar yüksek miktarda metan, metan olmayan uçucu bileşikler, amonyak ve diğer azot bileşikleri üretirler (Podkówka ve diğerleri, 2015). Tek mideli çiftlik hayvanları ve kanatlı hayvanlar da gerek sindirim sistemi gerekse dışkıları ile belirli miktarlarda sera gazı oluşumuna katkıda bulunurlar. Dünyada domuz ve kümes hayvanlarının hayvansal kaynaklı sera gazı üretimine katkısı sırasıyla %9 ve %8 civarında olduğu belirtilmektedir (Gerber etal, 2013). Kümes hayvanı üretiminden kaynaklanan sera gazı emisyonlarına en büyük katkı yem üretimidir. Çiftlikteki kümes hayvanı faaliyetlerinden kaynaklanan en yüksek emisyonlar enerji kullanımı ve gübre yönetimi için gereken yakıt kullanımından kaynaklanır. Etlik piliç üretiminde çiftlik kapısı sonrası emisyonlar tüm emisyonların yarısından fazlasını oluştururken, yumurtacı işletmelerden kaynaklanan çiftlik kapısı sonrası emisyonlar toplam emisyonların dörtte birinden daha azını oluşturur (Dunkley and Dunkley, 2013).

4. KÜRESEL ISINMA VE İKLİM DEĞİŞİKLİĞİNİN BİTKİSEL ÜRETİM ÜZERİNE OLAN ETKİLERİ

Küresel ısınmanın, tarım üzerindeki temel olumsuz etkileri; Sıcaklık ve yağışların ortalama uzun vadeli değerlerden sapmaları ve verimde azalmaya neden olan bazı diğer olumsuz hidrometeorolojik olaylardır. İklim değişikliği; tarım, orman ve bitki örtüsü, temiz su kaynakları, deniz seviyesi, enerji, insan sağlığı ve biyolojik çeşitliliği doğrudan veya dolaylı olarak çeşitli şekillerde etkileyebilmektedir. Tüm bunların yanında, iklim değişikliği sosyal ve ekonomik sorunsallara neden olarak tarım üzerinde baskı oluşturabilmektedir. İklim değişikliği nedeniyle toprak ve su rejimleri değişime uğramakta, tarımsal üretim azalmakta ve gıda güvenliği tehlikeye girmektedir. İklim değişikliğinin uzun dönemde; su ve diğer kaynaklar üzerinde stres oluşturması, toprakları verimsizleştirmesi, tarım alanlarının durumlarını kötüleştirmesi, geniş çapta çölleşmelere neden olması, tarım mahsullerinde zararlı ve hastalıkların çoğalmasına sebep olması ve deniz seviyesini yükselterek kıyı ekosistemlerini tahrip etmesi beklenmektedir. Afrika, en az sera gazı salmasına rağmen, iklim değişikliğinin tahmin edilen etkilerinden en çok etkilenen kıtadır. Afrika da 2050'ye kadar 1,5–3,0 °C'lik,

önümüzdeki 100 yıl içinde 2–6°C'lik bir artış beklenmektedir ve bu diğer bölgelerden daha şiddetlidir.

5. KÜRESEL ISINMA VE İKLİM DEĞİŞİKLİĞİNİN HAYVANCILIK SEKTÖRÜNE ETKİLERİ

Hayvancılık sektöründe hayvanların termal konforuyla ilgili artan endişe yalnızca tropikal bölgelerdeki ülkeler için değil, aynı zamanda yüksek ortam sıcaklıklarının sorun olmaya başladığı ılıman bölgelerdeki ülkeler için de problem oluşturmaktadır. Son çeyrek yüzyılda, hayvancılık sektörü büyük oranda yüksek verimli hayvanlar geliştirmeye, çevreyi değiştirmeye ve beslenme yönetimini iyileştirmeye odaklanmış, hayvanların stresle baş edebilme kapasiteleri pek dikkate alınmamıştı. Bu yaklaşım çiftlik hayvanlarında verimi önemli ölçüde artırmakla birlikte sıcak ortamlara karşı duyarlılıklarını da artırarak termal esnekliklerini azaltmıştır. Hayvanların çevrelerindeki değişikliklere tepki verdiği süreçler onların hayatta kalmaları için kritik öneme sahipken, genellikle hayvancılık sistemlerinin verimliliğini ve karlılığını olumsuz etkiler (Bernabucci, 2019). Yoğunluğuna ve süresine bağlı olarak, ısı stresi hayvanlarda metabolik değişikliklere, oksidatif strese, bağışıklık baskılanmasına ve ölümlere neden olarak onların sağlığını olumsuz etkileyebilir. İklim değişikliğinin dolaylı etkileri, hayvanların değişen iklim koşullarına adaptasyonu olumsuz etkileyen yem ve su kıtlığı, beslenme kaynaklı hastalıklar, bulaşıcı konukçuların direnci, vektör kaynaklı hastalıkların yayılması şeklinde de ortaya çıkabilir. Yüksek sıcaklıklar patojen veya parazitlerin gelişimini destekleyebilir, rüzgarlardaki değişimler ise bazı patojen ve hastalık taşıyıcıların daha geniş bir alana yayılmasına yol açarak, hastalıkların yayılımında değişimler oluşturabilir (Petrovica ve ark., 2015). Sıcakkanlı hayvanlar yüksek sıcaklıklarda vücut sıcaklığının artmasını önlemek için ısı kaybını artırarak ve ısı üretimini azaltarak tepki verirler (hipertermi). Bu tür tepkiler arasında solunum ve terleme oranlarında artış ve yem tüketiminde azalma bulunur. Isı stresi, süt ve et ineklerinde topallamalara sebep olabilir (Shearer, 1999).

Küresel ısınmanın neden olduğu çölleşme süreci, yem bitkisi ekili alanlar da verim kayıplarına sebep olduğundan, üretim maliyetlerinin artmasına da sebep olmaktadır. Küresel ısınmanın, hayvansal üretimin yoğun olarak yapıldığı ülkelerde doğrudan etkilerinin yanı sıra su kıtlığı, kaba/kesif yem üretiminde azalma ve patojenler gibi dolaylı etkiler ile de hayvansal üretimi çok daha olumsuz etkileyebilmektedir (Koyuncu, 2017).

6. KÜRESEL ISINMA VE İKLİM DEĞİŞİKLİĞİNİN KANATLI HAYVANLAR VE SEKTÖRE ETKİLERİ

İklim değişikliği ve küresel ısınmanın kanatlı sektörü üzerinde doğrudan ve dolaylı etkileri olmaktadır. Yüksek sıcaklık, sel, kuraklık ve su kıtlığı gibi İklim değişiklikleri kanatlı hayvanların homeostazileri üzerinde stres oluşturarak onları olumsuz yönde etkiler. İklim değişikliğinin en yaygın olan etkisi yüksek sıcaklıklar olup, yem tüketiminde azalma, canlı ağırlık artışında düşüş, yem değerlendirme oranında artış, metabolizma hızının azalması, lipid peroksidasyonu, hormonal bozukluklar, bağışıklık sisteminin baskılanması ve bağırsak mikrobiyal simbiyozunda bozulmalara sebep olabilmektedir (Biswal vd. 2020; Vandana vd.

2021). Yumurtacı tavuk ve etlik piliçlerde optimum sıcaklık aralığı yaklaşık 18-22 °C arasındadır. Ortam sıcaklıkları bu sıcaklıkların üzerine çıkmaya başladığında ısı kaybetme mekanizmaları devreye girer. Tavuklarda ter bezi yoktur. Fazla ısıyı vücuttan uzaklaştırmak için solunum hızını arttırarak buharlaşma yoluyla ısı kaybetmeye çalışırlar. Aynı zamanda kanatlarını açarak tüylerin az olduğu kanat altı kısımlarından ısı kaybetmeye çalışırlar. Vücutlarını daha soğuk zeminlere temas ettirerek ısı kaybetmeye çalışırlar. Kanatlı hayvanlar belirli sıcaklıklara kadar uyum sağlayabilirler, ancak yüksek sıcaklıklarda, metabolik ısı üretimini sınırlamak için yem tüketimini azaltarak, kas gelişimi ve ya yumurta üretimi için gereken besin maddelerini ısı kaybı mekanizmaları için harcarlar. Sindirim sistemi faaliyetleri azalarak bağırsaklardaki besin maddesi sindirimi ve emilimi düşer. Yapılan çalışmalar sıcaklık stresinin bağırsak epitel hücrelerini etkilediğini ortaya koymuştur (Santos et al, 2015). Yumurtacı tavuklarda yumurta sayısı ve boyutunda düşüşlere sebep olmakla birlikte, yumurta iç ve dış kalite özelliklerinde de düşüşlere sebep olmaktadır. Damızlık tavukçulukta yumurta verimi, kalitesi, kuluçka randımanı ve civciv kalitesinde de düşüşlere sebep olabilmektedir (Ayo et al, 2011). İklim değişikliği üreme hormonları üzerinde de etkiye sahiptir. FSH, LH, progesteron, östrojen, testesteron salınımı üzerinde etkili olarak, erkeklerde spermatogenez ve dişilerde gametogenez üzerinde etkili olabilmektedir (Abioja ve Abiona, 2021). Isı stresi altındaki horozlar düşük sperm konsantrasyonu ve kalitesine sahip semen üretir. Tavukların bağışıklığı sıcaklık stresi koşulları altında düşer (Calefi ve ark. 2017). Sıcaklığın nem ile yakından ilişkili olmasından dolayı nemle birlikte sıcaklık artışlarının daha fazla olumsuz etkileri olmaktadır. Daha hızlı büyüme performansı sergileyen etlik piliçler yumurtacı tavuklara nazaran yüksek sıcaklığa daha hassastırlar.

İklim değişikliği ve küresel ısınmanın doğrudan etkilerinin yanında dolaylı olarak da hayvanlar ve sektör üzerinde etkileri olmaktadır. Kanatlı hayvanları beslemek için yem hammaddesi üretiminde ve tedarikinde, yeterli ve kaliteli su temininde de sorunlara yol açabilmektedir. Yağışların azalması veya aşırı yağışlar yem hammaddeleri üretimi üzerinde etkilidir ve her ikisi de verimi olumsuz olarak etkilemektedir. Bazı hastalıkların görülme sıklığında artış görülebilirken hayvanların düşmüş olan bağışıklık sistemleri onları daha savunmasız duruma getirebilecektir. Bütün bunlar sağlık için yapılan harcamalarda artışa sebep olacaktır. Bu etkiler özellikle güney yarım kürede Afrika kıtasında daha bariz görülebilmektedir.

7. YÜKSEK SICAKLIK STRESİNE KARŞI ALINABİLECEK ÖNLEMLER

Tamamen kapalı ve ısı yalıtımı iyi olan kümeslerde serinletme pedleri, sisleme, fanlar gibi ekipmanlarla sıcaklığı düşürmek tropik ve sıcak ve gelişmekte olan ülkelerde yaygın olan yarı açık kümeslerden kısmen daha kolaydır. Yarı açık kümeslerde havalandırmayı etkin hale getirecek önlemler alınmalı, kümeslerin etrafı hava akımını engelleyecek şekilde kapatılmamalı, etkili rüzgar yönü hesaba katılarak kümesler planlanmalı, kümes etrafına ağaç dikilmesi gölgelik ve serinlik sağlayabilir, özellikle sac çatı malzemeleri güneşte kızıp, ısıyı kümes içerisine yansıtacağından tercih edilmemelidir. Tel ızgaralı zeminler derin altlıklı sistemlere nazaran tavukların vücudundan daha fazla ısı kaybını sağlayıp avantaj oluşturabilir.

Yüksek sıcaklıklar tavuklarda yem alımının düşmesine sebep olduğundan verim kayıplarına sebep olur. Yem alımı azalacağından özellikle lisin ve metionin alımı azalabileceğinden

bunların ayarlanması gerekir. Yemlere enerji kaynağı olarak nişasta yerine yağ katılması yağların metabolizması sırasında karbonhidratlardan daha az ısı oluşturduğundan dolayı avantaj sağlar. Proteinlerin metabolik parçalanması en yüksek ısı oluşumuna sebep olduğundan düşük proteinli yemler sıcaklık stresi ile mücadelede avantaj sağlayabilir. Yemlere A, C ve E vitamini ve bitki ekstraktları gibi antioksidanların katılması ısı stresinde etkili olabilir. Sıcaklık stresi koşullarında ıslak yem ile beslemenin su alımını arttırdığından, klasik yemlere göre avantaj sağlayabileceği ile ilgili çalışmalar vardır (Syafvan et al, (2011). Yemleme zamanının günün en serin zamanlarında yapılması metabolik ısı artışının yüksek sıcaklık ile çakışmasını engelleyerek etkili olabilir. Yüksek sıcaklıklarda tavuklara sürekli, temiz ve serin su temini çok önemlidir. Yüksek sıcaklıklarda solunum sayısı ve hızı artacağından, buharlaşma ile su kaybı artar. Tavuklar ılık suyu içmekten pek hoşlanmazlar, sıcaklık stresinde özellikle serin su verilmesi oldukça etkilidir. Çıplak boyunlu tavuklar daha fazla ısı kaybı yaşayacaklarından, sıcak bölgelerde avantaj sağlayabilir. Yerleşim sıklığı yoğun olduğu durumlarda tavukların ısı kaybı azalır, sıcaklık stresi durumunda yerleşim sıklığının düşürülmesi etkili olmaktadır. Epigenetik adaptasyon uygulamalarının sıcaklık stresi ile baş etmede etkili olabileceği çalışmalar mevcuttur (Zulkifli ve ark. 2000; Liew ve ark. 2003).

8. SONUÇ

Küresel ısınma ve iklim değişikliğinin etkilerinin artarak devam edeceği öngörülmektedir. Doğa ve çevresel şartlarla direkt bağlantılı olan hayvancılık sektörünün bundan çok fazla etkileneceği açıktır. Isınmanın dolaylı etkileri ile birlikte, kanatlı sektöründe hayvanların çok büyük oranda kapalı barınak şartlarında yetiştirilmesi, onların stresli ortamlardan uzaklaşabilmelerini imkansız kılmaktadır. Kanatlı yetiştiriciliğinde sıcaklık stresini kontrol edebilecek barınakların planlanması başta olmak üzere yukarıda açıklamaya çalıştığımız önlemlerin alınması hem hayvan sağlığı ve refahı yönünden hem de karlılık açısından uygun olacaktır.

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POTENTIAL USE OF PROBIOTIC SPORE-FORMING BACTERIA IN DAIRY TECHNOLOGY

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ABSTRACT

In dairy technology, many species belonging to different genera such as *Lactobacillus*, *Bifidobacterium*, and *Lactococcus* are currently used as probiotics due to their immune system support and digestive system benefits. However, there has been an increasing interest in the probiotic properties of spore-forming bacteria in recent years.

Although probiotic microorganisms mostly have characteristics such as growth in different salt concentrations and resistance to pH changes, they do not show viability for a relatively long time when used in foods. Bacterial spores are more resistant to extreme environmental conditions such as high heat treatment, low pH, antimicrobial compounds, etc. than their vegetative forms. Due to the high viability of spores during storage at different temperatures depending on the product characteristics, it is important to evaluate them as probiotics in foods. In addition, due to the high acidity content in foods such as yogurt and cheese, it is generally not possible for spores to germinate. In this way, there are no significant changes in the sensory properties of the food and it is possible to remain a high level of vitality until consumption. It is also very important for spores to be able to show high viability in environments such as stomach acidity and bile salts in the gastrointestinal system of humans and animals.

Probiotic spore-forming microorganisms are currently commercially available and are being evaluated in the fields of medicine and veterinary. Therefore, its use in foods is expected to become widespread. The best-known spore-forming bacteria in dairy technology belong to the *Bacillus* and *Clostridium* genera. Although it is known that there are many harmful types of these microorganisms in terms of technology and health, when we look at the latest research, it is understood that some types can be evaluated as probiotics. *Bacillus coagulans*, *B. clausii*, *B. pumilus*, *B. subtilis*, and *Clostridium butyricum* are important spore-forming probiotic bacteria.

In this review, the properties of spore-forming bacteria, known for the problems they cause in dairy technology for many years, the metabolites they produce, their technological use and their effects on health are discussed.

Keywords: Probiotic, Spore forming bacteria, Dairy products, *Bacillus*, *Clostridium*

SÜT TEKNOLOJİSİNDE PROBİYOTİK SPOR OLUŞTURAN BAKTERİLERİN POTANSİYEL KULLANIMI

ÖZET

Bağışıklık sistemini destekleyici ve sindirim sistemi için önemli faydalarından dolayı süt teknolojisinde *Lactobacillus, Bifidobacterium* ve *Lactococcus* gibi farklı cinslere ait birçok tür probiyotik olarak hali hazırda kullanımı mevcuttur. Fakat son yıllarda spor oluşturan bakterilerin de probiyotik özellikleri üzerine artan bir ilgi gözlenmektedir.

Probiyotik mikroorganizmalar çoğunlukla farklı tuz konsantrasyonlarında gelişim, pH değişimlerine dayanıklılık gibi özelliklere sahip olmasına rağmen gıdalarda kullanıldıklarında nispeten çok uzun bir süre canlılık göstermemektedir. Bakteri sporları ise yüksek ısıl işlem, düşük pH, antimikrobiyal bileşikler vb. gibi zor çevre şartlarına vejetatif formlarına göre daha dayanıklı olmaktadır. Sporların ürün özelliklerine bağlı olarak farklı sıcaklıklardaki depolama süresince yüksek canlılık göstermeleri nedeniyle gıdalarda probiyotik olarak değerlendirilmeleri önem kazanmaktadır. Ayrıca yoğurt, peynir gibi gıdalarda yüksek asitlik içeriğinden dolayı sporlarının çimlenmesine genel olarak mümkün olmamaktadır. Bu sayede gıdanın duyusal özelliklerinde önemli değişiklikler meydana gelmemekte ve tüketime kadar yüksek canlılık seviyesinde kalabilmesi mümkün olmaktadır. İnsan ve hayvanlarda gastroinstenstinal sisteminde mide asitliği, safra tuzu gibi ortamlarda sporların yüksek canlılık gösterebilmesi de oldukça önemlidir.

Probiyotik spor oluşturan mikroorganizmalar hali hazırda ticari olarak ulaşılabilmekte tıp ve veterinerlik alanlarında değerlendirilmektedir. Bu nedenle gıdalarda kullanımınında yaygınlaşması beklenmektedir. Süt teknolojisinde bilinen en iyi spor oluşturan bakteriler *Bacillus* ve *Clostridium* cinsleri aittir. Bu mikroorganizmaların teknolojik ve sağlık açısından birçok zararlı türünün olduğu bilinsede yapılan son araştırmalara bakıldığında bazı türlerinin de probiyotik olarak değerlendirilmelerinin mümkün olduğu anlaşılmaktadır. *Bacillus coagulans, B. clausii, B. pumilus, B. subtilis* ve *Clostridium butyricum* spor oluşturan önemli probiyotik bakterilerdir.

Bu derleme makalede uzun yıllardır süt teknolojisinde neden oldukları olumsuzluklarla bilinen spor oluşturan bakterilerin özellikleri ve oluşturdukları metabolitler ile birlikte teknolojik olarak kullanım durumları ve sağlık üzerine etkileri tartışılmıştır.

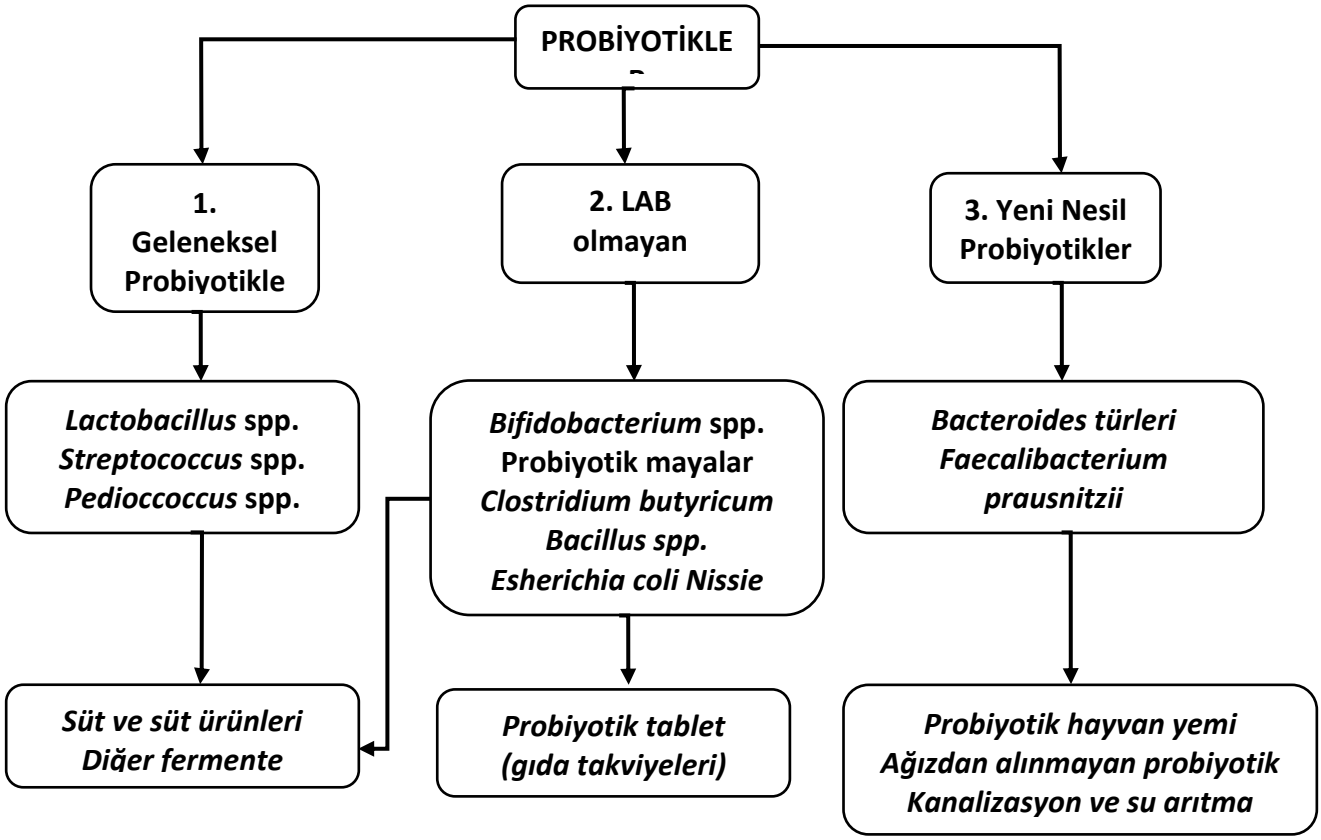
Anahtar Kelimeler: Probiyotik, Spor-oluşturan bakteriler, Süt ürünleri, *Bacillus, Clostridium*

1. GİRİŞ

Probiyotikler, "yeterli miktarlarda uygulandığında konak sağlığı üzerinde yararlı bir etki sağlayan canlı mikroorganizmalar" olarak tanımlanmaktadır (Hill ve ark., 2014). Bu mikroorganizmalar, işlevsel özellikleri ve besinsel değerleri nedeniyle ilgi görmekte ve insan vücudundaki etki mekanizmalarını aydınlatmak için çeşitli çalışmalar yapılmaktadır (Marzorati ve ark., 2021; Xavier-Santos ve ark., 2019; Soares ve ark.,2023).

Probiyotiklerin, işlevsel bileşenler olarak antikanserojen, antijenotoksik, profilaktik, antioksidan, antiinflamatuar, antiosteoporotik, antihipertansif ve antidiyabetik potansiyele sahiptir. Probiyotiklerin uyku, ruh hali ve bilişsel tepkilerin düzenlenmesi yoluyla psikolojik refah üzerinde olumlu etkisi olduğuna dair kesin kanıtların olduğu da bildirilmiştir. (Marotta ve ark., 2019; Gao ve ark., 2021).

Probiyotikler, LAB tabanlı geleneksel probiyotikler, LAB olmayan probiyotikler ve yeni nesil probiyotikler (NGP'ler) olarak sınıflandırılır (Şekil 1). Tüm bu probiyotik türleri probiyotik gıda ürünlerinde, hayvan yemlerinde, probiyotik farmasötik ürünlerde, oral olmayan probiyotik formülasyonlarında ve kanalizasyon ve atık su arıtımında kullanılmaktadır. Faydalı etkilere ulaşmak için gereken minimum probiyotik miktarı, insan veya hayvan çalışmalarından elde edilen bilimsel kanıtlarla, ürünün son kullanma tarihinin sonunda ve kullanım, dağıtım ve depolama koşullarında belirlenmelidir. Bir gıda ürününde sağlık etkilerini garanti edebilecek bir probiyotik suşunun hücre sayısı düzeyi yoktur; ancak, 10^6 ila 10^8 kob/g, probiyotik faydalarından yararlanmak için yeterli bir sayı olarak algılanmaktadır (Champagne ve ark., 2011; Gao ve ark., 2021).



Şekil 1. Probiyotiklerin sınıflandırılması (Gao ve ark., 2021)

Probiyotik mikroorganizmaların gıda üretiminden tüketiciler tarafından tüketilmesine ve gastrointestinal sistemden (GIT) geçişine kadar metabolik aktivitesini ve canlılığını sürdürmelidir. Birçok araştırma probiyotik olarak *Lactobacillus* spp. ve *Bifidobacterium* spp. üzerine yoğunlaşmıştır. Endüstriyel uygulamalarda, terapötik özellikler ve biyogüvenlik gibi çeşitli yönleri araştırarak bu probiyotik türlerine odaklanmıştır (Forssten ve ark., 2011; Kanmani ve ark.,2013). Bu mikroorganizmalar mide asitliği ve safra tuzları gibi fizyolojik koşullara duyarlıdır. Ayrıca bu bakterilerin biyoyararlanımı çeşitli üretim, depolama ve taşıma koşullarından etkilenmektedir (Graff ve ark., 2008; Cutting, 2011; Adibpour ve ark., 2019) Probiyotiklerin canlılık süresini artırmak için mikrokapsülleme ve soğuk zincir uygulaması gibi yöntemler kullanılmaktadır, ancak bu uygulamalarda üretici ve tüketici için ek bir harcama oluşturmaktadır.

Mikroorganizmaların yıllardır gıda teknolojisinde faydalarından ve kullanımlarından dolayı farklı mikrobiyal türlerin/suşların probiyotik özellikleri halen araştırılmakta ve uygulanmaktadır. Bu amaçla umut vadeden bir alternatif, spor oluşturan probiyotiklerdir. Bakteriyel sporlar, vejetatif hücrelere kıyasla termal öldürücü etkilere, kurumaya, donmaya, toksik kimyasallara ve radyasyona karşı daha fazla direnç gösterir (Sanders ve ark.,2003;

Elshaghabee ve ark., 2017; Adibpour ve ark., 2019). Ayrıca düşük pH'a ve yüksek basınca karşı direnci, iyi stabilite ve hızlı çimlenme gibi özellikleri düşünüldüğünde çeşitli probiyotik gıdaların formülasyonunda kullanımları dikkat çekici bir duruma gelmektedir (Folign´e ve ark., 2012; Permpoonpattana ve ark., 2012; Zhao ve ark., 2021). Spor oluşturan probiyotikler günümüzde insan tüketimi için takviyeler (kapsüller) olarak yaygın bir şekilde pazarlanmakta ve kullanılmaktadır. Tavuk, domuz ve su ürünleri yetiştiriciliği için hayvan yemlerinde uygulamaları mevcuttur (Mohammed ve ark., 2021; Mun ve ark., 2021; Rodigues ve ark., 2021). Spor oluşturan probiyotik mikroorganizmalar arasında en önemlileri *Bacillus, Clostridium, Sporolactobacillus* ve *Brevibacillus* cinsine ait olanlardır.

Bu derlemede, uzun yıllardır süt teknolojisinde saprofit ve patojenik özellikleri ile bilinen sporlu mikroorganizmaların probiyotik olarak değerlendirilmesi ele alınmıştır.

2. PROBİYOTİK *BACİLLUS* TÜRLERİ

Bacillus türleri çoğunlukla gram pozitif, çubuk şeklinde, spor oluşturan, hareketli ve aerobik bakterilerdir. Bu mikroorganizmaların sporlarının ana yaşam alanları toprak ve bitki örtüsüdür ve bu nedenle doğada yaygın olarak dağılmışlardır (Bergey & Holt, 1994).

Memeli bağırsağı anaerobik bir ortam olduğundan bağırsakta sporların çimlenmesi ve vejetatif hücrelerin gelişmesinin zor olduğu görünmektedir. *Bacillus* suşlarının potansiyel bir probiyotik adayı olabilmesi için iyi bir tutunma ve biyoterapötik özelliklere sahip olmanın yanı sıra gastroinstentinal (GIT) sistemdeki stres toleransının yüksek olması gerekmektedir (Thakur ve ark., 2016).

Basiller normalde toprak organizmaları olarak kabul edilmesine rağmen *B. subtilis* ve diğer *Bacillus* türleri gönüllü bireylerin dışkılarında ve ileal biyopsilerinde bulunduğu bildirilmiştir (Fakhry ve ark., 2008). Bu bağlamda Hong ve ark. (2009)'ın, *B subtilis* ve muhtemelen diğer türlerin insan GIT'inde yaşama adapte olduğu, biyofilm oluşturma, anaerobik sporlanma ve antimikrobiyal üretme yeteneklerine sahip olduğu ve yalnızca toprak mikroorganizmaları olmaktan ziyade bağırsak kommensalleri olarak kabul edilmesi gerektiği yönünde görüşleri de bulunmaktadır.

Bacillus türleri farklı besin kaynaklarında yetiştirilmesi kolaydır ve çoğu FDA tarafından genel olarak güvenli (GRAS) olarak kabul edilir; bu nedenle kendileri ve ürettikleri metabolitler insan tüketiminde kullanılabilir (Mercado ve ark., 2022). *Bacillus* türlerinin gıda ürünlerinde kullanımı 50 yıldan uzun süredir belgelenmiştir. Bu mikroorganizmalar, ilk olarak 1958'de İtalya'da Avrupa pazarlarına Enterogermina® firması aracılığıyla tıbbi bir takviye olarak tanıtılmış ve tescil edilmiştir (Hong ve ark., 2008; Cutting, 2011). Spor oluşturan *Bacillus*'un en kapsamlı araştırılan türleri arasında *B. licheniformis, B. clausii, B. coagulans, B. cereus* ve *B. subtilis* bulunmaktadır (Shahcheraghi ve ark., 2015). Günümüzde ticari probiyotik *Bacillus* türlerinin kullanıldığı bazı gıda takviyeleri tablo 1'de verilmiştir.

Tablo 1. Probiyotik *Bacillus* türleri içeren bazı ticari gıda takviyeleri

Ticari ürün	**İçerik**
Enterogermina®	*B. clausii*
BioPlus 2B®	*B. subtilis* CH201/DSM5749/ *B. licheniformis* CH200/DSM5749
GanedenBC^{30}	*B. coagulans*
Anaban^{TM}	*B. subtilis*
Biosporin®	*B. subtilis/ B. licheniformis*
LifeinU^{TM}	*B. subtilis* CU1
Just Thrive	*B. indicus* HU36/ *B. coagulans*/ B. *clausii/B.subtilis* HU58
MegaSporeBiotic	*B.indicus, B. subtilis, B. coagulans, Bacillus licheniformis, B. clausii*
Flora3	*B. coagulans / Saccharomyces boulardii*
NutriCommit	*B. coagulans /B. subtilis*

2.1. *Bacillus coagulans*

B. coagulans hareketli, termofilik, asit toleranslı ve katalaz pozitif özellik gösteren bir mikroorganizmadır. Fermente edilmiş yiyecek ve içecekler için sertifikalı bir probiyotiktir. GRAS olarak adlandırılmıştır. Yüksek sıcaklıklara, asidik koşullara ve tuzluluğa sahip ortamlara dayanabilir ve bu da onu termal olarak işlenmiş ürünlerde kullanım için uygun bir aday haline getirmektedir (Poshadri ve ark., 2022). 15 ile 60 °C ve pH 4–5 aralığında gelişim gösterebilmektedir. *B. coagulans*, laktik asit, 2,3-bütandiol, asetoin, asetik asit ve etanol üreterek glikozu fermente eder ve ayrıca asidik gıdalarda çoğalabilmekte ve ayrıca süt ürünlerini pıhtılaştırabilmektedir. Morfolojik olarak, mikroorganizma 1 µm'den daha küçük bir çapa sahip bir basildir. Sporları küresel ve subterminal olarak bulunur. %5 tuz (NaCl) konsantrasyonunda inhibe olmaktadır (Soares ve ark.,2023).

B. coagulans, laktik asit, γ-aminobütirik asit (GABA), mannitol ve diğer aktif maddeleri üretebilir. Hayvancılıkta *B. coagulans*'ın kullanımı besin metabolizmasını teşvik etme, antibakteriyel/antioksidan etki ve ağır metal toksisitesini azaltma gibi birçok önemli etki göstermiştir (Zhang ve ark., 2021). Bu mikrooganizmayı içeren probiyotik preparatların düzenli uygulanmasının insanlarda laktoz intoleransını ve huzursuz bağırsak sendromunu (IBS) hafiflettiği, ishali önlediği, oksidatif stresi ortadan kaldırdığı ve bağırsak iltihabını iyileştirdiği bildirilmiştir (Sen ve ark., 2010; Sudha ve ark., 2018; Du ve ark., 2018; Madempudi ve ark., 2019; Zhao ve ark., 2023). Ayrıca, *B. coagulans*'ın immünomodülatör özellikler ve hipokolesterolemik etki sergilediği de bildirilmiştir (Kumar, 1989; Mohan ve ark., 1990; Baron, 2009; Babar ve ark., 2012). Çeşitli çalışmalar, probiyotik olan bu mikrooganizmanın rotavirüs

ishalinin önlenmesi ve süresinin kısaltılmasında da önemli olduğunu vurgulamıştır (Chandra, 2002). Ayrıca Crohn Hastalığı Aktivite İndeksi ve dışkı sıklığında azalma olduğu ortaya bildirilmiştir (Keller ve ark., 2010). Bunların dışında *B. coagulans* çeşitli antibakteriyel özelliklere sahip bakteriyosin olan 'coagulin' üretmektedir. *B. coagulans* bakteriyosinlerden başka peptitler, kısa zincirli yağ asitleri, riboflavin ve hidrojen peroksit üretimi de dahil olmak üzere başka önemli metabolitlerde üretmektedir (Poshadri ve ark., 2022).

2.2. *Bacillus clausii*

B. clausii toprakta bulunan gram pozitif bir mikroorganizmadır; çubuk şeklindedir ve pH 7.0-10.5'te 15 ve 50 °C arasında gelişim gösterir. Endosporlar üreten aerobik, alkali toleranslı, patojenik olmayan bir bakteridir (Schallmey ve ark., 2004). İnsan bağırsağı da dahil olmak üzere çeşitli bir ekosistemde gelişim gösterebilmektedir (Troeger ve ark., 2020). Ürettikleri sporlar genellikle besin azlığı, kuraklık, alkalinite, UV radyasyonu, yüksek sıcaklık ve aşırı fiziksel/kimyasal etkilere karşı iyi direnç göstermektedir (Cutting & Ricca, 2014). Vejetatif hücrelerine göre safra tuzunun veya gastrik HCl'nin asitliğine daha iyi dayanabilirler (Hong ve ark., 2005; Cutting & Ricca, 2014; Elshaghabee ve ark., 2017).

İtalya'da 1958'den beri *B. clausii* sporlarının süspansiyonu, insan tüketimi için spor bazlı bir probiyotiğin parçası olarak mevcuttur. 2001'den beri, *B.clausii* kişisel bakım endüstrisi tarafından çeşitli faydalı preparatlarda yaygın olarak pazarlanmaktadır (Senesi ve ark., 2001; Todorov ve ark., 2022). *B. clausii*'nin fizyolojik faydaları arasında, çalışmalar bakterinin bağırsaktaki kusurlu zarları iyileştirme veya antibiyotikler/kemoterapik ajanların neden olduğu bağırsaktaki vitamin eksikliklerini giderme yeteneğine sahip olduğunu göstermektedir. *B. clausii*'in en dikkat çekici probiyotik özelliğinden birisi de antibiyotik dirençleridir. Eritromisin de dahil olmak üzere çok sayıda antibiyotiğe dirençlidir. *B. clausii*, antibiyotik alımı kaynaklı bazı ishaller sonucu tetiklenen akut bağırsak enfeksiyonunun önlenmesinde veya tedavisinde önemli bir role sahip olduğu ifade edilmiştir (Abbrescia ve ark., 2014; De Castro ve ark., 2020 ; Sadrimovahed& Ulusoy, 2024).

2.3. *Bacillus subtilis*

B. subtilis, topraktan ve sudan sıklıkla izole edilen, spor oluşturan ve patojenik olmayan saprofit bir bakteridir. *B. subtilis*, 5–55 °C'de, pH'ı 5,5 ile 8,5 arasında, glikoz içeren ortamda gelişim göstermektedir. Ayrıca karbon ve azot kaynakları olarak sırasıyla sitrat ve amonyak kullanmaktadır. Mikroorganizmanın çeşitli suşları antimikrobiyal aktiviteye sahip peptitler üretir ve hızlı kazein sindirimini destekleme yeteneğine sahiptir. Bu mikroorganizma, antifungal ve antimikrobiyal aktiviteye sahip metabolitlerin üretimi için en önemli türlerden biri olduğu bilinmektedir (Bergey & Holt, 1994; Gomes, 2013).

Probiyotik *B. subtilis* suşlarının anti *H. pylori* aktivitesi de rapor edilmiştir; bu durum, 'aninocoumacin A' antibiyotiğinin salgılanması ile ilişkilendirilmiştir (Pinchuk ve ark., 2001). Ayrıca *B. subtilis* önemli bakteriosin üreticisidir. Örneğin, bu mikroorganizmaya ait farklı suşların subtilin, erisin S, erisin A, sublansin 168, mersasidin gibi bakteriyosinler ürettiği bildirilmiştir (Basi-Chipalu ve ark., 2022).

2.4. *Bacillus licheniformis*

B. licheniformis, toprakta ve bitkide yaygın olarak bulunan, 15-55 °C aralığında gelişim gösteren termofilik bir bakteridir. Morfolojik olarak, çapı 1 µm'den küçük bir basildir. Mikroorganizma, hücreyi deforme etmeyen merkezi veya terminal, küresel veya oval sporlar oluşturabilmektedir. Bağırsakta çoğalabilmek için oksijeni tüketir ve bağırsakta hızla düşük oksijenli bir ortam yaratabilir. Bu durum istenilen bağırsak florasının (*Bifidobacterium* ve *Lactobacillus* gibi) gelişimini destekleyebileceği düşünülmektedir (Kaewtapee ve ark., 2017; Song ve ark., 2014; Zhao ve ark., 2023).

B. licheniformis çeşitli antimikrobiyal aktif maddeler (likenin vb.) üretebilmekte ve antibiyofilm aktivitesi oluşumunu önleyerek ve bozarak *Staphylococcus aureus* ve *Candida albicans* gibi patojenik bakterileri inhibe edebilmektedir (Dalvand ve ark., 2018; Muras ve ark., 2021). Bu nedenle bakteri ve mantarların neden olduğu akut ve kronik enterit ve ishallerde etkili olduğu düşünülmektedir (Zhao ve ark., 2023). *B. subtilis* ve *B. licheniformis* suşlarını içeren BiosporinVR (Biofarm, Ukrayna), *Heliobacter pylori*'ye karşı tedavide klinik uygulama için probiyotik takviyesi olarak kullanılmıştır (Pinchuk ve ark. 2001).

2.5. *Bacillus pumilus*

B. pumilus, geniş bir sıcaklık aralığında 5–50 °C gelişim gösteren aerop ve termofilik bir bakteridir. Bazı suşlar gelişimleri için biyotine ihtiyaç duyar. Bazı *B. pumilus* türleri taksonomik olarak *B. subtilis* ile ilişkilidir (Bergey & Holt, 1994). Yarı saydam ve opak olmak üzere iki koloni formunda bulunur. Mikroorganizma, çapı 1 µm'den küçük bir basildir. Hücreyi deforme etmeyen, küresel veya oval, merkezi veya terminal sporlar oluşturmaktadır. Mikroorganizma %7 w/v NaCl çözeltisinin varlığında gelişebilmektedir (Gomes, 2013).

Vücuda faydalı olan birçok biyoaktif maddeyi sentezleme yeteneğine sahiptir. Farklı hidrolitik enzimler (proteaz, lipaz, α-amilaz), vitaminler, amino asitler üretebilmektedir. Ayrıca lizozim etkinliği olarak belirli bakterileri (*Escherichia coli, Aspergillus, Staphylococcus*, vb.) doğrudan lize etme kapasitesine sahiptir. Bu mikroorganizma bağırsakta biyolojik oksijen yakalama işlemini gerçekleştirebilir, yararlı anaerobik mikroorganizmaların büyümesini ve üremesini teşvik edebileceği ifade edilmektedir (Zhao ve ark., 2023).

3. PROBİYOTİK *CLOSTRİDİUM* TÜRLERİ

Clostridium spp. gram pozitif, çubuk şeklinde, fermentatif, spor oluşturan ve anaerobik bir bakteridir. *Clostridium* spp. yaygın olarak toprakta, suda, tozda, çamurda, insan ve hayvanların bağırsaklarında, ayrıca çiftlik ortamlarında ve süt/süt ürünlerinden izole edilebilmektedir (Storari ve ark., 2016; Khomeiri ve ark., 2023; Akbal & Öner, 2025)

Clostridia, erken kolonize olmuş bakterilerin üyelerinden biridir ve doğumdan sonraki ilk hafta içinde dışkıda tespit edilebilirler. Bu türler çoğunlukla *C. paraputrifikum C. difficile* ve *C. butyricum* 'dur (Guo ve ark. 2020).

Clostridium spp. probiyotik olarak önemli bir potansiyele sahiptir. Bulaşıcı hastalıklarda rol oynayan birkaç *Clostridium* türünün patojenik olduğu, esasen insanlarda ve diğer hayvanlarda yaşamı tehdit eden hastalıklardan sorumlu olan güçlü toksinler ürettiği bilinmektedir. Toksin üreterek önemli gıda zehirlenmelerine neden olabilmektedir. Fakat, toksinleri güçlü bir tedavi aracı olabilmekte ve kozmetik ürünlerinde kullanılabilmektedir. Önemli olarak süt ürünleriyle ilişkili *Clostridium* türlerinin çoğu insanlar için patojenik değildir. Ayrıca bazı suşlar organik çözücüler, organik asitler ve enzimlerin üretimi için yaygın olarak kullanılmıştır (Khomeiri ve ark., 2023).

3.1. *Clostridium butyricum*

Bilinen en önemli probiyotik *Clostridium* türü *C. butyricum*'dur. Bu mikroorganizma yüksek miktarda bütirik asit üretme kapasitesi nedeniyle adlandırılan, mutlak anaerobik, Gram pozitif, spor oluşturan bir basildir. İlk olarak 1880'de Prazmowski tarafından domuz bağırsaklarından izole edilmiştir. O zamandan beri, çeşitli ortamlarda *C. butyricum*'un birkaç suşu tanımlanmış ve bunlar yaygın insan/hayvan bağırsak kommensal bakterileridir.

C. butyricum onlarca yıldır güvenli bir probiyotik olarak kullanılmaktadır. Japonya ve Kore gibi bazı Doğu Asya ülkelerinde, *C. butyricum*'un belirli bir suşu ticari olarak probiyotik bir bakteri olarak üretilmektedir. İnsan bağırsağında, *C. butyricum* sindirilmemiş diyet liflerini tüketebilmekte ve kısa zincirli yağ asitleri, özellikle bütirat ve asetat üretebilmektedir. Asetat ve bütiratın bağırsak bariyerinin fizyolojisini etkilediği birçok yol vardır. Ayrıca, iltihabı hafifletme ve bağırsak düzenleme konusunda önemli etkileri bulunmaktadır. Ayrıca *C. butyricum*'un bağırsak mikrobiyomunun bileşimini düzenleyerek *Bifidobacterium ve Lactobacillus* gibi özel yararlı bakteri türlerini artırabileceği öne sürülmektedir (Courvalin, 2006; Guo ve ark. 2020; Stoeva ve ark., 2021, Khomeiri ve ark., 2023).

C. butyricum patojenik bakterileri antagonize ve bağırsaktaki yararlı bakterilerin çoğalmasını teşvik etmektedir (Li ve ark., 2016; Li ve ark., 2019). Bu nedenle, insan bağışıklığını iyileştirmek ve bağırsak fora dengesizliğini tedavi etmek için kullanılabilir. Hayvancılıkta *C. butyricum*, hayvan sağlığı koruma özelliği nedeniyle antibiyotik yerine umut vadeden bir pazar beklentisine sahiptir (Yi ve ark., 2020).

C. butyricum ve *B. coagulans*, *H. pylori*'yi birkaç farklı yolla etkili bir şekilde inhibe edebileceği bildirilmiş (Zhang ve ark. 2020) ve alternatif bir anti-*H. pylori* ilacı olarak kullanılabileceği düşünülmektedir. Ayrıca akut enterit ve bağırsak mikrobiyolojik bozukluklarının klinik tedavisinde de kullanılmıştır (Li ve ark., 2022). Shin & Eom (2020), *C. butyricum* hücresiz üst sıvılarının (süpernatant) *Acinetobacter baumannii*'ye karşı antimikrobiyal ve antibiyofilm aktivitesini incelemiş ve *C. butyricum* süpernatantının *A. baumannii* hücre gelişimini engellediğini göstermiştir. Ayrıca *C. butyricum* süpernatantının hücrelerin metabolik aktivitesini baskılayarak anti-biyofilm aktivitesi gösterdiği görülmüştür. *C. butyricum* MIYAIRI 588'in (CBM 588) probiyotik etkileri ve güvenliği 20 yıldan uzun süredir araştırılmaktadır. Suşun probiyotik etkileri kemirgenlerde, bazı üretim hayvanlarında ve insanlarda incelenmiştir. Suş günümüzde takviye olarak ticari şekilde şatışı bulunmaktadır. Bu suşun deney hayvanlarında enfeksiyonu önlediği, bağışıklık sistemini güçlendirdiği, kolite

karşı ve yağlı karaciğer hastalığına karşı koruyucu olduğu ortaya konmuştur. Ayrıca bu suşun çocukları antibiyotikle ilişkili ishalden koruduğu ifade edilmiştir (Saarela, 2019).

4. SPORLU PROBİYOTİK BAKTERİLERİN SÜT ÜRÜNLERİNDE OLASI KULLANIMI

Geleneksel olarak, küresel düzeydeki tüketiciler arasında süt ürünleri, iyi kabul görmeleri ve fermantasyon teknolojisinin kullanımından dolayı probiyotik kültürlerin eklenmesi için önde gelen/en popüler gıda sınıfıdır (Cruz ve ark., 2007; Zhao ve ark., 2021; Granato ve ark., 2010; Soares ve ark.,2023).

Spor oluşturan probiyotiklerin gıdalara eklenmesi son zamanlardaki bir gelişmedir. Spor oluşturan probiyotikler, uygun koşulların varlığında gıdayı bozabilecekleri için gıda matrisinde çimlenmemelidir. Bu nedenle, gıda matrisi seçimi probiyotik olarak kullanılan türe veya suşa bağlıdır (Ranadheera ve ark., 2010).

Yoğurt, tadı, kokusu ve dokusu kullanılan kültür ve meyve aromalarıyla olumlu şekilde değişebilen fermente bir süt ürünüdür. Süt endüstrisinde, *B. coagulans*-70'in eklenmesi yoğurt ürünlerinin görünümü ve dokusu üzerinde olumlu bir etkiye sahip olduğu ve ayrıca 2-heptanon, 2-nonanon, pentanol ve 2-hidroksi-3-pentanon seviyelerini artırarak daha fonksiyonel bir süt ürününün geliştirilmesi için uygun bir suş haline getirebileceği ifade edilmiştir (Ma ve ark., 2021). *B. coagulans*'ın yoğurtta starter olarak kullanımı ile gerçekleştirilen bir başka çalışmada, *Streptococcus thermophilus* ve *Lactobacillus delbrueckii* subsp. *bulgaricus*'un geleneksel uygulamasıyla ve bu mikroorganizmaların kombinasyonuyla karşılaştırılarak değerlendirilmiştir. Kombinasyon daha iyi lezzet, daha yüksek titre edilebilir asitlik, kohesiflik ve daha iyi bir uçucu bileşik profili sergilemiş ve *B. coagulans*'ın geleneksel yoğurt kültürüyle birlikte kullanımının probiyotik yoğurtların duyusal profilini iyileştirmek için iyi olabileceği ifade edilmiştir (Zhao ve ark., 2021).

B. clausii ile üretilen yoğurtta yapılan çalışmada, *B. clausii*'nin 150 günlük depolama süresince fenolik içeriği, DPPH ve FRAP gibi antioksidan aktivite değerleri üzerinde çok düşük bir etkisi olmuştur. pH değerlerine bakıldığında *B. clausii* etkilemiş yoğurt kontrole göre daha düşük bir asitlik göstermiştir. 150 günlük depolama boyunca probiyotik *B. clausii* sayısı 4,1 x 10^8 kob/g'lık seviyesinde canlılık göstermiştir (Ramos ve ark., 2019).

S. thermophilus ve *B. coagulans* MTCC 5856 ile üretilen fermente süt ürünlerinde yapılan bir çalışmada, protein ilavesi ürünün reolojik özelliklerini iyileştirmiştir. Ayrıca *B. coagulans* ve *S. thermophilus*, 60 gün içinde ürünün depolanması sırasında önemli ölçüde canlılığını korumuş ve antioksidan aktiviteyi de iyileştirdiği tespit edilmiştir (Elshaghabee ve ark., 2017). *B. indicus* HU36, probiyotik bir takviye olarak güvenliği ve karotenoid üretmedeki yüksek kapasitesi nedeniyle özel ilgi görmektedir. *B. indicus* HU36'nın vejetatif formdaki canlılığı, set tipi rekombinasyonlu yağsız yoğurttaki yoğurt kültürleriyle birlikte 4 °C'de depolanan üründe yapılan çalışmada kalite üzerindeki etkiler belirlenmiştir. Yoğurttaki *B. indicus* HU36 hücrelerinin sayısı 14 gün sonra yaklaşık 5 log kob/ml olarak kalırken, 21 gün sonra 3,5 log kob/ml'e düşmüştür. Bakteri sarılığın artmasına neden olmuş ancak yoğurdun reolojik özelliklerini etkilememiştir. Araştırmacılar, yoğurdun duyusal özellikleri ticari probiyotik

yoğurtla karşılaştırıldığında kabul edilebilir düzeyde olduğu ve *B. indicus* HU36'nın yoğurt üretiminde probiyotik kültür olarak kullanılabileceğinin düşünüldüğü ifade edilmiştir.

Bacillus'ların spor oluşturma yeteneği, diğer önemli bir süt ürünü olan peynirde kullanımınında iyi sonuçlar verebileceği düşünülmektedir. Çünkü geleneksel olarak üretilen birçok peynirin uzun olgunlaştırma süresine ihtiyacı vardır ve bu süreçte peynir matrisinde serbest su azalır ve mikroorganizmalar için yarayışlı su oranı da düşmüş olur. Dolayısıyla zor çevre koşullarına dayanıklı suşlara ihtiyaç olabilmekte ve en iyi alternatifinde spor oluşturan türler olduğu görülmektedir. Ayrıca telemesi haşlanan birçok peynirde probiyotik özellik gösteren geleneksel suşlar inaktif olabilmekte ve spor oluşturan kültürlerin bu peynirlerde kullanımı daha cazip hale gelebilmektedir. İran işlenmiş peynirinde yapılan bir çalışmada, 60 günlük depolama süresince *Bacillus* sporları içeren peynirlerin kontrole kıyasla daha yüksek titre edilebilir asitliğe ve daha düşük pH değerlerine sahip olduğu bildirilmiştir. Depolama sırasında bakteri popülasyonu azalsa da 10^6 kob/g'ın üzerinde kalmıştır. Probiyotik peynirlerin duyusal değerlendirmesi, bu örneklerin kontrol peynirlerine kıyasla daha düşük lezzet ve genel kabul gördüğünü ifade edilmiştir. Probiyotik *Bacillus* suşlarının (*Bacillus flexus HK1, B. subtilis PB6, B. subtilis PXN 21, B. coagulans GBI-30 6086, B. coagulans MTCC 5856*) Brezilya'da "requeijao ˜ cremoso" işlenmiş peynirinde üretim aşamalarında ve depolama süresinde (6 C'de 45 gün) hayatta kalmasının değerlendirildiği bir başka çalışmada, *B. coagulans* GBI-30 6086'nın üretim aşamalarında en dirençli suş olduğu ve peynir raf ömrü boyunca yüksek popülasyonlarını koruduğu belirtilmiştir.

Bacillus türlerinin son 20 yılda farklı gıdalarda probiyotik olarak kullanımı ile ilgili araştırma sayısı az olsada arttığı görülmektedir. Fakat diğer bir spor oluşturan bakteri cinsi *Clostridium*'lara ait çalışmalar özellikle güvenlik endişeleri nedeniyle henüz gıdalarda kullanım noktasına gelememiştir.

5. SONUÇ VE ÖNERİLER

Bacillus ve *Clostridium* türlerine ait bakterilerin sporları yüksek asit içeriğine sahip yoğurt ve peynir gibi ürünlerde çimlenmesi zordur. Bu nedenle ürünün duyusal özelliklerini bozmadan probiyotik özelliği yüksek bir ürün geliştirilmesi mümkün olduğu görünmektedir. Ayrıca süt ürünlerinde zor çevre sartlarına sporlar daha dayanıklı oldukları için LAB'e ait probiyotik türlerden daha uzun süre canlılık gösterebilmektedir.

Probiyotiklerin sıcaklığa karşı toleransları da oldukça önemlidir. Bu bağlamda dünya genelinde telemesi haşlanan birçok peynir üretilmektedir. Termofilik karakterde kültür kullanımı bu ürünler için önemlidir. Spor oluşturan probiyotik kültür kullanımı bu ürünler için kolaylık olabilir. Ayrıca yüksek tuz içeren ortamlara dirençli olduklarından salamurada olgunlaştırılan peynirlerde kültür olarak kullanılabilir.

B. coagulans ve *B. clausii* gibi GRAS kabul edilen türlerin gıdalarda kullanımında literatürde önemli bir boşluk bulunmaktadır. Bu nedenle sporlu probiyotikler ile ilgili ürün geliştirme araştırmalarının yapılması önerilmektedir. Ayrıca sporlu bakterilerin olası yararlı etkileri ile birlikte ishal-kabızlık gibi bağırsak rahatsızlıkları, karaciğer rahatsızlıkları, toksin ve kansorejen madde üretimine neden olabileceğinden kullanımına oldukça dikkat edilmelidir.

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PESTICIDE APPLICATIONS AND RESIDUE PROBLEMS IN GREENHOUSE AGRICULTURE

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ABSTRACT

Greenhouse farming not only enables higher yield and quality per unit area but also offers the opportunity for early harvest, creating a high-profit margin. Due to these advantages, the use of pesticides in greenhouse farming often becomes inevitable in the fight against diseases and pests. Many pesticides have toxic properties and can cause serious health problems if used incorrectly. This review discusses the effects of pesticides used in greenhouse farming on the environment and human health, their pathways into the food chain, and their significance in terms of public health.

Keywords: Pesticide, Greenhouse, Residue

ÖRTÜ ALTI TARIMINDA PESTİSİT UYGULAMALARI VE KALINTI PROBLEMLERİ

ÖZET

Örtü altı tarımı, hem birim alandan daha yüksek verim ve kalite elde edilmesini sağlamakta hem de erken hasat imkânı sunarak yüksek kâr marjı oluşturmaktadır. Bu avantajları nedeniyle, örtü altı tarımında hastalık ve zararlılarla mücadelede pestisit kullanımı genellikle kaçınılmaz hale gelmektedir. Birçok pestisit toksik özelliklere sahiptir ve yanlış kullanıldıklarında ciddi sağlık sorunlarına yol açabilirler. Bu derlemede, örtü altı tarımında kullanılan pestisitlerin çevre ve insan sağlığı üzerindeki etkileri, gıda zincirine bulaşma yolları ve halk sağlığı açısından önemi ele alınmıştır.

1. GİRİŞ

1.1. ÖRTÜ ALTI NEDİR

Sebze yetiştiriciliğinde, cam veya plastik örtüler kullanılarak yapılan yetiştirme yöntemine "örtü altı yetiştiricilik" denir. Özellikle vejetasyon süresi kısa olan bölgelerde, uygun yer ve yöneyin yanı sıra plastik örtüler de kullanılarak sebzeler donlardan ve iklimin diğer olumsuz şartlarından korunur. Bu sayede, ürün alma süresi erkene çekilebilir veya uzatılarak turfanda sebzecilik yapılabilir (Anonim, 2015).

Sera, iklimle ilgili çevre koşullarına tamamen veya kısmen bağımlı olmadan, gerektiğinde sıcaklık, nem, ışık ve havalandırma gibi faktörler kontrol edilerek, yıl boyunca çeşitli kültür bitkileri, tohumlar, fideler ve fidanların üretildiği, saklandığı ve sergilendiği bir yapıdır. Seralar, genellikle cam, plastik gibi ışık geçirebilen maddelerle kaplanarak inşa edilir ve yüksek sistemde bir örtü altı yetiştiriciliği yapısına örnek oluşturur (Öneş, 1986; Yüksel 1990).

Ülkemizde örtüaltı alanı 2008 ve 2018 yılları arasında %42.4 oranında artmıştır (Tarım ve Orman Bakanlığı, 2019a). Ülkemizdeki örtüaltı alanlarının %84'ü Akdeniz bölgesinde bulunmaktadır.

Antalya, 28,828.3 hektar ile bu alanın en önde gelen merkezidir ve bu ili sırasıyla 19,655.5 hektar ile Mersin ve 15,072.9 hektar ile Adana takip etmektedir. Adana ve Hatay (1,109.6 hektar), özellikle alçak plastik tünel alanlarının yoğun olduğu bölgelerdir.

Akdeniz ve Ege Bölgeleri arasında bir geçit konumunda olan Muğla, 3,904.9 hektar ile bu illeri izlemektedir. İzmir ve Aydın ise sırasıyla 1,572.6 ve 1,501.8 hektar örtüaltı alanına sahiptir (Tarım ve Orman Bakanlığı, 2019b). Örtüaltı tarım alanı dağılımı incelendiğinde Orta Karadeniz Bölgesinde yeralan Amasya 10. Sırada yeralmaktadır (Tablo 1).

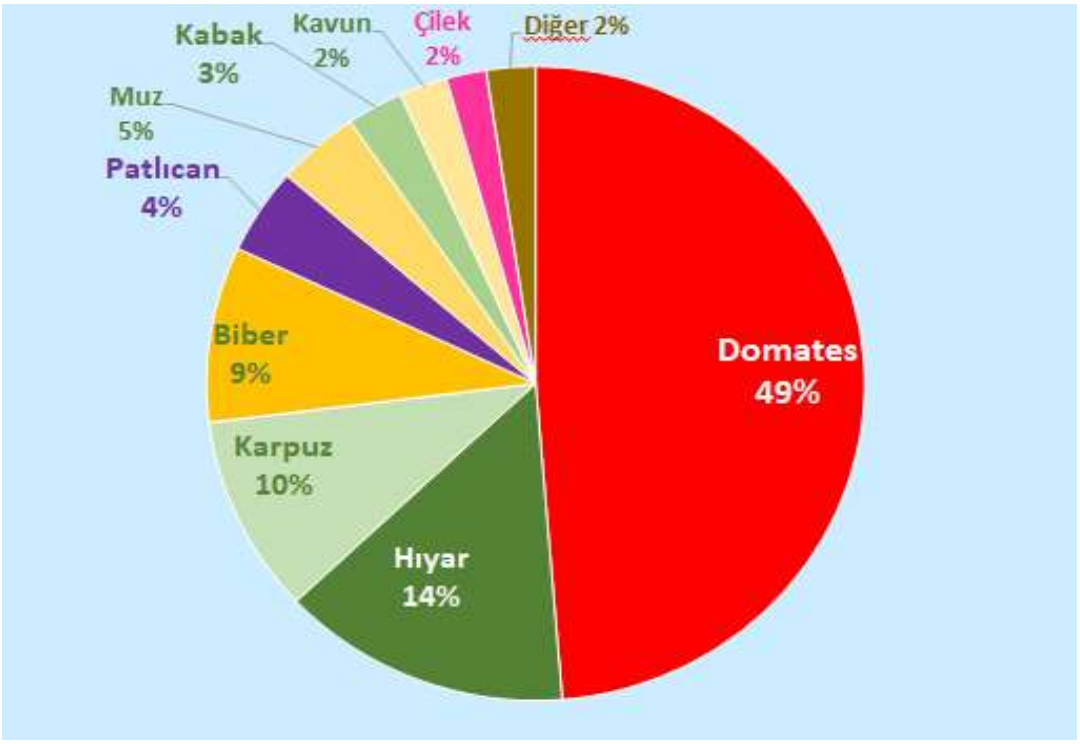
Tablo 1. İllere göre örtü altı tarım alanları

İller		Örtü altı Tarım Alanı (da)
1	Antalya	286.522
2	Mersin	201.060
3	Adana	160.493
4	Muğla	39.048
5	İzmir	14.016
6	Aydın	12.717
7	Hatay	11.456
8	Burdur	9.843
9	Isparta	4.942
10	**Amasya**	4.881

Kaynak: Tarım ve Orman Bakanlığı, 2019b

1.2 NEDEN ÖRTÜ ALTI TARIMI

Seracılık, açık tarla yetiştiriciliğine kıyasla 2-5 kat daha fazla ürün ve 5-10 kat daha fazla gelir elde edilmesine olanak tanımaktadır. Örtü altı tarımı, birim alandan daha yüksek verim ve kalite sunarken, erkencilik sayesinde yüksek kâr marjı sağlar. Yıl içerisindeki yetiştirme dönemi uzatılarak, aynı araziden yılda 2-3 kez ürün alınabilir. Bu durum, özellikle küçük arazi sahipleri için işgücü istihdamı ve işgücünün yıl boyu eşit dağılımını sağlamaktadır (Doğaka, 2015; Anonim, 2025a). Şekil 1 de görüldüğü gibi Türkiye örtü altında üretilen ürünlerin dağılımı verilmiştir.



Şekil 1. Örtü altında üretilen ürünker Kaynak: Tarım ve Orman Bakanlığı, 2023

Seracılık, işletme sahiplerine sürekli gelir sağlayan ve pazarda sürekli taze meyve, sebze ve çiçek bulunmasını sağlayan önemli bir sektördür. Sera ürünleri, daha kararlı ve cazip fiyatlarla hem yurt içinde hem de yurt dışında kolayca pazarlanabilmektedir. Ayrıca, sera tesislerinde kullanılan malzemeler, sera imalat sanayiinin kurulmasına ve gelişmesine katkı sağlar (Doğaka, 2015).

Örtü altında kültür bitkilerinde olduğu gibi bitki koruma problemleri görülmektedir. Bunların başında ise sırasıyla; Kırmızı örümcekler [*Tetranychus urticae* Koch.], Domates pasakarı [*Aculops lycopersici*, Domates güvesi [*Tuta absoluta* (Meyrick)], Danaburnu [*Gryllotalpa gryllotalpa* (L.)], Kök ur nematodları *(Meloidogyne spp.,* Goeldi*),* Tütün beyazsineği [*Bemisia tabaci* (Genn.)] (Şekil 2) ve Hıyar mozaik virüsü *(Cucumber mosaic virus),* Kabakgillerde

Mildiyö (*Pseudoperonospora cubensis* Berk. and Curt.), Kurşuni Küf *(Botrytis cinerea* Pers.), *Domates lekeli solgunluk virüsü (*Tomato spotted wilt virus) Şekil 3.

Şekil 2. Örtüaltında sorun olan başlıca zararlılar

Şekil 3. Örtüaltında sorun olan başlıca hastalıklar

Örtü altı tarımı, yüksek verim ve kalite elde etmek amacıyla yoğun olarak pestisit kullanımını gerektirir. Ancak, pestisitlerin toksik özellikleri nedeniyle bilinçsiz ve kontrolsüz kullanımları, doğada ve gıdalarda kalıntıya neden olurken aynı zamanda, ciddi sağlık sorunlarına yol açabilir ve çevresel dengenin bozulmasına sebep olabilir. Ayrıca; Pestisitlerin yanlış ve yoğun kullanımı, bitkilerde fitotoksisiteye neden olur ve hedef dışı organizmalara zarar vererek, doğal dengeyi bozar. Peki o halde;

2.PESTİSİT NEDİR

Pestisitler, tarım ürünlerini korumak ve insan sağlığını tehdit eden zararlıları kontrol altına almak amacıyla kullanılan kimyasal maddelerdir. Bu maddeler, böcekler, yabani otlar, mantarlar ve diğer zararlı organizmaları hedef alarak, onları yok eder veya büyümelerini engeller. Böylece, tarım ürünlerinin verimliliği ve kalitesi korunmuş olur (Garud et al., 2024) Biyolojik Hedeflere Göre sınıflandırılması;

1. İnsektisitler (böcek öldürücü ilaçlar)
2. Akarisitler (kırmızı örümcek öldürücü ilaçlar)
3. Fumigantlar
4. Nematisitler (nematot öldürücüler)
5. Rodentisitler (kemirgen öldürücüler)
6. Mollusitler (salyangoz öldürücüler)
7. Fungusitler (mantar öldürücü ilaçlar)
8. Bakterisitler (bakteri öldürücü ilaçlar)
9. Herbisitler (yabancı ot öldürücüler)
10. Afisitler (yaprakbiti öldürücüler)
11. Repellentler (kaçırıcılar)

Zirai mücadele ilaçları, tarımda kolay uygulanabilirliği ve hızlı sonuç alınabilirliği nedeniyle dünya genelinde vazgeçilmez maddeler olarak kabul edilmektedir (Yıldırım, 2000). Bu kimyasal maddeler, bitki koruma amacıyla yaygın olarak kullanılmakta ve zararlılarla etkin bir mücadele sağlamaktadır. Türkiye'de 2022 yılında toplam pestisit kullanım miktarı, 2021 yılına göre 4,5% artarak 55.374 ton'a yükselmiştir. Tarım ilacı kullanım miktarları gruplar bazında incelendiğinde Dünyada olduğu gibi Ülkemizde de en büyük grubu fungusitler (mantar öldürücü) oluşturmuştur (Anonim, 2022). Ancak, verim artışında büyük rol oynayan zirai mücadele ilaçlarının bilinçsiz ve kontrolsüz kullanımı, bazı bitki koruma sorunlarına yol açmaktadır. Kimyasal mücadelede pestisitlerin bilinçsiz ve kontrolsüz kullanımı, hedef organizma gruplarında pestisitlere karşı direnç gelişimine sebep olmaktadır. Ayrıca, yoğun pestisit kullanımı, ürünlerde kalıntı sorunlarına, çevreye ve insan sağlığına olumsuz etkiler doğurmaktadır. Kontrollü olmayan yoğun kimyasal uygulamalar doğal dengeyi bozabilir ve bitkilerde fitotoksiteye neden olabilir (Delen, 2005; Yıldırım, 2000).

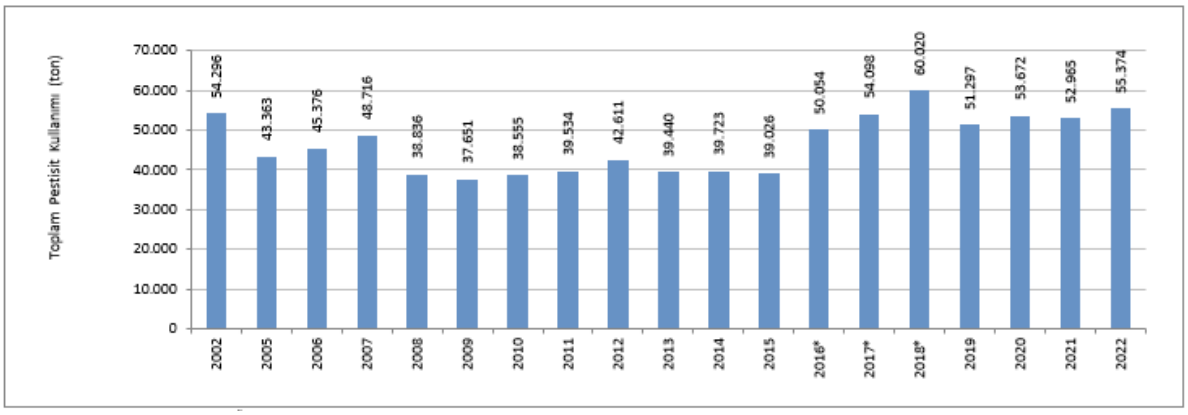
2.1 TÜRKİYE'DE PESTİSİT KULLANIM MİKTARLARI

Tarım ilaçlarının gruplar bazında kullanım miktarlarına bakıldığında, en büyük grubun fungusitler (mantar öldürücüler) olduğu görülmektedir. 2022 yılında toplam tarım ilacı

kullanımının %35,1'ini fungusitler, %26,3'ünü herbisitler (yabancı ot öldürücüler), %22,0'sini insektisitler (böcek öldürücüler), %4,5'ini akarisitler (akar öldürücüler), %0,5'sini rodentisitler (kemirgen öldürücüler) ve %11,6'sını diğerleri (bitki aktivatörü, bitki gelişim düzenleyici, böcek cezbedici, fumigant, nematosit, kükürt, madeni yağlar) oluşturmuştur (Anonim, 2022).

Yıllara göre pestisit kullanımına bakıldığında 2022'de yaklaşık 55 bin ton oldu görülmektedir (Tablo 2).

Tablo 2. Yıllara göre toplam pestisit kullanım miktarları *(Tarım ve Orman Bakanlığı, 2023)*



2.2 KALINTI NEDİR

Yoğun pestisit kullanımı sonucu bu maddeler gıda, toprak, su ve havada kalıntı olarak birikebilir. Pestisit kalıntıları hedef dışındaki organizmalar ve insanlara zarar verebilir. 1948 ve 1951 yıllarında insan vücudunda organik klorlu pestisit kalıntıları bulunduğundan beri pestisitlerin önemi anlaşılmıştır (Anonim,2025b).

Gıdalar, pestisit kalıntılarının başlıca kaynağıdır. FAO ve WHO, 1960 yılında "Pestisit Kalıntıları Kodeks Komitesi"ni kurarak gıdalarda izin verilen maksimum kalıntı seviyelerini belirlemiştir. Türkiye'de de tarımsal ürünlerdeki pestisitlerin limitleri Tarım Bakanlığı tarafından belirlenmiş olup, bu bilgiler bakanlığın web sitesinde mevcuttur (Yücel, 2006).

2.3 PESTİSİTLERİN İNSAN VE ÇEVRE ÜZERİNE ETKİLERİ NEDİR?

Pestisitlerin İnsanlar Üzerine Etkileri

Pestisitler, dünya pazarları için yeterli gıda üretiminin sağlanmasında ve modern gıda üretiminde önemli bir rol oynamaktadır. Artan dünya nüfusuyla birlikte gıda ihtiyacını karşılamak amacıyla günümüzde pestisit kullanımı birçok alanda yer almaktadır (Shaw ve Chadwick, 2002).

Pestisitlerin insanlarda belirli miktarlarda toksik olmaları nedeniyle savaşımda çalışan herkesin bunların kullanımı sırasında meydana gelebilecek potansiyel zarardan sakınmaları gerekir. Pestisitlerin kalıntı yoluyla kronik toksisiteleri yanında bazılarının insanlarda mutajenik, teratojenik ve kanserojen etkilerinin de olduğu son yıllarda yapılan çalışmalarla saptanmıştır. İnsanların pestisitlere maruz kalması mesleki zehirlenmeler veya kaza ile meydana gelebilmektedi (Gül, 2017).

Her iki tür zehirlenmenin ana nedenleri:

1. Halkın bu konuda yetersiz eğitime sahip olması ve pestisitlerin toksisite potansiyellerinin bilinmemesi,

2. Uygun olmayan koşullarda depolama,

3. Kaza ile saçılma sonucu gıdaların kontamine olması,

4. Dikkatsiz yükleme ve taşıma,

5. Yıkanmamış pestisit kaplarının kullanımı,

6. Genel bakım ve atık değerlendirme işlemleri

Mesleki zehirlenmeler:

Üretim, formülasyon hazırlama, taşıma, yükleme ve uygulama sırasında deri ve solunum yoluyla maruz kalma (akut zehirlenme) olarak tanımlanabilir. Daha çok organik fosforlular ve karbamatlılar bu tip zehirlenmeye neden olurlar. Bunlar vücutta kolinesteraz enzimini inhibe ederek asetil kolin birikimine yol açarlar (Gül, 2017).

Kaza ile meydana gelen zehirlenmeler:

Pestisitlerin yaprak ve topraktaki kalıntıları veya onların toksik dönüşüm ürünleriyle temas sonucu hastalıklar meydana gelebilmektedir. Aşırı dozlarda alınmadıkça organik klorlu pestisitlerin insanlara akut zehirlilikleri enderdir. Bu bileşikler daha çok kronik zehirlenmeler meydana getirmektedir. Sinir sistemini etkiler ve karaciğere zarar verirler (Anonim, 2025c). Son yıllarda ilaçların besin maddelerindeki kalıntılarının insanlar için kronik toksisitesi iki şekilde ele alınmaktadır:

1. Kabul edilebilir günlük alım (Acceptable Daily Intake-ADI): Bir kişinin bir günde alabileceği kabul edilebilir günlük ilaç miktarını mg/kg olarak ifade eden değerdir.

2. Maksimum kalıntı limitleri (Maximum Residue Limits-MRL): Gıda maddelerinde bulunmasına izin verilen en fazla ilaç miktarını (ppm) ifade eden değerdir.

“Codex Alimentarius”, USEPA (United States Environmental Protection Agency) gibi kuruluşların bu değerleri içeren listeleri mevcuttur. Bu miktarlar tarımsal ürünlerin dış pazarlaması bakımından da önemlidir. Zira tolerans miktarını aşan değerlerde pestisit kalıntısı tespit edilen tarımsal ürünler alıcı ülkeler tarafından geri çevrilmektedir.

Çevre Üzerine Etkileri

Pestisitler tarımsal alanlar, ormanlar veya bahçelere uygulandığında havaya, suya ve toprağa geçmekte ve bu ortamlarda yaşayan diğer canlılara ulaşmaktadır. Bir pestisitin çevredeki hareketleri kimyasal yapısı, fiziksel özellikleri, formülasyon tipi, uygulama şekli, iklim ve tarımsal koşullar gibi faktörler tarafından belirlenmektedir (Yıldırım, 2008).

Pestisitlerin püskürtülerek uygulanması sırasında, bir kısmı buharlaşma ve yayılma nedeniyle kaybolmakta; diğer kısmı ise bitki üzerinde ve toprak yüzeyinde kalmaktadır. Atmosfere karışan pestisitler rüzgarlarla taşınabilir ve yağmur, sis veya kar yağışı ile tekrar yeryüzüne dönebilir. Bu şekilde hedef dışındaki organizma ve bitkilere ulaşan pestisitler, bu canlılarda kalıntı ve toksisiteye yol açabilir (Öğüt ve Seçilmiş, 2009).

Hedef Olmayan Organizmalar Üzerine Etkisi

Hemen bütün insektisitler spesifik olmadıkları için sadece hedef organizmaları öldürmez, omurgalı ve omurgasız diğer organizmaları da etkilerler. Zararlı etkilerin şiddeti, insektisitin ve formülasyonun tipine, uygulama şekline ve tarımsal arazinin tipine bağlı olarak değişmektedir (Tiryaki, Canhilal ve Horuz, 2010). En genel yan etkiler şunlardır:

1. Arılar, kuşlar ve balıklar, mikroorganizmalar ve omurgasızlar gibi hedef olmayan organizmalarda ölümler,

2. Kuş, balık ve diğer organizmalarda üreme potansiyelinin azalması,

3. Hedef olamayan organizmalarda dayanıklılık oluşması sonucu insanlara hastalık taşıyan böcek ve parazitlerin kontrolden çıkması,

4. Ekosistemin yapısının ve türlerinin sayılarının değişmesi gibi uzun dönemli etkiler.

Pestisitler, toprak ve bitki uygulamalarından sonra yağmur suları ile yüzey akışı veya toprak içerisinde yıkanarak taban suyu ve diğer su kaynaklarına ulaşabilir. Bu pestisitler, balık ve diğer su organizmalarının ölümüne yol açabilir; ayrıca insanların gıda zincirine girerek kronik toksisiteye neden olabilir (Yücel, 2007).

Toprağa geçen pestisitler fotokimyasal, biyolojik ve kimyasal degradasyona uğrayabilir; ayrıca emilip salınabilir. Kapiller su aracılığıyla yüzeye taşınan pestisitler havaya karışabilir. Pestisitlerin hareketi ve dönüşümü, toprağın yapısı, pH seviyesi ve mikroorganizma türlerine bağlıdır. Pestisitlerin toksik özelliklerini yitirmesi veya daha zehirli metabolitlere dönüşmesi çevre açısından önemlidir. Bu nedenle, pestisitlerin toprak içindeki davranışları incelenmelidir (Sarıoğlu ve Taş, 2023).

2.4 PESTİSİT KALINTILARIYLA İLE İLGİLİ YAPILAN BAZI ÇALIŞMALAR

Balkan ve Kenan (2019) Tokat ilinde tüketime sunulan domateslerde neonikotinoid grubu insektisitlerin kalıntı düzeylerinin belirlenmesi üzerinde araştırmalar yapmışlardır. Toplam 30 domates örneğinden 16 örneğin her birinde en az bir neonikotinoid kalıntısına rastlanmış ve bu örnekler toplam numunenin %53,33'ünü temsil etmiştir. Ayrıca, bir örnekte Türk Gıda Kodeksi

(TGK) ve Avrupa Birliği (AB) Maksimum Kalıntı Limitleri (MRLs)'nin üzerinde pestisit kalıntısı tespit edilmiştir1. Bu sonuçlar, domates ürünlerinde pestisit kalıntılarının yaygın olduğunu ve bazı örneklerde güvenlik limitlerinin aşılmasını göstermektedir. Bu nedenle, domates yetiştiriciliğinde pestisit kullanımının dikkatli yapılması ve kalıntı limitlerinin dikkate alınması önemlidir.

Hepsağ (32) Akdeniz Bölgesi'nde domates numunelerinin %26'sında pestisit (dimethoate, chlorpyrifos, endosülfan, methomyl ve acetamiprid) kalıntısı bulmuş olup ancak bunların hiçbiri MRL değerinin üzerinde değildir.

Altındağ ve Özgökçe (2006) Van ilinde örtü altında yetiştirilen hıyar üzerinde Dichlorvos ve Dicofol pestisitlerinin parçalanma süreleri araştırılmıştır. Pestisitlerin kalıntı miktarları, ilaçlamadan önce ve ilaçlamadan sonra 1, 3, 5, 9 ve 13 gün geçtikten sonra alınan örneklerde gaz kromatografisi cihazı kullanılarak analiz edilmiştir. Sonuçlar, Dichlorvos kalıntısının 5. gününde tolerans düzeyinin altına düşmesine ve Dicofol kalıntısının 9. gününde tolerans değerinin üzerinde tespit edilmesine göz atıyor. 13. gününde ise Dicofol kalıntısı tolerans düzeyinin altına düşmüştür.

Burcak ve ark. (1998) tarafından sera domateslerinde bazı fungisitlerin kalıntı düzeylerini araştırmıştır. Çalışmada, rnetiram kompleks, iprodione ve vinclozoline'in son ilaçlama ile hasat arasındaki süreleri tespit etmeye yönelik parçalanma seyirleri ortaya koymuştur. Bekleme süresinin metiram kompleks için 8 gün, iprodione için 6 gün ve vinclizolin için ise 1 gün olması gerektiğini bildirmişlerdir.

Zengin ve Karaca (2017) Uşak ilinde 2015 ve 2016 yıllarında örtü altı sera alanlarından topladıkları 60 adet domates örneklerinde LC/MS/MS (Sıvı Kromatografi/Kütle Spektrometresi) ve GC/MS (Gaz Kromatografi/Kütle Spektrometresi) cihazları ile 249 etken maddesi analizi yapmışlar. Elde edilen sonuçlar, domates örneklerinin büyük çoğunluğunda çeşitli pestisit kalıntılarının bulunduğunu göstermiştir. Özellikle bazı örneklerde, pestisit kalıntı seviyelerinin Türk Gıda Kodeksi ve Avrupa Birliği Maksimum Kalıntı Limitlerinin üzerinde olduğu belirlenmiştir.

Polat ve Tiryaki (2018) Çanakkale ilinde açık alanda yetiştirilen domateslerdeki pestisit kalıntılarını tespit etmek amacıyla gerçekleştirilmiştir. Araştırmada, pestisit kalıntılarının belirlenmesinde QuEChERS yöntemi kullanılmıştır. Bu yöntem, pestisit kalıntılarının hızlı ve etkin bir şekilde analiz edilmesine olanak tanımaktadır. Çalışma kapsamında, açık alanda yetiştirilen domates örnekleri toplanmış ve laboratuvar analizlerine tabi tutulmuştur. Elde edilen sonuçlar, incelenen domates örneklerinin önemli bir kısmında çeşitli pestisit kalıntılarının bulunduğunu göstermiştir. Özellikle bazı örneklerde, kalıntı seviyelerinin güvenlik sınırlarını aştığı belirlenmiştir.

3.SONUÇ VE ÖNERİLER

Örtü altı tarımı, yüksek verim ve kalite elde etmek amacıyla yoğun olarak pestisit kullanımını gerektirir. Ancak, pestisitlerin toksik özellikleri nedeniyle bilinçsiz ve kontrolsüz kullanımları ciddi sağlık sorunlarına yol açabilir ve çevresel dengenin bozulmasına sebep olabilir.

Pestisitlerin yanlış ve yoğun kullanımı, bitkilerde fitotoksisiteye ve hedef dışı organizmalara zarar vererek, doğal dengeyi bozabilir.

Çiftçilerin pestisit kullanımı konusunda bilinçlendirilmesi ve eğitim verilmesi gerekmektedir. Pestisitlerin doğru dozajda ve uygun zamanlarda kullanılması, kalıntı problemlerinin önlenmesine yardımcı olacaktır. Ayrıca, biyolojik mücadele yöntemlerinin ve entegre zararlı yönetimi tekniklerinin teşvik edilmesi, pestisit kullanımının azaltılmasına katkı sağlayabilir.

Pestisit kullanımı ve kalıntı seviyelerinin denetimi için etkili kontrol mekanizmalarının oluşturulması gereklidir. Tarım Bakanlığı ve ilgili kuruluşlar, pestisitlerin doğru kullanımı ve denetimi konusunda sıkı tedbirler almalıdır. Bunun yansıra gıda ürünlerinde düzenli pestisit kalıntı analizleri yapılmalı ve sonuçlar kamuoyuyla paylaşılmalıdır.

Organik tarım, biyolojik mücadele ve entegre zararlı yönetimi gibi alternatif tarım yöntemlerinin teşvik edilmesi, yeni ve daha güvenli pestisit formülasyonlarının geliştirilmesi ve alternatif mücadele yöntemlerinin etkinliğinin araştırılması da oldukça önemlidir. Bu şekilde, pestisit kullanımını azaltarak hem çevresel etkileri minimize eder hem de insan sağlığını korur.

Sürdürülebilir tarım, çevre ve insan sağlığı için tüketicilerin pestisit kalıntıları konusunda bilinçlendirilmesi ve organik ürünlere yönlendirilmesi, pestisit kalıntılarının insan sağlığı üzerindeki olumsuz etkileri hakkında bilgilendirme kampanyaları düzenlenmesi ve tüketicilere sağlıklı gıda seçenekleri sunulması çerçevesinde ele alınarak kimyasalların olumsuz etkilerinin azaltılmasında şüphesiz fayda sağlayacaktır.

Örtü altı tarımında yoğun kimyasal kullanımı nedeniyle ortaya çıkacak pestisit kalıntı problemleri hem çevre hem de insan sağlığı açısından büyük önem taşımaktadır. Pestisitlerin bilinçli ve kontrollü kullanımı, verimliliği artırırken olumsuz etkileri minimize etmek için kritiktir. Bu nedenle, pestisit kullanımının etkin bir şekilde yönetilmesi ve denetlenmesi, gıda güvenliğinin sağlanması ve çevrenin korunması açısından hayati öneme sahiptir.

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EVALUATION OF STABILITY FOR SOME YIELD COMPONENTS OF TRITICALE (X *Triticosecale* Wittmack) ELITE LINES

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ABSTRACT

The study was carried out with a total of 25 triticale genotypes, including 17 triticale elite lines developed through selection by the Department of Field Crops, Faculty of Agriculture, Tekirdağ Namık Kemal University and 8 triticale varieties (Focus, Mikham 2002, GK Maros, Tatlıcak 97, Presto 2000, Karma 2000, Truva and GK Szemes) in 2019 and 2020, in 4 locations (Tekirdağ-Süleymanpaşa, Edirne-Merkez (Sarayakpınar), Tekirdağ-Hayrabolu and Kırklareli-Lüleburgaz) according to the randomized block design with 4 replications. It was aimed to determine suitable triticale genotypes for the conditions of the Thrace Region. As it is difficult to understand and reliably determine the complex genotype × environment interaction (GEI) with variance analysis, graphical method GGE-biplot analyse was used to explain GEI. Plant height, harvest index, plant weight and spike weight traits of triticale genotypes were examined, and genotype × environment interactions were found statistically significant at 1% level in all traits except harvest index. In the study, the plant height value in 2019 was 6.05 cm shorter than in 2020, and the harvest index, plant weight and spike weight traits showed similar values in both years. The NZFT 11, Tatlıcak 97 and Presto 2000 genotypes with high plant height and high stability were found to be suitable for green grass production, while the NZFT 7, NZFT 13 and NZFT 17 elite lines with short height and high stability were found to be suitable for grain production. In addition, in terms of harvest index, NZFT 13 and NZFT 17 elite lines and GK Szemes variety, in terms of plant weight, Mikham 2002, Tatlıcak 97 and Focus varieties, in terms of spike weight, NZFT 17 and NZFT 13 elite lines and GK Szemes variety were determined as suitable genotypes. When all characteristics are considered, NZFT 13, NZFT 17 elite lines with Tatlıcak 97 and GK Szemes varieties were the most suitable genotypes.

Keywords: Plant Height, Genotype × Environment Interaction, Stability, Triticale.

TRİTİKALE (X *Triticosecale* Wittmack) İLERİ HATLARINDA BAZI VERİM UNSURLARI İÇİN STABİLİTE DEĞERLENDİRMESİ

ÖZET

Çalışma, Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü öğretim üyeleri tarafından seleksiyon yoluyla geliştirilen 17 adet tritikale ileri hattı ile standart olarak 8 adet tritikale çeşidi (Focus, Mikham 2002, GK Maros, Tatlıcak 97, Presto 2000, Karma 2000, Truva ve GK Szemes) olmak üzere toplam 25 tritikale genotipi ile 2019 ve 2020 yıllarında 4 lokasyonda (Tekirdağ-Süleymanpaşa, Edirne-Merkez (Sarayakpınar), Tekirdağ-Hayrabolu ve Kırklareli-Lüleburgaz) tesadüf blokları deneme desenine göre 4 tekrarlamalı olarak yürütülmüştür. Karmaşık olan genotip × çevre interaksiyonunu (GEI) genel varyans analizi ile anlamak ve güvenilir bir şekilde belirlemek zor olduğundan Trakya Bölgesi koşulları için uygun tritikale genotiplerinin belirlenmesinde grafiksel yöntem olan GGE-biplot analizi kullanılmıştır. Tritikale genotiplerinin bitki boyu, bitki ağırlığı, başak ağırlığı ve hasat indeksi özellikleri incelenmiş, hasat indeksi hariç tüm özelliklerde genotip × çevre interaksiyonları istatistiki olarak % 1 düzeyinde önemli bulunmuştur. Çalışmada, 2019 yılı ortalama bitki boyu değeri, 2020 yılına göre 6,05 cm daha kısa, bitki ağırlığı, başak ağırlığı ve hasat indeksi özellikleri her iki yılda da yakın değer göstermiştir. Bitki boyu bakımından stabilitesi yüksek olan NZFT 11, Tatlıcak 97 ve Presto 2000 genotipleri uzun boyları ile yeşil ot üretimi, yüksek stabilite gösteren kısa boylu NZFT 7, NZFT 13 ve NZFT 17 ileri hatları ise tane üretimi açısından uygun bulunmuştur. Ayrıca hasat indeksi yönünden NZFT 13 ve NZFT 17 ileri hatları ile GK Szemes çeşidi, bitki ağırlığı yönünden Mikham 2002, Tatlıcak 97 ve Focus çeşitleri, başak ağırlığı yönünden NZFT 17 ve NZFT 13 ileri hatları ile GK Szemes çeşidi, tüm özellikler göz önüne alındığında NZFT 13, NZFT 17 ileri hatları ile Tatlıcak 97 ve GK Szemes çeşitleri en uygun genotipler olarak belirlenmiştir.

Anahtar Kelimeler: Bitki Boyu, Genotip × Çevre İnteraksiyonu, Stabilite, Tritikale.

1. GİRİŞ

Son yıllarda artan küresel iklim değişikliği etkilerinin belirginliği, daha çok kurak alanlarda tarımı yapılan buğday, arpa, yulaf, çavdar gibi serin iklim tahıllarının üretim miktarlarında beklenen artışın olamayabileceğini göstermektedir. Araştırıcılar küresel iklim değişiminin bitkisel üretimi olumsuz yönde etkileyeceğini ve gıda güvenliğinin sağlanması için ele alınması gereken önemli bir konu olduğunu belirtmişlerdir (Tripathi ve ark., 2016; Howden ve ark., 2007). Buğday özellikle abiyotik ve biyotik stres faktörlerinden bazı yıllar oldukça etkilenmekte ve üretimde önemli azalmalar görülmektedir. Küresel iklim değişiminin sonucu olarak sıcaklığın 1 derece artması buğday veriminde % 3-10 arasında azalmaya neden olabilecektir. Bu nedenle bitki ıslahçıları stres faktörlerinden daha az etkilenen türler ve cinsler üzerine çalışmalarını yoğunlaştırmışlardır. Buğdayın verim ve kalite özellikleri ile çavdarın biyotik ve abiyotik stres şartlarına tolerans ve/veya dayanıklılık özellikleri bir araya getirilerek gelecek vadeden yeni bir tür olarak tritikale elde edilmiştir.

Tritikale; ana ebeveyni buğday, baba ebeveyni ise çavdar olan bir melezdir (Müntzing, 1989; Dodge, 1989). Elde edilen melezlerin kromozom sayısının iki katına çıkarılmasıyla fertil bitkiler elde edilmiştir. Bu yeni bitkiye Triticum ve Secale isimlerinden oluşan Tritikale adı verilmiştir. Tritikale, kendine döllenen bitki olarak kabul edilse de çeşitli araştırıcılar tarafından % 10.1 - 47.5 arasında yabancı döllenme oranı saptanmıştır (Demir ve ark., 1978). Ebeveynlerinin poliploidi düzeylerine göre tetraploid, hekzaploid ya da oktoploid olabilmektedir. Tarımsal üretimde yer alan tritikale çeşitlerinin çoğu hekzaploid'dir (Lukaszewski ve Gustafson, 1987). Soğuk, kurak ve marjinal toprak koşullarına dayanıklı, çoğu hastalık ve zararlıdan etkilenmeyen bir bitki olan tritikale, hayvan yemi olarak yaygın şekilde kullanılmasının yanında ABD, Polonya, Kanada ve Meksika gibi birçok ülkede uzun süre devam eden ıslah çalışmaları sonucu marjinal, fakir tarım alanlarından dekardan alınan verimi arttırarak, hızla artan Dünya nüfusunun gıda ihtiyacını da karşılamak amacıyla geliştirilmiştir. Ülkemizde de marjinal alanların değerlendirilmesi ve hayvancılığa katkı sağlanması açısından tritikale üretiminin yaygınlaştırılması ve farklı bölgelere uygun tritikale çeşitlerinin geliştirilmesi büyük önem taşımaktadır (Şentürk ve Akgün, 2014).

Dünyada ve ülkemizde kontrolsüz koşullarda yapılan bitkisel üretimlerde abiyotik ve biyotik streslere dayanıklı, stabilitesi yüksek türlerin ve genotiplerin belirlenmesi gün geçtikçe önem kazanmaktadır. Islah çalışmalarının esas amacı, verim yönünden stabil ve kaliteli, abiyotik ve biyotik streslere dayanıklı çeşitlerin geliştirilmesidir. Günümüzde buğday ve arpa üretiminde kullanılacak çeşitlerin farklı agroekolojik bölgelerdeki stabilitesinin ortaya konmasına yönelik çok sayıda çalışma olmasına rağmen, tritikale gibi son yıllarda giderek önemi ve üretimi artan genotiplerin stabilitesine yönelik çalışmalar hala yeterli düzeyde değildir. Verim ve kalite, genetik faktörler ile çevresel faktörlerin ortak bir kombinasyonu olarak ortaya çıkmaktadır. Çevresel faktörlere en iyi uyumu sağlayan genetik faktörlerin (genotip) belirlenmesi için birden fazla çevrede genotiplerin performasının belirlenmesi gerekmektedir. Farklı ekolojilere uygun çeşitlerin bulunması için yürütülen çalışmalarda çeşit, çevre ve interaksiyon faktörlerinin her biri ayrı öneme sahiptir. Özellikle interaksiyon farklı çevrelerde genotiplerin performansı hakkında bilgi vermekte ve ıslah programlarında verim stabilitesinin belirlenmesinde önemli rol oynamaktadır (Kılıç ve ark., 2005). Tritikalede stabiliteye yönelik yapılan çalışmalarda,

genotip, çevre ve genotip x çevre interaksiyonunun (genotiplerin farklı çevrelerde gösterdikleri farklı tepkiler) tane verimini büyük oranda etkilediği görülmektedir (McGoverin ve ark., 2011).

İstatistiki olarak genotip × çevre interaksiyonunun önemli olduğu durumlarda, genotiplerin performans stabilitelerini belirleyen farklı stabilite analiz yöntemleri geliştirilerek yaygın olarak kullanılmaktadır. Birçok özellik bakımından iyi performans gösteren ve stabil olan genotipleri belirlemek oldukça zordur. Bu amaçla GGE-biplot yöntemi yaygın olarak kullanılmaktadır. GGE-biplot analiz yönteminin hem iki yönlü (genotip ve çevre etkisinin PC1ve PC2 ile gösterilmesi) veri yapısını sunması hem de ıslahçıların genetik potansiyeli ve genotip üzerindeki çevresel etkileri tahmin etmesini mümkün kılan ana etkiler ve çarpımsal interaksiyonları içeren kompleks birer model olması, stabiliteyi belirlemede kullanılmasını uygun hale getirmektedir (Kılıç ve ark., 2014; Kendal ve Tekdal, 2016; Sayar ve ark., 2016). Birçok araştırıcı bu model ile farklı çevrelerde ileri kademedeki tescil adayı hatların test edilerek, performanslarının ve stabilitelerinin tahmin edilmesinin mümkün olduğunu dile getirmiştir (Hagos ve Abay, 2013; Rad ve ark., 2013; Kendal ve Şener, 2015). Son yıllarda farklı genotiplerle, farklı çevrelerde veya yıllarda yürütülen araştırmalarda kullanılan GGE-Biplot analiz yöntemi, birçok özelliği aynı anda görsel açıdan değerlendirme fırsatını sağladığı ve seleksiyonda başarıyı etkilediği için bitki ıslahında uygulanan yenilikçi bir yöntem olarak kabul edilmiştir (Yan ve Tinker, 2006).

Çalışmada, Tekirdağ-Süleymanpaşa, Edirne-Merkez (Sarayakpınar köyü), Tekirdağ-Hayrabolu ve Kırklareli-Lüleburgaz lokasyonlarında tritikale ileri hatlarının bitki boyu, bitki ağırlığı, başak ağırlığı ve hasat indeksi özelliklerinin genotip, çevre ve genotip × çevre interaksiyonları açısından grafiksel yöntemlerle değerlendirilerek stabilitesi yüksek, çevreden en az ya da fazla etkilenen, çevresel iyileşmelere karşı tepkileri olumlu yönde yüksek olan ve her bir özel çevre için en iyi genotiplerin belirlenmesi amaçlanmıştır.

2. MATERYAL VE YÖNTEM

Çalışmada; 17 adet tritikale ileri hattı (Çizelge 1) ile standart olarak 8 adet tritikale çeşidi (Focus, Mikham 2002, GK Maros, Tatlıcak 97, Presto 2000, Karma 2000, Truva ve GK Szemes) olmak üzere toplam 25 tritikale genotipi materyal olarak kullanılmıştır. Kullanılan tüm genotipler hekzaploid formda ve 2n=42 kromozomludur. Denemeler iki yıl (2019 ve 2020) boyunca Süleymanpaşa (Tekirdağ), Hayrabolu (Tekirdağ), Lüleburgaz (Kırklareli) ve Edirne lokasyonlarında yürütülmüştür. Deneme alanlarının coğrafi açıklamaları da Çizelge 2'de verilmiştir.

Çizelge 1. Çalışmada materyal olarak kullanılan tritikale ileri hatları ve pedigri bilgileri

Elit Hat No	Elit Hat	Pedigri	Elit Hat No	Elit Hat	Pedigri
1	*NZFT 4*	GAUR_2/HARE_3//JLO97/CIVET/5/DISB5/3/SPHD/…	10	*NZFT 15*	DAHBI/COATI_1//ONA_1/ERIZO_12/4/ERIZO_10/…
2	*NZFT 5*	GAUR_2/HARE_3//JLO97/CIVET/5/DISB5/3/SPHD/…	11	*NZFT 17*	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/DAGRO/…
3	*NZFT 6*	GAUR_2/HARE_3//JLO97/CIVET/5/DISB5/3/SPHD/…	12	*NZFT 19*	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/DAGRO/…
4	*NZFT 7*	GAUR_2/HARE_3//JLO97/CIVET/5/DISB5/3/SPHD/…	13	*NZFT 20*	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/DAGRO/…
5	*NZFT 8*	GAUR_2/HARE_3//JLO97/CIVET/5/DISB5/3/SPHD/…	14	*NZFT 23*	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/DAGRO/…
6	*NZFT 11*	DAHBI/COATI_1//ONA_1/ERIZO_12/4/ERIZO_10/…	15	*NZFT 24*	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/DAGRO/…
7	*NZFT 12*	DAHBI/COATI_1//ONA_1/ERIZO_12/4/ERIZO_10/…	16	*NZFT 27*	DAHBI_6/3/ARDI_1/TOPO1419//ERIZO_9/4/DAGRO/…
8	*NZFT 13*	DAHBI/COATI_1//ONA_1/ERIZO_12/4/ERIZO_10/…	17	*NZFT 28*	GAUR_2/HARE_3//JLO97/CIVET/5/DISB5/3/SPHD/…
9	*NZFT 14*	DAHBI/COATI_1//ONA_1/ERIZO_12/4/ERIZO_10/…			

Dört lokasyon ve iki yılda kurulan denemeler tesadüf blokları deneme desenine göre 4 tekrarlamalı olarak yürütülmüştür. Deneme parsellerinin ekimleri ekim sırasında tüm lokasyonlarda 8,16 m^2, hasat sırasında hasat alanı 7,5 m^2 olan parsellere metre kareye 500 adet tohum hesabı ile sıra arası 17 cm olan 6 sıralı özel deneme mibzeri ile gerçekleştirilmiştir. Denemelerde, ekim ile birlikte 4 kg/da saf azot ve 4 kg/da saf fosfor olacak şekilde 20.20.0 kompoze gübresi, kardeşlenme döneminde 9,2 kg/da saf azot olacak şekilde üre gübresi (%46 azot) ve sapa kalkma döneminde 3,9 kg/da saf azot olacak şekilde kalsiyum amonyum nitrat gübresi (% 26 azot) uygulanmıştır. Deneme alanında görülen yabancı otlara karşı kimyasal ilaçlama yapılmıştır. Denemeler parsel biçerdöveri ile hasat edilmiştir.

Çizelge 2. Deneme alanlarının coğrafi bilgileri

Lokasyon	Enlem Boylam	Yükseklik, m	Toprak Yapısı	Sıcaklık (°C) Min.	Sıcaklık (°C) Max.	Yağış, mm	Sıcaklık (°C) Min.	Sıcaklık (°C) Max.	Yağış, mm
				2019			2020		
Süleymanpaşa	40° 59′ 37" K 27° 34′ 53" D	20	Silt-Tın	3,1	28,2	404,4	2,8	25,1	394,1
Hayrabolu	41° 12′ 49" K 27° 6′ 22" D	81	Kil-Tın	0,8	31,7	381,8	- 0,7	30,2	411,2
Lüleburgaz	41° 24′10" K 27° 21′ 56" D	45	Kil-Tın	- 0,2	32	350,4	- 2,4	28,5	394,4
Edirne	41° 40′ 38" K 26° 33′ 21" D	252	Kil-Tın	1,1	32	478,3	- 0,9	30,1	393,2

Toprak Sınıflandırma Sistemi (Ülgen ve Yurtsever, 1995).

Denemelerden elde edilen bitki boyu, bitki ağırlığı, başak ağırlığı ve hasat indeksi özelliklerine ilişkin verilerin birleştirilmiş varyans analizleri için JMP Pro 17 paket programı, genotiplerin toplam sekiz çevrede stabilitelerini (genotip × çevre interaksiyonlarını (GEI)) belirlemek için BAFR paket programı (Kahrıman, 2020) kullanılmıştır. Genotip ortalamaları arasındaki farklılıkların önemlilik grupları $Tukey_{HSD}$ testi ile kontrol edilmiştir.

Yirmi beş tritikale genotipi ile 8 farklı çevrede yürütülen çalışmadan elde edilen veriler öncelikli olarak varyans analizine tabi tutulmuş, sonuçların yorumlanmasında GGE-biplot analiz yöntemi kullanılmıştır. GGE-biplot grafikleri genotip, çevre ve genotip × çevre interaksiyonlarının değerlendirilmesinde çevrelerin etkisini daha net göstermektedir. GGE-biplot analizinde yıllara göre çevre, karakterler ve genotip arasındaki farklılıklar daha fazla açıklanabilmektedir. İncelenen her karakter için genotip odaklı oluşturulan GGE-biplot grafikleri kullanılarak görsel olarak genotip × çevre interaksiyonları değerlendirilmiştir.

3. BULGULAR VE TARTIŞMA

Araştırmada incelenen özellikler için gerçekleştirilen varyans analiz sonuçlarına göre bitki boyu, bitki ağırlığı ve başak ağırlığı için genotip, çevre ve genotip × çevre interaksiyon ortalamaları arasında farklılıklar % 1 düzeyinde önemli iken hasat indeksi için genotip ve çevre ortalamaları arasındaki farklılıklar % 1 düzeyinde önemli, genotip × çevre interaksiyon ortalamaları arasında farklılıklar istatistiki olarak önemsiz bulunmuştur. Sekiz çevreden (iki yıl ve dört lokasyon) elde edilen genotip ve çevre ortalama değerleri ile genotip etkisi, çevre etkisi ve önemlilik testi sonuçları Çizelge 3'te verilmiştir.

Çizelge 3. Tritikale genotiplerinin ortalama değerleri ile genotip ve çevre etkisi

Genotip	Bitki Boyu (cm)		Bitki Ağırlığı (g)		Başak Ağırlığı (g)		Hasat İndeksi (%)	
	Genotip Ort.	*Genotip Etkisi*	*Genotip Ort.*	*Genotip Etkisi*	*Genotip Ort.*	*Genotip Etkisi*	*Genotip Ort.*	*Genotip Etkisi*
NZFT 4	101,50 hıj	-3,96	5,23 b-h	0,04	3,03 a-f	0,07	42,95 a-d	0,78
NZFT 5	95,74 k	-9,72	5,19 c-h	0,00	2,98 a-f	0,02	42,97 a-d	0,80
NZFT 6	95,97 k	-9,49	4,94 g-k	-0,25	2,98 a-f	0,02	42,54 a-d	0,37
NZFT 7	100,27 ıj	-5,19	4,87 h-k	-0,32	2,80 d-h	-0,16	42,85 a-d	0,68
NZFT 8	98,42 jk	-7,04	5,16 d-ı	-0,03	2,96 a-f	0,00	42,76 a-d	0,59
NZFT 11	109,79 d	4,33	5,54 a-e	0,35	3,09 a-e	0,13	41,88 a-d	-0,29
NZFT 12	90,29 l	-15,17	4,59 jk	-0,60	2,61 fgh	-0,35	41,12 bcd	-1,05
NZFT 13	102,62 f-ı	-2,84	5,42 a-g	0,23	3,18 a-d	0,22	46,30 a	4,13
NZFT 14	90,60 l	-14,86	4,90 h-k	-0,29	2,86 c-h	-0,10	41,25 a-d	-0,92
NZFT 15	90,49 l	-14,97	4,99 f-k	-0,20	2,86 c-h	-0,10	40,75 bcd	-1,42
NZFT 17	105,15 efg	-0,31	5,68 abc	0,49	3,35 a	0,39	43,92 abc	1,75
NZFT 19	105,28 efg	-0,18	5,83 a	0,64	3,39 a	0,43	42,95 a-d	0,78
NZFT 20	103,02 f-ı	-2,44	5,70 ab	0,51	3,27 abc	0,31	42,51 a-d	0,34
NZFT 23	101,99 ghı	-3,47	5,29 b-h	0,10	3,12 a-e	0,16	43,55 a-d	1,38
NZFT 24	102,88 f-ı	-2,58	5,66 a-d	0,47	3,30 ab	0,34	42,98 a-d	0,81
NZFT 27	104,06 fgh	-1,40	5,54 a-e	0,35	3,19 a-d	0,23	43,06 a-d	0,89
NZFT 28	100,01 ıj	-5,45	5,16 d-ı	-0,03	2,88 b-h	-0,08	41,74 a-d	-0,43
Focus	108,56 de	3,10	4,53 k	-0,66	2,47 gh	-0,49	41,09 bcd	-1,08
Mikham 2002	120,28 bc	14,82	5,07 e-j	-0,12	2,73 e-h	-0,23	39,68 cd	-2,49
GK Maros	105,93 ef	0,47	5,08 e-j	-0,11	2,99 a-f	0,03	43,44 a-d	1,27
Tatlıcak 97	130,71 a	25,25	4,67 ıjk	-0,52	2,46 h	-0,50	40,78 bcd	-1,39
Presto 2000	121,83 bc	16,37	5,23 b-h	0,04	2,90 b-g	-0,06	40,02 cd	-2,15
Karma 2000	119,62 c	14,16	4,57 jk	-0,62	2,46 h	-0,50	38,98 cd	-3,19
Truva	123,46 b	18,00	5,42 a-g	0,23	2,92 b-f	-0,04	38,58 d	-3,59
GK Szemes	108,09 de	2,63	5,48 a-f	0,29	3,26 abc	0,30	45,61 ab	3,44
Genel Ort.	*117,31*		*5,01*		*2,77*		*41,02*	
	Çevre Ort.	Çevre Etkisi	Çevre Ort.	Çevre Etkisi	Çevre Ort.	Çevre Etkisi	Çevre Ort.	Çevre Etkisi
E1	112,54 b	7,08	5,79 b	0,60	3,38 a	0,42	42,25 bc	0,08
E2	105,45 d	-0,01	4,84 de	-0,35	2,70 c	-0,26	39,96 c	-2,21
E3	106,04 d	0,58	5,29 c	0,10	2,99 b	0,03	40,06 c	-2,11
E4	109,93 c	4,47	4,62 e	-0,57	2,61 c	-0,35	42,02 bc	-0,15

E5	98,13 e	-7,33	5,58 b	0,39	3,35 a	0,39	43,22 b	1,05
E6	97,05 e	-8,41	4,11 f	-1,08	2,34 d	-0,62	41,62 bc	-0,55
E7	119,71 a	14,25	6,29 a	1,10	3,40 a	0,44	41,74 bc	-0,43
E8	94,85 f	-10,61	4,99 d	-0,20	2,92 b	-0,04	46,48 a	4,31
Genel Ort.	*105,46*		*5,19*		*2,96*		*42,17*	

E1, 2019 yılı Tekirdağ-Süleymanpaşa lokasyonunu; E2, 2019 yılı Edirne lokasyonunu; E3, 2019 yılı Tekirdağ-Hayrabolu lokasyonunu; E4, 2019 yılı Kırklareli-Lüleburgaz lokasyonunu; E5, 2020 yılı Tekirdağ-Süleymanpaşa lokasyonunu; E6, 2020 yılı Edirne lokasyonunu; E7, 2020 yılı Tekirdağ-Hayrabolu lokasyonunu ve E8, 2020 yılı Kırklareli-Lüleburgaz lokasyonu.

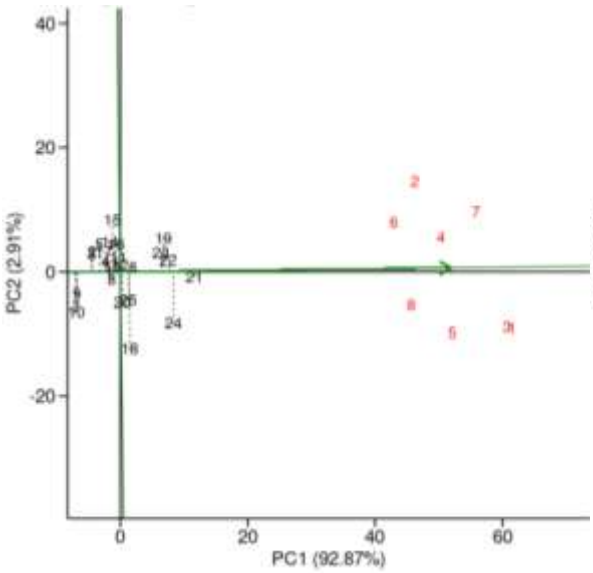
3.1. Bitki Boyu (cm)

Çizelge 3'de görüldüğü gibi tritikale genotiplerinde ortalama bitki boyu değerleri 90,29-130,71 cm arasında değişmiştir. Farklı araştırıcılar tarafından yürütülen çalışmalarda bitki boyunun 44-173 cm arasında değiştiği belirlenmiştir (Gill ve ark., 1990; Ünver, 1999; Mut ve Erbaş Köse, 2018; Dolgun ve Aydoğan Çifçi, 2019). Bitki boyu yönünden en yüksek değer Tatlıcak 97 standart çeşidinden elde edilirken, bunu 123,46 cm ile Truva, 121,83 cm ile Presto 2000, 120,28 cm ile Mikham 2002 ve 119,62 cm ile Karma 2000 genotipleri izlemiştir. Genel ortalama (105,46 cm)'ya göre ileri hatlar değerlendirildiğinde tüm ileri hatların genel ortalamadan daha düşük bitki boyuna sahip olduğu görülmekle birlikte NZFT 17 (105,15 cm), NZFT 19 (105,28 cm) genotipleri genel ortalamaya en yakın genotipler olmuştur. Standart çeşitler değerlendirildiğinde ise tüm çeşitlerin genel ortalamadan daha yüksek bitki boyuna sahip olduğu görülmektedir. Tane üretimi için genel ortalamanın altında değer veren NZFT 14 ve NZFT 15 ileri hatları uygun olurken, yeşil ot verimi yönünden ileri hatlar arasında en uzun bitki boyuna sahip olan NZFT 11, NZFT 17 ve NZFT 19 ileri hatları uygun genotipler olarak belirlenmiştir.

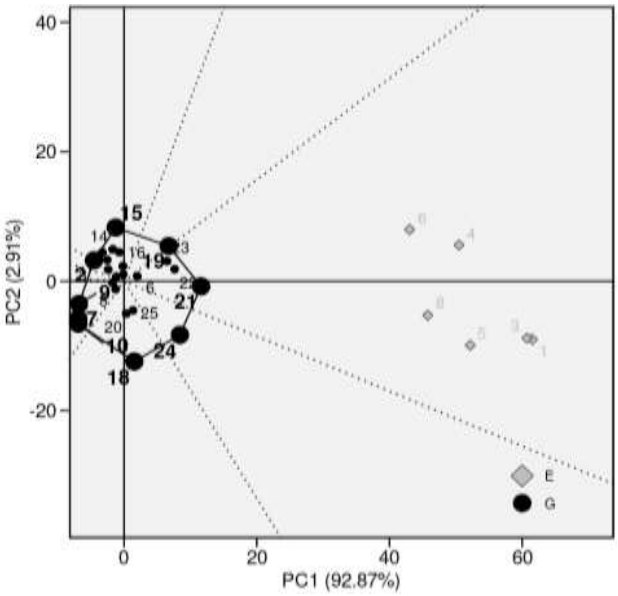
Çalışmada çevre ortalamalarına göre tritikale genotiplerinin bitki boyu değerleri 94,85-119,71 cm arasında değişmiştir. En yüksek bitki boyu 2020 yılında Tekirdağ-Hayrabolu lokasyonundan (E7) elde edilmiş, bunu 112,54 cm ile 2019 yılında Tekirdağ-Süleymanpaşa lokasyonu (E1) izlemiştir.

Sekiz farklı çevreden elde edilen ortalama bitki boyu genotipik etkileri incelendiğinde NZFT 11 ileri hattı dışındaki tüm ileri hatların negatif genotipik etkiye sahip olduğu, tüm standart çeşitlerin ise pozitif genotipik etkiye sahip olduğu görülmüştür. Ortalama bitki boyu çevre etkileri incelendiğinde ise E7, E1, E4 ve E3 pozitif etkiye sahip olurken diğer çevreler negatif etkiye sahip olmuştur.

Bitki Boyu Değerlerine İlişkin GGE-Biplot Analizi



Şekil 1. Genel ortalama ve stabilite grafiği



Şekil 2. Hangi genotip nerede kazandı grafiği

Bitki boyu değerlerine ilişkin genel ortalama ve stabilite grafiği (Şekil 1) incelendiğinde 6, 4, 8, 12, 21 ve 22 numaralı genotiplerin iz düşüm çizgileri en kısa olan genotipler oldukları görülmektedir. Bu genotiplerden genel ortalamanın üzerinde bitki boyu değeri veren 21, 22 ve 6 numaralı genotipler yeşil ot üretimi açısından yüksek stabilite gösterirken, 4, 8 ve 11 numaralı genotipler ise kısa iz düşüm çizgilerine sahip olmasına rağmen genel ortalamanın altında bitki boyu değerleri vermeleri nedeniyle tanelik tritikale üretimi için yüksek stabilite gösteren genotipler olmuşlardır. Çalışmada 10, 15, 18, 19 ve 24 numaralı genotipler uzun iz düşüm çizgileri ile bitki boyu yönünden düşük stabilite göstermektedir. Bitki boyu yönünden çevreler incelendiğinde eşitlik çizgisi merkeze en yakın olan 2, 6 ve 8 numaralı çevreler stabilitesi yüksek çevreler olarak belirlenmiştir.

Hangi genotipin nerede uygun olduğunu gösteren GGE-biplot analiz görüntüsünde (Şekil 2) 6 sektör oluşmuş ve tüm çevreler bir sektör içinde yer almıştır. Çalışmada incelenen çevreler üçüncü sektör içinde toplanmıştır. Bu da bitki boyu yönünden 8 çevre yerine 1 mega çevrenin yeterli olabileceğini ortaya koymaktadır. Bitki boyu yönünden genotipik seçim için daha farklı çevrelerin belirlenmesi yararlı olacaktır. Poligonun köşelerinde yer alan genotipler bir veya birden fazla ortamda en iyi ya da en kötü performansı gösterirler. Poligonun köşe noktalarında yer alan 18, 21 24, 19, 15, 2, 9 ve 7 numaralı genotipler çevreler için değerlendirilecek genotipler olarak belirlenmiştir. Çalışmada tüm çevrelerin bir sektörde yer alması stabilite yönünden poligonun bu sektöre yakın köşelerinde bulunan genotiplerin dikkate alınması gerektiğini gösterir. On sekiz ve 24 numaralı genotipler arasındaki eşitlik çizgisi, tüm çevreler için 24 numaralı genotipin 18 numaralı genotipten daha uygun olduğunu ortaya koymaktadır.

Aynı şekilde 24 ve 21 numaralı genotipler arasındaki eşitlik çizgisi, 21 numaralı genotipin tüm çevrelerde daha üstün olduğunu göstermektedir. Buna göre 21 > 19 > 15 > 2 > 9 > 7 sıralaması ile genotiplerin tüm çevrelere daha iyi uyum gösterdiği belirlenmiştir. Genotipler yönünden çevreler değerlendirildiğinde 6 ve 8 numaralı çevreler bitki boyu yönünden en uygun çevre olmuştur.

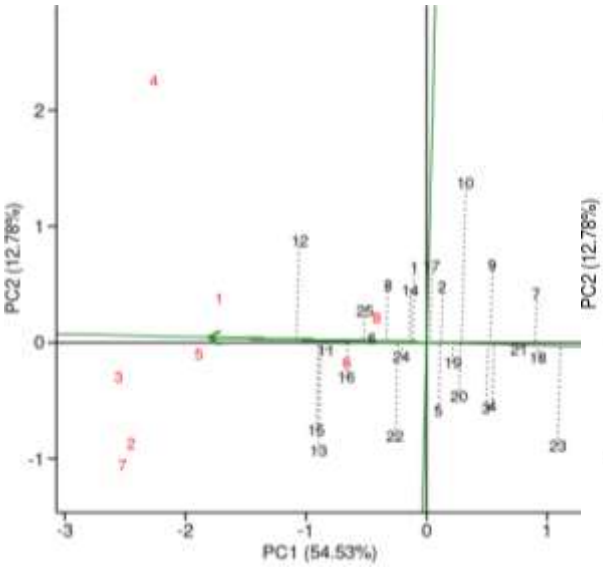
3.2. Bitki Ağırlığı (g)

Farklı tritikale genotiplerinin ortalama bitki ağırlığı değerleri 4,53-5,83 g arasında değişmiştir. Bitki ağırlığı bakımından en yüksek değer NZFT 19 ileri hattından elde edilirken, bu genotipi 5,70 g ile NZFT 20, 5,66 g ile NZFT 24, 5,54 g ile NZFT 27 ve NZFT 11 ileri hatları izlemiştir. Standart çeşitler arasında en yüksek bitki ağırlığı 5,48 g ile GK Szemes ve 5,42 g ile Truva çeşitlerinden elde edilmiştir. GK Szemes, Truva ve Presto 2000 standart çeşitleri genel ortalama (5,19 g)'nın üzerinde bitki ağırlığına sahipken, diğer standart çeşitler genel ortalamanın altında kalmıştır. İleri hatlar değerlendirildiğinde de NZFT 12, NZFT 7, NZFT 14, NZFT 6, NZFT 15, NZFT 8 ve NZFT 28 ileri hatları genel ortalamadan daha düşük bitki ağırlığına sahip olmuştur.

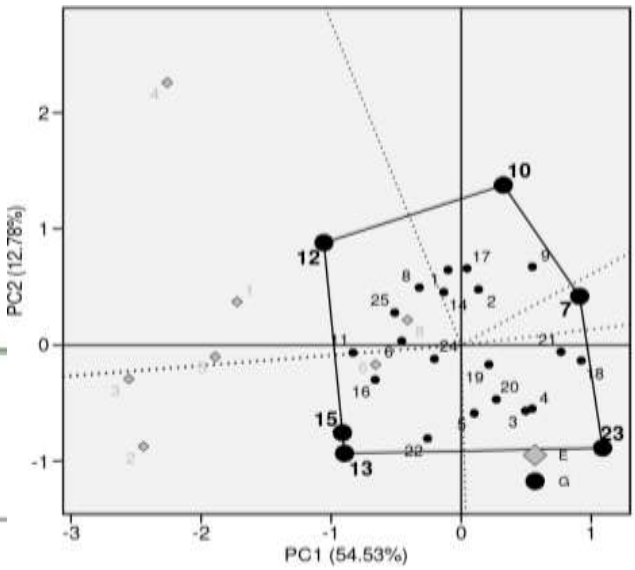
Çevre ortalamalarına göre tritikale genotiplerinin bitki ağırlığı değerleri 4,11-6,29 g arasında değişmiştir. En yüksek bitki ağırlığı 2020 yılı Tekirdağ-Hayrabolu lokasyonundan (E7) elde edilmiş, bu değeri aynı istatistiki grupta yer alan 5,79 g ile 2019 yılında Tekirdağ-Süleymanpaşa lokasyonu (E1) ve 5,58 g 2020 yılında Tekirdağ-Süleymanpaşa lokasyonu (E5) izlemiştir.

Çalışmada ortalama bitki ağırlığı genotipik etkileri incelendiğinde GK Szemes, Truva ve Presto 2000 standart çeşidi dışındaki tüm standart çeşitler negatif genotipik etkiye sahip olmuştur. NZFT 12, NZFT 7, NZFT 14, NZFT 6, NZFT 15, NZFT 8 ve NZFT 28 ileri hatları negatif genotipik etkiye sahipken, diğer ileri hatlar pozitif genotipik etkiye sahip olmuştur. Ortalama bitki ağırlığı çevre etkileri bakımından 2020 yılı Tekirdağ-Hayrabolu lokasyonu (E7), 2019 yılı Tekirdağ-Süleymanpaşa lokasyonu (E1), 2020 yılı Tekirdağ-Süleymanpaşa lokasyonu (E5) ve 2019 yılı Tekirdağ-Hayrabolu lokasyonu (E3) pozitif çevre etkisine sahipken, diğer çevreler negatif etki göstermiştir.

Bitki Ağırlığı Değerlerine İlişkin GGE-Biplot Analizi



Şekil 3. Genel ortalama ve stabilite grafiği



Şekil 4. Hangi genotip nerede kazandı grafiği

Elde edilen genel ortalama ve stabilite grafiği incelendiğinde stabilite bakımından 11, 6, 24, 19, 21 ve 18 numaralı genotipler iz düşüm çizgileri en kısa olan genotiplerdir. Bu genotiplerden genel ortalamanın üzerinde bitki ağırlığı veren 19, 21 ve 18 numaralı genotipler bitki ağırlığı yönünden hem üstün özellik hem de yüksek stabilite göstermiştir. Buna karşın 11, 6 ve 24 numaralı genotiplerin ise kısa iz düşüm çizgisine sahip olmalarına rağmen genel ortalamanın altında bitki ağırlığı değerleri ile stabilite yönünden dikkati çeken genotipler olmadıkları belirlenmiştir. Çalışmada 10, 13, 15, 22, 23 ve 12 numaralı genotipler uzun iz düşüm çizgileri ile bitki ağırlığı yönünden stabiliteleri en düşük olan genotiplerdir. Bitki ağırlığı özelliği için çevreler incelendiğinde eşitlik çizgisi merkeze en yakın olan 6 ve 8 numaralı çevreler stabilite yönünden üstün özellik gösteren çevreler olmuştur.

Hangi genotipin nerede uygun olduğunu gösteren GGE-biplot analiz görüntüsünde 5 sektör oluşmuş ve çevreler 2 sektör içine dağılmıştır. Birinci, ikinci ve üçüncü sektörde çevre dağılımı görülmezken, çevreler dördüncü ve beşinci sektörlerde dağılım göstermiştir. Genotiplerin mümkün olduğunca farklı sektörlere dağılması bitki ağırlığı özelliği bakımında tritikale genotiplerinin seçiminde yararlı olacaktır. Her bir sektör için uygun genotipler poligonun köşe noktalarında yer alan 23, 7, 10, 12, 15 ve 13 numaralı genotipler olmuşlardır. On ve 12 numaralı genotipler arasındaki eşitlik çizgisi, 12 numaralı genotipin 1 ve 8 numaralı çevreler için 10 numaralı genotipten daha uygun olduğunu ortaya koymaktadır. Aynı şekilde 12 ve 15 numaralı genotipler çevrelere göre karşılaştırıldığında 15 numaralı genotipin 2, 3, 6 ve 7 numaralı çevreler bakımından daha uygun olduğu ortaya konmuştur. Çevrelere göre uygunluk yönünden genotipler değerlendirildiğinde 15 > 13 > 23 > 7 > 10 sıralaması oluşmaktadır. Genotipler yönünden çevreler değerlendirildiğinde 8 numaralı çevrelerin bitki ağırlığı yönünden en uygun çevre olduğu belirlenmiştir.

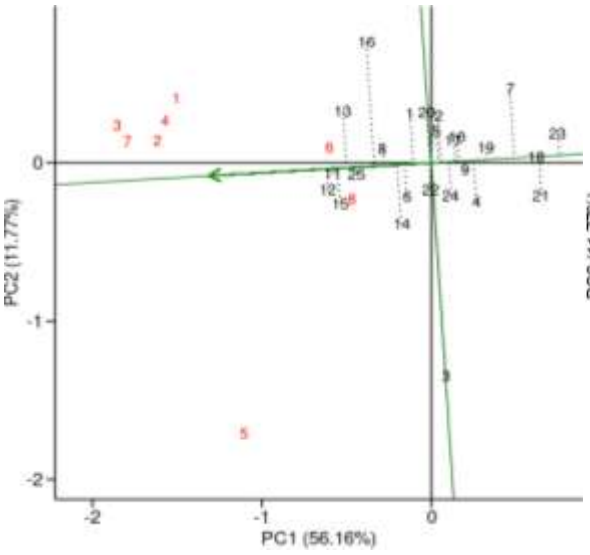
3.3. Başak Ağırlığı (g)

Çizelge 3'e göre farklı tritikale genotiplerinde ortalama başak ağırlığı değerleri 2,46-3,39 g arasında değişmiştir. En yüksek başak ağırlığı değeri NZFT 19 genotipinden elde edilirken, bunu aynı istatistiki grupta yer alan 3,35 g ile NZFT 17, 3,30 g ile NZFT 24, 3,27 g ile NZFT 20 ve 3,26 g ile GK Szemes genotipleri izlemiştir. Genel ortalama (2,96 g)'ya göre NZFT 12, NZFT 7, NZFT 14, NZFT 15 ve NZFT 28 ileri hatlarının genel ortalamadan daha düşük başak ağırlığı değerlerine sahip olduğu görülmüş, NZFT 8 (2,96 g), NZFT 5 ve NZFT 6 (2,98 g) genotipleri ileri hatlar arasında genel ortalamaya en yakın genotipler olarak belirlenmiştir. Standart çeşitler arasında GK Szemes ve GK Maros genel ortalamadan daha yüksek başak ağırlığına sahip olurken, diğer standart çeşitler genel ortalamanın altında yer almıştır.

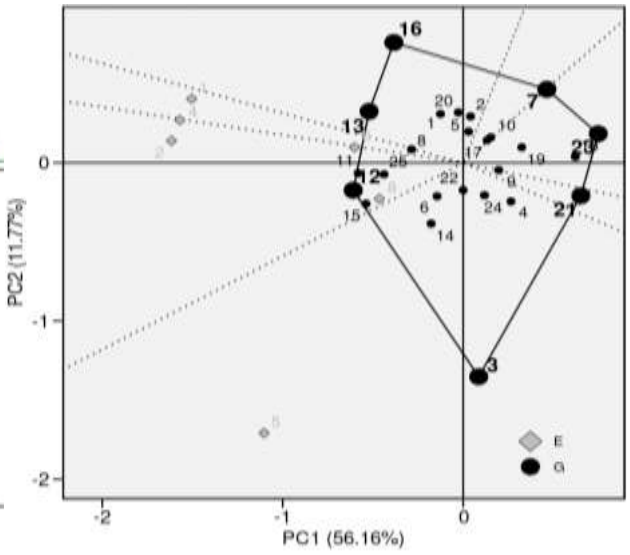
Çevre ortalamalarına göre tritikale genotiplerinin başak ağırlığı değerleri 2,34-3,40 g arasında değişmiştir. En yüksek başak ağırlığı 2020 yılında Tekirdağ-Hayrabolu lokasyonundan (E7) elde edilmiş, bunu aynı istatistiki grupta yer alan 3,38 g ile 2019 yılında Tekirdağ-Süleymanpaşa lokasyonu (E1), 3,35 g ile 2020 yılı Tekirdağ-Süleymanpaşa lokasyonu (E5) izlemiştir.

Sekiz farklı çevreden elde edilen ortalama başak ağırlığı genotipik etkileri bakımından NZFT 12, NZFT 7, NZFT 14, NZFT 15, NZFT 28 ileri hattı dışındaki tüm ileri hatlar, standart çeşitler arasından da GK Szemes, GK Maros çeşitleri pozitif genotipik etkiye sahip olmuştur. Ortalama başak ağırlığı çevre etkileri incelendiğinde ise 2020 yılı Tekirdağ-Hayrabolu lokasyonu (E7), 2019 yılı Tekirdağ-Süleymanpaşa lokasyonu (E1), 2020 yılı Tekirdağ-Süleymanpaşa lokasyonu (E5) ve 2019 yılı Tekirdağ-Hayrabolu lokasyonu (E3) pozitif etkiye sahip olurken diğer çevrelerde negatif etki görülmüştür.

Başak Ağırlığı Değerlerine İlişkin GGE-Biplot Analizi



Şekil 5. Genel ortalama ve stabilite grafiği



Şekil 6. Hangi genotip nerede kazandı grafiği

Şekil 5 incelendiğinde stabilite bakımından 11, 25, 8, 10, 17, 9, 19 ve 18 numaralar iz düşüm çizgileri en kısa olan genotiplerdir. Bu genotiplerden genel ortalamanın üzerinde başak ağırlığı veren 11, 8 ve 25 numaralı genotipler başak ağırlığı yönünden hem üstün özellik hem de yüksek stabilite göstermiştir. Buna karşın 10, 17, 9, 19 ve 18 numaralı genotipler ise kısa iz düşüm çizgisine sahip olmalarına rağmen genel ortalamanın altında başak ağırlığı değerleri ile stabilite yönünden önem taşımamaktadır. Çalışmada 16, 7, 14, 13, 1, 12 ve 20 numaralı genotipler uzun iz düşüm çizgileri ile başak ağırlığı yönünden stabiliteleri en düşük olan genotipler olarak belirlenmiştir. Başak ağırlığı özelliği için çevreler incelendiğinde eşitlik çizgisi merkeze en yakın olan 6 ve 8 numaralı çevreler stabilite yönünden üstün özellik gösteren çevreler olmuştur.

Hangi genotipin nerede uygun olduğunu gösteren GGE-biplot analiz görüntüsünde (Şekil 6) 7 sektör oluşmuş ve çevreler 3 sektör içine dağılmıştır. İkinci, üçüncü, dördüncü ve beşinci sektörde çevre dağılımı görülmezken, çevreler birinci, altıncı ve yedinci sektörlerde dağılım göstermiştir. Başak ağırlığı yönünden seleksiyon için genotiplerin daha farklı sektörlere dağılması yararlı olacaktır. Her bir sektör için uygun genotipler poligonun köşe noktalarında yer alan 3, 21, 23, 7, 16, 13 ve 12 numaralı genotipler olmuşlardır. Üç ve 21 numaralı genotipler arasındaki eşitlik çizgisi, 3 numaralı genotipin 5 numaralı çevre için 21 numaralı genotipten daha uygun olduğunu ortaya koymaktadır. Aynı şekilde 13 ve 12 numaralı genotipler çevrelere göre karşılaştırıldığında 13 numaralı genotipin 1, 2, 3, 4, 6 ve 7 numaralı çevreler bakımından, 12 numaralı genotipin de 8 numaralı çevre için uygun olduğu ortaya konmuştur. Genotipler yönünden çevreler değerlendirildiğinde 6 ve 8 numaralı çevrelerin başak ağırlığı yönünden en uygun çevreler oldukları belirlenmiştir.

3.4. Hasat İndeksi (%)

İncelenen özelliklerden hasat indeksinde çevre etkisi ve genotip etkisi istatistiki olarak % 1 düzeyinde önemli olsa da genotip × çevre interaksiyon etkisi önemsiz bulunmuştur. Bu nedenle hasat indeksi özelliğinde yalnızca birleştirilmiş varyans analiz yorumlaması yapılmıştır.

Yirmi beş tritikale genotipinin ortalama hasat indeksi değerleri %38,58-46,30 arasında değişmiştir. En yüksek hasat indeksi değeri NZFT 13 genotipinden elde edilirken, bu genotipi %45,61 ile GK Szemes ve %43,92 ile NZFT 17 genotipleri takip etmiştir. On dört tritikale genotipi de (%41,25-43,55) aynı istatistiki grupta yer almıştır. En düşük hasat indeksi değeri Truva genotipinden elde edilmiş, bu genotipi %38,98 ile Karma 2000, %38,68 ile Mikham 2002, %40,02 ile Presto 2000, %40,75 ile NZFT 15, %40,78 ile Tatlıcak 97, %41,09 ile Focus ve %41,12 ile NZFT 12 genotipleri izlemiştir. Genel ortalama (%42,17)'ya göre ileri hatlar arasından NZFT 15 (%40,75), NZFT 12 (%41,12), NZFT 14 (%41,25), NZFT 28 (%41,74) ve NZFT 11 (%41,88) genel ortalamadan düşük hasat indeksi değerlerine sahip olmuştur. Standart çeşitler arasından GK Szemes (%45,61) ve GK Maros (%43,44) çeşitlerinin genel ortalamadan daha yüksek hasat indeksi değerine sahip olduğu görülmektedir.

Çevreler ortalama değerlere göre değerlendirildiğinde genotiplerin hasat indeksi değerleri %39,96-46,48 arasında değişmiştir. En yüksek hasat indeksi 2020 yılında Kırklareli-Lüleburgaz lokasyonundan (E8) elde edilmiş, bu çevreyi %43,22 ile 2020 yılı Tekirdağ-Süleymanpaşa lokasyonu (E5) izlemiştir. Çevreler arasında en düşük hasat indeksi değeri ise

2019 yılı Edirne lokasyonundan (E2) elde edilirken, bu çevreyi %40,06 ile 2019 yılı Tekirdağ-Hayrabolu lokasyonu (E3) izlemiştir. Çalışmanın yürütüldüğü diğer dört çevreden elde edilen değerler (%41,62-42,25) aynı istatistiki grupta yer almıştır.

İleri hatlardan NZFT 11, NZFT 12, NZFT 14, NZFT 15 ve NZFT 28 negatif genotipik etki gösterirken, diğer ileri hatların da pozitif genotipik etki gösterdiği belirlenmiştir. GK Szemes ve GK Maros dışındaki tüm standart çeşitlerin de negatif genotipik etkiye sahip olduğu görülmüştür. Ortalama hasat indeksi çevre etkileri incelendiğinde 2019 yılı Tekirdağ-Süleymanpaşa lokasyonu (E1), 2020 yılı Tekirdağ-Süleymanpaşa lokasyonu (E5) ve 2020 yılı Kırklareli-Lüleburgaz lokasyonu (E8) pozitif etkiye sahip olurken, diğer çevreler negatif çevre etkisine sahip olmuştur.

4. SONUÇ VE ÖNERİLER

Bitki boyu bakımından 2019 yılı ortalama bitki boyu değeri, 2020 yılına göre 6,05 cm daha kısa olmuştur. Stabilitesi yüksek olan NZFT 11, Tatlıcak 97 ve Presto 2000 genotipleri uzun boyları ile yeşil ot üretimi için, genel ortalamanın altında ve yüksek stabilite gösteren NZFT 7, NZFT 13 ve NZFT 17 genotipleri ise tane üreticileri ve ıslahçılar açısından ön plana çıkan genotipler olarak belirlenmiştir. 2019 ve 2020 yılı ortalama bitki ağırlığı değerleri oldukça yakın değerler göstermektedir. Bitki ağırlığı bakımından en yüksek değerler NZFT 19, NZFT 20, NZFT 24, NZFT 27 ve NZFT 11 ileri hatlarından alınmış ancak stabilitelerinin düşük olmasından dolayı önem taşımamaktadır. Mikham 2002, Tatlıcak 97 ve Focus standart çeşitleri yüksek stabilite göstermeleri nedeniyle lokasyonlar için en uygun genotipler olmuşlardır. Başak ağırlığı yönünden 1. ve 2. yıl oldukça yakın değerlere sahip olmuştur. Ortalamanın üzerinde başak ağırlığı değerine sahip olan NZFT 17, NZFT 13 ve GK Szemes yüksek stabilite göstererek dört lokasyon için de önerilebilecek en uygun genotipler olmuşlardır. Genotip × çevre interaksiyonunun önemsiz bulunduğu hasat indeksi özelliği için önerilebilecek genotipler ancak genel ortalamanın üzerinde yer alan ve en yüksek değere sahip olan bu genotipler olacaktır. Tüm özellikler göz önüne alındığında NZFT 13, NZFT 17 ileri hatları ile Tatlıcak 97 ve GK Szemes çeşitleri en uygun genotipler olarak belirlenmiştir.

Yazar Katkı Beyanı

Tüm yazarlar bildirinin hazırlanmasına eşit oranda katkı sağlamıştır.

Çıkar Çatışması Beyanı

Tüm yazarlar bu makaleyle ilgili herhangi bir çıkar çatışması olmadığını beyan etmektedir.

Teşekkür

Bu çalışma ilk yazarın doktora tezinin bir bölümünden üretilmiştir.

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ALTERNATIVE APPROCHES TO CHEESE: PLANT- BASED CHEESES

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ABSTRACT

Animal-based cheeses, rich in calcium, phosphorus, protein, fat and vitamins (A, B_{12}, D, E, K), have an important place in human nutrition. However, recently, due to the increasing interest in vegan nutrition, the importance of sensitivity towards animals and environmental approach, ethical values, sustainable approach, socio-economic factors, the belief that plant-based foods are healthier than animal-based foods, allergy or intolerance to dairy products, alternative foods to animal-based cheeses have been sought and plant-based cheeses have begun to be produced and preferred in this context. In plant-based cheeses, vegetable oil is generally used instead of animal fat, and plant proteins are used instead of animal protein. Some plant-based protein sources used instead of animal protein in plant-based cheeses include soybeans, almonds, peas, peanuts, chickpeas, wheat gluten, and tapioca flour. Plant-based cheeses have many advantages such as low cost, longer shelf life, and nutritional diversity, but they also have disadvantages. It is quite challenging for the texture and flavor characteristics, vitamin, mineral and other nutritional composition and quality of plant-based cheeses to be the same as those of animal milk-based cheeses. However, many studies are being carried out to ensure that the quality characteristics of plant cheeses are close to those of animal milk-based cheeses and to strengthen and functionalize the contents. In this study, the current status of plant-based cheeses that can be an alternative to cheeses produced using animal milk was examined. In summary, considering the developing technology and the increasing popularity of the product, the plant-based cheese production sector is developing and spreading and it is seen that it comes with many varieties. It is thought that there is a significant difference when compared to animal milk-based cheese equivalents and that more studies should be done on the product, especially in terms of nutrition.

Keywords: nutrition, plant nutrition, dairy products, cheese

PEYNİRE ALTERNATİF YAKLAŞIMLAR: BİTKİSEL BAZLI PEYNİRLER

ÖZET

Kalsiyum, fosfor, protein, yağ ve vitaminler (A, B_{12}, D, E, K) açısından zengin olan hayvansal kaynaklı peynirler insanların beslenmesinde önemli bir yere sahiptir. Ancak son zamanlarda vegan beslenmeye olan ilginin artması, hayvanlara olan hassasiyetin ve çevresel yaklaşımın önem kazanması, etik değerler, sürdürülebilir yaklaşım, sosyo-ekonomik faktörler, hayvansal kaynaklı gıdalara kıyasla bitkisel kaynaklı gıdaların daha sağlıklı olduğuna dair inanç, süt ürünlerine olan alerji veya intolerans gibi birçok etkenden dolayı hayvansal süt kaynaklı peynirlere alternatif gıdalar aranmış ve bu kapsamda bitkisel bazlı peynirler üretilmeye ve tercih edilmeye başlamıştır. Bitkisel bazlı peynirlerde genellikle hayvansal yağ yerine bitkisel yağ, hayvansal protein yerine ise bitkisel proteinler kullanılmaktadır. Bitkisel bazlı peynirlerde hayvansal protein yerine kullanılan bazı bitkisel kaynaklı protein kaynakları arasında soya fasulyesi, badem, bezelye, yer fıstığı, nohut, buğday glüteni, tapyoka unu yer almaktadır. Bitkisel bazlı peynirlerin maliyetinin düşük olması, daha uzun raf ömrü, besinsel çeşitlilik gibi birçok avantajı bulunmasıyla birlikte dezavantajları da bulunmaktadır. Bitkisel peynirlerin doku ve lezzet özellikleri ile vitamin, mineral ve diğer besinsel bileşimi ve kalitesinin hayvansal süt kaynaklı peynirler ile aynı olması oldukça zorlayıcıdır. Ancak bitkisel peynirlerin kalite karakteristiklerinin hayvansal süt kaynaklı peynirlere yakın olması, içeriklerin güçlendirilmesi ve işlevselleştirilmesi amacıyla birçok çalışma yapılmaktadır. Bu çalışmada hayvansal kaynaklı süt kullanılarak üretilen peynirlere alternatif olabilecek bitkisel peynirlerin mevcut durumları incelenmiştir. Özetle, gelişen teknoloji ve ürünün artan popülerliği göz önünde bulundurulduğunda bitkisel peynir üretim sektörü giderek gelişmekte ve yaygınlaşmakta olup birçok çeşidiyle karşımıza çıktığı görülmektedir. Hayvansal süt kaynaklı peynir muadilleri ile kıyaslandığında oldukça büyük bir fark olduğu ve özellikle besleyicilik açısından ürün üzerinde daha çok çalışma yapılması gerektiği düşünülmektedir.

Anahtar Kelimeler: beslenme, bitkisel beslenme, süt ürünleri, peynir

1.INTRODUCTION

Nutrition is a fundamental prerequisite for the maintenance of a healthy lifestyle. Cheese, a dairy product, occupies a significant position in a healthy diet (Doğan et al., 2022). Cheese is the most widely consumed dairy product (Çetinkaya, 2021) and is the most produced (Doğan et al., 2022). The production of traditional cheese involves the utilisation of milk from various animal sources, including cows, buffalo, sheep, and goats (Craig et al., 2022). According to the Turkish Food Codex Cheese Communiqué, cheese is defined as "dairy products obtained by coagulating the raw material using a suitable coagulant and separating the whey from the curd or by coagulating the milk after separating the permeate, with different hardnesses and fat contents, These cheeses can be produced with or without salting with brine or dry salting, with or without starter culture, with or without boiled curd, with or without flavour, and in accordance with specific techniques. They can be consumed either without ripening or after ripening, and they typically exhibit characteristics that are specific to their type (Anonymous, 2015). Cheese constitutes a significant source of minerals such as phosphorus and calcium, vitamins (A, B_{12}, D, E, K), protein, essential amino acids and essential fatty acids (Doğan et al., 2022). It has been documented that approximately 75-80% of the proteins present in milk are retained in the final cheese, and it has been reported that the human body utilises approximately 89% of the amino acids contained within cheese (Demiral, 2022). In addition to these observations, there has been an increasing interest in alternative food sources to animal-based cheeses, with a notable shift towards the production and consumption of plant-based cheeses. There are numerous factors driving this quest for alternatives. These include product development studies aimed at enhancing product diversity, the emergence of sensitivity towards animals, the ethical considerations surrounding the consumption of animal-based foods, the growing interest and popularity of vegan nutrition, the significance of environmental and sustainable living, and studies conducted in this context. Socio-economic factors, the potential for shortages of animal-based food and protein, particularly in the context of a growing population, are also considered. The notion that plant-based foods are healthier than animal-based foods, the presence of allergies or lactose intolerance in some people to dairy products, the desire to consume different types of proteins, the search for healthy alternative products, concerns about the depletion of water resources, the need for land use for animal-based milk production, the increase in greenhouse gas emissions and the desire to take precautions are some of these reasons (Yılmaz, 2023). The present study examined the current status of plant-based cheeses as a potential alternative to cheeses produced using animal-based milk.

2. PLANT- BASED CHEESES

Cheeses that are devoid of animal-based ingredients and are produced exclusively from plant-based components, thereby resembling the taste and appearance of cheeses made from animal milk, are called plant-based cheeses. These cheeses are a viable option for consumers who adhere to a vegan diet or seek to avoid animal-based products. Plant-based products have been shown to contain lower levels of saturated fat in comparison to milk and dairy products, thus rendering them a healthier alternative for individuals with high cholesterol and those suffering from heart disease (PM et al., 2024). Plant-based cheeses can be consumed as a standalone

product, but they are also frequently used in combination with other products or as an ingredient in various dishes. Their use is pervasive in numerous food products, including frozen ready-made pizza, pasta and chip sauces, cheese sauces, cold sandwiches, and hamburgers (Esen et al., 2020). Cheeses manufactured using animal-based milk contain protein, fat, water- and fat-soluble vitamins, minerals, calcium and phosphorus, and amino acids that the human body is incapable of synthesising (Kekik, 2023). Since plant-based cheeses cannot exactly match the content of cheeses made from animal milk, there are difficulties in reflecting the similarity of the cheese's taste, flavor, sensory experience and texture (Kekik, 2023). The elevated levels of plant proteins in plant-based cheeses, in conjunction with the specific functional properties of casein in milk, are the primary factors contributing to this discrepancy (Mefleh et al., 2022).

The production of plant-based cheese is typically undertaken in accordance with a sequence of steps that include formulation, mixing, heating, hot packaging and cooling. The sequence of ingredient addition is dictated by the specific processes involved. Initially, the powdered ingredients are amalgamated with water, subsequently heated to 50 °C using steam, and then subjected to a further 2-3 minutes of mixing. Subsequently, plant-based oils are incorporated, and the mixture is subjected to an average temperature of 85 °C for 5-8 minutes until it becomes molten. Following this, the addition of acidity regulators and flavouring agents such as salt initiates the cooling process. It is important to note that the temperatures and times during cheese making can affect the properties and shelf life of the cheese. In addition, the type, properties and amount of ingredients added can affect many cheese quality parameters such as the structure, taste and hardness of the cheese (Suna and Ersan, 2020). The production of plant-based cheeses involves the utilisation of plant-based products, including fruit, seeds, and vegetables. The production of plant-based cheese typically involves the utilisation of palm, cocoa or coconut oils as a source of vegetable oil; nuts, legumes or seed proteins as a source of plant protein; potato, tapioca or corn starches as a source of carbohydrates; alginic acid, xanthan gum or agar as thickeners; sodium phosphate or sodium citrate as a source of salt; lactic acid, citric acid or acetic acid as acidity enhancers (Kovačević et al., 2024). The utilisation of powdered cellulose as an anti-caking agent is a common practice in the industry. Plant-based cheeses contain significant amounts of nutritional supplements and proteins, the levels of which vary depending on the types of plant ingredients used in their production (Craig et al., 2022). Each constituent employed in the fabrication of plant-based cheeses fulfils a specific function. Plant-based oils play a pivotal role in achieving the desired composition, texture, and dissolvability of plant-based cheeses. Plant protein sources have been shown to increase nutritional value, increase the viscosity of the aqueous phase, and provide emulsification of fat thanks to soluble proteins (Jones et al., 2021). In addition, parameters such as the type, structure, content, and solubility rate of proteins affect the properties of cheese. The water employed in the production process fulfils several functions, including hydrating the protein, preventing the cheese from becoming excessively solid, enhancing its melting capability, and facilitating the dissolution of certain components in the cheese matrix. Starch is often utilised in lieu of casein, exhibiting the capacity to facilitate fat emulsification. Substances utilised as acidifiers contribute to its microbiological stability by ensuring that the pH is appropriately adjusted. As Suna and Ersan (2020) demonstrate, the addition of mineral and vitamin supplements results in an increase in the nutritional components present in plant-based cheeses when compared to those derived from animal milk. These include vitamins, magnesium, zinc, and iron. Plant-

based cheeses can be categorised as either spreadable or solid. In the assessment of the quality characteristics of cheeses with a solid structure, their hardness, brittleness, flexibility, chewiness, and internal stickiness are typically evaluated. In the case of spreadable cheeses, the focus is typically on extensibility, meltability, and viscosity (Beykont, 2009). A study examined vegan cheese substitutes and reported that they were nutritionally different from cheeses containing milk, with higher fat and carbohydrate content and lower protein, sugar, and salt content (Boukid et al., 2022).

Plant-based cheeses offer numerous advantages. The cost-effectiveness of plant-based products, which are generally more affordable than milk, is a key advantage in their production. Plant-based cheeses also have a longer shelf life. They also generally contain a lower saturated fat content. The use of soy in place of milk allows for the production of cheeses with high-quality protein. The use of more sustainable sources other than almond milk is also a key advantage. Furthermore, when sweetened, the taste profile of plant-based cheeses can be enhanced in comparison to conventional cheeses. Fermentation is a key factor in enhancing the nutritional bioavailability and sensory properties of plant-based cheeses (Kilci, 2023). It is estimated that approximately 14.5% of greenhouse gas emissions and around 30% of biodiversity loss are attributable to the animal husbandry sector for the purpose of feeding people (Kilci, 2023). Consequently, the utilisation of non-dairy alternatives in cheese production is hypothesised to engender favourable environmental outcomes (Demirci, 2024). In addition to the advantages, there are many disadvantages. These include the potential for an undesirable taste profile due to the absence of added sweeteners and sugars, which may be a concern for consumers. The environmental impact of almond milk is already detrimental, and this is further exacerbated by its use in plant-based cheese production. Plant-based cheeses exhibit a distinct nutritional profile from their dairy counterparts, potentially leading to nutritional deficiencies. Furthermore, some plant-based cheeses may contain saturated fats from coconut and palm oils, which are high in saturated fat (Kilci, 2023).

3.CONCLUSION

In response to the increasing demand for food, driven by the expanding population and the recognition that existing resources are inadequate, there has been a surge in the development of novel, sustainable products. These novel foods have only recently begun to gain ground in our country, and the production and consumption of plant-based cheeses remain negligible. Conversely, shifting nutritional patterns, the growing inclination towards plant-based nutrition, and the pursuit of novel food products have led to a steady rise in plant-based cheese production and consumption. This development can be attributed to the fact that plant-based cheese is perceived as a viable alternative by a significant proportion of the population who, for various reasons, cannot or do not wish to consume animal-based dairy products. While there are ongoing studies investigating the rate of imitation of animal-based cheese using plant-based products, the inability of plant-based cheese to match the nutritional and sensory properties of animal-based cheese is a significant challenge for the industry. It is anticipated that a significant number of studies will be conducted on plant-based cheeses in the future, leading to the expectation that properties such as texture, taste, and sensory perception will become more

comparable to those of animal-based cheeses. This has the potential to generate a substantial increase in demand for plant-based cheeses, resulting in a notable rise in production and consumption rates.

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APPLICATIONS OF INTELLIGENT PACKAGING TECHNOLOGY IN FOODS

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ABSTRACT

Packaging, which is an important element for packaged foods, is defined as "a material made of paper, cardboard, wood, plastic, etc. that protects the product from external factors, keeps the products inside together, and facilitates transportation, storage, distribution, promotion, and advertising." A new concept, "smart packaging", has emerged due to many reasons such as the desire for more functions than these basic functions to be present in the packaging for packaging a food, developing technology, consumer preferences and expectations. Smart packaging technology meets all the functions in the packaging concept and provides information to the producer and consumer by detecting changes such as humidity, temperature, and deterioration in and around the product during the entire process from the production of food to its consumption. There are basically three different technologies used in intelligent packaging systems. These are sensors, indicators and data carriers. Sensors provide information about temperature changes, freshness, microbiological spoilage and oxidative rancidity changes in foods. While indicators provide information about the quality of the food, data carriers record certain information in the supply chain. Different features can be added to smart packaging according to the needs of the food. For example, there are many features such as freshness indicator for fruits and vegetables, oxygen sensors for oxygen-sensitive foods, and pathogen indicators for meat, poultry, and fish products. Thanks to these features of smart packaging technology, problems that may occur in food can be monitored, economic loss is reduced, food safety is increased, food loss and waste are reduced, consumer satisfaction is increased by protecting the consumer, and thanks to timely information, precautions can be taken, and the shelf life of foods can be extended. Considering the advantages of smart packaging technology, it is thought that its use in foods will be beneficial and that many features will be added in the future and become more useful. This review includes current information and developments about smart packaging systems and technology used in foods.

Keywords: packaging, packaging in foods, intelligent packaging

GIDALARDA AKILLI AMBALAJLAMA TEKNOLOJİSİ UYGULAMALARI

ÖZET

Paketli gıdalar için önemli bir unsur olan ambalaj; "Ürünü dış etkenlerden koruyan, içine konan ürünleri bir arada tutarak taşıma, depolama, dağıtım, tanıtma, reklam gibi işlemleri kolaylaştıran, kâğıt, mukavva, ahşap, plastik ve benzerinden yapılan malzeme." olarak tanımlanmaktadır. Bir gıdayı paketleme için bu temel fonksiyonlardan daha fazla fonksiyonun ambalajda bulunmasının istenmesi, gelişen teknoloji, tüketici tercihi ve beklentileri gibi birçok sebepten dolayı yeni bir kavram olan "akıllı ambalajlama" kavramı ortaya çıkmıştır. Akıllı ambalajlama teknolojisi, ambalaj kavramındaki tüm fonksiyonları karşılamakla birlikte gıdanın üretiminden tüketimine kadar olan tüm süreçte, üründeki ve ürün etrafındaki nem, sıcaklık, bozulma gibi değişikliklerin tespit edilmesini sağlayarak üretici ve tüketiciyi bilgi sahibi yapmaktadır. Akıllı ambalajlama sistemlerinde temelinde üç farklı teknoloji kullanılmaktadır. Bunlar; sensörler, indikatör ve veri taşıyıcılarıdır. Sensörler; gıdalardaki sıcaklık değişimi, tazelik, mikrobiyolojik bozulma ve oksidatif acılaşma değişimleri hakkında bilgi verir. İndikatörler gıdanın kalitesine yönelik bilgi verirken, veri taşıyıcıları tedarik zincirindeki belirli bilgileri kaydederler. Gıdaların ihtiyaçlarına göre akıllı ambalajlara farklı özellikler de eklenebilmektedir. Örneğin meyve ve sebzeler için tazelik göstergesi, oksijene duyarlı gıdalar için oksijen sensörleri ve et, kanatlılar ve balık ürünleri için patojen indikatörü kullanılabilmesi gibi birçok özellik mevcuttur. Akıllı ambalajlama teknolojisinin bu özellikleri sayesinde gıdalarda meydana gelebilecek sorunlar izlenebilir hale gelir, ekonomik kayıp azalır, gıda güvenliği artar, gıda kaybı ve israfı azalır, tüketiciyi koruyarak tüketici memnuniyet oranını yükseltir ve zamanında bilgilendirme sayesinde önlem alınıp gıdaların raf ömrü uzatılabilir. Akıllı ambalajlama teknolojisinin avantajları göz önünde bulundurulduğunda gıdalarda kullanımının yararlı olacağı ve gelecekte birçok özellik eklenip daha faydalı hale geleceği düşünülmektedir. Bu derlemede gıdalarda kullanılan akıllı ambalaj sistemleri ve teknolojisi hakkında güncel bilgi ve gelişmelere yer verilmiştir.

Anahtar Kelimeler: ambalajlama, gıdalarda ambalajlama, akıllı ambalajlama

1. INTRODUCTION

Food packaging is defined as a tool used to protect food against undesirable physical and mechanical external effects, and to prevent deterioration and damage caused by these effects. It is also used to deliver food to the end consumer in a way that ensures food safety (Kocaman and Sarımehmetoğlu, 2010; Karagöz and Demirdöven, 2017). The material composition of packaging may vary, with examples including paper, cardboard, wood, and plastic (Öcal and Çakmak Karapınar, 2016). The primary functions of food packaging can be categorised as follows: promotion and information provision about the product, facilitation of ease of transportation and storage, enhancement of aesthetic appearance and integrity, and protection of food from moisture, pressure, direct contact with light, and undesirable oxidation reactions (Karagöz and Demirdöven, 2017; Yüceer and Caner, 2023). Despite the implementation of physical, microbial, chemical, and sensory analyses prior to the packaging of a food product, it remains impossible to ascertain the product's condition upon reaching the consumer (Ma et al., 2022). The advent of diverse packaging technologies can be attributed to numerous factors, including the aspiration for packaging to serve multifaceted functions beyond mere product protection, advancements in technology, consumer demands, and the competitive landscape. One such technology is smart packaging technology (Takma and Nadeem, 2019). According to the European Food Safety Authority (EFSA), smart packaging technology is defined as "Materials and substances that monitor the condition of packaged food or the conditions around it" (Müller and Schmid, 2019). This technology involves the recording of physical and chemical changes that occur in the product, enabling the producer and consumer to monitor food safety and quality (Takma and Nadeem, 2019). The utilisation of smart packaging technology confers numerous advantages. The technology has the capacity to detect potential issues with food items prior to their occurrence, thereby enabling the implementation of preventative measures. The utilisation of smart packaging facilitates the extension of food shelf life, leading to a reduction in economic losses. Additionally, the technology contributes to a decline in food safety risks, food loss and waste, and the deterioration of food quality. Furthermore, it enhances the perception of freshness and consumer satisfaction by safeguarding against the potential risks of food poisoning. However, it is important to note that this technology is not without its drawbacks. These include the necessity for separate packaging designs for each food item, as well as high production costs (Kasım ve Kasim, 2019). This study aims to provide current information and developments on smart packaging systems and technologies used in foods.

2. APPLICATIONS OF SMART PACKAGING TECHNOLOGY

Smart packaging technology can be defined as a packaging system that uses science and technology to communicate changes in the conditions of food and its external environment, as well as various quality parameters (e.g. humidity, temperature, pH) to the producer and consumer. The purpose of this communication is to make it easier to follow and be informed (Ghaani et al., 2016). A multitude of packages has been conceptualised within the ambit of the smart packaging system. These designs can be categorised into three distinct types: sensors, indicators, and data carriers.

2.1.SENSORS

Sensors utilised within the domain of food packaging are employed to measure and monitor physical or chemical quality parameters in packaged foods. In the event of any change, the sensor emits a signal, thereby alerting the producer or consumer, thus preventing spoilage (Takma and Nadeem, 2019). The sensor is composed of two primary components: a transducer and a receptor. The sensor functions on the principle that the receptors within it convert physical or chemical data into energy, which is then converted into a signal by the transducer (Akkemik and Güner, 2020). Sensors are utilised in the packaging of food products to monitor a variety of features, including the assessment of food freshness, the identification of pH variations and microbiological spoilage, the regulation of temperature fluctuations and oxidative reactions (Çelik and Tümer, 2016; Kadağan and Gürbüz, 2022). A classification of sensors can be established, categorising them into three primary groups: biosensors, gas sensors and nanoscale sensors (Kadağan and Gürbüz, 2022).

A biosensor is a type of sensor that facilitates the monitoring, determination and transmission of biological and biochemical reactions occurring in packaged foods (Kasım and Kasim, 2019). The preference for biosensors can be attributed to their numerous advantages, including cost-effectiveness, compact size, and portability. Applications in the food sector include freshness monitoring of meat, poultry, and seafood; sugar and total microbial load measurement in beverages; and contamination detection (Akkemik and Güner, 2020). A notable example of a biosensor is the "Food Sentinel System". This barcode system functions by ensuring that if the microbial load in a food product exceeds the amount stipulated by the manufacturer or if the product's expiration date has been exceeded, the ink, which is typically invisible, will transfer from the packaging to the barcode, rendering the barcode unusable. This prevents the purchase of the product and the potential consequences of microbial load, such as poisoning (Akkemik and Güner, 2020; Anonymous, 2025).

Gas sensors represent a category of sensor that functions on the principle of the sensor's responsiveness to the gas to be monitored. In the context of the food industry, gas sensors play a pivotal role in the detection of leakage and the assessment of product quality by measuring the levels of oxygen and carbon dioxide. This application was pioneered by Öksüztepe and Beyazgül (2015).

Nano sensors are sensors used to detect spoilage in foods. In the event of foods becoming contaminated with pathogens during transportation or storage, or for any other reason, these sensors are capable of detecting the gases that are produced as a result of spoilage. The sensors then report the status of the spoilage using a colour grading system. The capacity of nano sensors to detect unwanted microorganisms, thereby playing a role in the prevention of food poisoning, has been well documented (Karagöz and Demirdöven, 2017).

2.2. INDICATORS

Indicators represent a subset of smart packaging systems that facilitate the monitoring of the quality of foodstuffs, the external environmental conditions in which food is stored, and the internal environmental conditions of the packaging, including the headspace. It should be noted

that indicators can be categorised as either contact or non-contact with food. The classification of indicators is determined by their function (Hepsağ and Varol, 2018).

Time-temperature indicators, for instance, provide information to the consumer about unwanted temperature changes that occur. In the event of a temperature change resulting from mechanical, chemical, microbial or enzymatic reactions during transportation and storage, a colour change is observed on the label of the packaging, depending on the temperature (Özçildir ve Yetim, 2010). These indicators can be attached to the packaging surfaces separately in each package or as one per batch (Purma and Serdaroğlu, 2006). Time-temperature indicators are of great importance in terms of food safety and quality. As these indicators are based on the shelf life of food items when stored within the required temperature range, depending on the food type, they are not suitable in cases of temperature fluctuations (Yüceer and Caner, 2023). The application of this indicator is particularly relevant in the context of perishable foods, including fresh and frozen meat, poultry, dairy products, and frozen foods (Kocaman and Sarımehmetoğlu, 2010).

Freshness indicators are defined as analytical tools that detect the presence of specific metabolites, including carbon dioxide, ammonia, trimethylamine, dimethylamine, organic acids, ethanol, hydrogen sulfide, toxins, enzymes, glucose, and fluctuations in gas concentrations. These indicators are utilised to assess the shelf life of food products, particularly in instances where storage conditions are suboptimal, there is contact with pathogens, undesirable reactions occur, or microbial spoilage is present. The colour change of the label on the package serves as an indicator of the freshness of the product. (Öksüztepe and Beyazgül, 2015; As stated by Özçildir and Yetim (2010), the colour change function can be utilised to determine the food's consumption status. The colour change function enables the determination of whether the food will be consumed or not. Numerous illustrations of the implementation of these indicators in food products can be provided. A notable example is the "FresTag®" indicator, which provides information regarding the freshness of fish by undergoing a colour change in response to the concentration of volatile amine compounds present within the fish (Purma and Serdaroğlu, 2006). Indicators labelled "It's Fresh®" are employed in meat and seafood packaging, where they convert the pH change into a colour change in the presence of volatile amines or sulfides in the packaging. In the case of chicken and chicken products, indicators provide information about the product by causing the color to change with the reaction of myoglobin and hydrogen sulfide (Öksüztepe and Beyazgül, 2015). Furthermore, indicators known as "RepeSenses®" have been developed for the purpose of determining the ripeness of various fresh fruits. The principle underlying this technology is the identification of metabolites that are characteristic of the ripening process in fresh fruits, in conjunction with the colour change of the indicator. This technology has been employed in a variety of fruits, including pears, avocados, melons, kiwis, and mangoes (Akkemik and Güner, 2020).

Leak indicators are devices that provide information about the presence of gases in packaging by showing a colour change. Given the critical importance of ascertaining the absence of leaks to ensure optimal shelf life, particularly in contexts where gases are employed to prevent the development of microorganisms, the significance of leak indicators cannot be overstated. An illustration of the utilisation of such indicators in the sector is the oxygen gas indicator, termed

"Ageless-Eye®", which undergoes a colour change in accordance with the oxygen gas concentration within the packaging (Hepsağ and Varol, 2018).

The operation of pathogen indicators is underpinned by immunochemical and chemical methodologies, which facilitate the detection of toxins. These indicators provide information about the detection of specific pathogenic bacteria. An illustration of its application in the field of food analysis is its use in the detection of *Escherichia coli* O157:H7 bacteria in meat, poultry, and fish-like products (Yüceer and Caner, 2023).

2.3.DATA CARRIERS

The system under discussion is an intelligent packaging system that records the history of many features of packaged products throughout the supply chain and provides instant traceability. The system offers numerous advantages, including the capacity for remote control and security of the product, as well as the capability to detect and rectify any issues (Çelik et al., 2024).

The barcodes, which are arranged with vertical lines and spaces of varying thicknesses, indicate the product's features and price, allowing electronic devices to read the data and transfer it to another system (Yüceer and Caner, 2023). The numerous advantages of barcodes include their versatility, allowing for use across diverse sectors and products; universality, facilitating seamless integration into existing systems; cost-effectiveness, ensuring affordability without compromising on precision; rapid and instantaneous updates, enabling real-time monitoring and adjustments; compact size, enhancing portability and ease of use; and high data storage capacity, ensuring comprehensive inventory control and efficient data management (Kocaman and Sarımehmetoglu, 2010).

Radio frequency identification (RFID) is a system that facilitates the tracking of products through the utilisation of a reader that employs radio waves. The RFID system comprises a controller, a reader, an interrogator, an antenna and a label (Kadağan and Gürbüz, 2022). The efficacy of this system is evidenced by its ability to facilitate comprehensive control over product inventory throughout the supply chain. In addition, it enables the documentation of fundamental information such as temperature, relative humidity, barcode details, and microbiological data. The system's capabilities extend further, including the identification of counterfeit products and its utilisation in recall scenarios (Özçildir and Yetim, 2010; Kasim and Kasim, 2019).

3. CONCLUSION

The fundamental purpose of packaging is to protect the product; however, with the advancement of technology, a multitude of additional functions have been incorporated into packaging. Consequently, a novel packaging system known as smart packaging technology has emerged. As research progresses, the capabilities of smart packaging are being enhanced, leading to a steady increase in its utilisation and a corresponding strengthening of its position within the sector. The technology offers numerous advantages, including enhanced food quality and safety, reduced food waste, extended shelf life, and facilitated food traceability, which has

been met with approval by producers and consumers alike. However, this technology is not without drawbacks, including its high cost and the necessity for the development of bespoke packaging for certain foods. Therefore, it is considered that the use of smart packaging technology in food is beneficial and will become more widespread in the future.

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ADULT POPULATION DEVELOPMENT AND DAMAGE RATES OF THE CODLING MOTH *CYDIA POMONELLA* (L.) (LEPIDOPTERA: TORTRICIDAE) IN PEAR ORCHARDS OF KOCAELI PROVINCE

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ABSTRACT

The codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae) is a significant pest of pome fruits globally. The present study aimed to monitor the seasonal adult population dynamics and damage rate of the codling moth in pear orchards located in Kocaeli province of Türkiye. The field observations were made from April to October once a week during the 2024 growing season. The research was conducted in five pear orchards (four treated, one untreated) in Kartepe and Gölcük districts. Three pheromone traps were placed in each orchard to monitor the adult population dynamics of codling moths. The first adults of the codling moth were captured in pheromone traps on April 12 in Gölcük and April 27 in Kartepe. The pest populations reached their highest level in the Hisareyn location of the Gölcük district on July 27, with an average of 10 adults per trap. In the Kartepe district, the populations peaked on August 3, recording 16.3 adults per trap in the Maşukiye-2 location, and on August 17, with 8 adults per trap in the Balaban location. Adult pests were last detected in pheromone traps in Kartepe and Gölcük on September 21. To evaluate the damage rates of the fruits, a total of 100 fruits were examined from 10 randomly selected trees, with 10 fruits per tree representing the orchards. The assessment of damage rates was conducted weekly during the initial phase of the first adult flights. The damage rates of fruits in the pear orchards located in Hisareyn and İhsaniye in Gölcük were 4.95% and 1.78%, respectively. In the Balaban, Maşukiye-1, and Maşukiye-2 (untreated) orchards in Kartepe were 1.5%, 1.2%, and 23.95%, respectively. The corrugated board method was employed to monitor the initial emergence of adult codling moths for the summer and autumn generations. The adults of the 2nd generation emerged on July 14, while the adults of the 3rd generation emerged on September 1.

Keywords: Population dynamics, Damage rate, *Cydia pomonella*, Pear, Kocaeli

KOCAELİ İLİ ARMUT BAHÇELERİNDE ELMA İÇKURDU *CYDIA POMONELLA* (L.) (LEPIDOPTERA: TORTRICIDAE)'NIN ERGİN POPÜLASYON GELİŞİMİ VE ZARAR ORANLARI

ÖZET

Elma içkurdu, *Cydia pomonella* L. (Lepidoptera: Tortricidae), dünya genelinde yumuşak çekirdekli meyvelerin önemli bir zararlısıdır. Bu çalışma, Elma içkurdu'nun Kocaeli (Türkiye) ilindeki armut bahçelerinde mevsimsel ergin popülasyon dinamiklerini izlemeyi ve zarar oranlarını belirlemeyi amaçlamaktadır. Arazi çalışmaları, 2024 yılının Nisan-Ekim ayları arasında haftalık olarak gerçekleştirilmiştir. Çalışma, Kartepe ve Gölcük ilçelerinde bulunan beş armut bahçesinde (dört ilaçlı, bir ilaçsız bahçe) yürütülmüştür. Elma içkurdu'nun ergin popülasyon dinamiklerini izlemek amacıyla her bahçeye üçer adet feromon tuzağı yerleştirilmiştir. Elma içkurdu erginleri ilk olarak Gölcük ilçesinde 12 Nisan'da, Kartepe ilçesinde ise 27 Nisan'da feromon tuzaklarında tespit edilmiştir. Zararlının popülasyonları, Gölcük ilçesinin Hisareyn lokasyonunda 27 Temmuz'da ortalama 10 birey/tuzak ile en yüksek seviyeye ulaşmıştır. Kartepe ilçesinde ise zararlının popülasyonları, Maşukiye-2 lokasyonunda 3 Ağustos'ta 16.3 birey/tuzak ve Balaban lokasyonunda 17 Ağustos'ta 8 birey/tuzak ile tepe noktasına ulaşmıştır. Ergin bireyler, Kartepe ve Gölcük ilçelerindeki feromon tuzaklarda son olarak 21 Eylül'de tespit edilmiştir. Meyve zarar oranlarını belirlemek amacıyla her bahçede 10 ağaçtan rastgele ağaç başına 10 meyve olmak üzere toplam 100 meyve incelenmiştir. Zarar oranlarının değerlendirilmesi, ilk ergin uçuşlarının başlangıç döneminden itibaren haftalık olarak yapılmıştır. Gölcük ilçesinin Hisareyn ve İhsaniye lokasyonlarında bulunan armut bahçelerinde meyve zarar oranları sırasıyla ortalama %4.95 ve %1.78 olarak belirlenmiştir. Kartepe ilçesinde ise Balaban, Maşukiye-1 ve Maşukiye-2 (ilaçsız) bahçelerinde meyve zarar oranları sırasıyla ortalama %1.5, %1.2 ve %23.95 olarak tespit edilmiştir. Elma içkurdu'nun yaz ve sonbahar döllerine ait ilk ergin çıkışlarını belirlemek amacıyla tuzak bant yöntemi kullanılmıştır. Zararlının ikinci döle ait erginlerinin 14 Temmuz'da, üçüncü döle ait erginlerinin ise 1 Eylül'de çıkış yaptığı belirlenmiştir.

Anahtar Kelimeler: Popülasyon takibi, Zarar oranı, *Cydia pomonella*, Armut, Kocaeli

1. GİRİŞ

Armut (*Pyrus comminus* L.) Rosales takımından, Rosaceae familyası, *Pyrus* cinsi içerisinde bulunmaktadır. Dünyada üretimi yapılan ve 24 türü bulunan *Pyrus* cinsinin içerisinde *P. communis* ekonomik açıdan üretimi yapılan en önemli türdür (Özbek, 1978; Hancock ve Lobos, 2008). Türkiye pek çok meyve türünün anavatanı veya anavatanları arasında yer almakta olup, armutun da anavatanları arasında bulunmaktadır. Ülkemizde yetiştirilen meyve türlerinin bir kısmı kendiliğinden var olmuşken, bir kısmı ise farklı ülkelerden veya bölgelerden ülkemize taşınmıştır (Özbek, 1978). Dünya'daki armut üretim miktarlarına bakıldığında 2023 yılında Çin yaklaşık 20 milyon ton ile birinci sırada yer alırken Türkiye 534.513 ton ile dördüncü sırada yer almaktadır (FAO, 2023). 2024 yılında Türkiye'de bu miktar 630.500 ton olarak gerçekleştirilmiş olup, Kocaeli ilinde ise 5.644 ton üretim yapılmıştır (TÜİK, 2024).

Meyve yetiştiriciliğinde karşılaşılan en önemli sorunların başında zararlı organizmaların etkin mücadelesi gelmektedir. Diğer meyve türlerinde olduğu gibi, armut üretiminde de çeşitli hastalık ve zararlılar önemli verim kayıplarına neden olmaktadır. Bu zararlılar arasında özellikle Elma içkurdu, *Cydia pomonella* L. (Lepidoptera: Tortricidae), ülkemiz meyveciliğinde büyük ekonomik öneme sahip zararlılardan biri olarak öne çıkmaktadır. Elma içkurdu'nun Türkiye'deki en önemli meyve zararlılarından biri olduğu ve bazı yıllarda neden olduğu zarar oranlarının %100'e kadar ulaşabildiği bildirilmiştir (Özbek ve ark. 1995; Yeşilırmak ve ark., 2025). Elma içkurdu'nun neden olduğu zararlar, doğrudan meyve üzerinde beslenen larvaların faaliyetleri sonucu ortaya çıkmaktadır. Larvalar, meyvenin içine doğru ilerleyerek beslenme esnasında galeri açmakta, bu süreçte meyve içinde pislik ve dışkı bırakmakta ve böylece meyvenin pazar değerini önemli ölçüde düşürmektedir. Dişi bireyler yumurtalarını genellikle meyve yüzeyine veya yapraklara bırakmaktadır. Yumurtadan çıkan larvalar kısa süre içerisinde uygun bir meyve bulup kabuk üzerinden giriş yaparak, meyvede derin delikler ve zarar oluşturmaktadır. Larvalar meyvenin çekirdeğine kadar ilerleyerek hem meyvenin gelişimini engellemekte hem de ürün kalitesini ciddi şekilde düşürmektedir (Beers ve ark., 1993; Pajač ve ark., 2011; Kaplan ve Bayram, 2019; Depalo ve ark., 2022).

Fitofag böceklerin popülasyon dinamiklerine ilişkin bilgiler, zararlı böceklerin etkin şekilde yönetilmesinde büyük önem taşımaktadır. Bu tür bilgiler, hedef zararlının bitkiler üzerinde ekonomik zarar oluşturduğu dönemlerin belirlenmesine ve popülasyonu düzenleyici en önemli ölüm kaynaklarının ortaya konmasına olanak tanımaktadır. Özellikle entegre zararlı yönetimi stratejilerinin etkin planlanabilmesi için zararlının biyolojisinin, popülasyon artış eğilimlerinin ve çevresel faktörlerle etkileşiminin ayrıntılı şekilde anlaşılması oldukça önemlidir (Telli ve Yiğit, 2019).

Çalışmanın amacı, Kocaeli ilinde armut bahçelerinde ekonomik kayıplara yol açan başlıca zararlılardan biri olan *C. pomonella*'nın ergin popülasyon gelişimini, ilk ergin çıkış tarihini, popülasyonun oluşturduğu tepe noktalarını, ergin bireylerin doğada aktif olduğu dönemleri ve zararlının neden olduğu zarar oranlarını belirlemektir. Bu veriler, zararlının izlenmesi ve zamanında mücadele edilmesi açısından önemli bir temel oluşturmakla birlikte bölgesel düzeyde uygulanacak entegre mücadele programlarına katkı sağlayacaktır.

2. MATERYAL VE METOT

Cydia pomonella'nın ergin popülasyonlarının takibi ve zarar oranlarının belirlenmesi amacıyla 2024 yılında yapılan çalışma, Kocaeli ilinin Gölcük ve Kartepe ilçelerine bağlı Hisareyn, İhsaniye, Balaban ve Maşukiye lokasyonlarında yer alan toplam beş adet armut bahçesinde yürütülmüştür. Çalışmaların yürütüldüğü dört bahçede kimyasal mücadele uygulanmış olup bir bahçede (Maşukiye-2) herhangi bir mücadele programı uygulanmamıştır. Çalışmaların yürütüldüğü armut bahçelerine ait bilgiler Çizelge 1'de verilmiştir. *Cydia pomonella*'ya karşı yapılan mücadele kapsamında, takip edilen bahçelere göre değişmekle birlikte Nisan ve Eylül ayları arasında üreticiler tarafından ilaçlamalar gerçekleştirilmiştir. Bu uygulamalarda, farklı etken maddelere sahip insektisitler (deltamethrin, emamectin benzoate, diflubenzuron, spinetoram, methoxyfenozide+spinetoram, cypermethrin) kullanılmıştır.

Çizelge 1. Kocaeli ilinde 2024 yılında çalışmanın yürütüldüğü bahçelere ait bilgiler

Lokasyon	Koordinatlar	Alan (da)	Bahçe Yaşı	Çeşit	Ağaç Sayısı
Hisareyn (Gölcük)	40° 41' 54.2" N 29° 50' 56.2" E 0 m	10	15	Margarita	240
İhsaniye (Gölcük)	40° 41' 21.6" N 29° 50' 28.2" E 7 m	14	20	Margarita	300
Balaban (Kartepe)	40° 41' 32.5" N 30° 04' 48.4" E 20 m	12	25	Santamaria Margaritta	260
Maşukiye-1 (Kartepe)	40° 42' 20.9" N 30° 08' 56.6" E 10 m	15	20	Margarita	360
Maşukiye-2 (Kartepe)	40° 42' 15.0" N 30° 08' 48.1" E 10 m	6	16	Margarita	120

2.1 Feromon Tuzakları ile *Cydia pomonella* Erginlerinin Popülasyon Değişimlerinin Tespiti

Cydia pomonella erginlerinin popülasyon değişimlerini takip etmek amacıyla, eşeysel çekici feromon tuzaklar (1.5 mg E.E-8.10- dodecadien-1-ol, Kapar, Türkiye) kullanılmıştır. Feromon tuzaklar bahçeyi temsil edecek şekilde hâkim rüzgar yönünde ve yerden yaklaşık olarak 1.5-2.0 m yüksekliğe asılmıştır. Her bir araziye üçer adet delta tipi feromon tuzak 4 Nisan 2024 tarihinde yerleştirilmiştir (Şekil 1). Armutların hasadına kadar tuzaklar haftalık olarak kontrol

edilerek yakalanan ergin sayıları kaydedilmiştir. Çalışmada kullanılan tuzaklardaki feromon kapsülleri ayda bir kez, yapışkan tablalar ise kirlenmeleri durumunda yenisiyle değiştirilmiştir.

Şekil 1. Armut ağaçlarına asılan delta tipi feromon tuzaklar ve tuzaklarda yakalanan *Cydia pomonella* erginleri

2.2 *Cydia pomonella*'nın Meyve Esaslı Metot ile Bulaşıklık Oranlarının Belirlenmesi

Cydia pomonella'nın armut meyvelerinde meydana getirdiği zarar oranlarının belirlenmesi amacıyla ilk ergin uçuşlarının başlaması ile birlikte haftalık olarak bahçeleri temsil edecek şekilde ağacın farklı yönlerinden ağaç başı 4 meyve olmak üzere rastgele seçilen 25 ağaçtan toplam 100 meyve kontrol edilmiştir (Mamay ve Yanık, 2013). Hasat zamanına kadar haftalık olarak meyve esaslı zarar oranı verileri kaydedilmiş ve çalışmanın yürütüldüğü armut bahçelerindeki meyvelerin zarar oranı belirlenmiştir.

2.3 Tuzak Bant Yöntemi ile Ergin Çıkışlarının Belirlenmesi

Cydia pomonella'nın yaz ve sonbahar dölüne ait ilk ergin çıkışlarının belirlenmesi amacıyla, zararlının pupa olma döneminde ağaç gövdelerinde saklanma eğiliminden yararlanmak adına oluklu kartondan hazırlanan tuzak bantlar kullanılmıştır (Zeki ve Özdem, 2013). Bu kapsamda, çalışmaların yürütüldüğü armut bahçelerinde tesadüfi olarak seçilen 10 ağacın gövdesine, yerden yaklaşık 50 cm yüksekliğe 2.5–3.0 cm eninde oluklu karton şeritler haziran ayı başında sarılarak sabitlenmiştir. Karton bantlar, zararlının pupa dönemine geçmesi için uygun mikro-habitatlar oluşturmak amacıyla kullanılmıştır. Temmuz ayından itibaren haftalık olarak yapılan kontrollerde, bu kartonlar dikkatlice çıkarılmış ve *C. pomonella*'nın ikinci ve üçüncü dölüne ait bireylerinin varlığını gösteren pupa ve pupa gömlekleri incelenmiştir. Böylece, ikinci ve üçüncü

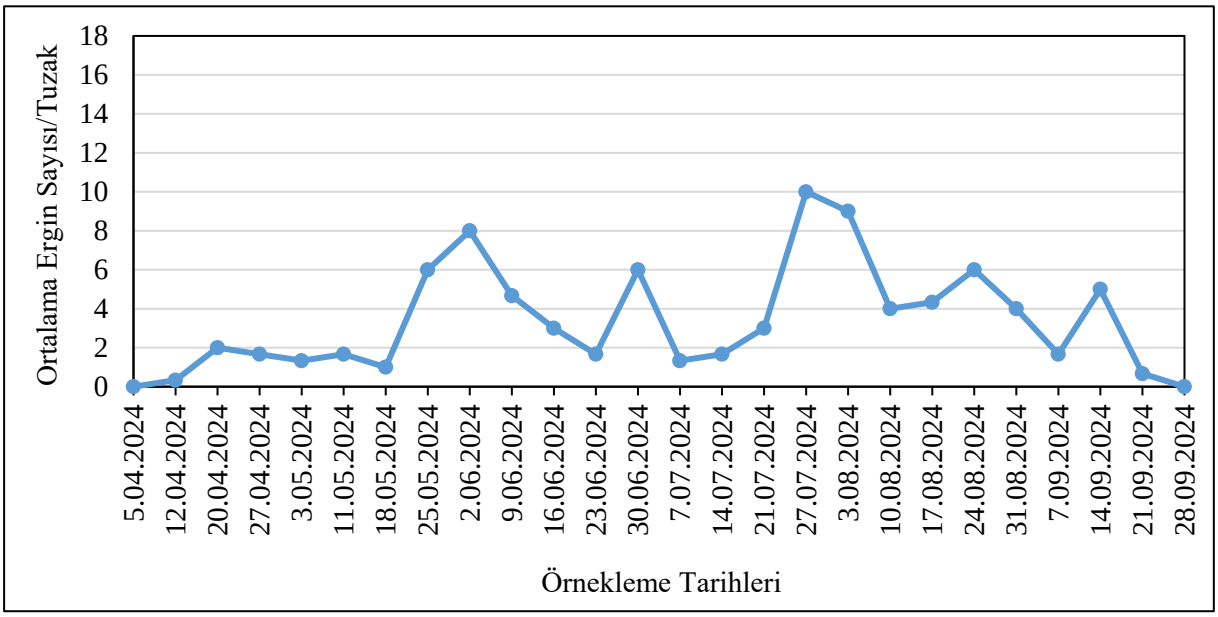
döl ergin çıkışlarının başlangıç zamanı ile popülasyonun gelişim süreci hakkında bilgi elde edilmiştir.

3. BULGULAR VE TARTIŞMA

3.1 Feromon Tuzakları ile *Cydia pomonella* Erginlerinin Popülasyon Değişimlerinin Tespiti

Kocaeli ilinin Gölcük ve Kartepe ilçelerinde 2024 yılının Nisan ve Eylül ayları arasında *C. pomonella* erginlerinin feromon tuzakları kullanılarak popülasyon takibi çalışmaları yürütülmüştür.

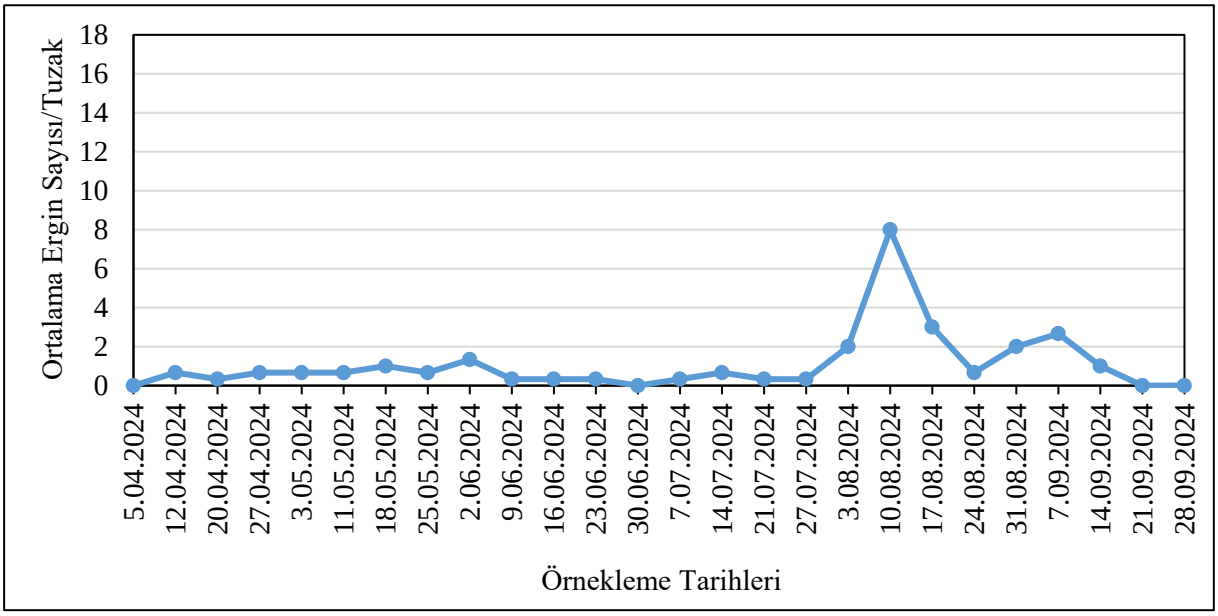
Gölcük ilçesinde yer alan Hisareyn lokasyonunda *C. pomonella*'nın 2024 yılına ait ergin popülasyon değişimi Şekil 2'de verilmiştir. Zararlının ilk ergin bireyleri 12 Nisan'da tuzaklarda tespit edilmiştir. Ergin birey sayısında mayıs ayının sonunda belirgin bir artış gözlenmiş ve ergin popülasyonları 2 Haziran'da ilk tepe noktasına tuzak başına ortalama 8 ergin ile ulaşmıştır. Zararlının erginleri 27 Temmuz tarihinde ise ikinci ve yıl içerisindeki en yüksek seviyesine ulaşmıştır. Bu dönemde ortalama ergin sayısı 10 birey ile popülasyonun tepe noktasını oluşturmuştur. Hisareyn lokasyonundaki erginlerin tuzaklarda yakalandığı son tarih ise 21 Eylül olarak kaydedilmiştir.



Şekil 2. Hisareyn (Gölcük) lokasyonunda *Cydia pomonella*'nın ergin popülasyon değişimi

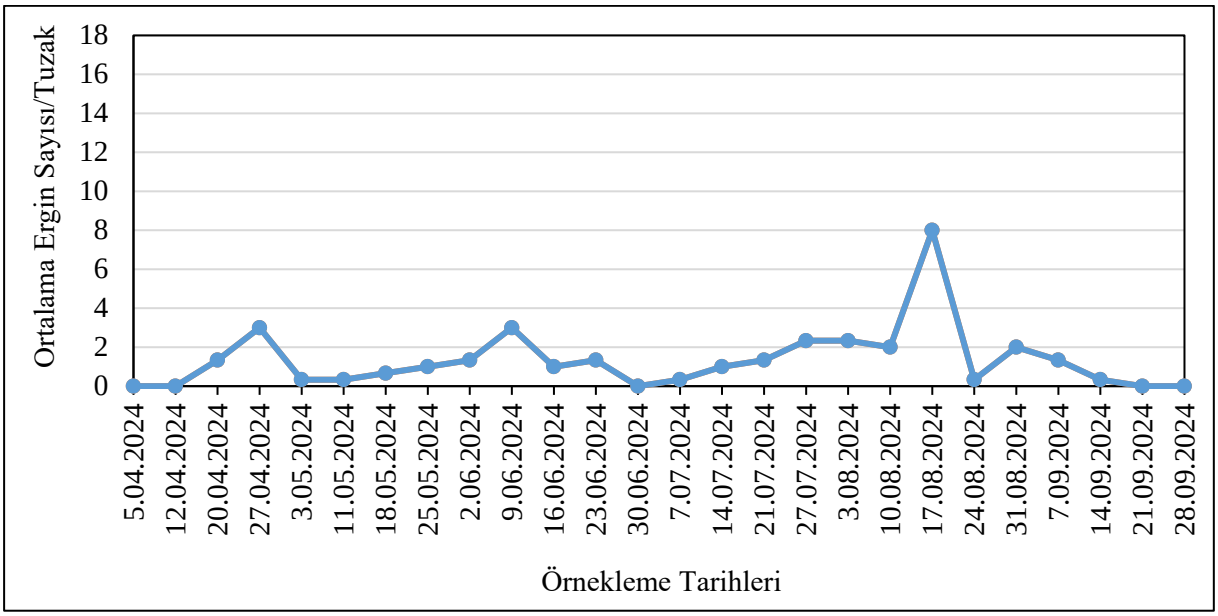
Gölcük ilçesinde yer alan bir diğer lokasyon olan İhsaniye'de ise zararlının ilk erginleri Hisareyn lokasyonu ile benzer şekilde 12 Nisan tarihinde tuzaklarda yakalanmıştır. Zararlının yıl içerisindeki genel popülasyon dinamikleri incelendiğinde Hisareyn lokasyonuna göre daha düşük seviyelerde seyir gösterdiği görülmektedir. İhsaniye lokasyonunda 10 Ağustos tarihinde

zararlının ergin popülasyonları tepe noktasına ulaşmış olup, tuzak başına ortalama 8 ergin yakalanmıştır. Erginlerin son görüldüğü tarih ise 14 Eylül olarak kaydedilmiştir (Şekil 3).



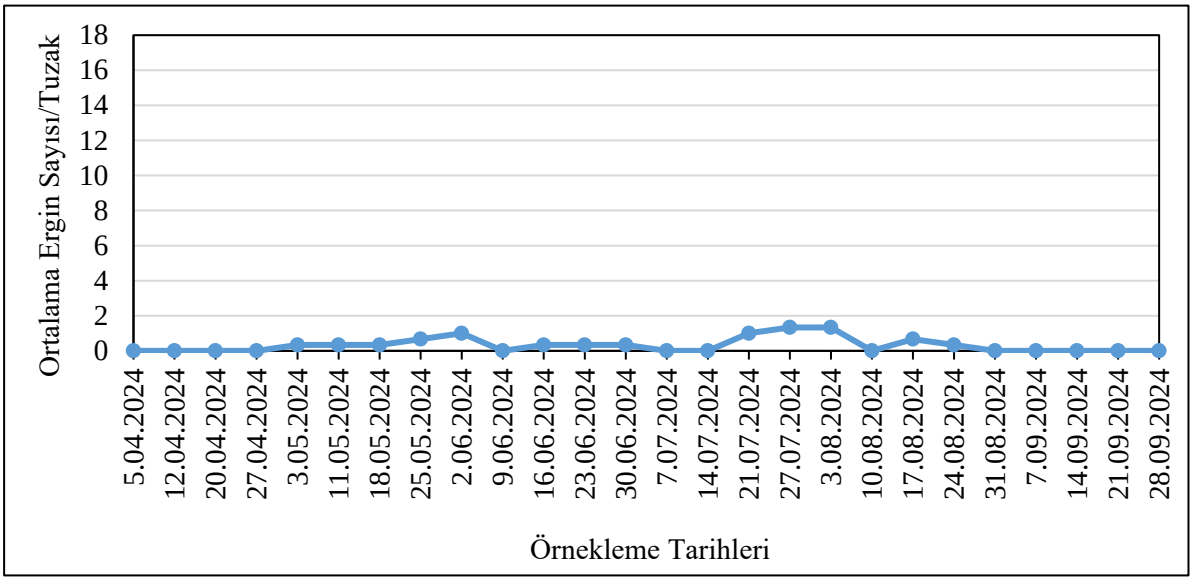
Şekil 3. İhsaniye (Gölcük) lokasyonunda *Cydia pomonella*'nın ergin popülasyon değişimi

Kartepe ilçesinde yer Balaban lokasyonunda *C. pomonella*'nın erginleri ilk olarak Gölcük ilçesindeki lokasyonlardan yaklaşık bir hafta sonra 20 Nisan'da feromon tuzaklarda tespit edilmiştir. Zararlının popülasyonları genel itibariyle düşük seyirde devam etmiş olup, yıl içerisinde yalnızca bir kez tepe noktası oluşturmuştur. Erginlerin popülasyonları tepe noktasına tuzak başına ortalama 8 ergin ile 17 Ağustos tarihinde ulaşmıştır. Erginlerin son görüldüğü tarih ise 14 Eylül olarak kaydedilmiştir (Şekil 4).



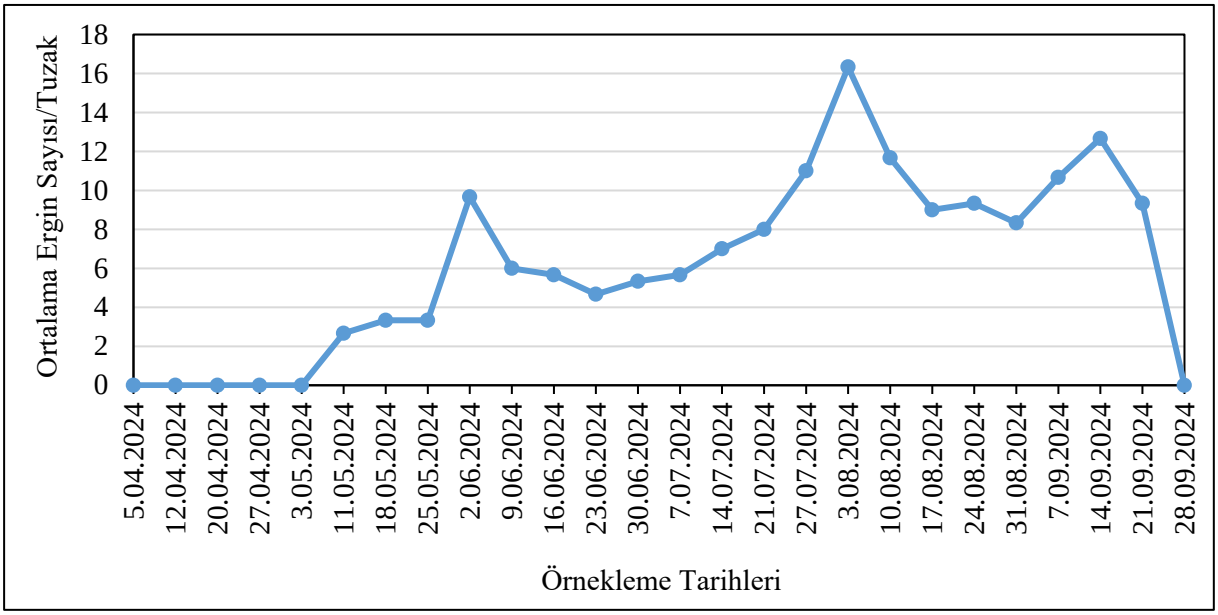
Şekil 4. Balaban (Kartepe) lokasyonunda *Cydia pomonella*'nın ergin popülasyon değişimi

Maşukiye-1 lokasyonunda ise zararlının popülasyonları diğer bahçelerle kıyaslandığında en düşük popülasyonun seyrinin görüldüğü bahçe olarak gözlemlenmiştir. Genel popülasyon düzeyi sürekli olarak düşük seviyelerde kalmış ve en fazla erginin tuzaklarda yakalandığı haftalarda tuzak başına 1.3 ergin birey tespit edilmiştir (Şekil 5). Bahçede yapılan kültürel ve kimyasal mücadelenin *C. pomonella* popülasyonlarını baskı altına aldığı anlaşılmaktadır.



Şekil 5. Maşukiye-1 (Kartepe) lokasyonunda *Cydia pomonella*'nın ergin popülasyon değişimi

Herhangi bir mücadele programının uygulanmadığı Maşukiye-2 lokasyonunda yer alan armut bahçesinde *C. pomonella*'nın ergin popülasyon dinamikleri Şekil 6'da verilmiştir. İlaçlamanın yapılmadığı söz konusu bahçede, zararlının popülasyonları diğer bahçelerdeki popülasyonlara kıyasla oldukça yüksek seviyelere ulaştığı görülmektedir. Zararlının erginleri ilk olarak 11 Mayıs tarihinde tuzaklarda tespit edilmiştir. Ergin popülasyonları yıl içerisinde üç kez tepe noktası oluşturmuştur. Zararlının popülasyonları ilk tepe noktasını tuzak başına 9.7 ergin ile 2 Haziran'da, ikinci tepe noktasını tuzak başına 16.3 ergin ile 3 Ağustos'ta ve üçüncü tepe noktasını ise tuzak başına 12.7 ergin ile 14 Eylül'de oluşturduğu tespit edilmiştir. Bahçedeki armutların hasadı ise 27 Eylül tarihinde gerçekleşmiştir.



Şekil 6. Maşukiye-2 (Kartepe) lokasyonunda *Cydia pomonella*'nın ergin popülasyon değişimi

Kocaeli ili Gölcük ve Kartepe ilçelerinde beş farklı armut bahçesinde yürütülen bu çalışmada *C. pomonella*'nın ilk erginlerinin nisan ayının ilk yarısında eşeysel çekici tuzaklarda yakalandıkları belirlenmiştir. Çanakkale ilinde gerçekleştirilen çalışmalarda, *C. pomonella*'nın ilk ergin çıkışının nisan ayında gerçekleştiği (Özpınar ve ark., 2009) ve Mayıs-Eylül ayları arasında yaklaşık beş ay boyunca aktif kaldığını ortaya koymuştur (Kuyulu ve Genç, 2018). Şanlıurfa ve Bursa illerinde yapılan araştırmalarda ise *C. pomonella*'nın ilk ergin bireylerinin nisan sonu ile mayıs ayının ilk yarısında eşeysel çekici tuzaklarda yakalandığı bildirilmiştir (Kovancı ve ark., 2000; Mamay ve Yanık, 2013). Konya ilinde elma ve ceviz bahçelerinde yürütülen çalışmalarda, *C. pomonella*'nın ilk erginlerinin mayıs ayı sonlarında yakalandığı, popülasyonların üç tepe noktası oluşturduğu bildirilmiştir. Ayrıca zararlının doğada 4-5 ay aktif olduğu ve eylül sonuna kadar popülasyon yoğunluğunu sürdürdüğü kaydedilmiştir (Çelik ve Ünlü, 2017; Aydoğan ve Ünlü, 2019; Işık, 2020). Mersin ve Aksaray illerinde yapılan çalışmalarda da *C. pomonella*'nın mayıs ayında ilk ergin çıkışını gerçekleştirdiği, Eylül sonuna

kadar popülasyonunu koruduğu tespit edilmiştir (Gilik, 2019; Aydın, 2019). Benzer şekilde, Isparta ilinde yapılan bir çalışmada da *C. pomonella* erginlerinin eşeysel çekici tuzaklarda mayıs ayının ilk haftasında ilk olarak yakalandığı bildirilmiştir (İşçi, 2008). Bingöl'de ise ilk ergin çıkışlarının haziran ayı başında başladığı, eylül ayının ilk yarısına kadar sürdüğü ve zararlının doğada yaklaşık 3.5 ay aktif kaldığı rapor edilmiştir (Kaplan ve Bayram, 2019).

3.2 *Cydia pomonella*'nın Meyve Esaslı Metot ile Bulaşıklık Oranlarının Belirlenmesi

Cydia pomonella'nın 2024 yılında Kocaeli'nin Gölcük ve Kartepe ilçelerindeki armut bahçelerinde zarar oranını belirlemek için ilk ergin uçuşlarının tespit edildiği tarihten hasata kadar olan haftalık periyotlarla meyve kontrolleri gerçekleştirilmiştir. Gölcük ilçesindeki Hisareyn lokasyonunda meyvelerdeki ilk zarar 16 Haziran'da, İhsaniye lokasyonunda ise 23 Haziran'da tespit edilmiştir. Haftalık olarak yapılan meyve kontrollerinde ortalama zarar oranı sezon sonunda sırasıyla %4.95 ve 1.78 olarak kaydedilmiştir. Kartepe ilçesinde ise meyvelerdeki ilk zararlanma Balaban lokasyonunda 16 Haziran'da, Maşukiye-1'de 14 Temmuz'da ve ilaçlama yapılmamış bahçe olan Maşukiye-2'de ise 11 Mayıs'ta tespit edilmiştir. Balaban'da yer alan armut bahçesinde ortalama zarar oranı %1.5 olarak tespit edilmiştir. Maşukiye lokasyonunda ise ilaçlama yapılan bahçedeki zarar oranı %1.2 iken, ilaçlama yapılmayan bahçedeki zarar oranı %23.95 olarak kaydedilmiştir. Üreticiler tarafından daha sık ve düzenli ilaçlama yapılan İhsaniye, Balaban ve Maşukiye-1 lokasyonlarında gözlemlenen düşük zarar oranlarının, Hisareyn ve özellikle de hiçbir mücadele programının uygulanmadığı Maşukiye-2 lokasyonuna kıyasla oldukça düşük düzeyde olduğu belirlenmiştir. Elma, Armut ve Ayva Entegre Mücadele Teknik Talimatları'nda *C. pomonella*'nın %2'ye kadar olan zararın tolere edilebileceği bildirilmektedir (Anonim, 2017). İhsaniye, Balaban ve Maşukiye-1'deki bahçelerdeki zarar oranları tolere edilebilir seviyenin üzerinde kalırken Hisareyn lokasyonunda kimyasal mücadele yapılmasına rağmen bu seviyenin üzerinde kalmıştır. Herhangi bir mücadele programının uygulanmadığı Maşukiye-2 lokasyonunda ise oldukça yüksek oranlarda zarar kaydedilmiştir.

Literatürde *C. pomonella*'nın hem ülkemizde hem de dünya genelinde elma ve armut üretiminde en önemli zararlılar arasında yer aldığı vurgulanmaktadır. Croft (1982) dünya genelinde mücadele uygulanmayan alanlarda %25'in üzerinde meyve kaybı yaşandığını ortaya koymuştur. Pedigo (1996), *C. pomonella*'nın zarar oranlarının %20 ile %95 arasında değişebileceğini rapor etmiştir. Özbek ve ark. (1995), *C. pomonella*'nın Türkiye'de elma üretiminde başlıca zararlı türlerden biri olduğunu ve bazı yıllarda zarar oranlarının %100'e kadar ulaşabildiğini bildirmişlerdir. Benzer şekilde, Elma, Armut ve Ayva Entegre Mücadele Teknik Talimatları'nda, mücadele yapılmayan bahçelerde zararın %60, hatta %100 düzeyine çıkabileceği belirtilmiştir (Anonim, 2017). Aydar ve ark. (2007), Isparta ili Eğirdir ilçesinde yaptıkları çalışmada, ilaçsız kontrol parsellerinde bulaşık oranının %74.15 olduğunu belirlemişlerdir. İşçi (2008), Isparta ilinde elma bahçelerinde erkenci çeşitlerin yalnızca *C. pomonella*'nın birinci dölünden etkilendiğini ve bu nedenle zarar oranlarının %35–50 seviyelerinde kaldığını, ancak orta ve geççi çeşitlerde hasat geciktikçe ikinci döl zararlarının artarak %80'e ulaştığını belirtmiştir. Kuyulu ve Genç (2018), Çanakkale ilinde yürüttükleri

çalışmada *C. pomonella* bulaşıklık oranlarını %5 ile %95 arasında değişen değerlerde tespit etmişlerdir. Aydoğan ve Ünlü (2019) ise Konya ilindeki elma bahçelerinde, ortalama zarar oranlarını %10.5-33.9 aralığında belirlemiştir. Farklı bölge ve illerde önceki yıllarda yapılan çalışmalarla bu çalışmadan elde edilen bulgular birlikte değerlendirildiğinde, özellikle ilaçlama yapılmayan Maşukiye-2 lokasyonunda gözlemlenen yüksek zarar oranlarının bu çalışmalarla paralellik gösterdiği anlaşılmaktadır.

Çalışmanın genel bulguları değerlendirildiğinde, *C. pomonella*'nın etkin bir şekilde mücadele edilmediği koşullarda ekonomik kayıpların oldukça ciddi boyutlara ulaşabileceği anlaşılmaktadır. Özellikle Maşukiye-2 lokasyonunda tespit edilen yüksek zarar oranı, üreticilerin doğrudan ürün kaybı yaşamasına ve dolayısıyla ekonomik olarak önemli kayıpların meydana gelmesine neden olmuştur. Bu durum, entegre zararlı yönetimi stratejilerinin, özellikle de zamanında yapılan doğru müdahalelerin, ürün kaybını minimize etmede kritik bir rol oynadığını ortaya koymaktadır.

3.3 Tuzak Bant Yöntemi ile Ergin Çıkışlarının Belirlenmesi

Kocaeli ilinde 2024 yılında yürütülen çalışmalarda, armut bahçelerinde *C. pomonella*'nın yaz ve sonbahar dölüne ait erginlerin çıkış zamanlarının belirlenmesi amacıyla armut ağaçlarının gövdelerine oluklu karton şeritler sarılmıştır. Karton şeritler, zararlının ikinci döl erginlerinin tespiti için 16 Haziran'da, üçüncü döl erginlerinin tespiti için ise 17 Ağustos'ta ağaçlara sarılmıştır. Yapılan gözlemler sonucunda, ikinci döle ait erginlerin ilk çıkışı 14 Temmuz'da, üçüncü döle ait erginlerin çıkışı ise 1 Eylül'de tespit edilmiştir. Zararlının tahmini döl sayısını ve döllere ait erginlerin ilk çıkış tarihlerini belirlemek amacıyla yapılan gözlemler sonucunda, ilk döl erginlerinin nisan ayının ilk yarısında feromon tuzaklarda yakalandığı, temmuz ayında ikinci döle ait erginlerin görüldüğü, eylül ayında ise üçüncü döle ait erginlerin çıkış yaptığı belirlenmiştir. Eylül ayının sonunda ağaçlara yerleştirilen karton şeritlerde ise zararlının larva evresine ait bireyler tespit edilmiş, ancak pupa ve pupa gömleklerine rastlanmamıştır. Eylül ayının sonunda meyve hasadının yapılması, üçüncü dölde çıkan bireylerin uygun besin kaynağı bulamadan yaşam döngüsünü tamamlamasını zorlaştırmasının yanı sıra, düşen sıcaklıklar ve kısalan gün uzunluğu gibi çevresel koşullar da göz önünde bulundurulduğunda, bu bireylerin diyapoz evresine geçerek kışlamaya hazırlandığı düşünülmektedir. Sonuç olarak, Kocaeli ilinde *C. pomonella*'nın üç döl verdiği belirlenmiştir.

Zararlının Türkiye'nin farklı bölgelerinde verdiği döl sayılarındaki farklılıkları, çevresel koşulların popülasyon dinamikleri üzerindeki etkisini açıkça ortaya koymaktadır. Antalya'nın Korkuteli ilçesinde yılda 2 döl verdiği bildirilmiştir (Çiftçi, 1995). Bursa'da 3 döl (Kovancı ve ark., 2000), Şanlıurfa'da ise 3 döl verebildiği bildirilmiştir (Mamay ve Yanık, 2013). Mersin, Konya ve Aksaray illerinde zararlının iklim koşullarına bağlı olarak yılda 2-3 döl verdiği tespit edilmiştir (Çelik ve Ünlü, 2017; Aydın, 2019; Gilik, 2019; Aydoğan ve Ünlü, 2019; Önemli, 2024). Ilgaz (2024), Niğde'de yaptığı çalışmada, yüksek rakım ve düşük sıcaklık nedeniyle Çamardı ve Ulukışla'da zararlının yılda 2 döl, sıcaklığın daha yüksek olduğu Merkez ve Bor'da ise 3 döl verdiğini bildirmiştir. Bu çalışmalar birlikte değerlendirildiğinde, *C. pomonella*'nın döl sayısının iklim koşulları, rakım, sıcaklık, gün uzunluğu ve besin kaynağının mevcudiyeti gibi çevresel faktörlerle doğrudan ilişkili olduğu görülmektedir. Kocaeli ilinde yapılan bu

çalışma, zararlının uygun iklim koşullarında üç döl verebildiğini ortaya koyarak literatürdeki bulguları desteklemekte ve *C. pomonella*'nın bölgesel biyolojisi hakkında önemli katkılar sunmaktadır.

Çalışmadan elde edilen sonuçlar, özellikle entegre zararlı yönetimi uygulamaları açısından büyük önem taşımaktadır. İkinci ve üçüncü döllere ait ergin çıkışlarının izlenmesi, kimyasal ve biyoteknik mücadele zamanlarının doğru belirlenmesine ve gereksiz uygulamaların önlenmesine katkı sağlayabilmektedir. Bu kapsamda, tuzak bant yöntemi gibi basit, maliyeti düşük ve etkili izleme yöntemlerinin yaygınlaştırılması, üreticilerin zararlı popülasyonlarını daha etkin kontrol etmelerine yardımcı olacaktır. Ayrıca, hasat sonrası dönemde ağaçlardan dökülen meyvelerin toplanması ve yok edilmesi gibi kültürel önlemlerle, kışlama potansiyeline sahip larva popülasyonunun azaltılması mümkün olabilecektir.

Şekil 7. Karton tuzak bantlarda tespit edilen *Cydia pomonella*'nın larva (a), pupa (b) ve pupa gömlekleri (c)

4. SONUÇLAR

Cydia pomonella'nın Kocaeli ili armut bahçelerinde ilk ergin uçuşunun nisan ayının ilk yarısında başladığı ve uçuşların eylül sonuna kadar yaklaşık altı ay aktif olarak sürdüğü belirlenmiştir. Zararlının ergin popülasyonlarının oluşturduğu tepe noktaları ve tuzak bant

yönteminden elde edilen sonuçlar dikkate alındığında zararlının üç döl verdiği tespit edilmiştir. Ayrıca, Kocaeli ili armut bahçelerinde *C. pomonella*'nın oluşturduğu zarar seviyelerinin, özellikle mücadele uygulanmayan alanlarda ekonomik zarar eşiğinin üzerinde gerçekleştiği ve zarar oranlarının %25 seviyelerine kadar ulaşabildiği tespit edilmiştir. Bu durum, bölgedeki *C. pomonella* popülasyonunun etkin bir şekilde izlenmesi ve zamanında mücadele programlarının uygulanmasının gerekliliğini ortaya koymaktadır.

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MODELING OF DAIRY ANIMAL MILK PRODUCTION USING NADARAJAH–HAGHIGHI BUR TYPE-X DISTRIBUTION

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ABSTRACT

Over the years, several researchers have worked to model lifetime data in which the distribution of data is skewed to the left. With this aim, several generalizations or extensions of the Bur Type-X distribution have been proposed. In this paper, an attempt is made to develop a hybrid distribution by compounding the Nadarajah–Haghighi and Bur Type-X distributions, namely the Nadarajah–Haghighi Bur Type-X (NHBTx) distribution. It can also be thought of as an extension of the Bur Type-X distribution. The NHBTx distribution has the features of having four parameters exhibiting flexible distributional functions, including a decreasing or unimodal probability density function and an increasing, decreasing, or upside-down bathtub hazard rate function. The statistical applicability of the NHBTx model is demonstrated by using milk production data. In particular, results are compared with Bur Type-X models of importance, such as the Generalized Rayleigh, and Rayleigh models, and it is observed that the NHBTx model fits better.

Keywords: Nadarajah–Haghighi distribution; moments; Bur Type-X distribution; hazard rate function.

1.0 Introduction

several generalizations of the standard probability distributions have been developed and studied in the past decades, and are used as lifetime models in applied sciences. The most popular among the life-time model is the so-called generalized beta-g family of distributions developed and studied by Eugene (2002), the others includes: Kumaraswamy generalized family was developed by Cordeiro and Castro (2011), exponentiated generalized family studied by Cordeiro et al. (2013) Transformed-Transformer (T-X) developed and studied Alzaatreh et al. (2013), Weibull-G family developed by Bourguignon et al. (2014), Exponentiated half-logistic family by Cordeiro et al. (2014), Mead et al. (2020) proposed and studied the Kumaraswamy alpha power-G, modified Kies-G family by Al-Babtain et al. (2020), and generalized linear failure rate-G family was developed by Afify et al. (2022). The characteristics of the generalized family of distributions is to introduce flexibility into the standard probability distribution by controlling its tail weights.

Motivation of the Study

The main motivation of this study is to extend the two-parameter Bur Type-X distribution to a more flexible distribution called Nadarajah- Haghighi Bur Type-X model which is capable of modeling lifetime data of different failure pattern. The new developed model can be applied in agriculture, medicine, reliability study, seismography, insurance, etc.

Burr (1942) introduced twelve different forms of cumulative distribution functions for modeling lifetime data, where among them is the Burr Type X distribution (BX). Several authors considered different aspects of the Burr Type X, for example Ahmad (1997), Raqab (2005), among others. Surles (2005) introduced two-parameter Burr Type X distribution known as the generalized Rayleigh (GR) distribution. The two-parameter generalized Rayleigh distribution is a particular member of the generalized Weibull distribution. Surles (2001) showed that the two-parameter Burr Type-X distribution can be effectively used in modeling strength data. The cumulative distribution function (cdf) of Burr Type-X distribution is given by

$$G(x) = \left(1 - e^{-(\alpha x)^2}\right)^{\theta}, \qquad x > 0 \tag{1}$$

where $\alpha > 0$ is the scale parameter $\theta > 0$ is the shape parameters.

And the associated pdf is given by

$$G(x) = 2\alpha^2\theta x e^{-(\alpha x)^2}\left(1 - e^{-(\alpha x)^2}\right)^{\theta-1} \tag{2}$$

Several generalizations of the Bur Type-X distribution have been developed, for example Half logistic generalized Rayleigh distribution was studied by Ogunde et al. (2023), beta generalized Rayleigh (BGR) by Cordeiro et al. (2013), the exponentiated generalized Burr type X (EGBX)

by Khaleel et al. (2017), beta Burr X by Merovci et al. (2016), and beta compound Rayleigh by Reyad and Othman (2017), among others.

2.0 Nadarajah Haghighi Bur X distribution

A random variable X follows a Nadarajah and Haghighi Bur Type-X ($NHBT-X$) distribution if is cdf is given by

$$F(x) = 1 - e^{1-\left\{1+\beta\left(1-e^{-(\alpha x)^2}\right)^{\theta}\right\}^{v}}, x > 0 \quad (3)$$

The corresponding probability

$$f(x) = 2\alpha^2\beta\theta v e^{-(\alpha x)^2} x\left(1-e^{-(\alpha x)^2}\right)^{\theta-1}\left\{1 + \beta\left(1-e^{-(\alpha x)^2}\right)^{\theta}\right\}^{v-1} e^{1-\left\{1+\beta\left(1-e^{-(\alpha x)^2}\right)^{\theta}\right\}^{v}} \quad (4)$$

where $\alpha > 0$ is the scale parameter β, θ, and $v > 0$ is the shape parameters. The graphs of the distribution and the density function is given in Figure 1.0 for arbitrary values of the parameters of the $NHBT-X$ distribution.

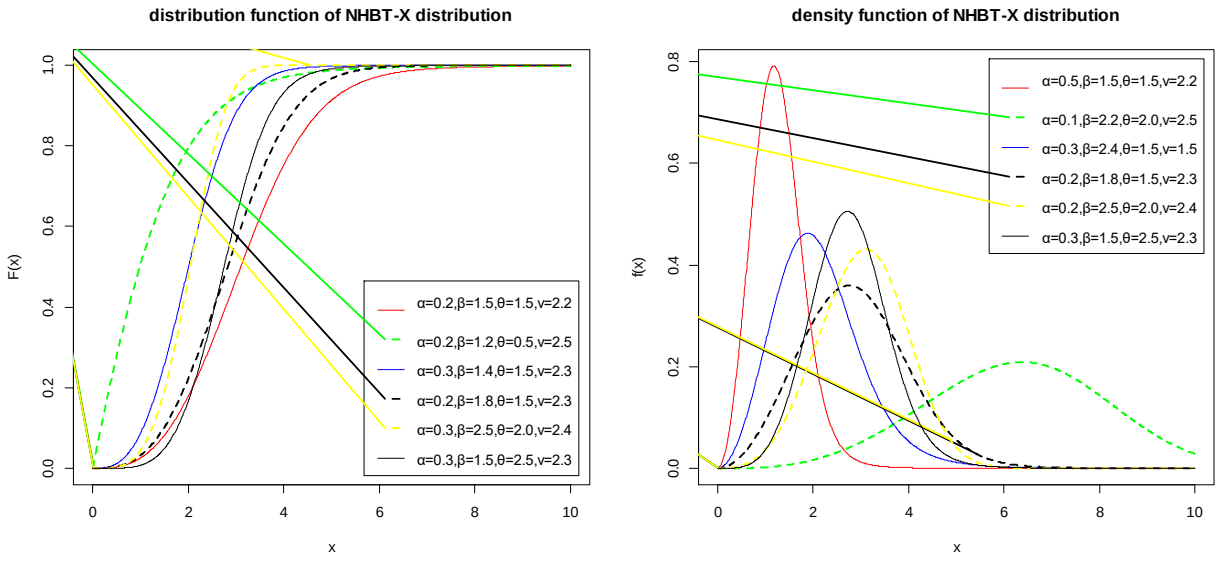

Figure 1.0 Graph of the distribution and the density functions of the NHBT-X model

an expression for the Reliability and the hazard functions is given by

$$R(x) = 1 - F(x) = e^{1-\left\{1+\beta\left(1-e^{-(\alpha x)^2}\right)^{\theta}\right\}^{v}} \quad (5)$$

And

$$h(x) = \frac{f(x)}{R(x)} = 2\alpha^2\beta\theta v e^{-(\alpha x)^2} x\left(1-e^{-(\alpha x)^2}\right)^{\theta-1}\left\{1+\beta\left(1-e^{-(\alpha x)^2}\right)^{\theta}\right\}^{v-1} \quad (6)$$

The graph of the reliability and the survival function is given in Figure 2 for various values of the parameters of the $NHBT-X$ distribution.

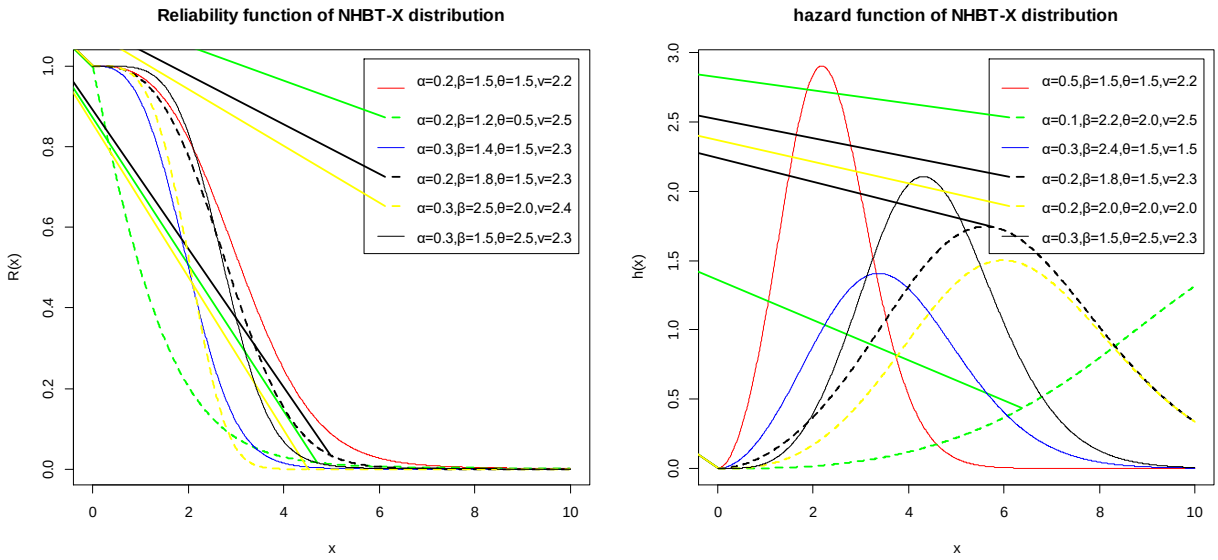

Figure 2.0 Graph of the reliability and the hazard function of the $NHBT-X$ model

3.1 Important representation

In this subsection, an important tool for the expansion of the PDF for $NHBT-X$ is provided. From the generalized binomial series given by

$$(1+m)^{-y} = \sum_{i=0}^{\infty}(-1)^i\binom{y+i-1}{i}m^i \quad (7)$$

For $|m|<1$ and y is a positive real non-integer. Then, by applying the binomial theorem (7) in (4), the density function of $NHBT-X$ distribution becomes

$$f(x) = 2\alpha^2\beta\theta v\sum_{i=j=k=l}^{\infty}(-1)^{j+k+l}\binom{v(j+1)-1}{k}\binom{\theta(k+1)-1}{l}xe^{-(l+1)(\alpha x)^2}. \quad (8)$$

3.2 Moments of $NHBT-X$ distribution

Thus, the r^{th} ordinary moment of a distribution is given by

$$\mu_r' = E(x)^r$$

Thus the r^{th} moment of $NHBT-X$ distribution is given by

$$\mu_r' = \int_{-\infty}^{\infty} x^r f(x;\alpha,\beta,\theta,v)dx \quad (9)$$

Putting equation (8) in (9), we have

$$\mu_r' = 2\alpha^2\beta\theta v \sum_{i=j=k=l}^{\infty} (-1)^{j+k+l} \binom{v(j+1)-1}{k} \binom{\theta(k+1)-1}{l} \int_{-\infty}^{\infty} x^r e^{-(l+1)(\alpha x)^2} dx \quad (10)$$

By letting $m = (l+1)(\alpha x)^2, x = \frac{m^{1/2}}{\alpha^2(l+1)^{1/2}}, dx = \frac{m^{-1/2}}{2\alpha^2(l+1)^{1/2}}$, then we have

$$\mu_r' = \beta\theta v \sum_{i=j=k=l}^{\infty} (-1)^{j+k+l} \binom{v(j+1)-1}{k} \binom{\theta(k+1)-1}{l} \frac{\alpha^{2-r}}{(l+1)^{r+1/2}} \int_{-\infty}^{\infty} m^{r-1/2} e^{-m} dx \quad (11)$$

Finally, we have

$$\mu_r' = \beta\theta v \sum_{i=j=k=l}^{\infty} (-1)^{j+k+l} \binom{v(j+1)-1}{k} \binom{\theta(k+1)-1}{l} \frac{\alpha^{2-r}}{(l+1)^{r+1/2}} \Gamma\left(\frac{r+1}{2}\right) \quad (12)$$

By substituting $r = 1$ in (12), we obtain the first moment which is equivalent to the mean of $NHBT-X$ distribution. Higher moments can be obtained by taking $r = 2,3,4,\ldots$.

4.0. Applications

In this section, we illustrate the performance of the NHBT-X distribution as compared to some alternative distributions using a real data application. For the data set, the estimates of the model parameters by maximum likelihood estimation, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Hanna Quinn Information Criterion (HQIC), and Consistent Akaike Information Criterion (CAIC) are calculated to compare the fitted models. The data is about the total milk production in the first birth of 107 cows from SINDI race. The data is as follows: 0.5140, 0.6907, 0.7471, 0.2605, 0.6196, 0.8781, 0.4990, 0.6058, 0.6891, 0.5770, 0.5394, 0.1479, 0.2356, 0.6012, 0.1525, 0.5483, 0.6927, 0.7261, 0.3323, 0.0671, 0.2361, 0.4800, 0.5707, 0.7131, 0.5853, 0.6768, 0.5350, 0.4151, 0.6789, 0.4576, 0.3259, 0.2303, 0.7687, 0.4371, 0.3383, 0.6114, 0.3480, 0.4564, 0.7804, 0.3406, 0.4823, 0.5912, 0.5744, 0.5481, 0.1131, 0.7290, 0.0168, 0.5529, 0.4530, 0.3891, 0.4752, 0.3134, 0.3175, 0.1167, 0.6750, 0.5113, 0.5447, 0.4143, 0.5627, 0.5150, 0.0776, 0.3945, 0.4553, 0.4470, 0.5285,

0.5232, 0.6465, 0.0650, 0.8492, 0.8147, 0.3627, 0.3906, 0.4438, 0.4612, 0.3188, 0.2160, 0.6707, 0.6220, 0.5629, 0.4675, 0.6844, 0.3413, 0.4332, 0.0854, 0.3821, 0.4694, 0.3635, 0.4111, 0.5349, 0.3751, 0.1546, 0.4517, 0.2681, 0.4049, 0.5553, 0.5878, 0.4741, 0.3598, 0.7629, 0.5941, 0.6174, 0.6860, 0.0609, 0.6488, 0.2747, 0.4365, 0.4260. Table 1 gives the Summary statistics of the Milk data which indicates that the milk data is negatively skewed, under-dispersed and mesokurtic and Table 2 present the measures of the goodness of fit for the data. Figure 3.0 is the plot of the Total Time on Test (TTT) plot which shows that the data exhibits an increasing failure rate and the violin plots.

Table 1 Exploratory data analysis of Milk data

Min.	q_1	*median*	*mean*	q_3	*max*	*Range*	*Skewness*	*Kurtosis*	*variance*
0.02	0.35	0.47	0.47	0.60	0.88	0.86	−0.33	2.68	0.04

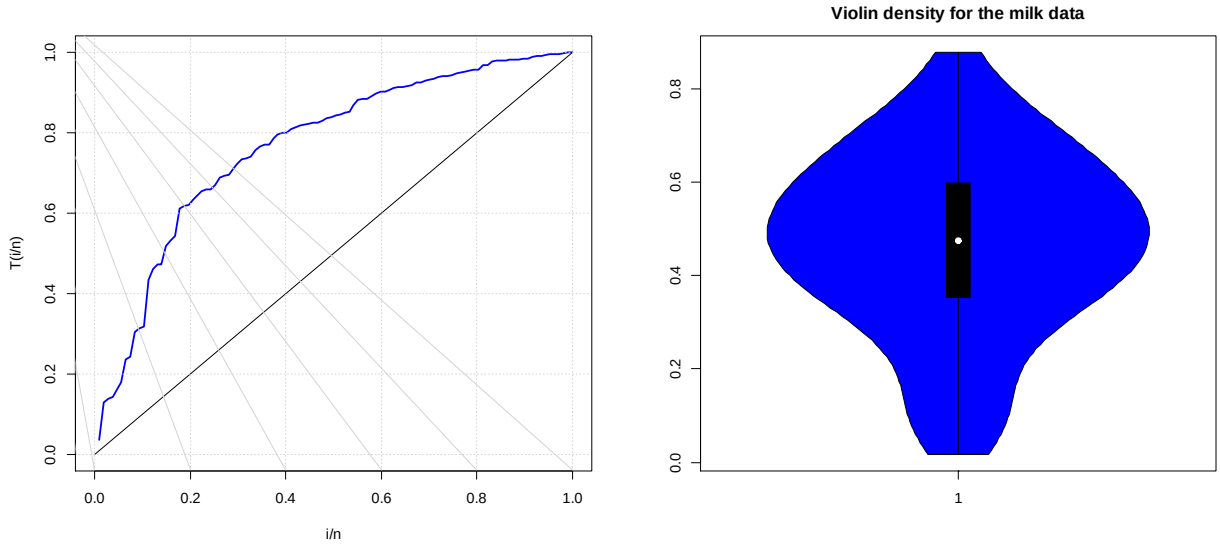

Figure 3.0. TTT and the Violin plot for the milk data.

The model with the smallest values of these measures represents the data better than the others. The numerical values of these measures for the NHBT-X and the other competing distributions of the milk data is provided in Table 2.

Table 2. Measures of goodness of fit of Milk data

	Parameter estimate				*Measures of goodness of fit*				
Model	α	β	θ	v	$-l$	*AIC*	*CAIC*	*HQIC*	*BIC*
$NHBT-X$	0.14 (0.40)	6.748 (3.254)	1.01 (0.09)	19.17 (28.56)	-26.89	-45.80	-45.41	−41.47	-35.11
NHR	0.40 (0.21)	−2.47 (1.96)	– (−)	−5.62 (4.39)	−27.25	−48.49	-48.26	−45.24	-40.47
$BT-X$	2.64 (0.09)	– (−)	1.74 (0.20)	– (−)	52.43	108.87	108.98	111.03	114.21
R	2.42 (0.09)	– (−)	– (−)	– (−)	63.30	128.61	128.64	129.69	131.28

5. Conclusion

In this paper, we have derived and studied the properties and application of the Nadarajah Haghighi Bur Type X distribution also called the generalized Nadarajah Haghighi generalized Rayleigh distribution. The model extends the Burr Type-X ($BT-X$) (or generalized Rayleigh (GR)) distribution. We provide an explicit mathematical expression for some of its statistical properties. We estimated the model parameters by the method of maximum likelihood. Finally, we fit the model to a milk data set to demonstrate its usefulness and flexibility; the results show that the Nadarajah Haghighi Bur Type X distribution provides a better fit than some other competing distributions as measured regarding the AIC, BIC, HQIC, and CAIC. We hope that this distribution will attract wider applications in the areas of sciences and applied sciences.

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HEAVY METAL REMOVAL FROM TEXTILE EFFLUENT USING ACTIVATED CARBON PREPARED FROM COCONUT SHELL-ORANGE PEEL

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ABSTRACT

This study evaluates the adsorption performance of activated carbons derived from coconut shell (CS) and orange peel (OP), both individually and in composite formulations, for the removal of chromium (Cr) and lead (Pb) from aqueous solutions under neutral pH (7.0), 25 °C, and a 60 min contact time. Pure CS exhibited the highest efficiencies, achieving 81.5% Cr and 86.5% Pb removal, attributed to its high surface area (>800 m^2/g) and microporous structure. OP alone yielded 77.5% Cr and 82.4% Pb removal, driven by abundant surface functional groups. Composite adsorbents demonstrated ratio-dependent behaviors: CS-rich blends favored

Cr uptake (up to 79.8%), while OP-rich blends enhanced Pb selectivity (up to 84.1%). Physicochemical characterization supported these findings, highlighting the role of porosity, functional groups, and ash content in binding performance. The results underscore the versatility of biomass-derived carbons: CS for broad-spectrum heavy-metal removal, OP for targeted Pb remediation, and tailored mixtures for specific contaminant profiles. Future work should explore adsorbent regeneration, cost benefit analyses, and pilot-scale trials to facilitate practical wastewater treatment applications.

Keywords: Chromium, lead, adsorbents, textile effluent, pollution, environment

1.0 INTRODUCTION

Textile industry plays a crucial role in our lives, providing an employment opportunity that requires minimal skills. This contributes a vital part in the world economy. Textile have a wide range of application, such as clothing and apparel, home furnishing and decor, medical textiles (e.g., wound dressings and medical clothing), technical textiles (e.g. automotive, aerospace and construction materials) etc. Textile industry contributes significantly to the pollution of the environment, with wastewater generated from various stages of production, including dyeing, printing, finishing and washing. This wastewater contains mixtures of pollutants, including heavy metals, dyes, pigment, and other chemicals (Kumar et al, 2020). Textile waste water can cause different health hazards for human being like hemorrhage, ulcers, skin irritation and dermatitis. The increased pollution of the aquatic environment by heavy metals and artificial coloring compounds has negatively impacted many aspects, especially in health terms. Previous studies have reported that effluent from several industries contains heavy metals (Cu, Cr, Pb, Fe, and Zn) with concentrations far above the standards set by WHO (Lewoyehu, 2021).

Heavy metals are naturally occurring metals in the earth's crust and they can be present in small amounts in groundwater due to leaching from the soil and rock formation. Human activities such as industrials processes, mining and agricultural runoff can increase the heavy metals deposition in the water bodies, posing risks to human health and environment. Textile industry significantly contributes to heavy metal pollution in soil and water due to the release of untreated effluent. This effluent contains plenty of heavy metals including chromium, copper, zinc, and nickel which can have devastating effects on the ecosystem. Various pollutants handling technique includes ion exchange, solvent extraction, thermal treatment, microbial reduction and electro dialysis, ultrafiltration chemical precipitation, Nano filtration and coagulation (lewoyehu, 2021) . Although, the methods above have disadvantages such as high operational cost, significant maintenance cost and substantial energy requirement.

Therefore, the efficient and cost effectiveness for handling pollutant in aquatic environment is still an aspect of research, attracting widespread interest and attention. There is need for sustainable solutions that can address these environmental challenges without economic viability. The adsorption method has been utilized as a treatment method for removing pollutants, including heavy metals and dyes; adsorption method has a simple design, easy operation and high adsorption efficiency (Zhang et al., 2012). An effective adsorption process requires adsorbent material with good performance and with high affinity for pollutant analystes. Many organic, inorganic, or a combination of both materials have been developed to produce high-energy adsorption processes. The abundance, renewability and cost effectiveness of carbon precursor materials have made them an attractive focus for researchers exploring carbon-based adsorbents. (Liu et al., 2020)

3 Materials and methodology

3.1 Sample Collection

Textile effluent sample was obtained from Kano state. The sample was collected from the effluent discharge drain originated from the textile waste water treatment plan of the factory. The sample was collected using a 5litres (HDPE) bottle, which was washed with clean water

and rinsed with effluent to be sampled. Orange peels and coconut shells were gotten from samaru market, Zaria.

3.2 Sample Analysis

The collected sample was analyzed for some major parameters of the textile effluent including the pH, and heavy metal. The heavy metals were analyzed using Atomic Absorption Spectroscopy (AAS)

3.3 Preparation of Activated Carbon of Coconut Shell and Orange Peel

Orange peel was washed several times with water to remove dirt and other impurities. Coconut shell was washed to remove impurities such as coconut fiber and sand. The materials were sundried and then dried in an oven at 100 ^{0}C for 24 hours to reduce moisture content. The dried sample was carbonized in a furnace at a temperature of 500^{0}C for 2hrs (absence of oxygen to produce a carbon-rich material). Activation of the carbonized material was done using an activating agent phosphoric acid (H3PO4). Heating the activated material at 450^{0}C for 1-2hours, then wash the activated carbon to remove impurities. Filter and rinse the material to remove any impurities. The activated carbon was then dried at 100^{0}C-150^{0}C for 2hrs. then grind into fine powder.

3.4 Proximate analysis:

Proximate analysis, as defined by ASTM D 121, is the process of determining moisture, ash content, pH, and bulk density using specified techniques. The following process was used to perform the proximate analysis of the various types of activated carbon.

3.4.1 Moisture content:

After measuring the weight of a small sample of activated carbon (soy shell), it was placed in a petri dish. It was evenly distributed across the plate. After that, it was baked for 1.5 hours at a temperature between 105 and 110 degrees Celsius. During the heating process, the petri dish was either left open or uncovered. Following heating, the petri dish was taken out and allowed to cool in a desiccator. The dried sample's weight was determined once it had cooled.

Moisture content M=100(B-F)/(B-G)

B=weight of petri dish +original sample

F=weight of petri dish+ dried sample

G= weight of petri dish

3.4.2 Ash content:

A silica crucible was filled with one gram of the sample. It was heated for one and a half hours to 750˚c in a muffle furnace. The crucible was left open throughout this heating process. The crucible was cooled in a desiccator following the necessary heating, and the weight of the ash was then determined.

Ash content A=100(F-G)/(B-G)

G=Mass of empty crucible

B=Mass of crucible + sample

F=Mass of crucible+ ash sample

3.4.3 Bulk Density:

The weight of a material per unit volume is known as its bulk density. Basically, it is applied to powdered materials. The bulk density test indicates the solid sample's packaging quantity and flow consistency. The unit of measurement is kilograms per cubic meter (kg/m³). The mass of the measuring cylinder used in this experiment should be determined first. After that, the provided activated carbon sample was put inside the cylinder and weighed again. After that, it was placed on the aluminum plate and oven-dried for 60 minutes at 105˚C. The dry sample's weight was determined after it had dried.

DB= (m2- m1)/v

M1= mass of measuring cylinder in grams

M2= mass of measuring cylinder + its contents

V= volume of the measuring cylinder in litre

3.4.4 pH

pH was determined using the standard method ASTMD 3838-80. 1g activated carbon of

soya shell sample was put in a conical flask and 100ml distilled water was added to it.

The mixture was stirred for 1hour. pH readings were taken using pH meter. Repeat the

Procedure for the other two type of activated carbon.

3.5 Textile effluent treatment using the composite (Coconut shell and Orange peel)

The activated carbon composite, prepared from coconut shell and orange peel was used in various ratios to assess its adsorption capacity for heavy metals (Cr, Pb) in 50ml effluent samples. The ratios used were 2g,0.8 -1.2g,1.6-0.4g, 2g,0.8-1.2g and 0.4-1.6g. The pH (7), dosage time and contact time were kept constant. After a contact 30minutes, the mixture was filtered and characterization was done.

4 RESULTS AND DISCUSSION

4.1 Chromium and Lead after Adsorption

Table 1 present the adsorption performance of coconut shell (CS) and orange peel (OP) based activated carbons demonstrated distinct affinities for chromium (Cr) and lead (Pb) ions under identical experimental conditions (pH = 7, contact time = 60 min, temperature = 25°C). Sample A (2.0 g CS) achieved the highest removal efficiencies of 81.5% for Cr and 86.5% for Pb, which

compares favorably with values reported by Rajkumar et al. (2018), who observed 78.2% Cr and 83.4% Pb removal using coconut shell-derived carbon at similar dosages (Rajkumar and Subramanian, 2018). The superior performance of CS can be attributed to its high surface area and abundant microporous structure, facilitating mass transfer and chemisorption of metal ions (Foo and Hameed, 2010).

By contrast, sample D (2.0 g OP) yielded 77.5% Cr and 82.4% Pb removal. These results are consistent with studies by Wang and Wang (2016), who reported 75.0% Cr and 80.0% Pb removal with orange peel biochar at 2 g/L dosage under neutral pH,

Table 1: Percentage removal of chromium and lead after adsorption

S/N	SAMPLE ID	% REMOVAL OF CHROMIUM	% REMOVAL OF LEAD
1	A	81.5	86.5
2	B	79.8	54.8
3	C	78.3	65.3
4	D	77.5	82.4
5	E	72.8	68.0
6	F	75.6	84.1

The composite adsorbents (samples B, C, E, F) exhibited synergistic behaviors. Sample B (0.8 g CS + 1.2 g OP) and C (1.6 g CS + 0.4 g OP) achieved moderate Cr removals (79.8% and 78.3%, respectively) but lower Pb removal (54.8% and 65.3%). This observation aligns with the competitive adsorption reported by Li et al. (2019), who noted that mixed-biomass carbons can experience metal ion competition at active sites, reducing selectivity toward Pb at certain ratios (Li et al., 2019). Sample F (1.6 g OP + 0.4 g CS) yielded 84.1% Pb removal, surpassing both individual adsorbents.

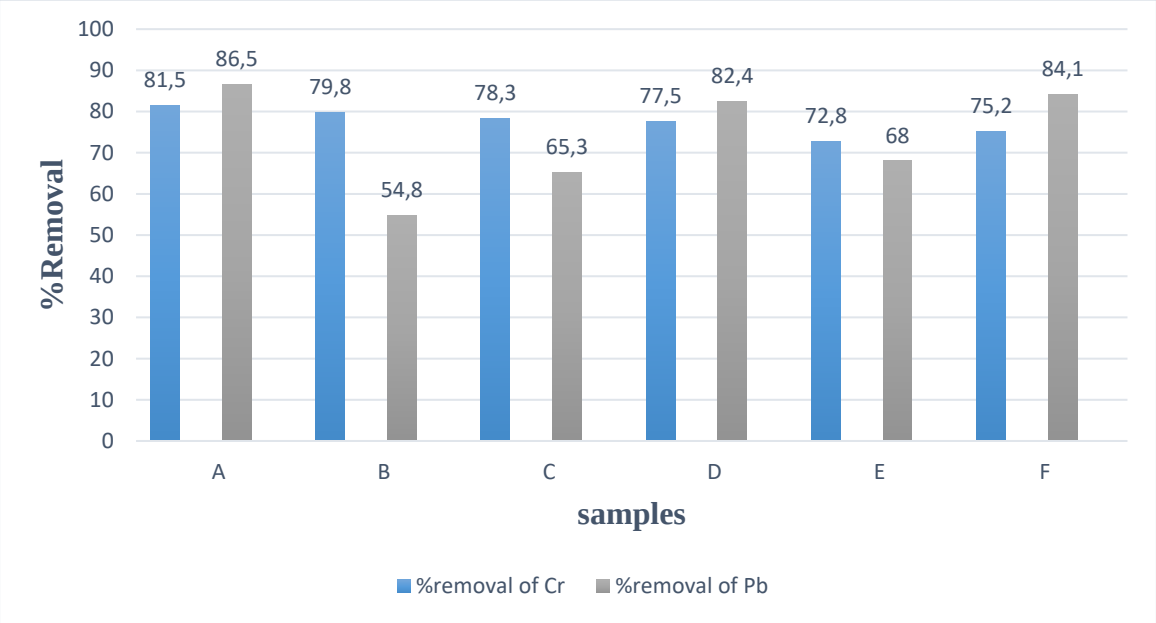

Figure 1: Effect of Activated Carbon on Removal of Heavy Metals (chromium and lead)

4.2 Physical Analysis

Physicochemical characterization (Table 2) showed that CS carbon has slightly higher ash content (9.82%) than OP (8.8%), which can influence pore blockage but also provide additional mineral oxides that act as binding sites (Ahmad and Hameed, 2010). The bulk densities (0.569 vs. 0.553 g/mL) and moisture contents (8.7% vs. 6.2%) are within expected ranges for biomass-derived carbons, ensuring adequate handling and suspension in aqueous media (Downie et al., 2009).

Table 2: Physical analysis of orange peel and coconut shell activated carbon

S/N	characteristics	Coconut shell	Orange peel
1	Moisture content (%)	8.7	6.2
2	Bulk density (g/ml)	0.569	0.553
3	Ash content (%)	9.82	8.8
4	Ph	7	7.5

Overall, the study confirms that coconut shell-derived activated carbon exhibits strong dual-metal removal performance, while orange peel carbon enhances Pb selectivity. Composite formulations can be tailored to target specific contaminants, offering a cost-effective and sustainable approach to wastewater treatment. Future work should include regeneration and reuse cycles, cost–benefit analyses, and pilot-scale trials to validate field applicability.

5 Conclusion

The comparative adsorption study demonstrates that coconut shell-derived activated carbon (CS) offers robust dual-metal removal capabilities, achieving removal efficiencies up to 81.5% for Cr and 86.5% for Pb under neutral conditions. Orange peel-based carbon (OP), while slightly less effective for Cr, shows enhanced Pb selectivity (up to 86.5% in composite adsorbents), composite formulations reveal synergistic and competitive interactions, mixtures rich in CS excel in Cr uptake, whereas OP-rich blends favor Pb adsorption. These findings underline the versatility of biomass-derived CS is optimal for broad-spectrum heavy-metal removal, OP targeted Pb remediation respectively. Future work should prioritize regeneration cycles, economic assessments, and pilot-scale validations to translate laboratory efficacy into field-applicable wastewater treatment solutions.

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COMPARISON OF RICE HUSK AS A PLANTING MEDIA IN URBAN AGRICULTURE TO CONVENTIONAL FARMING

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ABSTRACT

Urban agriculture is gaining momentum as a sustainable solution to food security, environmental conservation, and resource efficiency in urban stings. Rice husk, an abundant agricultural byproduct, has emerged as a promising substrate for urban farming due to its lightweight nature, high porosity, and cost effectiveness. This study explores the potential of rice husk as a growing medium, highlighting its advantages, challenges, and practical applications in urban agriculture systems such as hydroponics, vertical farming, and rooftop gardens. Rice husk was used as substrate in a hydroponic structure for tomato farming in Agricultural & Bioenvironmental Engineering Department, FPI, Ilaro, Ogun State. The study revealed that rice husk provided better aeration and drainage, reducing root diseases and promoting faster plant growth. Germination rates were higher in rice husk (85%) compared to soil (75%). The average plant height and biomass yield were significantly higher in rice husk, with lettuce showing a 20% increase in yield. Water consumption was lower in rice husk-based systems due to its moisture-retentive properties, leading to a 30% reduction in water usage. By repurposing rice husk in urban agriculture, cities can reduce agricultural waste, promote circular economy and enhance food production in limited space.

Keywords: Rice husk, urban agriculture, Substrate, Sustainable farming, Comparative advantage.

Introduction

Urban agriculture faces challenges such as limited arable land, soil degradation, and high input costs. Alternative growing media, such as rice husk, present a sustainable solution for soilless farming. Rice husk, an agricultural byproduct, is lightweight, abundant, and rich in silica, which improves plant growth. This study evaluates the comparative advantage of rice husk as a substrate in urban agriculture compared to conventional soil-based farming, focusing on crop growth, resource efficiency, and sustainability.

Materials and Methodology

A controlled experiment was conducted using rice husk as a substrate and conventional soil as a control. Selected leafy vegetables (lettuce and spinach) were grown in containers under identical conditions. Growth parameters such as germination rate, plant height, leaf count, and biomass yield were measured over six weeks. Water and nutrient consumption were recorded to assess resource efficiency. Soil and rice husk samples were analyzed for their physical and chemical properties, including aeration, moisture retention, and nutrient availability. Statistical analysis was performed to compare the performance of plants grown in rice husk versus conventional soil.

Results and Discussion

The study revealed that rice husk provided better aeration and drainage, reducing root diseases and promoting faster plant growth. Germination rates were higher in rice husk (85%) compared to soil (75%). The average plant height and biomass yield were significantly higher in rice husk, with lettuce showing a 20% increase in yield. Water consumption was lower in rice husk-based systems due to its moisture-retentive properties, leading to a 30% reduction in water usage. However, rice husk required nutrient supplementation due to its low inherent fertility. Despite this, its lightweight nature and recyclability made it a cost-effective and eco-friendly alternative for urban farming.

Conclusion

Rice husk demonstrates significant advantages over conventional soil in urban agriculture by enhancing plant growth, reducing water usage, and promoting sustainability. Its availability as an agricultural byproduct makes it a viable and environmentally friendly substrate for soilless farming. However, proper nutrient supplementation is essential to maximize crop productivity.

Integrating rice husk into urban farming practices can contribute to sustainable food production in space-constrained environments.

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FROM FARM TO FORK: NEXT-GENERATION DEVELOPMENT THROUGH CIRCULAR ECONOMY

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ABSTRACT

The traditional linear economy model, with its "take-make-dispose" approach, leads to the rapid depletion of natural resources and environmental degradation. As an alternative to this model, the circular economy aims to minimize waste generation, enhance resource efficiency, and establish closed-loop systems supported by renewable energy sources. The agricultural sector, in particular, represents a significant application area for circular economy strategies, as they contribute to efficient resource use, reduce dependence on external inputs, and support environmental sustainability.

The circular economy approach has the potential to generate environmental and economic benefits in the agricultural sector by optimizing resource use, minimizing waste, and promoting sustainable production systems. Circular farming practices, such as utilizing organic waste for composting, biogas production, and bio-based fertilizers, improve soil health and reduce dependency on chemical inputs. However, integrating circular economy principles into the agricultural sector faces challenges such as financial constraints, infrastructure requirements, and policy support. In this context, this study examines the economic, environmental, and social benefits of circular agriculture while discussing the obstacles encountered in implementation and proposing policy recommendations to facilitate a sustainable transition.

The integration of circular economy principles into agricultural systems not only enhances economic resilience but also ensures environmental sustainability and contributes to the development of policies aligned with the United Nations Sustainable Development Goals. Moreover, the "Farm to Fork Strategy," recognized as one of the key components of the Green Deal, plays a central role in the transition to a circular economy beyond just the food and agriculture sectors.

Unlike traditional linear economic models, the circular economy promotes the more efficient use of natural resources and encourages production and consumption patterns aligned with sustainable development principles. Circular economy strategies applicable in the agricultural sector can support rural development by balancing economic growth with environmental sustainability. The aim of this study is to assess the current state of the subject through a literature review and to present comprehensive policy frameworks that support sustainable agricultural transformation through circular economy practices.

Keywords: Circular Economy, Rural Development, New Green Deal**,** Sustainable Agriculture, Efficient Use of Resources

TARLADAN ÇATALA: DÖNGÜSEL EKONOMİ İLE YENİ NESİL KALKINMA

ÖZET

Geleneksel doğrusal ekonomi modeli, "al-kullan-at" yaklaşımıyla doğal kaynakların hızla tükenmesine ve çevresel bozulmaya neden olmaktadır. Bu modele alternatif olarak ortaya çıkan döngüsel ekonomi, atık oluşumunu en aza indirmeyi, kaynak verimliliğini artırmayı ve yenilenebilir enerji kaynaklarıyla desteklenen kapalı döngü sistemler oluşturmayı amaçlamaktadır. Özellikle tarım sektörü, döngüsel ekonomi stratejilerinin kaynak kullanımında verimlilik sağlama, dış girdilere bağımlılığı azaltma ve çevresel sürdürülebilirliği destekleme açısından önemli bir uygulama alanıdır.

Döngüsel ekonomi yaklaşımı, kaynak kullanımının optimize edilmesi, atıkların minimize edilmesi ve sürdürülebilir üretim sistemlerinin teşvik edilmesi yoluyla tarım sektöründe çevresel ve ekonomik faydalar yaratma potansiyeline sahiptir. Döngüsel tarım uygulamaları, organik atıkların kompost, biyogaz ve biyobazlı gübreler olarak değerlendirilmesi yoluyla toprak sağlığını iyileştirmekte ve kimyasal girdilere olan bağımlılığı azaltmaktadır. Ancak, döngüsel ekonomi ilkelerinin tarım sektörüne entegrasyonu, finansal kısıtlar, altyapı gereksinimleri ve politika desteği gibi çeşitli zorluklarla karşı karşıyadır. Bu bağlamda çalışma, döngüsel tarımın ekonomik, çevresel ve sosyal faydalarını ele alırken, uygulamada karşılaşılan engelleri ve bu dönüşümün sürdürülebilir şekilde gerçekleşmesini destekleyecek politika önerilerini tartışmaktadır.

Döngüsel ekonomi ilkelerinin tarımsal sistemlere entegrasyonu, ekonomik dayanıklılığı artırmanın yanı sıra çevresel sürdürülebilirliği sağlamakta ve Birleşmiş Milletler Sürdürülebilir Kalkınma Amaçları ile uyumlu politikaların geliştirilmesine katkı sunmaktadır. Ayrıca, Yeşil Mutabakat'ın temel unsurlarından biri olarak kabul edilen "Tarladan Çatala Stratejisi", yalnızca gıda ve tarım sektörleri ile sınırlı kalmayıp, döngüsel ekonomiye geçiş sürecinde de merkezi bir rol üstlenmektedir.

Döngüsel ekonomi geleneksel doğrusal ekonomik modellerin aksine, doğal kaynakların daha etkin kullanımını ve sürdürülebilir kalkınma ilkeleriyle uyumlu üretim ve tüketim modellerini teşvik etmektedir. Tarım sektöründe uygulanabilecek döngüsel ekonomi stratejileri, kırsal kalkınmayı destekleyerek ekonomik büyüme ve çevresel sürdürülebilirlik arasında denge kurulmasını sağlayabilir. Bu çalışmanın amacı, konuya ilişkin mevcut durumu değerlendirmek amacıyla literatür taraması yaparak döngüsel ekonomi uygulamaları ile sürdürülebilir tarımsal dönüşümü destekleyecek kapsamlı politika çerçevelerine yönelik öneriler sunmaktır.

Anahtar Kelimeler: Döngüsel Ekonomi, Kırsal Kalkınma, Yeni Yeşil Düzen, Sürdürülebilir Tarım, Etkin Kaynak Kullanımı

1. GİRİŞ

Döngüsel ekonomi, kaynakların etkin kullanımını, atıkların en aza indirilmesini ve sürdürülebilir üretim süreçlerinin teşvik edilmesini amaçlayan bir modeldir. Geleneksel tarım uygulamaları ise çoğunlukla doğrusal bir üretim yaklaşımına dayanır; yani doğal kaynaklar kullanılır, ürünler yetiştirilir ve ardından atıklar bertaraf edilir. Bu süreç, biyokütle geri kazanımı, organik atıkların değerlendirilmesi ve sürdürülebilir tarımsal girdilerin kullanımını içeren bütüncül bir dönüşümü gerektirmektedir. Söz konusu dönüşüm, atıkların geri dönüştürülmesi ve yeniden kullanımı yoluyla yeni değerlerin oluşturulmasını sağlarken, aynı zamanda ekonomik getirilerin artırılmasına da katkıda bulunmaktadır (Özkan 2024). Mevcut sistemlerde, bitkisel ve hayvansal atıklar büyük ölçüde değerlendirilememekte ve çevresel kirliliğe yol açmaktadır. Oysa bu atıklar, kompost veya biyogaz üretimi için kullanılabilir ve böylece hem toprak verimliliği artırılabilir hem de enerji üretimi sağlanabilir. Agegnehu vd. (2016) çalışmalarında tarımda döngüsel ekonomiyi teşvik etmek için biyokömür uygulamasının potansiyel katkılarını incelemiştir. Biyokömür, organik atıkların piroliz yoluyla işlenmesiyle elde edilen karbon açısından zengin bir maddedir ve toprak verimliliğini artırma, su tutma kapasitesini iyileştirme ve sera gazı emisyonlarını azaltma gibi faydaları bulunmaktadır. Makale, biyokömürün tarımsal atıkların yönetiminde sürdürülebilir bir çözüm sunduğunu ve böylece atıkların yeniden kullanımı yoluyla döngüsel ekonomi ilkelerine katkı sağladığını vurgulamaktadır. Ayrıca, biyokömürün toprak sağlığını iyileştirerek bitki büyümesini desteklediği ve kimyasal gübre kullanımını azaltarak çevresel etkileri minimize ettiği belirtilmektedir. Sonuç olarak, biyokömür uygulamasının tarım sektöründe döngüsel ekonomiyi destekleyen etkili bir strateji olduğu ve sürdürülebilir tarım uygulamalarına önemli katkılar sunduğu ifade edilmektedir. Cao vd. (2022), çalışmalarında biyokömürbazlı elektrotların sürdürülebilir enerji üretimine katkı sağlayabileceğini ve döngüsel ekonomi çerçevesinde tarımsal atık yönetiminin iyileştirilmesine yardımcı olabileceğini ortaya koymaktadır. Bulgular, biyokömür kullanımının teşvik edilmesi için politika yapıcılar ve enerji sektörü açısından önemli bilgiler sunmaktadır.Otero vd. (2023), tarımsal yan ürünlerin döngüsel ekonomi modellerine entegrasyonunda karşılaşılan zorlukları, özellikle İspanya'daki pestisit kullanımı bağlamında incelemiştir. Çalışma, pestisit kalıntılarının tarımsal atıkların yeniden kullanımını nasıl engellediğini ve bu durumun döngüsel ekonomi hedeflerini nasıl sekteye uğrattığını analiz etmektedir. Yazarlar, mevcut yasal düzenlemeler ve uygulamaların, pestisit kalıntıları nedeniyle tarımsal yan ürünlerin geri dönüşümünü sınırladığını belirtmektedir. Ayrıca, çalışmada pestisitlerin çevresel ve ekonomik etkileri değerlendirilerek, sürdürülebilir tarım uygulamalarının önemi vurgulanmaktadır. Sonuç olarak, makale, tarımsal yan ürünlerin döngüsel ekonomiye başarılı bir şekilde dahil edilmesi için pestisit kullanımının azaltılması ve daha etkili yönetilmesi gerektiğini önermektedir.

Döngüsel ekonominin etkin şekilde uygulanabilmesi için, atık yönetimi stratejilerinin geliştirilmesi ve çiftçilerin bu konuda bilinçlendirilmesi büyük önem taşımaktadır.Rótolo vd. (2022), Arjantin'de tarımla ilgili sektörlerde döngüsel ekonomi seçeneklerine yönelik algı ve farkındalığı incelemiştir. Çalışma, mevcut sosyo-ekonomik modelin kaynak kıtlığı, çevresel etkiler ve sosyo-ekonomik kısıtlamalar nedeniyle zorluklarla karşılaştığını ve bu nedenle döngüsel ekonomi paradigmasının giderek daha fazla ilgi gördüğünü belirtmektedir. Araştırma

bulguları, tarım sektöründe döngüsel ekonomi ilkelerinin benimsenmesini teşvik etmek için politika yapıcıların ve sektör liderlerinin stratejiler geliştirmesi gerektiğini vurgulamaktadır.

Bununla birlikte, döngüsel tarıma geçiş, tedarik zincirlerinde de yapısal değişiklikler gerektirmektedir.Tarımsal üretimde malzeme geri kazanımı, yeniden kullanım ve geri dönüşüm süreçlerinin iyileştirilmesi için lojistik ve teknik engellerin aşılması gerekmektedir. Santos vd. (2024), tarımsal üretimde döngüsel ekonomi çerçevesinin blokzincir teknolojisi ile entegrasyonunu incelemiştir. Çalışma, pestisit ambalajlarının geri dönüşümü ve tersine lojistik süreçlerinde blokzincirin şeffaflık ve izlenebilirlik sağlayarak sürdürülebilirliği nasıl artırabileceğini değerlendirmiştir. Literatür taraması ve kavramsal analiz yöntemleri kullanılarak yapılan araştırmada, blokzincir teknolojisinin pestisit ambalajlarının geri kazanımı ve bertarafında önemli avantajlar sunduğu bulunmuştur. Bu bulgular, tarımsal üretimde döngüsel ekonomi ilkelerinin uygulanmasını teşvik eden politika ve stratejilerin geliştirilmesi açısından önemli katkılar sunmaktadır.

Döngüsel tarımın başarısı, sadece üreticilerin değil, aynı zamanda tüketicilerin de bu dönüşüme katılımıyla mümkündür. Sürdürülebilir tüketimi teşvik etmek ve tüketici davranışlarını döngüsel ekonomiye uygun hale getirmek için farkındalık artırıcı kampanyalar yürütülmelidir (Lieder ve Rashid, 2016). Tüketicilerin sürdürülebilir ürünlere yönelik tutumlarını anlamak, döngüsel tarım ürünlerinin pazarda daha geniş kabul görmesini sağlayacaktır. Örneğin, biyolojik bazlı gübrelerin ve doğal haşere kontrol yöntemlerinin yaygınlaştırılması, kimyasal girdilere olan bağımlılığı azaltarak sürdürülebilirliği artırabilir. Ancak, bu tür dönüşümlerin başarılı olabilmesi için, tarımsal girdilerin ve çıktıların yeniden değerlendirilmesine yönelik politika ve teşvik mekanizmalarının geliştirilmesi gerekmektedir.

Döngüsel tarımın ekonomik etkileri de dikkatle ele alınmalıdır. Çevresel faydalar iyi belgelenmiş olmasına rağmen, iş yaratma, pazar dinamikleri ve rekabet avantajı gibi ekonomik etkilerin daha fazla araştırılması gerekmektedir (Johnson vd., 2024). Özellikle küçük ve orta ölçekli tarım işletmeleri (KOBİ'ler), döngüsel tarım uygulamalarını benimsemekte finansal zorluklarla karşılaşmaktadır. Bu noktada, yenilikçi finansman mekanizmaları ve kamu-özel sektör ortaklıklarının geliştirilmesi, döngüsel tarıma geçişi destekleyebilir (Durlak ve DuPre, 2008).

Ancak, döngüsel tarım uygulamalarının yaygınlaşmasını engelleyen bazı faktörler de bulunmaktadır. Bunlardan biri değişime karşı dirençtir. Kurumsal atalet ve paydaş direnci, yeni uygulamaların benimsenmesini zorlaştırabilir. Bu nedenle, döngüsel tarıma geçiş sürecinde paydaş katılımını artırmak, etkili iletişim stratejileri geliştirmek ve yeniliğe değer veren bir kültür oluşturmak kritik öneme sahiptir (Greenhalgh vd., 2004). Ayrıca, mevcut tarım sistemlerinin döngüsel modele uyarlanabilmesi için teknik rehberlik ve eğitim programları sağlanmalıdır (Sandelowski, 2000).

Velasco-Muñoz vd. (2021), döngüsel ekonominin tarımsal bağlamda nasıl anlaşılabileceğini tanımlayarak ve döngüsel ekonomi ilkeleri ile stratejilerini tarım sektörüne uyarlayarak mevcut literatürdeki boşluğu doldurmayı amaçladıkları çalışmalarında, literatürde vurgulanan döngüsel ekonomi ilkelerinin büyük ölçüde Ellen MacArthur Vakfı (EMF) tarafından önerilen prensiplerle örtüştüğünü belirterek, bu ilkeleri üç temel başlık altında sıralamaktadır. İlk olarak, "atık ve kirliliği ortadan kaldıran tasarım" ilkesi, sistemin etkinliğini artırmak için çevresel

olumsuz dışsallıkların belirlenmesini ve ortadan kaldırılmasını hedeflemektedir. Tarım sektörü bağlamında değerlendirildiğinde, gübre, herbisit ve pestisitlerin yanlış kullanımı nedeniyle toprak kirliliğine yol açıldığı belirtilmektedir. Bununla birlikte, birçok gelişmiş ülke, kimyasal girdilerin kullanımını sınırlayan veya yasaklayan düzenlemeler getirmiştir. Bu durum, organik gübre kullanımının artmasına ve biyolojik haşere kontrol yöntemlerinin geliştirilmesine katkı sağlamaktadır. İkinci olarak, "ürünleri ve malzemeleri kullanımda tutma" ilkesi, tedarik zincirinin tüm aşamalarında ve farklı tedarik zincirleri arasında, ürünler ile yan ürünlerin değerinin en üst düzeye çıkarılmasını amaçlamaktadır. Bu ilke, kaynakların maksimum fayda sağlayacak şekilde korunmasını ve sürdürülebilir kullanımını teşvik etmektedir. Son olarak, "doğal sistemleri yenileme" ilkesi, ekosistemlerin korunmasını ve iyileştirilmesini sağlamak amacıyla sonlu stokların yenilenebilir kaynaklarla değiştirilmesini kapsamaktadır. Bu ilke, yenileyici (rejeneratif) tarım uygulamalarının gelişmesine olanak sağlamaktadır. Yenileyici (rejeneratif) tarım, sera gazı emisyonlarını azaltma, toprakta ve bitki materyalinde karbon tutma, toprak bozulmasını en aza indirme ve su tutma kapasitesini artırma gibi çevresel faydalar sunmaktadır. Ayrıca, biyolojik olarak aktif toprakları teşvik ederek sentetik girdilere olan bağımlılığı azaltmaktadır. Yenilenme süreci, biyolojik olarak parçalanabilir ambalajların geliştirilmesi, bitki atıklarının yönetimi yoluyla karbon tutulumunun (sekestrasyon) artırılması ve kompostlama gibi malzeme geri dönüşüm uygulamalarını içermektedir. Ancak, bu ilkelerin tarımsal bağlama tam olarak uyarlanmadığı ve uygulamada entegrasyonunun henüz yeterince sağlanamadığı görülmektedir (Velasco-Muñoz vd., 2021).Nguyen vd. (2024), Vietnam'da tarımsal üretimde döngüsel ekonomi uygulamalarının benimsenme düzeyini etkileyen faktörleri incelemiştir. Araştırma, hükümet politikaları, üretim ölçeği, işletmelerin farkındalığı, teknolojik uygulamalar ve finansal yatırımların döngüsel ekonomi uygulamalarına etkisini değerlendirmiştir. Yapısal Eşitlik Modellemesi kullanılarak yapılan analizlerde, finansal faktörlerin en güçlü etkiye sahip olduğu, bunu sırasıyla teknolojik uygulamalar, farkındalık, üretim ölçeği ve hükümet politikalarının izlediği belirlenmiştir.

Tarımda sürdürülebilir bir döngüsel ekonomi yaratmak, devletlerin, uluslararası örgütlerin, kamu otoritelerinin, yerel ve bölgesel toplulukların, işletmelerin, hanelerin ve vatandaşların sorumluluğundadır. Tüm bu kavramlar iyi tanımlanmış olsa da, asıl soru bunların ekonomik veya sosyal olarak ne ölçüde uygulandığıdır. Her kavram evrensel çözümler sunamaz; bazıları eksikliklere sahip olabilir veya belirli koşullar altında uygulanamayabilir (Kadioglu vd., 2025).

Bu bulgular, politika yapıcılar için döngüsel ekonomi ilkelerinin tarımsal üretimde benimsenmesini artırmaya yönelik stratejilerin geliştirilmesinde önemli bilgiler sunmaktadır.

2. TARIMDA SÜRDÜRÜLEBİLİRLİK

Tarımda döngüsel ekonomi uygulamalarının incelenmesi sırasında öne çıkan temel kavramlardan biri de sürdürülebilirliktir. Döngüsel ekonomi, kaynak kullanımını optimize ederek atık oluşumunu ve çevresel kirliliği en aza indirmeyi hedeflemekte, böylece ekonomik ve sosyal refahı artırırken çevrenin korunmasına da katkı sağlamaktadır (Bencomo vd., 2019). Bu bağlamda, döngüsel ekonomi uygulamalarının sürdürülebilir kalkınmayı desteklediği söylenebilir.Dziedzic vd. (2022) uluslararası döngüsel ekonomi stratejilerinin tarımsal su yönetimi üzerindeki etkilerini incelemiş, döngüsel ekonomi ilkelerinin küresel ölçekte tarım

sektöründe sürdürülebilir su yönetimini nasıl destekleyebileceği araştırmıştır. Çalışma, suyun etkin kullanımını ve yeniden kullanımını teşvik eden döngüsel ekonomi stratejilerinin, su kıtlığı sorunlarının hafifletilmesine ve tarımsal üretkenliğin artırılmasına katkı sağlayabileceğini belirtmektedir. Ayrıca, bu stratejilerin uygulanmasının, su kaynaklarının korunması ve çevresel sürdürülebilirliğin sağlanması açısından önemli olduğu vurgulanmaktadır.

Döngüsel bir ekonomi, çiftçilere ve diğer girişimcilere değer yaratırken çevreyi iyileştirmeleri, eşitlik ve etkileşimin sosyal normlarını teşvik etmeleri için ek fırsatlar sunmaktadır (Özkan, 2024). Tarım sektöründe döngüsel ekonomi uygulamaları, organik atıkların biyogaz veya kompost üretiminde kullanılması, su kaynaklarının verimli yönetimi ve sürdürülebilir tarım teknikleri gibi birçok alanı kapsamaktadır. Dijitalleşme ve yapay zekâ teknolojilerinin entegrasyonu, döngüsel sistemlerin optimizasyonunu sağlayarak kaynak kullanımını daha verimli hale getirebilir.

Tarım sektöründe döngüsel ekonomi uygulamalarının en önemli faydalarından biri, biyokütle atıklarının yeniden kullanımı ve geri dönüştürülmesi yoluyla kaynak verimliliğinin artırılmasıdır. Tarımsal üretim süreçlerinde ortaya çıkan organik atıkların kompost, biyogaz veya biyoyakıt olarak değerlendirilmesi, kimyasal gübre kullanımını azaltarak toprak sağlığını iyileştirmekte ve tarımsal ekosistemlerin sürdürülebilirliğini desteklemektedir. Bu durum, çiftçilerin girdi maliyetlerini düşürmelerini sağlarken, tarımsal üretimin çevresel etkilerini de en aza indirir.

Ayrıca, döngüsel ekonomi ilkelerinin tarımsal üretime entegrasyonu, ürün tasarımı ve iş modellerinde inovasyonu teşvik etmektedir. Bu bağlamda, akıllı tarım uygulamaları, hassas tarım teknolojileri ve biyolojik bazlı girdilerin kullanımı gibi yenilikçi yaklaşımlar ile hem üretim verimliliğini artırılması hem de doğal kaynakların korunması amaçlanmaktadır.

Ekonomik faydaların yanı sıra döngüsel ekonomi ilkelerinin benimsenmesi, tarım sektörünün küresel sürdürülebilirlik hedeflerine uyum sağlamasına da yardımcı olmaktadır. Khajuria vd. (2022), döngüsel ekonomi stratejilerinin Birleşmiş Milletler Sürdürülebilir Kalkınma Hedefleri (SDGs) ile özellikle sorumlu tüketim ve üretim (SDG 12) ve iklim eylemi (SDG 13) açısından doğrudan ilişkili olduğunu belirtmektedir. Bu bakımdan döngüsel tarım uygulamaları, sera gazı emisyonlarını azaltarak ve tarımsal ekosistemlerin sürdürülebilirliğini artırarak küresel iklim değişikliğiyle mücadelede kritik bir rol oynamaktadır (EuropeanParliament, 2025).

Bununla birlikte, döngüsel ekonomi uygulamaları çiftçiler ve tarımsal işletmeler için yeni gelir modelleri oluşturma potansiyeline sahiptir. Örneğin, döngüsel sistemler sayesinde atıkların yeniden işlenmesi ve biyoteknolojik süreçlerle yeni ürünlere dönüştürülmesi, tarım sektöründe ek gelir kaynakları yaratabilir. Organik atıklardan biyogaz üretimi veya geri dönüştürülebilir tarımsal ambalajların geliştirilmesi gibi uygulamalar, hem çiftçilerin ekonomik refahını artırmakta hem de döngüsel iş modellerine olan ilgiyi artırmaktadır.

Günümüzde döngüsel ekonomi yaklaşımı, yalnızca endüstriyel süreçlerle sınırlı kalmayıp, kırsal kalkınma stratejilerinde de etkili bir model olarak değerlendirilmektedir. Sonuç olarak tarım sektöründe döngüsel ekonomi entegrasyonu, doğal kaynakların korunması, tarımsal üretimde verimliliğin artırılması, ekonomik sürdürülebilirliğin desteklenmesi ve küresel sürdürülebilirlik hedeflerine katkı sağlanması açısından kritik bir öneme sahiptir. Tarımsal

üretimin döngüsel ilkeler doğrultusunda yeniden tasarlanması, çevresel etkileri azaltırken, çiftçilerin rekabet gücünü artıran ve uzun vadede ekonomik kazanç sağlayan bir dönüşüm yaratacaktır.

2.1. Tarımda Döngüsel Ekonomi Entegrasyonu

Beklenen kaynak temelli, çevresel ve sosyo-ekonomik faydalara rağmen, tarımda döngüsel ekonominin benimsenmesi, uygun şekilde uygulanması için çeşitli engellerin üstesinden gelmelidir. Haque vd. (2023), tarımda döngüsel ekonomi entegrasyonunda mevcut literatüre dayanarak dört temel zorluk alanı belirlemiştir. Bu zorluk alanları; dönüşüm teknolojileri ve ilgili araştırmalar, tedarik zincirinde iş modelleri ile malzeme akışının yönetimi, döngüsel ekonomi uygulamalarına yönelik analitik araçların geliştirilmesi ve paydaş katılımının sağlanması şeklinde sınıflandırılmaktadır.

Bu engellerin başında, mevcut tarımsal üretim modellerinin döngüsel sisteme uyum sağlaması için gerekli olan büyük ölçekli yatırımlar ve devlet desteği gelmektedir. Döngüsel tarım sistemleri, atıkların yeniden kullanımı, organik gübreleme ve suyun verimli yönetimi gibi sürdürülebilir uygulamaları içermekte olup, bu sistemlerin hayata geçirilmesi önemli altyapı değişiklikleri ve teknolojik yatırımlar gerektirmektedir. Ancak, birçok çiftçi ve tarımsal işletme, özellikle de küçük ölçekli üreticiler, bu dönüşüm için gerekli finansmanı sağlamakta zorlanmaktadır. Üstelik, döngüsel tarıma yönelik mali teşvikler ve sübvansiyonlar sınırlıdır ve bu da geçiş sürecini ekonomik açıdan daha zor hale getirmektedir.

Döngüsel ekonominin tarıma entegrasyonundaki bir diğer büyük zorluk, mevcut tarım yöntemlerinin sürdürülebilirlik ilkelerine uygun hale getirilmesi sürecinin karmaşıklığıdır. Geleneksel tarım uygulamaları, yoğun kimyasal kullanımına ve doğrusal bir üretim-tüketim modeline dayanmaktadır. Bu modeli döngüsel hale getirmek, biyolojik döngüleri optimize etmek, toprağın verimliliğini artırmak ve atık yönetimini daha sürdürülebilir bir hale getirmek için yeni teknikler ve süreçler gerektirir.

Çiftçilerin döngüsel tarıma uyum sağlayabilmesi için yenilikçi tarımsal teknikler konusunda eğitilmeleri, sürdürülebilir gübreleme yöntemlerini benimsemeleri ve döngüsel üretim için uygun makinelerle donatılmaları gerekmektedir. Ancak, mevcut bilgi eksikliği ve yeni uygulamalara yönelik direnç, bu süreci zorlaştıran etkenler arasında yer almaktadır (Cantú vd., 2021).

Bunun yanı sıra, tarımsal tedarik zincirinin sürdürülebilir bir şekilde yeniden yapılandırılması da önemli bir lojistik sorundur. Döngüsel tarımın başarısı, organik atıkların verimli bir şekilde geri kazanılması, biyogaz ve kompost üretiminin artırılması ve alternatif pazar mekanizmalarının oluşturulmasıyla yakından ilişkilidir. Ancak, birçok bölgede geri dönüştürülebilir tarımsal atıkların toplanması, işlenmesi ve yeniden kullanımı için yeterli altyapı bulunmamaktadır. Ayrıca, sürdürülebilir tarım girdilerinin tutarlılığı ve kalitesinin sağlanması da üreticiler için bir başka önemli zorluk teşkil etmektedir.

Son olarak, tüketici davranışları ve pazar dinamikleri, tarım sektöründe döngüsel ekonominin yaygınlaşmasını etkileyen kritik faktörlerden biridir. Döngüsel tarım uygulamalarından elde edilen ürünlerin pazarda kabul görmesi ve talep edilmesi, bu dönüşümün sürdürülebilirliği

açısından büyük önem taşımaktadır. Ancak, tüketiciler arasında döngüsel tarım ürünlerine yönelik farkındalık eksikliği ve sürdürülebilir gıdaların maliyetine ilişkin algılar, bu ürünlerin benimsenmesini yavaşlatmaktadır. Döngüsel ekonomi ilkeleriyle üretilen gıdaların pazarda rekabet edebilir hale gelmesi için, bu ürünlerin fiyatlandırma stratejilerinin iyi belirlenmesi ve tüketiciye yönelik bilinçlendirme kampanyalarının artırılması gerekmektedir (Droege vd., 2021).

Döngüsel tarım ekonomisinin yaygınlaştırılması, yalnızca bireysel çiftçilerin veya işletmelerin çabalarıyla mümkün değildir. Bu dönüşüm sürecinde hükümetlerin, akademik kurumların, özel sektörün ve sivil toplum kuruluşlarının ortak hareket etmesi gerekmektedir. Politika yapıcıların, döngüsel tarıma geçişi teşvik edici düzenlemeler getirmesi, finansal destek mekanizmalarını genişletmesi ve sürdürülebilir tarım uygulamalarını destekleyen araştırmaları teşvik etmesi önem arz etmektedir.

Sonuç olarak, tarım sektöründe döngüsel ekonominin entegrasyonu finansal, yapısal ve davranışsal zorluklar içermektedir. Ancak, bu zorlukların üstesinden gelinmesi, yalnızca çevresel sürdürülebilirlik açısından değil, aynı zamanda tarım sektörünün uzun vadeli verimliliği ve gıda güvenliği açısından da kritik bir öneme sahiptir. Bu dönüşümün başarısı, çok paydaşlı iş birlikleri, yenilikçi çözümler ve güçlü bir politika desteği ile mümkün olacaktır.

3. SONUÇ

Döngüsel ekonomi, tarım ve kırsal kalkınma arasındaki ilişki, sürdürülebilir kaynak yönetimi, atıkların azaltılması ve ekonomik dayanıklılığın artırılması açısından kritik bir öneme sahiptir. Tarımsal üretimde döngüsel yaklaşımlar, girdi maliyetlerini düşürmek, ekosistem üzerindeki baskıyı azaltmak ve yerel ekonomileri güçlendirmek adına önemli fırsatlar sunmaktadır. Organik atıkların biyogaz ve kompost üretimi gibi yöntemlerle değerlendirilmesi, suyun yeniden kullanımı ve yenilikçi tarım teknikleri, kırsal bölgelerde ekonomik çeşitliliği artırarak kalkınmayı teşvik etmektedir.

Ancak, döngüsel ekonominin tarıma entegrasyonu ve kırsal kalkınmayı destekleyici hale getirilmesi için politika yapıcıların, çiftçilerin ve özel sektörün iş birliği içinde hareket etmesi gerekmektedir. Teknolojik yeniliklerin benimsenmesi, finansal teşvik mekanizmalarının oluşturulması ve çiftçilerin bilinçlendirilmesi, döngüsel ekonominin tarım sektöründe başarılı bir şekilde uygulanmasını sağlayacaktır.

Bu kapsamda, küçük ve orta ölçekli tarım işletmelerinin döngüsel uygulamalara geçişte yaşadığı finansal zorlukları aşabilmeleri için hibe, düşük faizli kredi ve vergi indirimleri gibi teşvik mekanizmaları oluşturulmalıdır. Özellikle biyogaz, kompost ve geri dönüşüm tesisleri gibi altyapı yatırımları desteklenmelidir. Çiftçilerin ve tarım işletmelerinin döngüsel ekonomi uygulamaları hakkında bilinçlendirilmesi amacıyla yaygın eğitim programları düzenlenmeli, teknik danışmanlık hizmetleri sağlanmalıdır. Sürdürülebilir gübreleme, atık yönetimi ve hassas tarım teknolojileri gibi konulara odaklanılmalıdır. Tarımsal atık yönetimi, organik gübre üretimi ve biyolojik bazlı girdilerin kullanımı gibi alanlarda mevzuat güncellenmeli, kalite standartları belirlenmelidir. Döngüsel tarım uygulamalarının takibini ve denetimini kolaylaştıracak bir yasal altyapı geliştirilmelidir. Tarımda döngüsel ekonomi yatırımlarının

artırılması için kamu-özel sektör ortaklıkları ve çiftçi kooperatifleri desteklenmelidir. Özellikle bölgesel biyogaz ve kompost tesislerinin kurulması için ortak girişim modelleri geliştirilebilir. Döngüsel tarım ürünlerinin pazarda rekabet edebilirliğini artırmak amacıyla tüketicilere yönelik bilinçlendirme kampanyaları yürütülmeli ve döngüsel ürün etiketleme sistemleri geliştirilmelidir. Böylece tüketici talebi güçlendirilerek piyasada sürdürülebilir ürünlere olan ilgi artırılabilir.

Tarımsal faaliyetlerin döngüsellik performansının belirlenmesi ve anlamlı çalışmaların geliştirilmesi için uluslararası kabul görmüş standartların ve yeterli ölçüm birimlerinin tanımlanması gerekmektedir.

Sonuç olarak, tarımda döngüsel ekonomi uygulamalarının yaygınlaştırılması, sadece ekonomik kazanç sağlamakla kalmayıp çevresel ve sosyal sürdürülebilirliği de destekleyerek kırsal kalkınmanın yeniden şekillenmesine önemli katkılar sunacaktır. Bu bağlamda, gelecekte yapılacak araştırmalar ve uygulamalar, döngüsel ekonominin tarımsal üretim sistemlerine entegrasyonunu daha da güçlendirecek ve kırsal bölgelerde refah seviyesinin artmasına katkı sağlayacaktır.

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DIGITAL TRANSFORMATION AND SUSTAINABLE MOBILITY IN AGRICULTURE

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ABSTRACT

Throughout history, humanity has made great efforts to find, develop and disseminate information. In this direction, new inventions have emerged for generations. The most important fact of this chain of stages that has continued for centuries is the discovery of writing and the ability to preserve these inventions for generations. In today's conditions, the greatest blessing that technology has offered us is the ease of recording information. Therefore, access to information and its distribution have gained great importance. Developing and changing technological attacks directly affect human life. The needs and habits of societies are evolving very quickly. This change includes all human-centered sectors. The name of this new process is digital transformation. The most important gain of this new period is that the storage and transfer of information has become much easier than before. With the triggering of this, information production has gained another dimension.

Digital transformation can be a good solution for our current economic, social and environmental problems. With the use of technological developments and the digitalization of processes, it may be possible to achieve the goal of a future in which all societies in the world live more equally and in prosperity.

Developments such as the Internet of Things, artificial intelligence, blockchain technology and big data have begun to increase the efficiency of business models by digitizing processes faster. The rapid increase in the speed of technological advances and socio-economic developments in the last century compared to the previous period has caused problems in the management of resources for the future. In order to eliminate these disruptions, it is valuable for digital transformation to be sustainable. Many studies are being carried out for the future of the world. If digital transformation is planned correctly, it may be possible to develop more sustainable business models. These developments should be evaluated as an opportunity to reduce natural resource consumption, minimize waste production and eliminate social injustice while benefiting from the advancement of technology. Global problems such as raw material scarcity, pollution and climate change caused or may be caused by traditional economic and production models are the biggest problems in terms of sustainability worldwide. In general, the traditional

perspective in the field of production and consumption forms the basis of these problems. In this context, new models based on sustainability have been needed instead of the traditional perspective. Circular economy can be defined as an economic paradigm that aims to find solutions to global sustainability problems such as climate change, biodiversity loss, material scarcity and pollution by using resources more efficiently and minimizing waste, in contrast to the current traditional economic model. In order for the transformation to be successful, digital technologies must be used more effectively. An important part of sustainability is that the circular economy model is supported by digital transformation. This study aims to clarify the concepts of digitalization-sustainability-circular economy, which are the three basic facts of our lives in the recent period, by examining internationally published reports and action plans.

Keywords: Circular Economy, Digitalization, Sustainability, Efficient Use of Resources

DİJİTAL DÖNÜŞÜM VE TARIMDA SÜRDÜRÜLEBİLİR HAREKETLİLİK

ÖZET

İnsanlık, tarih boyunca bilgiyi bulma, geliştirme ve yayma konusunda büyük bir çaba içerinde olmuştur. Bu doğrultuda nesiller boyu yeni icatlar ortaya çıkmıştır.Yüzyıllar boyunca süregelen bu aşamalar zincirinin en önemli olgusu yazının bulunması ve bu icatların nesiller boyunca saklanabilmesidir. Günümüz koşulalrında teknolojinin bizlere sunmuş olduğu en büyük nimet bilginin kayıt altına alınmasında ki kolaylıktır. Dolayısıyla, bilgiye erişim ve bunun dağıtılması çok büyük önem kazanmıştır. Gelişen ve değişen teknoloji atakları insan hayatını doğrudan etkilemektedir. Toplumların ihtiyaçları ve alışkanlıkları çok hızlı bir şekilde evrilmektedir. Bu değişim, insan odaklı tüm sektörleri içine almaktadır. İşte bu yeni sürecin adı dijital dönüşümdür.Bu yeni dönemin en önemli kazanımı ise bilginin saklanması ve aktarılması önceye göre çok kolaylaşmıştır. Bunun tetiklenmesiyle bilgi üretimi bir başka boyut kazanmıştır.

Dijital dönüşüm mevcut ekomik soyal ve çevresel kökenli sorunlarımız için iyi bir çözüm aracı olabilecek niteliktedir. Teknolojik gelişmelerin kullanımı ve süreçlerin dijitalleşmesiyle birlikte dünyadaki tüm toplumların daha eşit ve refah içinde yaşadığı bir gelecek hedefine ulaşma imkanı doğabilir.

Nesnelerin interneti, yapay zekâ, blok zinciri teknolojisi ve büyük veri gibi gelişmeler süreçleri daha hızlı dijitalleştirerek iş modellerindeki verimi arttırmaya başlamıştır.Teknolojik ilerlemelerin ve buna bağlı olarak sosyo-ekonomik gelişmelerinin hızının son yüz yılda önceki döneme göre yüksek oranda artması kaynakların yönetiminde gelecek adına sorunlar çıkmasına neden olmuştur. Bu aksaklıkları giderebilmek için dijital dönüşümün sürdürülebilir olması değerlidir. Dünyanın geleceği için birçok çalışma yapılmaktadır. Dijital dönüşüm doğru planlanırsa daha sürdürülebilir iş modellerini geliştirmek mümkün olabilir. Bu gelişmeler teknolojinin ilerlemesinden yararlanırken, doğal kaynak tüketimini azaltmak, atık üretimini minimize etmek ve sosyal adaletsizliği ortadan kaldırmak için bir fırsat olarak değerlendirilmelidir. Geleneksel ekonomik ve üretim modellerinin yol açtığı veya yol açabileceği hammadde kıtlığı, kirlilik, iklim değişikliği gibi küresel sorunlar, dünya genelinde sürdürülebilirlik açısından en büyük sorunlardır. Genel olarak üretim ve tüketim alanındaki geleneksel bakış açısı bu sorunların temelini oluşturmaktadır. Bu kapsamda geleneksel bakış açısı yerine sürdürülebilirliği temel alan yeni modellere ihtiyaç duyulmuştur. Döngüsel ekonomi, mevcut geleneksel ekonomik modelin aksine kaynakları daha verimli bir şekilde kullanarak ve atıkların en aza indirgendiği, iklim değişikliği, biyoçeşitlilik kaybı, malzeme kıtlığı ve kirlilik gibi küresel sürdürülebilirlik sorunlarına çözüm bulunmasını amaçlayan bir ekonomik paradigma olarak tanımlanabilir.Dönüşümün başarılı olması için dijital teknolojilerin daha etkin bir şekilde kullanılması şarttır. Sürdürülebilirliğin önemli bir parçası, döngüsel ekonomi modelinin dijital dönüşüm tarafından desteklenmesidir. Bu çalışma ile uluslararası yayınlanan raporlar ve eylem planları incelenerek hayatımızın son dönemde üç temel olgusu olan dijitaleşme-sürdürülebilirlik-döngüsel ekonomi kavramlarına açıklık getirilmeye çalışmıştır.

Anahtar Kelimeler: Döngüsel Ekonomi, Dijitalleşme, Sürdürülebilirlik, Etkin Kaynak Kullanımı

1. GİRİŞ

There are approximately 500 million small-scale farmers globally, and these farmers feed 70% of the world's population using only 30% of total resources (EMF, 2021). The Food and Agriculture Organization of the United Nations (FAO) emphasizes that global food production must increase by approximately 70% to meet food demand by 2050 (FAO, 2009). A production approach focused on the amount of production to meet food demand due to increasing population growth causes overuse of natural resources (Doğan and Adanacıoğlu, 2022). Current research examines the effects of the global food and agriculture industry on climate change and the global environmental crisis in detail (Crippa et al., 2021; Akram-Lodhi, 2021). Studies show that failure to manage natural resources effectively and sustainably leads to environmental problems such as soil and water pollution, soil losses, disruption of ecosystem balance and increased carbon emissions, and that unsustainable agricultural practices pose risks of degradation of agricultural lands, erosion, nitrogen, phosphorus and potassium pollution (Mısır and Arıkan, 2022).

Minimizing the environmental impacts of agricultural production necessitates the search for alternative and sustainable methods. In this context, the circular economy stands out as an important strategy that aims to increase resource efficiency and reduce the negative environmental impacts of agricultural activities while improving economic performance (Doğan and Adanacıoğlu, 2022; Velasco-Muñoz et al., 2021). In this context, the “farm to fork” strategy presented by the European Commission in May 2020 represents an important action under the European Green Deal framework. This strategy aims to achieve climate neutrality by 2050 by shifting the current EU food system towards more sustainable models. The “Farm to Fork Strategy”, which is considered one of the fundamental elements of the Green Deal, is not limited to the food and agriculture sectors only, but also plays a central role in the transition process to a circular economy. Circular economy is a critical approach that strengthens the relationship between agriculture and rural development, and aims to increase sustainable resource management, waste reduction and economic resilience. Adopting circular methods in agricultural production has the potential to strengthen local economies by reducing input costs and environmental pressure on ecosystems. At the same time, it represents a transition from the traditional industrial approach to development to an inclusive development paradigm that focuses on sustainability and restoring the ecological balance that has been disrupted (Kadiogluvd., 2025). In this context, the utilization of organic waste through methods such as biogas and compost production, water reuse and the implementation of innovative agricultural techniques increase economic diversity in rural areas and promote sustainable development.

2. RESEARCH AND FINDINGS

This study adopted a qualitative research method to examine the integration of circular economy practices into the agricultural sector. During the research process, the theoretical framework regarding the circular economy was created by reviewing the existing literature, and the European Union's "Farm to Fork" strategy and other sustainable agricultural policies were analyzed.

During the data collection phase, an assessment was made on the effects of circular economy practices in agriculture by examining academic articles, official reports and documents published by regulatory bodies. In addition, various case studies were included to understand the applicability of circular economy models in agriculture in different regions.

The obtained data were examined with the descriptive analysis method and the effects of circular agricultural practices on economic, environmental and social dimensions were determined. The findings were compared with the existing policy frameworks and suggestions were made on strategies that will support the transition to circular economy in the agricultural sector.

2.1. Circular Economy

While the traditional linear economy model, characterized by the “take-make-dispose” approach, leads to rapid depletion of natural resources and environmental degradation, the circular economy has emerged as an alternative to this unsustainable structure. The Ellen MacArthur Foundation (EMF, 2013) defines the circular economy as "an economic system consisting of closed loops in which raw materials, components, and products maintain their quality and value for the longest possible time and systems are powered by renewable energy sources". In this context, the circular economy is not only limited to waste management, but also aims to increase material and energy efficiency and make production and consumption processes more sustainable.

One of the fundamental dynamics of the circular economy is the increasing global demand for raw materials and the environmental pressures associated with it. Moraga et al. (2019) emphasize that circular economy indicators play a critical role in assessing the impact on material consumption, waste volume, and greenhouse gas emissions. These indicators are used to measure the effectiveness of circular approaches and to guide policy makers and businesses towards sustainability goals. In order to successfully implement circular economy strategies, it is not enough to focus only on technical solutions; the economic and social dimensions of this transformation must also be taken into account.

The concept of circular economy has an interdisciplinary perspective and is addressed with different interpretations in various sectors. It is emphasized that circular economy discourses include different approaches and that these discourses are based on different priorities such as technological innovation, social justice and ecological sustainability (Friant et al., 2020). This diversity reveals that circular economy policies and practices should be shaped according to sectoral and regional contexts. Especially in the context of agriculture and rural development, circular economy has great potential in terms of waste management, increasing soil fertility and improving biological cycles. Research conducted since the mid-20th century has revealed the importance of reducing waste and increasing resource efficiency by extending the life of products (Arruda, 2021). Especially in the 1970s and 1980s, the idea that the linear economy model was not sustainable in the long term became widespread and studies on the effective management of resources increased. During this period, the "closed loop economy" approach developed by Stahel and Reday-Mulvey stood out as a system that includes maintenance, repair

and reproduction processes, and the economic and ecological advantages of this model were emphasized (Friant et al., 2020).

Since the 1990s, the concept of circular economy has become more widely adopted in politics and business, and McDonough and Braungart's (2002) "Cradle to Cradle" approach has brought a new perspective on how material cycles can be optimized within sustainable systems. The European Union's implementation of circular economy principles in environmental policies has contributed to the spread of this transformation at the global level (Velenturf& Purnell, 2021).

2.2. The 3R Principle and Its Scope in the Circular Economy Context

The concept of the circular economy has emerged as a transformational approach that aims to promote sustainable development by addressing the limitations of the traditional linear economy. The linear model, characterized by the "take-make-dispose" model, leads to significant depletion of resources and environmental degradation. In contrast, the circular economy aims to create closed-loop systems where resources are reused, reproduced and recycled, thus minimizing waste and reducing environmental impact (Urbinati et al., 2017). The circular economy emphasizes the importance of designing products and processes that facilitate resource efficiency and sustainability, and encourages the transition from ownership to access and performance-based business models. This approach, which forms the basis of the circular economy, requires strategies that ensure efficient use of resources and minimize waste. One of these strategies is the "Reduce, Reuse, Recycle" principles, known as the 3R (the initials of the English concepts of Recycle, Reuse and Reduce). By utilizing the 3R principles, optimum production is aimed by using reduced natural resources and creating minimum pollution, emissions and waste (Gedik, 2020). In addition, 3R offers a framework that encourages sustainable transformations in production and consumption processes, not just waste management, in the circular economy approach (Geisendorf and Pietrulla, 2018).

Within the framework of the circular economy, the first R, "reduction", represents the eco-efficiency effort in both production and consumption processes. The concept of eco-efficiency is expressed as more product and service delivery or more economic and environmental efficiency with less energy and fewer natural resources (Güngör and Felekoğlu, 2018). This approach aims to provide economic and environmental improvements through the efficient use of resources. Although eco-efficiency targets do not directly address the social dimension, the efficient use of resources indirectly increases social welfare by ensuring that more resources are left for future generations.

The second R in the circular economy, "reuse", requires that products and business models be designed in accordance with the "disassembly and reuse" cycle. Reuse aims to extend the life cycle of products and reduce resource consumption and waste. Reuse also includes the full or partial evaluation of waste through repair, renewal or remanufacture, or in the production of other products. This process is an important tool in achieving resource efficiency and sustainability goals (Wang et al. 2014; Yong, 2007). The third R, "recycle", refers to the reprocessing of waste materials for original or different purposes. Recycling provides effective reuse of resources through direct use of waste or functionalization of waste recovery. This process includes the reprocessing of organic materials, but does not include activities such as

energy recovery or processing for use in landfill. In the context of the circular economy, recycling supports the goals of resource conservation and waste reduction, while also encouraging the use of renewable energy solutions (EMF, 2015). In this respect, recycling makes significant contributions to reducing natural resource consumption and increasing environmental sustainability.

Li et al. (2011) conducted a study on the agricultural circular economy model in the Erhai Lake Basin of China. The study evaluated sustainable development strategies based on the 3R principle, which includes the principles of reduce, reuse and recycle. The study analyzed the current agricultural practices in the region and revealed that the application of the 3R principles could make significant contributions to reducing environmental impacts and increasing resource efficiency. It was also emphasized that preferring approaches such as the integrated energy use model, ecological animal husbandry model, integrated agricultural waste use model and agricultural eco-tourism model would help control widespread agricultural pollution at its source and support the construction of an environmentally friendly ecological agriculture system that saves resources. In general, the 3R principle is not limited to waste management alone, but is also a critical tool for restructuring production and consumption processes in accordance with the circular economy approach. The effective application of the recycling principle is of strategic importance in terms of both reducing environmental impacts and increasing economic and social benefits.

2.3. Key Differences Between Linear and Cyclic Models

The transition from a linear economy to a circular economy means a fundamental change in resource management, product design and the perception of waste. In a linear economy, resources are extracted, transformed into products, used and then disposed of following a "take-make-dispose" model that emphasizes short-term economic gains over long-term sustainability (van Langen, 2021). In contrast, the circular economy aims to redefine growth by emphasizing social benefits. It focuses on designing products with their lifespan in mind, thus encouraging reuse, repair, renovation and recycling to establish a closed-loop system that minimizes waste. The main distinction between these models is the resource efficiency and waste management approaches. The linear model often leads to inefficient resource use, causing significant waste and environmental damage. In contrast, the circular model focuses on preserving the value of products, materials and resources within the economy for as long as possible. Using strategies such as product life extension, remanufacturing and recycling, the circular economy helps reduce environmental impact while offering economic advantages through cost savings and the development of new business opportunities.

In addition, the circular economy requires a fundamental change in business models. Companies in the circular framework must innovate to produce durable, repairable and recyclable products. Unlike the linear model, where product design focuses on reducing production costs and increasing sales volumes without considering environmental impacts, the circular model encourages sustainable practices. This includes designing products for longevity and recyclability, which can increase customer loyalty and create new market opportunities (van Langen, 2021). In essence, the transition from a linear economy to a circular economy

requires a comprehensive rethinking of production and consumption patterns. It requires collaboration across sectors and disciplines to develop and implement sustainable solutions that balance economic, environmental and social goals. The circular economy continues to gain traction and promises a more sustainable and resilient future.

As a result, the circular economy, unlike traditional linear economic models, encourages more efficient use of natural resources and production and consumption models that are compatible with sustainable development principles. Circular economy strategies that can be implemented in the agricultural sector can support rural development and provide a balance between economic growth and environmental sustainability. Dimitrov and Ivanova (2017) evaluated the development of organic agriculture in Bulgaria within the framework of the circular economy and examined the contributions of this approach to sustainable rural development. The study emphasized that organic agriculture is a growing sector in Europe and around the world and that consumer demand is increasing steadily. In this context, it was stated that organic agricultural enterprises and cultivated areas in Bulgaria have expanded significantly in recent years. In this context, it was concluded that the integration of organic agriculture with circular economy principles can promote rural development and provide long-term environmental benefits. Future studies can contribute to the development of more comprehensive strategies for policy makers by analyzing the social and economic impacts of circular economy practices in rural areas.

3. RESULT

The circular economy is of critical importance in terms of the relationship between agriculture and rural development, sustainable resource management, reducing waste and increasing economic resilience. Circular approaches in agricultural production offer significant opportunities to reduce input costs, reduce pressure on ecosystems and strengthen local economies. Evaluation of organic waste with methods such as biogas and compost production, water reuse and innovative agricultural techniques increase economic diversity in rural areas and encourage development. However, policy makers, farmers and the private sector need to act in cooperation in order to integrate the circular economy into agriculture and make it supportive of rural development. Adoption of technological innovations, establishment of financial incentive mechanisms and raising awareness of farmers will ensure the successful implementation of the circular economy in the agricultural sector.

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EFFECTS OF LEGISLATIVE CHANGES IN THE REGISTRATION OF PLANT VARIETIES ON COOL SEASON CEREALS

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ABSTRACT

It is of great importance to carry out comprehensive and multi-environmental Value for cultivation and use (VCU) experiments of the new candidate varieties, to register the ones with superior characteristics, to produce seeds and to deliver them to farmers. In addition, it is necessary to determine whether a candidate variety has the characteristics of a variety by performing distinctness, uniformity and stability (DUS) tests. The registration system in field crops is based on two basic principles: DUS tests and VCU experiments. In Türkiye, the Seed Law (No. 5553) was published in 2006 and many new practices have been implemented with the legislation enacted based on this law. The Regulation on the Registration of Plant Varieties was also issued in 2008, but revisions were made in the following years. Finally, the Regulation on the Registration of Plant Varieties was amended with the same name in 2024 and put into force as a new regulation. In this new regulation, the most important change made in the registration of field crops is the separation of plant species to be registered by conducting VCU. Among the cool season cereals, VCU experiments will be conducted in barley, bread and durum wheat, while registration procedures based only on DUS tests will be carried out in other cool season cereals. Varietal trueness tests have been introduced for the registration in Türkiye of varieties that have been registered in a member country of the International Union for the Protection of New Varieties of Plants and for which DUS tests have been conducted according to UPOV rules. Many new rules have been included in the latest regulation to facilitate the work and procedures of applicants and the Variety Registration and Seed Certification Center (VRSCC). VCU experiments in cool season cereals are carried out regionally and the number of locations should be increased especially in Central Anatolia, which is the most important region of Türkiye in wheat and barley agricultural production. In addition, the number of experiment locations where quality analyzes are carried out should be increased and disease tests should be carried out under artificial epidemic conditions. Plant varieties have a strategic

importance in the agricultural production of countries and it should be ensured that the VRSCC, which tests the performance and characteristics of new candidate varieties, has a strong structure.

Keywords: Registration, Distinctness, Uniformity, Stability, Value for cultivation and use

BİTKİ ÇEŞİTLERİNİN KAYIT ALTINA ALINMASINDA YAPILAN MEVZUAT DEĞİŞİKLİKLERİNİN SERİN İKLİM TAHILLARINA ETKİLERİ

ÖZET

Islah edilen yeni çeşit adaylarının, Tarımsal Değerleri Ölçme (TDÖ) denemelerinin kapsamlı ve çok çevreli yürütülmesi, üstün özelliklere sahip olanlarının tescil edilerek tohumluk üretiminin yapılması ve çiftçilere ulaştırılması büyük önem taşımaktadır. Aynı zamanda bir çeşit adayının Farklılık, Yeknesaklık ve Durulmuşluk (FYD) testlerinin yapılarak çeşit vasfı taşıyıp taşımadığının belirlenmesi gerekmektedir. Tarla bitkilerinde tescil sistemi, FYD testleri ve TDÖ denemeleri olmak üzere iki temel esasa dayanmaktadır. Türkiye'de 2006 yılında Tohumculuk Kanunu yayınlanmış ve bu kanuna istinaden çıkarılan mevzuatlarla birçok yeni uygulama hayata geçirilmiştir. Bitki Çeşitlerinin Kayıt Altına Alınması Yönetmeliği de 2008 yılında çıkarılmış ancak daha sonraki yıllarda yönetmelik üzerinde revizyonlar yapılmıştır. Son olarak Bitki Çeşitlerinin Kayıt Altına Alınması Yönetmeliği 2024 yılında aynı isimle değiştirilerek yeni bir yönetmelik olarak yürürlüğe sokulmuştur. Bu yeni yönetmelikte tarla bitkilerinin tescilinde yapılan en önemli değişiklik, TDÖ yapılarak tescil edilecek bitki türlerinin ayrılmasıdır. Serin iklim tahıllarından arpa, ekmeklik ve makarnalık buğdayda TDÖ denemeleri yapılacak, diğer serin iklim tahıllarında ise sadece FYD testlerine dayalı tescil işlemleri yürütülecektir. Uluslararası Yeni Bitki Çeşitlerinin Korunması Birliği (UPOV) üyesi bir ülkede tescil edilmiş ve FYD testleri UPOV kurallarına göre yapılmış çeşitlerin Türkiye'de tescilinde çeşit doğrulama testleri uygulaması getirilmiştir. Uygulamada başvuru sahipleri ve Tohumluk Tescil ve Sertifikasyon Merkez Müdürlüğü'nün (TTSM) iş ve işlemlerini kolaylaştıracak birçok yeni hüküm son çıkarılan yönetmelikte yer almıştır. Serin iklim tahıllarında TDÖ denemeleri bölgesel olarak yürütülmekte olup, özellikle ülkemizin buğday ve arpa tarımsal üretiminde en önemli bölgesi olan Orta Anadolu'da lokasyon sayısı arttırılmalıdır. Buna paralel olarak kalite analizlerinin yapıldığı lokasyon sayısı da arttırılarak, yapay epidemi koşullarında hastalık testleri yapılmalıdır. Bitki çeşitleri ülkelerin tarımsal üretimlerinde stratejik bir öneme sahip olup, yeni çeşit adaylarının performanslarını ve özelliklerini test eden TTSM'nin güçlü bir yapıya sahip olması sağlanmalıdır.

Anahtar Kelimeler: Tescil, Farklılık, Yeknesaklık, Durulmuşluk, Tarımsal değerleri ölçme

1. GİRİŞ

Ülkemizde çeşit tescilinin bilimsel ve teknik kurallar çerçevesinde yürütülebilmesi için ilk girişimler 1960 yılında Bölge Çeşit Deneme Enstitüsü'nün kurulmasıyla başlamıştır. Türkiye, 1963 yılında tohumculuk konusunda ilk yasal mevzuatlarını çıkarmaya başlamış ve uzun yıllar yürürlükte kalacak olan 308 Sayılı Tohumlukların Tescil, Kontrol ve Sertifikasyonu Hakkında Kanun kabul edilerek yürürlüğe girmiştir. 1986 yılında yapılan yasal bir düzenleme ile Tohumluk Kontrol ve Sertifikasyon Enstitüsü ile Bölge Çeşit Deneme Enstitüsü birleştirilmiş, bundan bir yıl sonra ise kuruluş Tohumluk Tescil ve Sertifikasyon Merkez Müdürlüğü adını almıştır. Bitki çeşitlerinin tanımlanması ve Farklılık, Yeknesaklık ve Durulmuşluk testlerinin yapılmasında uluslararası kural ve yöntemleri ortaya koyan UPOV'a (Uluslararası Yeni Bitki Çeşitlerini Koruma Birliği) 18 Kasım 2007 tarihinde Türkiye üye olmuştur. 2000'li yılların başında tohumculuk konusunda önemli gelişmeler olmuş ve ilk olarak 2004 yılında 5042 Sayılı Yeni Bitki Çeşitlerine Ait Islahçı Haklarının Korunmasına İlişkin Kanun çıkarılmıştır (Anonim, 2004). Bunu 2006 yılında kabul edilerek yürürlüğe sokulan 5553 Sayılı Tohumculuk Kanunu izlemiştir.

2006 yılında kabul edilen 5553 Sayılı Tohumculuk Kanunu ile uzun yıllar boyunca tohumculuk sektöründeki iş ve işlemlerin kurallarını belirleyen 308 Sayılı Kanun yürürlükten kalkmıştır. Tohumculuk Kanunu incelendiğinde, çeşit tescili ve tohumlukların sertifikasyonundan daha çok, Türkiye Tohumcular Birliği ve alt birliklerin kuruluşu, çalışma usul ve esaslarına yönelik hükümler içermektedir (Anonim, 2006). Tohumculuk Kanuna istinaden 2008 yılında Bitki Çeşitlerinin Kayıt Altına Alınması Yönetmeliği çıkarılarak çeşit tescil işlemleri 2024 yılına kadar bu yönetmelik hükümlerine göre yürütülmüştür. 17 Eylül 2024 tarihinde çıkarılan yeni Bitki Çeşitlerinin Kayıt Altına Alınması Yönetmeliği ile çeşit tescilinde önemli değişiklikler yapılmıştır (Anonim, 2024).

Ülkemizde milli çeşit listesinde tarla bitkileri grubunda toplam 3724 tescilli çeşit bulunmakta ve bunun %21.6'sını (806 adet çeşit) serin iklim tahıllarına ait çeşitler oluşturmaktadır (MÇL, 2025). Toplam tescilli çeşit sayısında en büyük oranı mısır, ayçiçeği ve bunlara ait ebeveyn hatlar oluşturmaktadır. 299 mısır ve 170 ayçiçeği çeşidi yanında, bu çeşitlere ait 976 adet ebeveyn hattı milli çeşit listesinde bulunmaktadır. Tarla bitkileri grubunda üretim izinli 820 çeşit bulunmaktadır ve bunun 162'si serin iklim tahıllarına aittir.

Serin iklim tahılları içerisinde ekmeklik buğdayda (*Triticum aestivum* L.) 441 adet, arpada (*Hordeum vulgare* L.) 194 adet, makarnalık buğdayda (*Triticum durum* Desf.) 108 adet, tritikalede (*Triticosecale*) 32 adet, yulafta (*Avena sativa* L.) 23 adet, kaplıca buğdayında (*Triticum monococcum* L.) 3 adet, kavılca buğdayında (*Triticum dicoccum* L.) 3 adet, kavuzlu buğdayda (*Triticum spelta* L.) 2 adet tescilli çeşit bulunmaktadır.

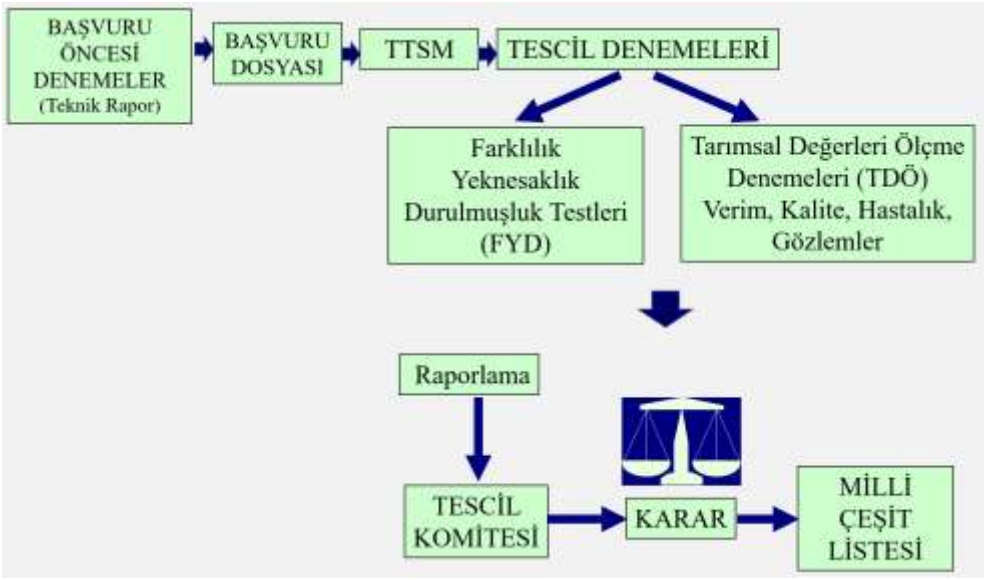
Ülkemizin son 35 yıllık buğday ekiliş alanı ve üretim miktarları üzerinde değerlendirme yapılacak olursa, 9.5 milyon hektar olan üretim alanının yıldan yıla düşerek 6.8 milyon hektarlara inmiştir (TÜİK, 2023). Ekiliş alanındaki düşüşe rağmen ülkemizde yıldan yıla değişmekle birlikte yaklaşık 20 milyon ton buğday üretimi yapılmaktadır. Yaklaşık 2.5 milyon hektarlık ekiliş alanındaki azalmaya karşın üretim miktarının düşmemesi ve hatta artmasındaki en büyük faktör birim alan tane verimindeki artıştır. Bunun da en önemli sebebi geliştirilen yeni çeşitlerin üretime girmesi ve verim seviyesini yükseltmesidir. Çeşitler ülkelerin milli değerleri

arasında yer almaktadır ve stratejik öneme sahiptir (Dönmez ve ark., 2008). Serin iklim tahılları Türkiye'nin sahip olduğu ekolojinin de etkisi ile en önemli tarımsal ürünlerinin başında gelmektedir. Bu çalışmada, çeşit tescil sisteminde ve teknik uygulamalardaki değişikliklerin çeşit geliştirme çalışmaları ile tescilindeki etkileri incelenerek değerlendirmeler yapılmıştır.

2. SERİN İKLİM TAHILLARINDA ÇEŞİT TESCİL SİSTEMİ

Ülkemizde tescil sisteminde bitkiler 4 grupta (Tarla bitkileri, meyve ve asma, sebze ve süs bitkileri) değerlendirilmektedir. Tarla bitkileri dışındaki bitki gruplarında sadece Farklılık, Yeknesaklık ve Durulmuşluk (FYD) testleri yapılarak kayıt altına alınmaktadır. Tarla bitkilerinde ise tescil sistemi FYD testleri ile Tarımsal Değerleri Ölçme (TDÖ) denemeleri olmak üzere iki ana temele dayanmaktadır (Şekil 1). FYD denemeleri Uluslararası Yeni Bitki Çeşitlerinin Korunması Birliği (UPOV) tarafından ortaya konulan kural ve yöntemlere göre TTSM tarafından yapılmaktadır.

Tescil başvurusunda bulunacak gerçek kişi veya kuruluşlar çeşit adayının gelişme tabiatına uygun bir yetiştirme dönemi iki lokasyonda veya bir lokasyonda iki yetiştirme dönemi olacak şekilde denemeler kurması gerekmektedir. Söz konusu denemeler bir araştırma kuruluşu tarafından yürütülerek raporlanmalıdır. Bu denemelerdeki amaç; çeşit sahibinin tescil başvurusunda bulunmadan önce, aday çeşidin yaygın yetiştirilen ve çeşit adayının özelliklerine uygun standart çeşitlerle yarıştırılmasıdır. Yani öncelikle başvuru sahibinin aday çeşidini tanıması ve üstün özelliklere sahip ise tescil başvurusunda bulunmasını sağlamaktır.



Şekil 1. Serin iklim tahıllarında tescil sisteminin genel aşamaları

Başvuru dilekçesi, çeşide ait teknik bilgi-belgeler ve ücret dekontundan oluşan başvuru dosyası ile ağustos ayı içerisinde tescil başvurusu yapılmaktadır. Tohumluk üretici kuruluşlar, gerçek

kişiler ya da bir araştırma kuruluşu tarafından geliştirilmiş çeşitler için tescil başvurusu yapabilmektedir. Başvuru dosyasında herhangi bir eksiklik yok ise TTSM tarafından çeşit adayı tescil denemelerine alınmaktadır. FYD testleri UPOV üyesi bir ülkede, UPOV yöntem ve kurallarına göre yapılmış ise çeşit adayı TDÖ denemelerine alınmaktadır. 2024 yılında yönetmelikte yapılan değişiklik ile serin iklim tahıllarında sadece arpa, ekmeklik buğday ve makarnalık buğdayda TDÖ denemeleri yapılmaktadır. Bitkisel Üretim Genel Müdürlüğü tarafından yayınlanan TDÖ yapılacak bitki türleri listesi bitki grupları bazında Çizelge 1'de verilmiştir (BÜGEM, 2025). TDÖ yapılmayacak diğer serin iklim tahıllarında FYD testleri UPOV kurallarına göre yapılmış olsa da bir yetiştirme dönemi doğrulama testlerine alınması hükmü getirilmiştir.

Çizelge 1. Tarımsal Değerleri Ölçme Denemeleri (TDÖ) yapılarak kayıt altına alınacak tarla bitkileri tür listesi

Serin iklim tahılları	
Arpa	*Hordeum vulgare* L.
Ekmeklik buğday	*Triticum aestivum* L.
Makarnalık buğday	*Triticum durum* Desf.
Sıcak iklim tahılları	
Çeltik	*Oryza* spp. L.
Mısır	*Zea mays* L.
Çayır mera yem bitkileri	
Adi fiğ	*Vicia sativa* L.
İtalyan çimi	*Lolium multiflorum* Lam.
Korunga (Mera tipi hariç)	*Onobrychis viciifolia* Scop.
Macar fiğ	*Vicia pannonica* Crantz
Yem bezelyesi	*Pisum sativum* ssp. *arvense* (L.) Poir
Yonca (Mera tipi hariç)	*Medicago sativa* L.
Endüstri bitkileri	
Ayçiçeği	*Helianthus annuus* L.
Kolza	*Brassica napus* L.
Pamuk	*Gossypium* spp.
Patates	*Solanum tuberosum* L.
Soya	*Glycine max* (L.) Merr.
Şeker pancarı	*Beta vulgaris* L.
Yemeklik baklagiller	
Kuru fasulye	*Phaseolus vulgaris* L.
Mercimek	*Lens culunaris* L.
Nohut	*Cicer arietinum* L.

FYD testlerinde UPOV tarafından oluşturulmuş çeşit özellik belgelerine göre ekmeklik buğdayda (*Triticum aestivum* L. emend. Fiori et Paol.) 27, makarnalık buğdayda (*Triticum turgidum* L. subsp. *durum* Desf. Husn.) 28, arpada (*Hordeum vulgare* L.) 29, yulafta (*Avena sativa* L. ve *Avena nuda* L.) 22, tritikalede (×*Triticosecale* Witt.) 24, çavdarda (*Secale cereale* L.) 21 karakter bakımından gözlemler alınmakta ve çeşit adaylarının özellik belgeleri hazırlanmaktadır (UPOV, 2025)

Serin iklim tahıllarında TDÖ denemeleri bölgesel bazda yürütülmektedir (SİTTT, 2025). Ayrıca bölgenin genel yetiştirme tekniklerinde kuruda veya suluda yetiştiricilik yapılıyorsa, tescil denemeleri de bu şekilde iki farklı set halinde yapılmaktadır (Çizelge 2). Bu bölgeler dışında önemli bir husus da çeşit adayının gelişme tabiatıdır. Başvuru yapılan bölge ile çeşit adayının gelişme tabiatı uyumlu olmalıdır. Çeşidin gelişme tabiatı ile baharlık veya yazlık ekiliş için tescil başvurusu karıştırılmamalıdır. Örneğin yazlık bir arpa çeşidi için Orta Anadolu Bölgesi yazlık ekiliş için tescil başvurusu yapılabilir.

Çizelge 2. Serin iklim tahıllarında TDÖ denemelerinin yürütüldüğü bölgeler ve koşullar

Deneme bölgesi	**Koşullar**
1. Doğu Anadolu Bölgesi	Doğal yağış ve sulu koşullar
2. Orta Anadolu Bölgesi	Doğal yağış ve sulu koşullar
3. Güneydoğu Anadolu Bölgesi	Doğal yağış ve sulu koşullar
4. Akdeniz Bölgesi	Doğal yağış
5. Güney Marmara ve Ege Bölgesi	Doğal yağış
6. Karadeniz Bölgesi	Doğal yağış
7. Trakya Bölgesi	Doğal yağış

TTSM iş birliği yaptığı araştırma enstitüleri ile TDÖ denemelerini iki yetiştirme dönemi süresince yürütmekte; tarla gözlemleri, kalite analizleri ve verim sonuçlarına göre bir sonuç raporu hazırlamaktadır. FYD testlerinde çeşit adayı başarısız olmuşsa, TTSM FYD sonuç raporunu başvuru sahibine göndermekte ve çeşit adayının tescil işlemleri sonlandırılmaktadır. FYD testlerinde başarılı olan çeşit adayları için hazırlanan rapor mart veya nisan aylarında tescil komitesine sunulmaktadır. Tarla Bitkileri Tescil Komitesi'ni oluşturan üyeler ve temsilci sayıları Çizelge 3'de verilmiştir (Anonim, 2024).

Çizelge 3. Tarla Bitkileri Tescil Komitesi üyeleri ve temsilci sayıları

Üye kurum/kuruluş	Temsilci sayısı
Bitkisel Üretim Genel Müdürlüğü	1
Ziraat Fakültesi	1
Kamu Tarımsal Araştırma Enstitüsü	1
TTSM	2
Türkiye Tohumcular Birliği	2
Türkiye Ziraat Odaları Birliği	1
İlgili Sanayi Sektörü	1
Toplam	**9**

Tescil komitesine, şartları ilgili yönetmelikte belirtilen özellikte danışman üye de davet edilebilir. Danışman üyelerin oy kullanma hakkı bulunmamaktadır. Tescil komitesi en az 7 asıl üyenin katılımıyla toplanmakta ve toplantıya katılan asıl üyelerin üçte ikisinin olumlu oyu ile tescil kararı alınmaktadır. Komite çeşit adayını bütün yönleriyle değerlendirmekte, ekonomik değer ifade eden bir veya birkaç karakter bakımından TDÖ'deki kontrol çeşitler ortalamasına eşdeğer ya da üstün çeşit adaylarını tescil etmektedir. Tescil kararı verilen çeşide başvuru sahibinin önerdiği ve komite tarafından ilgili hükümlere göre uygun görülen bir isim verilir. TTSM tarafından ilan edilen miktar ve kriterlere uygun standart numune, başvuru sahibi tarafından TTSM'ye teslim edildikten sonra çeşit milli çeşit listesinde yayınlanmaktadır. Böylece çeşidin ülkemizde sertifikalı tohumluk üretim ve ticareti yapılabilmektedir.

3. BİTKİ ÇEŞİTLERİNİN KAYIT ALTINA ALINMASI YÖNETMELİĞİNDEKİ ÖNEMLİ DEĞİŞİKLİKLER VE ETKİLERİ

17 Eylül 2024 tarih ve 32665 sayılı Resmî Gazete'de yayımlanarak yürürlüğe giren Bitki Çeşitlerinin Kayıt Altına Alınması Yönetmeliği'nde; uygulamalardaki zorlukları giderecek, sürecin hızlı ve etkin yürümesini sağlayacak değişiklikler yanında teknik konularda da önemli değişiklikler yapılmıştır. Tarla bitkileri çeşitlerinin kayıt altına alınması ile ilgili yapılan önemli değişiklikler ve bunların etkilerinin değerlendirilmesi aşağıda yapılmıştır.

Tescil başvurusunun yapılmasından tescil süreci sonlanıncaya kadar TTSM ile başvuru sahibi kişi, kurum veya kuruluşlarla birçok yazışma yapılmaktadır. Bu süreci hızlandırmak ve daha sağlıklı yürütmek için tescil başvuru sahiplerine Kayıtlı Elektronik Posta (KEP) adresi edinmeleri zorunluluğu getirilmiştir. KEP ile elektronik iletilerin gönderimi ve teslimatı hukukî delil niteliğinde olup, böylece yapılacak yazışma ve tebligatlar konusunda firmalar ile TTSM arasında daha hızlı ve etkin bir haberleşme sistemi kurulmuş olmaktadır.

Yeni yönetmelikteki en önemli değişikliklerin başında TDÖ denemeleri yapılacak bitki türlerinin ayrılması gelmektedir. Tarla bitkilerinde TDÖ denemeleri yapılacak bitki türlerini belirleme yetkisi Bitkisel Üretim Genel Müdürlüğü'nde (BÜGEM) olup, yayınlanan TDÖ yapılacak bitki tür listesi Çizelge 1'de verilmiştir. Serin iklim tahılları ülkemizin tarımsal alanlarında en fazla ekiliş alanına sahip türleri kapsamaktadır. Arpa, ekmeklik ve makarnalık buğdayda TDÖ denemeleri yapılmaya devam edilecektir. Ancak yulaf, tritikale, çavdar ve diğer serin iklim tahılları bitki grubunda yer alan türlerde (Karabuğday, kaplıca buğdayı, kavuzlu buğday, kavılca buğdayı, tritordeum) TDÖ denemeleri yapılmayacaktır. Yurtdışında VCU denemeleri (Value for Cultivation and Use) olarak isimlendirilen TDÖ denemelerinin amacı; çok geniş alanlarda tarımı yapılan ve ülke üretiminde stratejik öneme sahip bitki türlerinde üstün çeşitlerin kullanımının sağlanması ve çeşit kaynaklı üretim kayıplarının önüne geçilmesidir. BÜGEM tarafından serin iklim tahılları bitki grubunun en fazla ekiliş alanı ve üretime sahip türleri olan arpa, ekmeklik ve makarnalık buğdayda TDÖ denemelerine devam edilmesi yönünde karar verilmiştir. Bu türlerle karşılaştırıldığında yulaf, tritikale ve çavdarda ülkemiz ekiliş alanı ve üretimi oldukça sınırlıdır. Çavdarda şu an milli çeşit listesinde hiçbir çeşit yer almamaktadır. Bu veriler doğrultusunda, TDÖ denemelerinin yapılacağı serin iklim tahılları türlerinin seçiminde ülke tarımsal üretiminin korunması ve geliştirilmesi bakımından doğru tercihlerde bulunulduğu söylenebilir.

TDÖ denemeleri yapılmadan sadece FYD testlerine göre kayıt altına alınacak bitki türlerinde, bir çeşit UPOV üyesi bir ülkede tescil edilmiş ve FYD testleri UPOV kurallarına göre yapılmış ise; bir yetiştirme dönemi doğrulama testlerine alınması hükmü getirilmiştir. Yürürlükten kalkan yönetmelikte yurtdışında FYD testleri yapılmış çeşit adaylarının TDÖ denemelerinde, FYD kriterlerinde bir problem görülmesi durumunda tescil işlemlerinin sonlandırılması şeklinde bir uygulama yapılmaktaydı. Başvuru sahibinin talep etmesi durumunda, çeşit adayı FYD testlerine alınmak şartıyla tekrar tescil başvurusunda bulunabilmekteydi. Yeni yönetmelikte de benzer uygulama devam etmekte olup, TDÖ denemelerinde çeşidin karakterleri ile çeşit özellik belgesinde uyumsuzluk görülmesi durumunda, başvuru sahibi, durumdan yazılı olarak haberdar edilmekte ve çeşit adayı FYD testlerine alınmaktadır.

Serin iklim tahıllarında geçmişte temmuz ve ağustos aylarında tescil başvurusu yapılabilirken, yeni yönetmelikte tescil başvuruları sadece ağustos ayında yapılabilmektedir. Söz konusu durumun büyük bir etkisi olmayacaktır. Serin iklim tahıllarında hasat zamanı bölgelere göre değişmekle birlikte ağırlıklı olarak temmuz ayında yapılmaktadır. Başvuru öncesi denemelerin hasatlarının yapılarak kalite analizlerinin tamamlanması temmuz ayı başvuru dönemine yetişmemekte ve tescil başvurularının tamamına yakını ağustos ayında yapılmakta idi. Bu nedenle son değişiklik uygulamada bir problem veya hak kaybı oluşturmayacaktır.

Geçmişte TDÖ denemelerinde standart veya kontrol çeşitleri başvuru sahibi önerisi ile TTSM belirlerken, güncel yönetmelikte bu yetki tamamen TTSM'ye verilmiştir. Söz konusu değişikliğin olumsuz bir etkisi öngörülmemektedir. Ayrıca TTSM'nin TDÖ denemelerini yürütmekte zorlandığı bölge ve durumlarda başvuru sahibinden denemelerin yürütülmesinde lokasyon ve imkanları sağlaması istenebilecektir.

Tarla bitkilerinde tescil komitesinin yapısında önemli bir değişiklik yapılmamıştır. Tohum Sanayicileri ve Üreticileri Alt Birliği ile Bitki Islahçıları Alt Birliği komite üyesiyken, yeni mevzuatta 2 üye için Türkiye Tohumcular Birliği'nin üye göndermesi hükmü getirilmiştir.

Geçmişte kayıt süresi uzatımında özellikle serin iklim tahıllarında problemler yaşanabilmekteydi. Yapılan değişiklikle kayıt süresi uzatımında FYD testleri zorunluluğu kaldırılmıştır. Eğer çeşit listeden düşmemiş ise dilekçe ve ücret dekontu ile kayıt süresi uzatılabilecektir. Çeşit milli çeşit listesinden düşmüş ise FYD testlerine alınması hükmü yeni mevzuatta yer almıştır.

Deneme materyallerinin TTSM'ye teslim edilmesinde birçok bitki türünde problemler yaşanmıştır. Eski mevzuatta iki yetiştirme dönemi tohumluk materyal teslim edilmediğinde tescil işlemleri sonlandırılmaktaydı. Yeni mevzuatta deneme materyalinin herhangi bir yetiştirme döneminde teslim edilmemesi durumunda çeşit adayının tescil işlemleri sonlandırılacağına dair hüküm getirilmiştir. Eski mevzuattaki uygulama, TTSM için denemeleri yürütmede ve raporlamada büyük yük getirmekteydi. Bazı başvuru sahipleri ise üretim izni süresini uzatmak için kasıtlı olarak numune vermeme yolunu tercih etmekteydi. Yeni hüküm birçok problemi ortadan kaldıracak ve başvuru sahiplerini daha dikkatli davranmaya sevk edecektir.

Yukarıda açıklanan değişiklikler dışında, Bitki Çeşitlerinin Kayıt Altına Alınması Yönetmeliği'nde başvuru sahipleri ve TTSM'ye bürokratik ve teknik konularda kolaylık sağlayacak birçok değişiklik yapılmıştır.

4. SERİN İKLİM TAHILLARI TESCİL DENEMELERİNDEKİ TEKNİK UYGULAMALARIN DEĞERLENDİRİLMESİ

Serin iklim tahılları ülkemiz tarımında önemli bir yere sahip olması nedeniyle, yeni geliştirilen çeşitlerin tescil denemelerinin bilimsel ve teknik kurallara uygun yapılması stratejik bir öneme sahiptir. TTSM özellikle TDÖ denemelerini kamu tarımsal araştırma enstitüleri ile iş birliği içinde yürütmektedir. Tescil raporlarındaki deneme sonuçları incelendiğinde, TDÖ denemelerinde lokasyon sayılarında düşüşler görülmektedir. Ülkemizin en önemli serin iklim tahılları tarımının yapıldığı Orta Anadolu Bölgesinde yıllık lokasyon sayısının 3 civarında olduğu görülmektedir. Orta Anadolu Bölgesinin tümünü örnekleyecek sayıda lokasyon sayısına ulaşılması, çeşit adaylarının performanslarının daha doğru belirlenebilmesi için uygun olacaktır. Son yıllarda iklim koşullarında yaşanan ekstrem durumlar, deneme maliyetlerinin artması, TDÖ denemelerindeki çeşit sayılarının artması ve enstitülere büyük iş yükü getirmesi, başvuru sahiplerinin denemeler için yeterli tohumluk materyale sahip olmaması gibi nedenlerden dolayı TTSM lokasyon sayısında azaltmaya gitmek zorunda kalmaktadır.

TDÖ denemelerinde verim dışında özellikle kalite analizlerinin sayısında da büyük bir azalma söz konusudur. Geçmişte hemen hemen tüm lokasyonlar için kalite analizleri yapılırken, son yıllarda yetiştirme dönemi başına bir lokasyonda analiz yapılmaktadır. Analiz maliyetlerinin artması ve tescil başvuru ücretlerinin yetersiz kalması bu durumda en büyük faktör olarak görülmektedir.

Serin iklim tahıllarında yaşanan iklim değişikliğinin de etkisi ile hastalıklar daha önemli hale gelmiştir. Serin iklim tahıllarında hastalık testleri yapılmamakta, TDÖ denemelerinde tarla gözlemleri şeklinde çeşit adaylarının reaksiyonları belirlenmektedir. Yapılacak yönetmelik değişikliği ile tescil ücretlerine hastalık testleri için de ücretler eklenmeli ve hastalık testlerinin yapay epidemi koşullarında ilgili enstitü ve üniversiteler tarafından yapılmasının sağlanması gerekli görülmektedir.

SONUÇ

Serin iklim tahılları Türkiye'nin en önemli tarımsal ürünlerini oluşturan bitki grubudur. Biyotik ve abiyotik etmenlerin tarımsal üretimde öneminin arttığı yıllar yaşanmaktadır. Başta kuraklık olmak üzere stres faktörleri ile mücadelede en etkili, çevreci ve ekonomik yöntem, üstün genotiplerin geliştirilmesidir. Bitki ıslahçılarının uzun yıllar ve emek sarf ederek geliştirdiği yeni çeşitlerin en doğru şekilde test edilmesi ve böylelikle tarımsal, teknolojik ve hastalıklara dayanım özelliklerinin ortaya konulması büyük önem arz etmektedir. Bunun için de stratejik bir kurum olan TTSM'nin fiziki ve teknik kapasitesinin üst düzeye yükseltilmesi gerekmektedir.

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CHANGING CLIMATIC CONDITIONS AND BLACK POINT DISEASE IN COOL SEASON CEREALS

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ABSTRACT

Cool season cereals are the most widely cultivated plant group due to the ecological conditions in Türkiye. Wheat and barley are the two prominent species among cool season cereals and their cultivation in our country is mostly based on natural rainfall. Wheat provides raw materials for flour, pasta, bulgur, biscuits and other foodstuffs, and Türkiye is one of the leading exporters of flour and pasta in the world. Meteorological data, especially the amount of precipitation and its distribution during the growing period, is the main factor determining the amount of production and yield in wheat cultivation. The effects of global warming and climate change are also negatively affecting our country. Türkiye's average temperature between 1970 and 2024 was 13.3 °C, while 2024 was the warmest year recorded in this period with an average of 15.3 °C. Despite the upward trend in temperatures, the average rainfall and relative humidity continue to decline from year to year. Extreme conditions in meteorological data may cause an increase in fungal diseases that are effective in agricultural production. Black point disease, which manifests itself with brown and black discoloration in the area where the embryo is located in the kernel, is one of them. Biotic and abiotic factors can cause discoloration of the kernel. Among biotic factors, black point can be caused by pathogens such as *Alternaria* spp., *Cladosporium* spp., *Cochliobolus* spp., *Curvularia* spp. and *Fusarium* spp. Since black point affects the end product, many countries have imposed limitations on the proportion of infected grains in trade. Black point grains may pose a problem in flour and pasta production due to discoloration, and some fungal species may produce mycotoxins that are toxic and risky for humans and animals. Negative effects may also occur in the use of infected grains as seed material. Infected seeds may cause decreases in germination rate, germination power and emergence rate under field conditions. In the control of the disease, the breeding of resistant

varieties, which is the most economical and environmentally friendly method, should be given importance and care should be taken in irrigation during the grain filling period.

Keywords: Resistant genotypes, Relative humidity, Temperature, Precipitation

DEĞİŞEN İKLİM KOŞULLARI VE SERİN İKLİM TAHILLARINDA EMBRİYO KARARMASI

ÖZET

Serin iklim tahılları Türkiye'nin sahip olduğu ekolojik koşullar nedeniyle en fazla tarımı yapılan bitki grubudur. Serin iklim tahılları içerisinde buğday ve arpa öne çıkan iki cinstir ve ülkemizde daha çok doğal yağışa dayalı olarak yetiştiriciliği yapılmaktadır. Buğday; un, makarna, bulgur, bisküvi ve diğer gıda maddelerine hammadde sağlamakta olup, Türkiye un ve makarna ihracatında dünyada ilk sıralarda yer almaktadır. Meteorolojik veriler özellikle de yağış miktarı ve yağışın yetiştirme dönemindeki dağılımı buğday yetiştiriciliğinde üretim miktarını ve verimi belirleyen ana faktördür. Küresel ısınma ve iklim değişikliğinin etkileri ülkemizi de olumsuz etkilemektedir. Türkiye'nin 1970-2024 yılları arasındaki sıcaklık ortalaması 13.3 °C iken, 2024 yılı ortalaması 15.3 °C ile bu dönemde kaydedilmiş en sıcak yıl olmuştur. Sıcaklıklardaki artış trendine karşın, yağış miktarı ve oransal nem ortalamalarında yıldan yıla bir düşüş trendi devam etmektedir. Meteorolojik verilerdeki ekstrem durumlar, tarımsal üretimde etkili mantari hastalıkların da artışına sebep olabilmektedir. Tanede embriyonun bulunduğu bölgede, kahverengi ve siyah renk değişikliği ile kendini gösteren embriyo kararması hastalığı bunlardan birisidir. Biyotik ve abiyotik faktörler tanede renk bozulmasına neden olabilmektedir. Biyotik faktörler arasında embriyo kararmasına *Alternaria* spp., *Cladosporium* spp., *Cochliobolus* spp., *Curvularia* spp. ve *Fusarium* spp. gibi patojenler sebep olabilmektedir. Embriyo kararması son ürünü etkilediği için, birçok ülke ticarette enfekteli tane oranına yönelik sınırlamalar getirmiştir. Embriyo kararmasına uğramış taneler, renk bozulması nedeniyle un ve makarna üretiminde problem teşkil edebilmekte, ayrıca bazı mantar türleri insan ve hayvanlar için zehirli ve riskli mikotoksinler üretebilmektedir. Enfekteli tanelerin tohumluk materyal olarak kullanımında da olumsuzluklar ortaya çıkabilmektedir. Enfekteli tohumlar tarla koşullarında, çimlenme hızı, çimlenme gücü ve çıkış oranında azalmalara sebep olabilmektedir. Hastalıkla mücadelede en ekonomik ve çevreci yöntem olan dayanıklı çeşit ıslahına önem verilmeli, tane doldurma döneminde yapılacak sulamalarda dikkatli olunmalıdır.

Anahtar Kelimeler: Dayanıklı çeşit, Nispi nem, Sıcaklık, Yağış

1. GİRİŞ

Türkiye, tahıllarda 11.5 milyon hektar ekiliş alanına ve 39 milyon ton üretime sahiptir (TÜİK, 2024). Toplam üretim miktarında; buğday 20.8 milyon ton, arpa 8.1 milyon ton, mısır 8.1 milyon ton ve çeltik 1.0 milyon ton ile en önemli tarımsal ürünleri oluşturmaktadır. Diğer serin iklim tahıllarının (Yulaf, tritikale ve çavdar) yaklaşık 0,9 milyon tonluk üretim değeri mevcuttur. Ülkemizin sahip olduğu ekolojik koşullar serin iklim tahıllarının böylesine yaygın yetiştiriciliğinin temel nedenidir. Serin iklim tahılları tarımı ağırlıklı olarak doğal yağışa dayalı yapılmaktadır. Sulama imkanı olan alanlarda yoğun gübre kullanımı ile birlikte yüksek verim değerlerine de ulaşılabilmektedir. Buğday yetiştiriciliğinin yaklaşık %80'den fazlası doğal yağış koşullarında ve özellikle ülkemizin Orta Anadolu ve geçit bölgelerinde yapılmaktadır (Aydoğan ve Soylu, 2017).

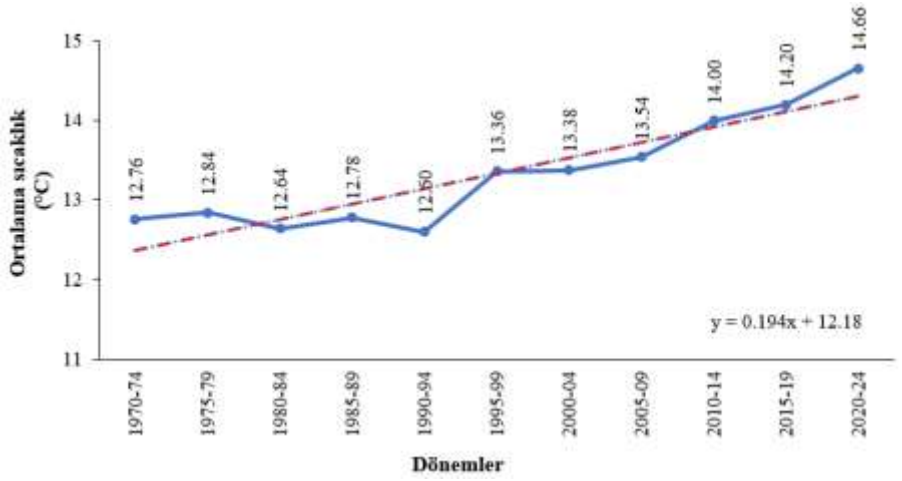
Ülkemiz buğday ekiliş alanı ve üretiminde olduğu kadar, buğdaya dayalı mamul üretiminde ve ihracatında dünyada önemli ülkelerden biridir. 2023 yılında toplam 3.66 milyon tonluk un ihracatından 1.47 milyar $ gelir elde etmiştir (TUSAF, 2023). Toplam makarna üretim kapasitesi 3 milyon ton kadar olup, 2023 yılında 907 bin tonluk ihracat miktarına ulaşılmıştır (TMSD, 2023). Dünyada makarna ihracatında Türkiye ikinci sırada konumlanmaktadır. Yine bulgur, bisküvi ve diğer mamul ürünler bakımından ülkemiz yüksek üretim ve ihracat değerlerine sahiptir.

Dünya nüfusundaki artışa paralel olarak artan gıda ihtiyacına karşın; savaşlar, salgın hastalıklar, iklim değişikliği ve diğer nedenlerden dolayı tarımsal üretimde dalgalanmalar yaşanmaktadır. 2008 ve 2009 yıllarında buğday ekiliş alanları benzer değerlerde iken, üretim miktarı 2008 yılında yaşanan kuraklıktan dolayı 17.8 milyon ton olurken, meteorolojik verilerin uzun yıllar ortalamalarının oldukça üzerinde olduğu 2009 yılında ise 20.6 milyon ton olarak gerçekleşmiştir (TÜİK, 2024). Bu durum ülkemizde buğday tarımının ağırlıklı olarak doğal yağışa dayalı yapılmasının da bir göstergesidir. Fazla yağışın ve ekstrem sıcaklık değerlerinin görüldüğü yıllarda ise görülen bitki fungal hastalıklarından kaynaklanan göreceli verim ve kalite kayıpları da ciddi problemler oluşturmaktadır. Birim alandan fazla tane verimi alınmasına yönelik olarak uygulanan yoğun girdi ve yetiştirme teknikleri, embriyo kararması gibi hastalıklara neden olmakta ve un, makarna, bulgur vs. mamul maddelerin üretiminde olumsuzluklar oluşturmaktadır.

2. TÜRKİYE'DE İKLİMSEL VERİLERDEKİ DEĞİŞİM

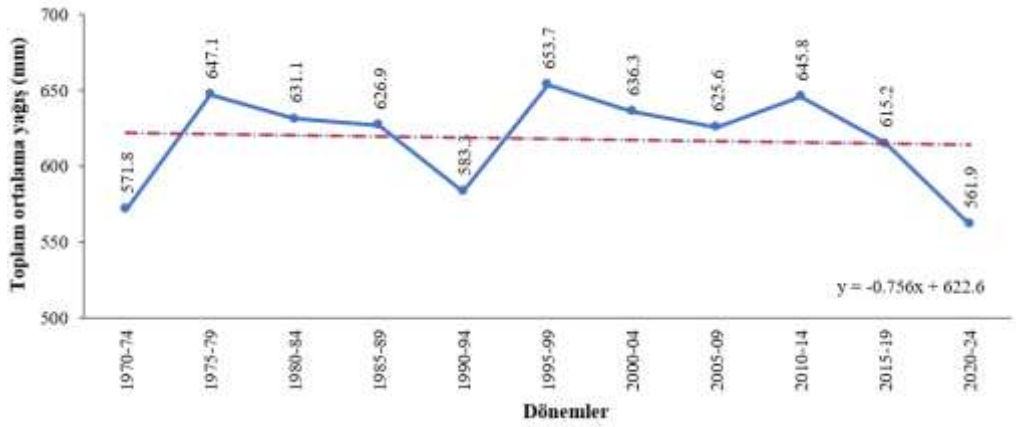
Küresel ısınma ve buna bağlı olarak yaşanan iklim değişikliğinin etkileri tüm dünyada artarak devam etmektedir. Bazı meteorolojik parametreler incelendiğinde Türkiye'nin de iklim değişikliğinden büyük ölçüde etkilendiğini göstermektedir. Meteoroloji Genel Müdürlüğü'nün Meteorolojik Parametrelerin Türkiye Analizi raporlarında 239 istasyondan elde edilen verilere göre; ülkesel ortalama sıcaklık 1970-2024 yılları arasında 13.3 °C'dir. Bu yıllar arasında en sıcak yıl 15.3 °C ile 2024 yılı, en soğuk yıl ise 11.4 °C ile 1992 yılıdır (MGM, 2024). Şekil 1'de Türkiye genelinin beşer yıllık sıcaklık ortalamaları verilmiştir. 1970-74 döneminde ortalama sıcaklık 12.76 °C, 2020-24 döneminde ise 14.66 °C olarak ölçülmüştür. Ortalama sıcaklıklardaki artış eğilimi regresyon sabiti 12.18 iken, regresyon katsayısı 0.194'dür (y=0.194x+12.18). Meteoroloji Genel Müdürlüğü'nün 239 istasyon verilerine dayanarak ortaya

koyduğu bu değerler, ülkemizin ortalama sıcaklıklarındaki artış eğilimini açıkça ortaya koymaktadır.



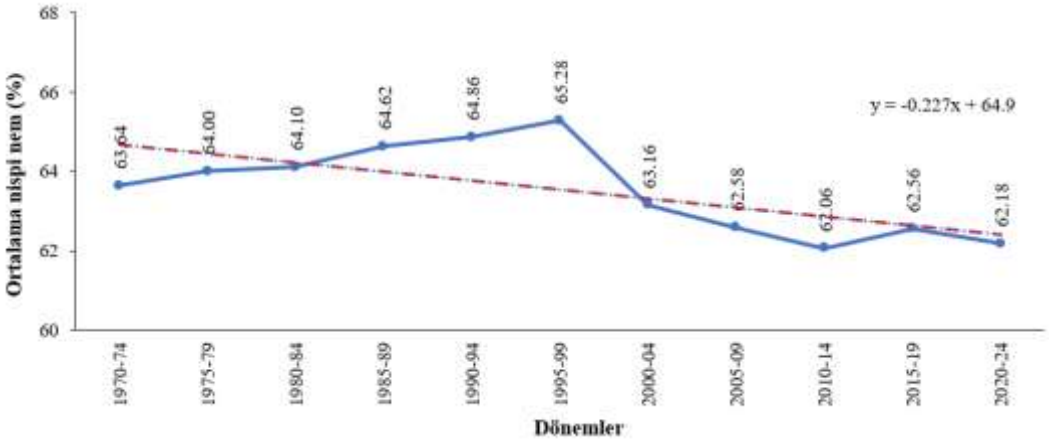
Şekil 1. Türkiye'de dönemsel ortalama sıcaklık (MGM, 2024)

Serin iklim tahılları yetiştiriciliğinde en önemli meteorolojik parametrelerden birisi de yağış ve bu yağışın mevsimsel dağılımıdır. Meteoroloji Genel Müdürlüğü'nün Meteorolojik Parametrelerin Türkiye Analizi raporlarında 224 istasyondan elde edilen verilere göre; ülkemizin ortalama toplam yağışı 618.1 mm'dir. 2009 yılı 793.8 mm ile en fazla yağışlı yıl olurken, yağışın en az kaydedildiği yıl ise 493.1 mm ile 2008 yılıdır. 1970-2024 yılları arasındaki beşer yıllık dönemler esas alındığında, yağış miktarının dalgalı bir seyir izlediği görülmektedir (Şekil 2). Tüm dönemlerdeki verilerin analizi sonucunda negatif regresyon katsayısı (-0.756) elde edilmiştir. Yani dönemsel olarak Türkiye'de yağış miktarında azalış eğilimi görülmektedir (MGM, 2024). Toplam yağışın aylara dağılımında da uzun yıllar ortalamasından sapmalar son yıllarda artmıştır. Embriyo kararmasına etkisi açısından tane doldurma dönemindeki yağışlar önemlidir. Örneğin haziran ayı uzun yıllar ortalaması 32.8 mm iken, 2023 yılı Haziran ayında 54.5 mm yağış düşmüştür.



Şekil 2. Türkiye'de dönemsel toplam ortalama yağış (MGM, 2024)

Şekil 3'de Meteoroloji Genel Müdürlüğü'nün Türkiye genelindeki 236 istasyondan elde ettiği dönemsel oransal nem değerleri verilmiştir. Özellikle 2000 yılından sonraki yıllarda nispi nem ortalamalarındaki düşüş trendi hızlanmıştır. Türkiye'nin uzun yıllar nispi nem ortalaması %63.5 olup, nispi nemin en yüksek (%66.7) kaydedildiği yıl 1991 ve nispi nemin en düşük (%59.6) kaydedildiği yıl ise 2013 yılıdır. Beşer yıllık dönemsel nispi nem ortalamalarının analizinde regresyon sabiti 64.9, regresyon katsayısı ise -0.227'dir (Şekil 3). Yağış miktarında olduğu gibi nispi nem ortalamalarında da yıldan yıla bir düşüş trendi devam etmektedir.



Şekil 3. Türkiye'de dönemsel ortalama nem (MGM, 2024)

Diğer meteorolojik parametreler bakımından Meteoroloji Genel Müdürlüğü'nün Meteorolojik Parametrelerin Türkiye Analizi raporlarında ülkemizin kar örtülü gün sayısında düşüş eğilimi (y =-0,164x + 32,37), farklı toprak derinliklerindeki sıcaklık bakımından yükseliş eğilimi olsa

da yataya yakın bir regresyon katsayısı belirlenmiştir (MGM, 2024). Tarımsal açıdan bir diğer önemli parametre ise dolu yağışının olduğu gün sayısıdır. Daha çok lokal yağışlar olsa da etkileri çok yıkıcı olmaktadır. Meteorolojik Parametrelerin Türkiye Analizi raporunda 1980-2008 yılları arasında, dolulu gün sayısı 0.44-0.99 gün arasında dağılım gösterirken, 2009-2024 yılları arasında ise dolulu gün sayısı 1.21-2.69 gün arasında dağılım göstermiştir.

Yukarıda Meteoroloji Genel Müdürlüğü'nce ortaya konulan parametrelerin analizi, ülkemizin iklimsel verilerinde bir değişimin olduğunu açıkça ortaya koymaktadır. Toplum, ülkemizdeki barajlardaki su seviyelerinin düşüşü, oluşan hortumlar, ceviz büyüklüğündeki dolu yağışları, seller, orman yangınları vs. ekstrem durumları basın yayın ve sosyal medyadan takip etmektedir. Ancak meteorolojik verilerdeki değişimin, insan ve hayvanların besin ihtiyacının karşılanması için yapılan bitkisel üretime etkileri daha geri planda kalmaktadır. Önümüzdeki yıllarda iklimdeki değişimin gerek doğal floradaki ve gerekse de tarımsal üretimdeki etkilerinin daha çok hissedileceği öngörülmektedir.

3. EMBRİYO KARARMASININ ÖNEMİ

Embriyo kararması, tanede embriyonun bulunduğu bölgede kahverengi ve siyah renk değişikliği ile kendini gösteren mantari bir hastalıktır (Masiello ve ark., 2020). Enfeksiyon şiddeti arttıkça embriyonal bölgedeki renk bozulması tanenin diğer kısımlarına da yayılabilir (Tunca ve ark., 2016). Embriyo kararmasına *Alternaria* spp., *Cladosporium* spp., *Cochliobolus* spp., *Curvularia* spp. ve *Fusarium* spp. gibi patojenler sebep olabilmektedir (Ünal ve Çakır 2017). Genellikle mantari etmenler embriyoda kararmaya veya renk bozulmasına neden olsa da bazen fizyolojik stres faktörleri de bu duruma yol açabilmektedir (Mak ve ark., 2006). Abiyotik stres faktörleri, özellikle de tane olum dönemlerindeki yoğun yağış ve nem ile ekstrem sıcaklıklar, embriyoda kararmalara neden olabilmektedir (Kumar ve ark., 2002). Şekil 4'de Yozgat ili Yerköy ilçesinde 2023-2024 yetiştirme döneminde, ekmeklik buğday denemelerindeki embriyo kararmasına uğramış, farklı hastalık şiddetindeki taneler görülmektedir.

Şekil 4. Ekmeklik buğdayda farklı hastalık şiddetindeki embriyo kararmalı taneler

Embriyo kararması ekmeklik ve makarnalık buğday yanında diğer serin iklim tahıllarında da görülebilir. Makarnalık buğday hassas türlerden olup, enfeksiyon görülme sıklığı ve şiddetine bağlı olarak ticaretinde problemler oluşturabilir (Tunca ve ark., 2016). Embriyo kararması son ürünü etkilediği için birçok ülke ticarette enfekteli tane oranına yönelik sınırlamalar getirmiştir. Avustralya'da %5, Kanada'da %10, ABD'de ise %2-4 embriyo kararmasında sınır değerler olarak uygulanmaktadır (Li ve ark., 2014). Türkiye'de buğdaydaki embriyo kararmalı tane oranı %8'i aştığında düşük vasıflı sınıfa girmekte, %14 ise Toprak Mahsülleri Ofisi için üst alım sınırıdır. Embriyo kararmasına uğramış taneler renk bozulması nedeniyle kalitede düşüşlere neden olması yanında, *Alternaria* spp. gibi bazı mantar türlerinin zehirli ve riskli olan mikotoksinleri üretmeleri de büyük problem teşkil etmektedir (Masiello ve ark., 2020; Amatulli ve ark., 2013).

Bazı mantar türlerinin neden olduğu embriyo kararması enfeksiyonu tohumluk materyal üzerinde olumsuzluklar meydana getirmektedir. Enfekteli tohumların kullanımı nedeniyle tarla koşullarında, çimlenme hızı, çimlenme gücü ve çıkış oranında azalmalar görülmektedir (Toklu ve ark., 2008). Bununla birlikte kök ve sürgün gelişimindeki bozukluklar nedeniyle verim üzerinde de etkileri vardır (Li ve ark., 2014; Tunca ve ark., 2016).

Embriyo kararmasında genetik ve çevresel faktörler etkilidir. Genetik olarak hassas olan çeşitlerde çevresel koşullar hastalık epidemisine uygun değilse, hastalık görülme sıklığı ve şiddeti düşük seviyelerde kalmaktadır. Dayanıklı genotiplerde ise hastalık gelişimi için çevresel koşullar uygun olsa da embriyo kararması görülme sıklığı çok düşük seviyelerde kalmaktadır. Aktaş ve Endes (2025) buğday genotiplerinin embriyo kararması hastalığına verdikleri tepkinin farklılık gösterdiğini ve bazı genotiplerin çevresel koşullara bağlı olarak hastalık görülme sıklığında 7-8 kat artış olduğunu ortaya koymuştur. Çevresel koşullar hastalık şiddetinin yüksek seviyede ortaya çıkmasına neden olabilir. Bu nedenle genotiplerin maksimum duyarlılığının belirlenmesi çok önemli hale gelmektedir. Khani ve ark. (2018) ile Li ve ark. (2020) buğdayda embriyo kararmasının ortaya çıkmasında genetik özelliklerin önemli bir faktör olduğunu bildirmişlerdir. Aktaş ve Endes (2025) ile Khani ve ark. (2018) yapılan melezleme çalışmalarında, melez döllerin ebeveynlerin göstermiş olduğu hastalık görülme sıklığı değerleri arasında hastalık gözlem değerleri aldıklarını bildirmektedir.

En yüksek enfeksiyon görülme sıklığı tane doldurma döneminin erken aşamalarında yoğun yağışların gerçekleştiği bölgelerde meydana gelmektedir (Conner ve Kuzyk, 1988). Benzer şekilde Conner (1989) yaptığı çalışmada, tane gelişiminden önceki dönemlerde yapılan sulamaların embriyo kararması görülme sıklığını etkilemediğini, süt veya hamur olum aşamalarında yapılan sulama ve yağış miktarının artmasının enfeksiyon görülme sıklığı ve şiddetini arttırdığını tespit etmiştir. Birim alan tane verimini arttırmak için yoğun gübre kullanımı ve sulamalar embriyo kararmasının ortaya çıkmasında etkilidir.

SONUÇ VE ÖNERİLER

Embriyo kararması son kullanım ürünü olan taneyi etkilemekte ve önemli ticari kayıplara yol açabilmektedir. Enfekteli taneler hem gıda olarak kullanılacak ürünün kalitesini düşürmekte hem de tohumluk olarak kullanılacak materyalin biyolojik değerini azaltmaktadır. Hastalık ile

mücadelede dayanıklı çeşit kullanımı, kimyasal mücadele ve biyolojik mücadele seçenekleri kullanılabilir. Ancak bu yöntemler arasında en çok öne çıkan dayanıklı çeşit ıslahı ve bu çeşitlerin tohumluklarının riskli bölgelerde kullanılmasıdır. Ayrıca yetiştirme tekniklerinde dikkatli olunmalı, özellikle hassas çeşitlerin yetiştirildiği alanlarda döllenme sonrasında yapılacak sulamaların enfeksiyonu tetikleyebileceği unutulmamalıdır. Ekonomik olması yanında, en çevreci mücadele yöntemi olan dayanıklı çeşit geliştirme çalışmalarına önem verilmelidir.

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EMBRACING CIRCULARITY: TRANSFORMING AGRICULTURE THROUGH SUSTAINABLE PRACTICES

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ABSTRACT

This study examines the circular economy practices that have the potential to transform the agricultural sector in Turkey and explores the possibilities of transitioning to more sustainable and resilient agricultural practices. Recognizing the environmental and economic challenges facing conventional agriculture, including resource depletion and pollution, this study explores specific applications of the circular economy that are relevant to the Turkish context. These applications include comprehensive organic waste management strategies such as composting and biogas production, innovative water recovery technologies to alleviate water scarcity exacerbated by climate change, and the integration of renewable energy sources to reduce dependence on fossil fuels and lower carbon emissions. The study quantifies the potential benefits by providing a detailed assessment of the environmental sustainability and economic efficiency gains that can be achieved by implementing these circular practices. A key component of this study is to identify the current state of circular agriculture initiatives in Turkey. This includes analyzing existing practices, highlighting key implementation barriers to wider adoption, such as lack of infrastructure and awareness, and identifying critical policy gaps that hinder progress. The analysis aims to contribute to the development of applicable strategies for Turkey by drawing on successful global examples of the circular agriculture examples in diverse geographical and economic contexts. Furthermore, the study explores domestic investment opportunities, including public-private partnerships, that could boost the growth of the circular agricultural practices across the country and improve the overall competitiveness of the sector. Based on the research findings, the study provides concrete and actionable policy recommendations designed to promote circularity within the Turkish agricultural sector. These recommendations are specifically tailored to guide decision makers at the government level, empower farmers to adopt sustainable practices through incentives and training programs, and inform policy makers in developing supportive regulatory frameworks and financial mechanisms. The ultimate goal is to facilitate the creation of a more environmentally sustainable, economically viable and resilient agricultural system in Turkey, contributing to long-term food security, environmental protection and rural development.

Keywords: Circular agriculture, Sustainability, Precision farming, Environmental impact, Resource efficiency, Regenerative practices, Controlled environment agriculture,

SÜRDÜRÜLEBİLİR BİR GELECEK İÇİN DÖNGÜSELLİĞİN BENİMSENMESİ: TARIMDA DÖNÜŞÜM

ÖZET

Bu çalışma, Türkiye'deki tarım sektörünü dönüştürme potansiyeline sahip döngüsel ekonomi uygulamalarını inceleyerek, daha dayanıklı ve sürdürülebilir tarımsal yapıya geçişin olanaklarını araştırmaktadır. Kaynak tükenmesi ve kirlilik de dahil olmak üzere geleneksel tarımın karşı karşıya olduğu çevresel ve ekonomik zorlukları göz önüne alan bu araştırma, Türkiye bağlamına uygun belirli döngüsel ekonomi uygulamalarını araştırmaktadır. Bu uygulamalar arasında kompostlama ve biyogaz üretimi gibi kapsamlı organik atık yönetimi stratejileri, iklim değişikliğiyle daha da şiddetlenen su kıtlığını hafifletmeye yönelik yenilikçi su geri kazanım teknolojileri ve fosil yakıtlara olan bağımlılığı azaltarak ve karbon emisyonlarını düşüren yenilenebilir enerji kaynaklarının entegrasyonu yer almaktadır. Araştırma, bu döngüsel uygulamaların benimsenmesiyle elde edilebilecek çevresel sürdürülebilirlik ve ekonomik verimlilik kazanımlarının ayrıntılı bir değerlendirmesini sunarak potansiyel faydaları nice olarak ortaya koymaktadır. Bu çalışmanın temel bir bileşeni, Türkiye'deki döngüsel tarım girişimlerinin mevcut durumunun ortaya konmasıdır. Bu kapsamda mevcut uygulamaları analiz edilmekte, altyapı ve farkındalık eksikliği gibi daha geniş bir benimsemeyi engelleyen temel uygulama engellerini belirlenmekte ve ilerlemeyi engelleyen kritik politika boşluklarını tespit edilmektedir Analiz, farklı coğrafi ve ekonomik bağlamlarda başarılı küresel döngüsel tarım örneklerinden yararlanarak Türkiye için uygulanabilir stratejileri geliştirilmesine katkı sunmayı amaçlamaktadır. Ayrıca, ülkedeki kamu-özel sektör iş birliği gibi yerel yatırım fırsatları incelenmekte ve bu yatırımların döngüsel tarım uygulamalarının yaygınlaştırılmasında nasıl bir kaldıraç rolü üstlenebileceği değerlendirilmektedir. Araştırma bulgularına dayanarak, çalışma Türk tarım sektöründe döngüselliği teşvik etmeye yönelik somut ve uygulanabilir politika önerileri sunmaktadır. Bu öneriler, özellikle hükümet düzeyindeki karar alıcılara rehberlik etmeyi, çiftçilerin teşvikler ve eğitim programları aracılığıyla sürdürülebilir tarım uygulamalarını benimsemelerini desteklemeyi ve politika yapıcıların uygun yasal çerçeveler ve finansal mekanizmaların geliştirilmelerine katkı sunmayı hedeflemektedir. Nihai hedef, Türkiye'de daha çevre dostu, ekonomik olarak uygulanabilir ve dayanıklı bir tarım sisteminin oluşturulmasını kolaylaştırmak, uzun vadeli gıda güvenliğine, çevre yönetimine ve kırsal kalkınmaya katkıda bulunmaktır.

Anahtar Kelimeler: Döngüsel tarım, Sürdürülebilirlik, Hassas tarım, Çevresel etki, Kaynak verimliliği, Onarımcı uygulamalar, Kontrollü çevre tarımı.

INTRODUCTION

Rising global populations, rapidly diminishing natural resources, climate change and environmental degradation are calling into question the sustainability of traditional economic models. In this context, the circular economy concept has become an important alternative in recent years. The circular economy is a model that aims to minimise waste in production and consumption processes, reuse resources to return them to the economy and create systems compatible with nature (Ellen MacArthur Foundation, 2013). In contrast to the linear economic model of "take-use-throw", the circular economy is based on "redesign, reuse, recycle".

The agricultural sector occupies an important place among the application areas of the circular economy due to its direct dependence on natural resources. Basic inputs such as soil, water, biodiversity and energy are now under severe threat in terms of both quantity and quality. In addition, large amounts of organic waste and greenhouse gas emissions, such as methane produced during agricultural production processes, contribute to global warming (FAO, 2015). In this context, the circular economy offers significant environmental and economic opportunities to ensure sustainability in agriculture. Thanks to applications such as composting, biogas production, wastewater reuse, and integrated farming systems, productivity is increased, and the negative impact on the environment is reduced (Kirchherr et al., 2017).

Global climate change and the resulting risks, such as increasing drought, flooding, and yield losses in agriculture, further exacerbate the problem of food security. According to the FAO (2022) report, around 828 million people worldwide are affected by chronic hunger. Solving this problem requires not only an increase in production but also an efficient and cyclical use of resources. Circular economy applications in agriculture have the potential to create income diversity by reducing costs, especially for small and medium-sized farms (Geissdoerfer et al., 2017).

Looking at Turkey in particular, circular economy approaches have great potential due to its geographical diversity and rural structure based on agriculture. Around 65 million tons of agricultural waste and 160 million tons of animal waste are produced in Turkey every year. a large proportion of which is not recycled economically (Buğday Ekolojik Yaşamı Destekleme Derneği & ACR+, 2016). In this context, the circular economy model can be a strategic tool to increase resource efficiency in agricultural production and contribute to rural development. Environmental sustainability and waste management are among the Ministry of Agriculture and Forestry's Strategic Plan 2023-2027 priorities (Tarım ve Orman Bakanlığı, 2023).

The circular economy approach thus contributes to environmental concerns and increases economic efficiency and social prosperity. The agricultural sector is at the centre of this change and can potentially be the key to sustainable development in Turkey, especially in developing countries (Özkan, 2024).

The main objective of this study is to explore the concept of circular economy in the agricultural sector and to assess the impact of this approach on sustainable agricultural production at conceptual and practical levels. In particular, the potential contribution of applications such as organic waste management, biogas production, water reuse and renewable energy integration to Turkish agriculture will be analysed. In addition, the current status of circular economy

applications in agriculture in Turkey, implementation limitations, policy gaps and structural barriers are discussed, and suggestions for improvement are presented. The study aims to contribute to the scientific literature and guide decision-makers, farmers, and policymakers.

THE CONCEPT OF THE CIRCULAR ECONOMY AND ITS APPLICATION IN AGRICULTURE

The circular economy is an economic model that aims to manage resources effectively and sustainably. Its main goal is to ensure that products, materials and resources remain in the cycle for as long as possible and to minimise waste production (Ellen MacArthur Foundation, 2013). Four basic principles of the circular economy are at the forefront: reuse, recycling, waste reduction and renewability. In line with these principles, it is possible to reduce the environmental impact of economic activities, protect natural resources and develop production processes compatible with ecosystems (Geissdoerfer et al., 2017).

The agricultural sector is one of the most critical areas in which the principles of the circular economy are applied, as it is directly dependent on natural resources such as soil, water and energy. The large amount of organic waste and wastewater generated in agriculture can create economic value if properly managed. In this context, several areas of application should be mentioned.

First, composting organic waste is an important way to improve soil health and reduce the use of chemical fertilisers. Biological materials such as plant residues, animal manure and food waste can be decomposed under controlled conditions and transformed into compost with high nutritional value. This increases soil fertility and reduces dependence on synthetic inputs (FAO, 2015).

Another application is biogas and energy production. Animal waste, agricultural residues and organic food waste can be used for biogas production through biological fermentation. The methane gas produced in this process can be used to generate heat and electricity, while the remaining fermented material can be used as agricultural fertiliser. This method both reduces energy dependency and ensures waste disposal (Gürbüz & Özkan, 2021).

Reusing wastewater through its treatment is also crucial for the sustainable management of water resources in agriculture. Especially in regions with a high drought risk, water savings can be achieved by using municipal wastewater or agricultural drainage water for irrigation. Such systems are increasingly common in Turkey's south-eastern and central Anatolian regions (Özkan, 2024).

Agricultural systems with integrated animal husbandry are another example demonstrating the multiple benefits of the circular economy. In these systems, where crop and animal production are practised together, animal manure is used in the fields, while crop residues can be utilised as animal feed. This model reduces costs and creates a closed cycle on farms (Kirchherr et al., 2017).

Finally, using renewable energy in agricultural production represents the energy dimension of the circular approach. Technologies such as solar-powered irrigation systems, wind-powered

pumping systems or biomass boilers contribute to environmental sustainability by reducing farms' carbon footprint.

Therefore, the principles of the circular economy enable versatile applications that offer both environmental and economic benefits in the agricultural sector. These applications increase resource efficiency and contribute to the sustainability of agriculture.

EXAMPLES FROM GLOBAL APPLICATIONS

Circular economy applications have begun to transform the agricultural sector in many countries globally and have accelerated the transition to sustainable production models. The steps taken in this area in developed and developing countries also provide an important reference for countries with transformation potential, such as Turkey.

The Netherlands: High efficiency, low resource consumption

One of the most impressive examples of circular agricultural applications is the Netherlands. Following the principle of "producing more with less", the Netherlands pursues a policy prioritising both efficiency and environmental sustainability in agriculture. The country adopted the "Circular Agriculture" strategy in 2016 and set itself the goal of making all agricultural systems circular by 2030 (Klerkx et al., 2025)

The use of animal manure in compost and biogas production is widespread in agricultural production in the Netherlands. In addition, energy efficiency is achieved through water recycling and using solar energy in greenhouses (van der Salm et al., 2020). By implementing these practices, the country has significantly reduced agricultural carbon emissions while remaining Europe's second-largest agricultural exporter.

European Union: “Farm to Fork” and “Green Deal” Strategies

The European Union has set ambitious targets for sustainable agriculture with the European Green Deal announced in 2019. The "Farm to Fork" strategy developed within this agreement envisages reducing pesticide use by 50% by 2030, increasing the area under organic farming to 25% and increasing recycling rates for agricultural waste (European Commission, 2020).

Among the circular agriculture projects supported in EU countries, the conversion of biological waste into energy, integrated plant-animal production systems and wastewater reuse stand out (Lange et al., 2021). These policies reflect a holistic approach that focuses on environmental objectives, food security, and rural development (Islam & Zheng, 2025).

China and India: Transformation in Developing Countries

In countries with large populations and agricultural economies, such as China and India, circular agriculture is important from an environmental and social perspective. In China, "Eco-agriculture" projects have become widespread (Lun et al., 2022), including the conversion of

agricultural waste into energy (Wei et al., 2020), the reuse of treated wastewater in irrigation systems (Lyu et al., 2022) and biogas production (Wang et al., 2012. The Chinese government encourages environmentally friendly production by incorporating such practices into rural development plans (Yuan & Bi, 2006).

Circular farming practices are supported in India through various projects that offer environmental and social benefits (Khan & Mahajan, 2023). Small-scale mango producers in India are increasing their crop yields and conserving natural resources by adopting sustainable farming practices (Bisht et al., 2020). Agricultural waste is converted into various types of biofuels, such as biomethane, biohydrogen, biodiesel and biobutanol and used for energy production (Bhatia et al., 2020). Agricultural waste is a raw material for biogas and biofuel production and offers solutions for energy production and waste management (Kapoor et al., 2020).

The Circularity Action Platform for Agriculture and Food Systems (IAFS-CAP) promotes the adoption of circular economy principles in the production, processing and distribution of agricultural products (Intellecap, 2021). Sustainable agricultural practices are encouraged by training farmers (Shetty et al., 2010) on the use of organic fertilisers and biological pest control methods (Chowdhury et al. 2024).

INVESTMENT OPPORTUNITIES AND POTENTIAL AREAS IN TURKEY

From a circular economy perspective, there is substantial investment potential in energy production, waste management and sustainable resource utilisation in the Turkish agricultural sector (Özkan, & Kadağan, 2019). The circular economy approach offers new opportunities for the Turkish agricultural sector in terms of environmental sustainability and economic development. In the face of increasing food demand, depletion of natural resources and climate change, investments in waste management, energy efficiency and water conservation in agriculture are strategically important. Turkey's biomass capacity, sunshine duration and widespread agricultural activities provide suitable grounds for turning this potential into concrete opportunities.

Biogas Plants: Integrated Energy Production with Livestock Farming

The farm manure obtained from large and small livestock amounts to 640,000 tons per day or 234 million tons per year, calculated based on animal units. Assuming that some of this remains on pasture, the amount of controllable farm manure accumulates in barns and stables is over 200 million tons (Baytekin, 2024). This manure can be a valuable resource for biogas production with appropriate facility infrastructure. However, only 5 million tons of waste is used for biogas facilities (Çağatay, 2024).

Farm manure can primarily be used in biogas plants to generate electricity. For this purpose, the highest biogas production capacities are associated with potential facilities in Konya and Ankara, where biogas plants already exist. However, provinces such as Erzurum, Kars, and Diyarbakır in Eastern Turkey (Ertop et al., 2022) and regions such as Biga, Bayındır, Burdur,

Tire, Ödemiş and Karapınar, where intensive dairy farming is concentrated (Baytekin, 2024) but currently have no biogas facilities, also demonstrate significant potential for electricity generation if new plants are established.

There are 273 biomass facilities in Türkiye, 98 of which are biogas, licensed by the Renewable Energy Resources Support Mechanism (Çağatay, 2024). The production capacities and benefits of some prominent biogas plants can be summarised as follows.

Ankara Biogas Plant – ASKOÇ Enerji has the capacity to process 900 tons of animal and green waste per day. This plant produces 12.5 million cubic meters of biogas annually and generates 27.3 million kWh of electrical energy. 90 tons of organic fertiliser from the facility are also offered to the market, providing an annual CO_2 reduction of 400,000 tons (ASKOC, n.d.).

The Diyarbakır Agricultural-Based Specialized Livestock OSB Biogas Facility processes 600 tons of animal waste daily, generating 2,000 kWh of electrical and 2,000 kW of heat energy. In addition, this facility produces 70 tons of organic fertiliser are produced per year, making an economic contribution of approximately 200 million TL to the economy (AA, 2019).

The Akıncı Enerji biogas plant produces biogas mainly from laying hen waste. By processing 120 tons of waste per year, the plant generates 12 million kWh of electricity and 6,750 tons of organic fertiliser (Akıncı Enerji, t.y.).

Bekmezci Energy – Cankiri Biogas Facility processes 194 tons of animal and plant waste daily, generating 4,879.24 kWh of electricity. This facility plays an important role in environmental sustainability by using waste such as cattle waste and chicken manure (Ticaret Bakanlığı, t.y.).

These biogas plants are important examples of energy production from animal waste in Turkey and contribute to reducing environmental impacts. The widespread use of these plants, which create sustainable models in energy production and organic fertiliser production, opens up important opportunities for the country's economy (Gürbüz & Özkan 2021).

Food Waste Processing Systems: Turning Waste into Resources

Approximately 18 million tons of food waste is generated annually in households and retail chains alone (UNFCCC, 2019). Processing and turning this waste into animal feed, compost, or biogas production provides economic and environmental benefits.

The "food banking" and food waste collection projects initiated by the Istanbul Metropolitan Municipality (İBB) are concrete examples of circular economy models in collaboration with the private sector. Food waste collection and redistribution projects carried out in collaboration with the Food Rescue Association bring social and environmental benefits. In addition, many TÜBİTAK- --supported university projects aimed to evaluate food industry wastes in areas such as feed additives or bioplastics production (Özçimen & Karaosmanoğlu, 2019).

The Food Rescue Association (GKTD) was established in Turkey in 2017 to prevent food waste and improve the food banking system. The association increased the national food bank capacity by 30 times and provided regular food aid to 1,100,000 people in need. It also

contributed to saving over 35 tons of food and preventing 80,000 tons of carbon emissions (Gıda Kurtarma Derneği, 2019).

Fazla, a technology-focused waste management platform based in Turkey, was founded in 2016 to bring food, packaging, textile and chemical waste into the circular economy. Among the services offered by Fazla are the Fazla Market, which offers surplus products at a discount, the donation system that allows food donations to those in need, and the channelling of food waste to animal feed producers (Fazla, 2025).

In addition, many university projects supported by TÜBİTAK have aimed to evaluate food industry waste in areas such as feed additives or bioplastic production (Özçimen & Karaosmanoğlu, 2019).

Composting Facilities: Revitalizing the Soil

In line with environmental sustainability goals in Turkey, many municipalities have established composting facilities to manage and utilise organic waste. Major urban centres, such as the Istanbul Metropolitan Municipality and district municipalities like Beyoğlu and Pendik, are engaged in composting activities. Similar infrastructures are also available in Keçiören and Mamak districts in Ankara, as well as in metropolitan municipalities such as Kayseri and Şanlıurfa. Facilities established in different regions such as Adana Seyhan, Mersin (both the Metropolitan Municipality and Yenişehir Municipality), Muğla, Balıkesir and Antalya Organized Industrial Zone process organic waste collected from neighborhood markets, parks and gardens, both to produce fertiliser and to contribute to waste management. Local governments such as Yıldırım and Nilüfer in Bursa, Keşan and Güney Edirne Solid Waste Union in Edirne, Körfez and Gebze Municipalities in Kocaeli, Aydın Söke, Pamukkale in Denizli, Selçuklu in Konya and Altınova and Çiftlikköy in Yalova also actively participate in this process with their compost facilities. These facilities produce environmental benefits, provide fertiliser support to farmers, and contribute to local development.

Solar and Biomass Supported Irrigation Systems

Renewable energy-supported irrigation systems are critical in terms of saving both energy and water, especially in arid regions (Alhejji et al., 2021). In Turkey, the energy consumption of agricultural irrigation is costly, mainly due to electric pumping systems (Yilmaz et al. 2005). Renewable energy-supported irrigation systems are being implemented with various projects to save energy and water, especially in arid regions. Some of the prominent projects in this field are:

In Turkey, renewable energy-supported irrigation systems are supported by important projects in terms of agricultural sustainability, especially in arid regions with limited energy access. The GAPTAEM Channel Solar Power Plant project, implemented in Şanlıurfa by the GAP Agricultural Research Institute and Orbit Energy, stands out as the first solar-powered system installed on an irrigation canal in Turkey. With a capacity of 160 kWe, this system enables off-grid irrigation and provides economic contribution by selling excess energy to the national grid

(Orbit Enerji, 2022). Similarly, solar-powered irrigation systems are being installed throughout Turkey, and projects carried out by CW Energy offer economical, environmentally friendly, and long-lasting solutions, especially in off-grid rural areas (CW Enerji, 2022). A solar energy system consisting of 240 panels was installed in a project supported by Dicle Electric in the Akçakale district of Şanlıurfato to meet the irrigation needs of 300 acres of land, thus eliminating farmers from energy costs (Dicle Elektrik, 2022). The systems installed by Eti Enerji in Tekirdağ and the Thrace region popularise the use of solar-powered irrigation systems in greenhouse farms and large-scale agricultural areas, ensuring both water and energy efficiency are provided (Eti Enerji, 2022). In addition, SolnovaTech in Ankara helps farmers to set up sustainable and integrated systems with solar-powered irrigation solutions and implements energy-efficient projects suitable for existing infrastructures (SolnovaTech, 2023).

Solar-powered drip irrigation systems are implemented to save energy and encourage sustainable agricultural practices, especially in regions where water resources are limited. For example, solar-powered irrigation systems are used as part of projects by the GAP Agricultural Research Institute in Şanlıurfa to meet the energy needs of irrigation channels and prevent water evaporation (Tarım ve Orman Bakanlığı, 2020). In Konya province, solar-powered irrigation systems provide efficiency, especially in the irrigation of agricultural areas. These systems provide energy efficiency by operating the pumps with the energy obtained through solar panels (Özdede et al., 2017). In addition, solar-powered irrigation systems in the Ayaş district of Ankara provide farmers with energy independence and save water (Şentürk, 2023). These projects stand out as important examples that increase efficiency in agricultural production with the effective use of solar energy in agricultural irrigation.

These examples show that the use of renewable energy in agricultural production in Turkey is becoming widespread and that environmental and economic gains are achieved with the modernisation of irrigation systems.

Biomass Supported Irrigation Systems

In recent years, solid waste storage facilities have been established in many cities in Turkey as part of the European Union's harmonisation process and biomass power plants are operating in these facilities. In addition, biogas plants have been built, and biogas power plants operate in regions where poultry, small cattle, and large livestock farming are intensively carried out. According to the 2022 Electricity Energy Outlook report, there are 152 licensed biomass power plants with a total power (MW) of 906,104 (EMO, 2023).

Uninterrupted production is provided throughout the year in the greenhouses heated using biomass energy in the Korkuteli district of Antalya. An evaluation conducted in 2023 found that the heating costs of the greenhouses have decreased by 40%, and the producers' profitability has increased by 25% thanks to biomass energy. A study conducted by Akdeniz University in 2023 stated that efficiency in greenhouses heated with biomass increased by 25%, and carbon emissions decreased by 30% (Altıkardeş, 2024).

In the Silifke district of Mersin, heat production is provided by using local biomass sources such as olive press and pruning waste with a biomass plant established by an agricultural

production cooperative. Thanks to this application, both wastes is utilised, and greenhouses are operated with a sustainable and domestic energy source (Çukurova Kalkınma Ajansı, 2021). Such projects offer important examples of the potential use of biomass energy in agricultural production and greenhouse heating.

RURAL DEVELOPMENT, EMPLOYMENT AND TECHNOLOGY TRANSFER

Circular economy practices provide environmental benefits, increase employment opportunities in rural areas, and encourage women and youth to remain in agriculture (European Parliament, 2015). It also supports the modernisation of domestic production and creates a multiplier effect in terms of technology transfer (Ren et al., 2023). With circular agricultural practices, both technological and managerial knowledge transfer accelerates; this increases resilience in rural areas (Shebanin et al., 2024). For example, the need for technical personnel arises for the operation of biogas facilities, and employment opportunities are opened up for the local young.

The operation of biogas plants in Türkiye creates a need for technical staff and provides employment opportunities for the local young workforce. For example, Konya Biogas Electricity Production Inc. employs approximately 200 people (Konya Biyogaz Elektrik Üretim, t.y.). In addition, the employment creation potential of biogas plants is emphasised in the Elazığ Province Biogas Production Facility Preliminary Feasibility Report and the anticipated salaries for technicians and other personnel are specified (Yatırım ve Destek Hizmetleri Genel Müdürlüğü, 2021).

Turkey also has an important financial infrastructure with mechanisms such as the EU-supported IPARD- IPARD III program (Özkan, 2024) and rural Development Support (Tarım ve Orman Bakanlığı 2025) and TÜBİTAK-TEYDEB (2025) to direct these investments. These funds should be prioritised for circular economy-focused projects.

The dissemination of training programs on circular agricultural practices increases the participation of women and young people, especially those living in rural areas, in agricultural entrepreneurship. Various projects and training initiatives carried out in this scope are noteworthy. For example, the "Sustainable Agricultural Food and Circular Economy Course Program" offered under the Horizon Europe Technical Assistance for Turkey (IPA) project is an important step in this field. Similarly, the Circular Economy Training Program organised by Uludağ College educates students and entrepreneurs about circular business models. In addition, the Circular Business Design Training Program offered by the Turkish Circular Economy Platform (TDEP) contributes to the development of sustainability-oriented business ideas. Such programs support the adoption and implementation of circular economy principles at the local level.

OPPORTUNITIES FOR DOMESTIC AND FOREIGN INVESTORS

To encourage investment in the circular economy investments, Turkey provides grant support of 50% to 75% for investments in biogas plants, compost production and renewable energy

systems under the IPARD III Program. These grants increase to up to 70%, especially for young farmers and organic producers, and can reach 75% with an additional 10% public contribution for investments in waste management and circular economy (Tarım ve Orman Bakanlığı, 2024).

There is a supportive legal framework in environment and energy as part of the EU harmonisation process for foreign investors. An example of environmental and energy projects with foreign partners in Türkiye is the activities of the Dutch company GiraSolar in Türkiye. GiraSolar has implemented various solar energy projects in Turkey. Another example is the PV4Plants Project, led by Kalyon PV. This project is supported by the European Union's Horizon Europe Program and includes 14 project partners from the United Kingdom, Denmark, the Netherlands, Spain, Italy, Greece, and Turkey. As part of the project, an agricultural solar power plant (solar power plant) with a capacity of approximately 100 kilowatts was built on a 1.6-hectare site in the Ayaş district of Ankara. This plant offers an agrovoltaic model that enables both the cultivation of agricultural products and the generation of solar energy to be produced in the same area (Kalyon PV, 2025). The Chinese energy group CEEC signed a strategic cooperation agreement with its investment company CEOIC and Sungen Solar Energy for a renewable energy generation project with a capacity of 250 megawatts (İhlas Holding, t.y.).

POLICY RECOMMENDATIONS

The circular economy stands out as an important tool for the agricultural sector to achieve environmental, economic and social sustainability goals. However, for this transformation to be implemented effectively, decisive and comprehensive strategies must be developed at the political level. The policies to be proposed for the dissemination of circular agriculture in Turkey require a multidimensional approach, ranging from legal regulations, education and financial incentives to technical infrastructure.

1. *A national strategy for the circular economy should be developed.* Circular economy practices in Turkey are currently progressing at a fragmented and sectoral level. Following the example of the "Circular Agriculture" strategy of the Netherlands, a holistic "Circular Agriculture National Action Plan" should be developed for Turkey specifically for agriculture. This strategy should include waste management, energy production, water efficiency, and local production systems and should be implemented under the coordination of the Ministry of Agriculture and Forestry and the Ministry of Environment, Urbanization and Climate Change.

2. *Financial incentives and grant mechanisms should be strengthened.* The scope of existing support programs such as IPARD and the Rural Development Investment Support Program (KKYDP) should be expanded, and innovative practices such as compost production, wastewater recycling and small-scale biogas systems should be included in the scope of incentives. In addition, tax exemptions and green credit schemes can be developed to pave the way for private-sector investment.

3. *Integrated waste management systems should be established in collaboration with local governments.* Municipalities should create an infrastructure to collect food and organic

waste from agriculture and transport it to central processing plants. Examples, such as those in Seferihisar and İzmir, should be disseminated.

4. *Education, dissemination and awareness-raising efforts should be strengthened. The* level of knowledge of farmers and local administrations about circular economy is quite limited. Farmers, especially small producers and cooperatives, should be informed about circular agriculture, and practical training programs should be organised. TÜBİTAK and agricultural faculties should play an active role in this area. Publication activities should be increased in cooperation with universities, chambers of agriculture and provincial agriculture directorates; training programs should be organised primarily for women and young farmers.

5 *Entrepreneurship of youth and women in rural areas should be supported.* Circular agricultural investments provide areas that can create jobs for women and young people. Women's cooperatives should be supported, and young farmers should have access to technology.

6 *Databases and tracking systems should be established.* Data such as agricultural waste, compost production and biogas capacity should be recorded regularly and shared transparently. In this way, investment decisions can be made on a more informed basis.

7. *Cooperation between the public and private sectors should be promoted*. Cooperation models should be created for the food industry, municipalities, agricultural cooperatives, and technology companies. For example, closed-loop systems can be supported, enabling waste to be used as energy or raw materials for industry.

8. The monitoring, measurement and database infrastructure should be strengthened. Indicators such as the amount of agricultural waste, water use efficiency and carbon footprint should be regularly monitored, and publicly accessible digital databases should be established. This system will ensure transparent and accountable monitoring of circular agricultural practices.

CONCLUSIONS

Turkey has great potential for the transformation of the agricultural sector when viewed from a circular economy perspective. Many applications, from biogas to compost, from solar energy to water reuse, can be developed to offer economic efficiency and environmental benefits. However, for this potential to become a reality, policymakers must act with a holistic vision, and local and national stakeholders must cooperate.

Turkey can ensure environmental sustainability and support economic and social development by integrating the circular economy approach into the agricultural sector. This shift points to a multidimensional development model that is not limited to environmental concerns but also increases rural welfare, supports employment and stimulates innovation. However, for this change to be realised, determination at the policy level, coordination between stakeholders and a long-term vision are required.

When looking at global examples, the steps that Turkey can take in circular agriculture become clearer. First, it is crucial to align agricultural policies with long-term sustainability goals. The

European Union's "Farm to Fork" strategy and China's eco-agriculture programs provide important examples for Turkey. As in the case of the Netherlands, creating a national strategy centred on circular agriculture and developing targeted incentive schemes, as in the EU, can provide direction for Turkey. In addition, low-cost, local solutions from China and India can be applied in Turkey's rural areas. Turkey can become one of the pioneer countries in circular agriculture if it develops policies compatible with these global trends. Global examples show that Turkey can make progress not only with advanced technology but also with community-based solutions. In this context, aligning Turkey's agricultural policy with circular economy principles will promote rural development and effectively combat climate change.

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EFFECT OF ORGANIC FERTILIZER USE ON YIELD AND QUALITY IN FIELD CROPS

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ABSTRACT

The use of fertilizers in field crops is an ancient practice dating back approximately 10,000 years, beginning with humanity's transition to agriculture. With the increase in agricultural activities, the natural state of the soil was no longer sufficient to meet human needs. As a result, producers sought different methods to enhance soil fertility. Initially, farmers used organic fertilizers (plant residues, wood ash, and animal manure) to supplement soil nutrients. Choosing the right fertilizer and applying it in the correct dosage is crucial for increasing soil productivity and improving the quality of crops. Organic fertilizers contain high levels of organic matter, microorganisms, and plant nutrients. Due to their composition, organic fertilizers enhance soil fertility and support the healthy growth of crops. These fertilizers include animal manure, biochar, compost, vermicompost, green manure, algae/seaweed fertilizers, microbial fertilizers, and mycorrhizal fertilizers. The excessive and unregulated use of chemical fertilizers leads to the accumulation of heavy metals (Cu, As, Cd, Ni, Pb, etc.) in the soil and increases soil salinity, which disrupts soil structure. The use of nitrogen- and phosphorus-based chemical fertilizers in agriculture contributes to the process of eutrophication as these fertilizers leach into water bodies. Eutrophication disrupts aquatic ecosystems by causing algal blooms, which deplete oxygen levels in the water, leading to the death of aquatic organisms. The acceleration of eutrophication further degrades water sources, reducing water quality and leading to marsh formation. Organic fertilizers play a significant role in sustainable agricultural practices. They optimize soil fertility, support plant growth, and reduce the need for chemical fertilizers. This reduction minimizes environmental pollution and contributes to ecological balance. The effective use of organic fertilizers, especially animal manure, compost, and vermicompost, ensures the slow release of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). This prevents the sudden nutrient uptake associated with chemical fertilizers, allowing for controlled nutrient absorption by plants, ultimately enhancing yield. This study aims to examine the effects of organic fertilizer use on yield and quality in field crops. The objectives of this research include: preventing agricultural pollution, contributing to climate change mitigation, reducing or eliminating the negative effects of chemical fertilizers on soil organisms, promoting the widespread use of organic fertilizers to achieve high-quality production, ensuring harmony with nature in agricultural production, supporting the sustainability of plant and animal production, fostering mutual input support in agricultural

systems, and addressing the economic, social, and ecological dimensions of agricultural production.

Keywords: Organic Fertilizer, Chemical Fertilizer Damage, Agriculture

TARLA BİTKİLERİNDE ORGANİK GÜBRE KULLANIMININ VERİM VE KALİTEYE ETKİSİ

ÖZET

Tarla bitkilerinde gübrenin kullanımı insanlığın tarıma başlangıcıyla beraber yaklaşık 10.000 yıllık eski bir uygulamadır. Tarımsal faaliyetlerin artışıyla beraber toprağın doğal saf hali insanlara yeterli gelmemeye başlamıştır. Bu durum sonucu üreticiler toprağın verimliliğini artırmaya yönelik farklı yöntemlere başvurmuştur. Farklı yöntemler arayan üreticiler ilk olarak organik gübre (bitki artıkları, odun külü ve hayvan gübresi) kullanımı ile toprağa besin desteği sağlamıştır. Toprak verimin artması ve üretilen ürünlerin daha kaliteli olması için doğru gübre seçimi ve uygulanacak gübrenin doğru dozda olması hayati önem taşımaktadır. Organik gübreler içerisinde organik madde, mikroorganizmalar ve bitki besin maddelerini yüksek düzeyde içermektedir. Organik gübreler içeriği gereği toprağın verimini ve üretilecek ürünün kaliteli bir şekilde yetişmesini sağlar. Organik gübreler hayvan gübresi, biyokömür, kompost, solucan gübresi, yeşil gübre alg/yosun gübresi, mikrobiyal gübreler ve mikoriza gübrelerini kapsamaktadır. Kimyasal gübrelerin bilinçsiz uygulanması sonucu toprakta ağır metal (Cu, As, Cd, Ni, Pb, vb.) birikimi ve toprak tuzluluk artışına sebep olarak toprağın yapısını bozmaktadır. Azot ve fosfor içerikli kimyasal gübrelerin tarımda kullanılması sonucu suya karışan gübre ötrifikasyon sürecinin başlamasına sebep olur. Ötrifikasyon, su ekolojik sistemini bozarak alg patlamalarına sebebiyet verir ve suda ki oksijen seviyesini düşürerek su canlılarının ölümüne sebebiyet verir. Ötrifikasyonun hızlanması bölgedeki su kaynaklarının yapısının bozulmasına sebebiyet vererek su kalitesinin düşmesine ve bataklıklaşmaya başlamasına sebebiyet verir. Organik gübreler, sürdürülebilir tarım uygulamaları için önemli bir etkiye sahiptir. Toprak verimini en iyi düzeye getirir ve bitki gelişimini destekler. Organik gübre kullanımını kimyasal gübre kullanımını azaltır. Bu durum çevresel kirliliği en aza indirerek çevre ekolojisine katkıda bulunur. Organik gübreler, sürdürülebilir tarım uygulamaları için önemli bir etkiye sahiptir. Toprak verimini en iyi düzeye getirir ve bitki gelişimini destekler. Organik gübre kullanımını kimyasal gübre kullanımını azaltır. Bu durum çevresel kirliliği en aza indirerek çevre ekolojisine katkıda bulunur. Özellikle ahır gübresi, kompost ve solucan gübresi (vermikompost) gibi organik gübrelerin etkili kullanımı, azot (N), fosfor (P) ve potasyum (K) gibi temel besin elementlerinin bitkilere daha yavaş salınımıyla uzun kullanılmasına yardımcı olur. Bu durum, kimyasal gübrelerin sebep olduğu ani besin alınımının önüne geçerek bitkilerin besin alımını kontrol ederek verim artışını sağlar .

Bu araştırma, tarla bitkilerinde organik gübre kullanımının verim ve kalite üzerindeki etkilerini incelemeyi amaçlamaktadır. Bu amaçların kapsamı şunlardır: Tarımsal kaynaklı kirliliği önlenmesine yardımca olmak, iklim değişikliğinin azaltılmasına katkıda bulunmak, kimyasal gübrelerin toprakta yaşayan canlıların sağlığı üzerindeki negatif etkilerini ortadan kaldırmak veya azaltmasında yardımcı olmak, organik gübrelerin kullanımın yaygınlaştırılmasına yardımcı olarak yüksek kalitede üretim yapılmasını sağlamak, Doğa ile uyumlu üretimde bulunmak, bitkisel ve hayvansal üretimin sürekliliğinin sağlanmasına yardımcı olmak, karşılıklı girdilerle üretimlerde karşılıklı desteği sağlamak, tarımsal üretimin ekonomik, sosyal ve ekolojik boyutunu birlikte ele almaktadır.

Anahtar Kelimeler: Organik Gübre, Kimyasal Gübre Zararı, Tarım

1. GİRİŞ

Tarla bitkilerinde gübrenin kullanımı insanlığın tarıma başlangıcıyla beraber yaklaşık 10.000 yıllık eski bir uygulamadır. Neolitik dönemde insanlar toprağı sürerek baklagiller ve tahıl bitkileri gibi ürünler yetiştirmişlerdir. Tarımsal faaliyetlerin artışıyla beraber toprağın doğal saf hali insanlara yeterli gelmemeye başlamıştır. Bu durum sonucu üreticiler toprağın verimliliğini artırmaya yönelik farklı yöntemlere başvurmuştur. Farklı yöntemler arayan üreticiler ilk olarak organik gübre (bitki artıkları, odun külü ve hayvan gübresi) kullanımı ile toprağa besin desteği sağlamıştır(1-3).

2017 yılında Birleşmiş Milletlerin yayınladığı rapora göre 2030 yılında 8,6 milyara, 2050 yılında 9,8 milyara ve 2100 yılında 11,2 milyara ulaşması bekleniyor. Bu verilere dayanarak ileride dünyada daha fazla tarımsal üretime ihtiyaç duyulacağı öngörülebilmektedir. Daha fazla üretim ihtiyacıyla beraber bilinçsiz gübre kullanımı da artmıştır. Toprak verimin artması ve üretilen ürünlerin daha kaliteli olması için doğru gübre seçimi ve uygulanacak gübrenin doğru dozda olması hayati önem taşımaktadır(4).

Organik gübreler içerisinde organik madde, mikroorganizmalar ve bitki besin maddelerini yüksek düzeyde içermektedir. Organik gübreler içeriği gereği toprağın verimini ve üretilecek ürünün kaliteli bir şekilde yetişmesini sağlar. Organik gübreler hayvan gübresi, biyokömür, kompost, solucan gübresi, yeşil gübre alg/yosun gübresi, mikrobiyal gübreler ve mikoriza gübrelerini kapsamaktadır(5).

Kimyasal gübrelerin bilinçsiz uygulanması sonucu toprakta ağır metal (Cu, As, Cd, Ni, Pb, vb.) birikimi ve toprak tuzluluk artışına sebep olarak toprağın yapısını bozmaktadır. Fazla azot içeren kimyasal gübreler toprağın simbiyotik azot sabitleme özelliğini negatif yönde etkileyerek mikroorganizma varlığını düşürmektedir(6). Kimyasal gübreler sadece toprak yapısını değil tarımın yapıldığı bölgedeki suyu ve havayı da kirletmektedir. Azot ve fosfor içerikli kimyasal gübrelerin tarımda kullanılması sonucu suya karışan gübre ötrifikasyon sürecinin başlamasına sebep olur. Ötrifikasyon, su ekolojik sistemini bozarak alg patlamalarına sebebiyet verir ve suda ki oksijen seviyesini düşürerek su canlılarının ölümüne sebebiyet verir. Ötrifikasyonun hızlanması bölgedeki su kaynaklarının yapısının bozulmasına sebebiyet vererek su kalitesinin düşmesine ve bataklıklaşmaya başlamasına sebebiyet verir(7-8). Azot içerikli kimyasal gübre kullanımı sonucu atmosfere azot oksitler (NO_x) ve amonyak (NH_3) yayılmaktadır. Azot oksitlerin atmosfere yayılmasından kaynaklanan sera gazı oluşumu küresel ısınmaya sebebiyet vermektedir. Amonyak (NH_3), sülfatlarla tepkimeye girerek atmosferde asidik bileşikler oluşmasına sebebiyet verir, bunun sonucunda da asit yağmurlarına oluşmaktadır(9-11).

Organik gübreler, sürdürülebilir tarım uygulamaları için önemli bir etkiye sahiptir. Toprak verimini en iyi düzeye getirir ve bitki gelişimini destekler. Organik gübre kullanımını kimyasal gübre kullanımını azaltır. Bu durum çevresel kirliliği en aza indirerek çevre ekolojisine katkıda bulunur(12).

Özellikle ahır gübresi, kompost ve solucan gübresi (vermikompost) gibi organik gübrelerin etkili kullanımı, azot (N), fosfor (P) ve potasyum (K) gibi temel besin elementlerinin bitkilere daha yavaş salınımıyla uzun kullanılmasına yardımcı olur. Bu durum, kimyasal gübrelerin

sebep olduğu ani besin alınımının önüne geçerek bitkilerin besin alımını kontrol ederek verim artışını sağlar (13).

Bu araştırma, tarla bitkilerinde organik gübre kullanımının verim ve kalite üzerindeki etkilerini incelemeyi amaçlamaktadır. Bu amaçların kapsamı şunlardır: Tarımsal kaynaklı kirliliği önlenmesine yardımca olmak, iklim değişikliğinin azaltılmasına katkıda bulunmak, kimyasal gübrelerin toprakta yaşayan canlıların sağlığı üzerindeki negatif etkilerini ortadan kaldırmak veya azaltmasında yardımcı olmak, organik gübrelerin kullanımın yaygınlaştırılmasına yardımcı olarak yüksek kalitede üretim yapılmasını sağlamak, Doğa ile uyumlu üretimde bulunmak, bitkisel ve hayvansal üretimin sürekliliğinin sağlanmasına yardımcı olmak, karşılıklı girdilerle üretimlerde karşılıklı desteği sağlamak, tarımsal üretimin ekonomik, sosyal ve ekolojik boyutunu birlikte ele almaktadır.

2. ORGANİK GÜBRELER VE ÖZELLİKLERİ

2.1. Hayvan Gübresi

Hayvan gübresi, ahır ve çiftlik hayvanlarının yataklık materyallerinin ve dışkılarının karışımından oluşan bir organik gübre çeşididir. Toprak yapısının kimyasal, biyolojik ve fiziksel olarak iyileştirir ve bitki gelişimine yardımcı olur. Hayvan gübreleri kullanılan hayvan kaynaklarına göre kendi arasında 8'e ayrılmaktadır bunlar; Koyun gübresi, sığır gübresi, tavuk gübresi, yarasa gübresi, güvercin gübresi, at gübresi, ördek gübresi, kaz gübreleridir. Hayvan gübrelerinin besin içeriği, gübrenin kaynağı, hayvanın yaşı, yedikleri yemin miktarı, yataklığın cinsi ve miktarı, hayvanların kullanım durumu, gübrenin depolanması faktörlerine bağlı olarak değişmektedir.

Hayvan gübreleri, bitki besin elementleri ve organik madde içeriği açısından zengin olup, araziye uygulandıklarında mineralizasyon ve parçalanma süreçleriyle bitkilerin gelişiminde önemli rol oynayan besin maddelerini serbest bırakırlar. Mineralizasyon ve parçalanma süreci, toprak yapısının kimyasal, biyolojik ve fiziksel olarak iyileştirir ve bitki gelişimine yardımcı olur(14).Hayvan gübresi, kompostlanarak ya da toprak veriminin artması için doğrudan uygulanabilir. Kompostlama, patojen miktarını azaltır ve bitkilerin besin elementlerine daha kolay ulaşabilir hale getirir (15).

Hayvan gübrelerinin uygulanma zamanı; iklim, toprak tekstürü, bitki çeşidi ve hayvan gübresinin olgunlaşma durumuna göre değişmektedir. Hayvan gübreleri mera ve çayır arazilerinde toprak yüzeyine direkt olarak uygulanırken tarla ve bahçe bitkileri yetiştiriciliğinde toprağa karıştırılarak uygulanmaktadır. Üretimde kullanılacak hayvan gübresi toprağın besin ihtiyacına, toprak tekstürüne, üretimi yapılacak bitkinin gübre ihtiyacı belirlenerek seçilmelidir (16).

2.2. Kompost ve Vermikompost

Kompost, organik atıkların biyolojik olarak aerobik veya anaerobik şartlar altında parçalanarak ve daha sonra stabilize edilerek oluşan organik bir üründür. Kompostlama işleminde sıcaklık 45-65°C'ye kadar yükselmektedir bunun nedeni mikroorganizmaların aktif faaliyetleridir.

Sıcaklığın yükselmesi zararlı patojenlerin inaktivasyonuna yardımcı olur. Kompostlama işlemini etkileyen ana faktörler arasında nem, sıcaklık, pH, oksijen seviyesi ve C/N oranı bulunur. Bu faktörler göz önünde bulundurularak, stabil bir kompost ürününün oluşmasına ve organik maddelerin iyi bir şekilde ayrışmasını sağlamaktadır. Ayrıca, patojenlerin inaktivasyonu, yeniden çoğalması ve kontrolü, kompostlama sürecinde kritik bir rol oynar (17).

Kompost 'un temel bileşenleri Azot (N), fosfor (P), potasyum (K), çinko (Zn), demir (Fe), magnezyum (Mg) ve kalsiyum gibi makro ve mikro besin elementleridir. Kompost organik madde yönünden zengin bir üründür. Humus benzeri organik maddeler toprağın su tutma kapasitesini yükseltir ve bitki büyümesini teşvik eder. Kompostun içerisinde mantar, bakteri ve aktinomisetler organik maddelerin ayrışmasında önemli rol alan canlı organizmalar bulunmaktadır. Kompost nem oranı yüksek bir üründür, bu da mikroorganizmalar aktive edilmesi için gereklidir (18-19).

Vermikompost, solucanların ot, çimen, koçan yaprakları, yonca, mısır sapları, çay posası, pancar yaprakları, talaş, karton parçaları ve mutfak artıkları gibi organik atıklarla beslenmesi sonucu dışkılayarak meydana getirdiği bir organik gübredir. Vermikompostun son yıllarda kullanımının artmasının başlıca nedenleri, kimyasal gübrelerin sebep olduğu toprak tekstürünün bozulmasını önlemek ve uzun vadede çevresel kirliliğin önüne geçmektir (20). Vermikompost uygulaması sonucu topraktaki organik madde miktarını artırarak mikrobiyal aktiviteyi teşvik eder ve bitkilerin ihtiyacı olan makro ve mikro besin elementlerini daha kolay bir şekilde alınımını sağlar (21). Vermikompost, içerisinde mikro besin elementleri ve azot (N), fosfor (P), potasyum (K) bulundurur bu sayede bitkilerin verimini ve kalitesini artırır. Vermikompost kullanımı aynı zamanda bitkinin kök sistemini güçlendirir ve içerisinde bulunan mikroorganizmalar sayesinde patojenlerle etkileşime girerek bitkinin hastalık ve zararlılardan korunmasını sağlar (22-23).

Vermikompost ve Kompost, tarımsal üretimde kullanılmak üzere ve organik atıkların işlenerek geri dönüştürülmesinde kullanın iki farklı yöntemdir. Her iki yöntem de bitkiler üzerinde farklı etkiler göstermektedir. Vermikompost ve Kompost kullanımı atıkların geri dönüşümü, toprak tekstürünün iyileştirilmesi ve toprağa gerekli besin maddelerinin kazandırılması gibi faydalı çevresel etkiler sunmaktadır. Fakat vermikompost ve kompost arasında belirgin farklar vardır. Bu farklılıklar organik tarımda hangi yöntemin daha avantajlı olduğunu belirlemektedir.

Özellik	Kompost	Vermikompost
pH Değeri	7.0-8.5	6.5-7.5
Organik Madde (%)	30-40	40-60
Azot (N, %)	1.0-1.5	2.0-3.5
Fosfor (P, %)	0.5-1.0	1.5-2.5
Potasyum (K, %)	0.8-1.5	1.5-2.5
Karbon/Azot Oranı	20-30:1	10-15:1
Toprak Mikrobiyal Aktivite	Orta	Yüksek
Nemin Korunumu	Orta	Yüksek
Parçalanma Süreci	2-6 ay	1-3 ay
Kaynak: (24,25,26)		

Tabloda belirtilen verilere göre, vermikompost komposta kıyasla besin elementleri(N,P,K) ve organik madde miktarı bakımından daha yüksektir. Ayrıca, vermikompost su tutma kapasitesini ve toprak Mikrobiyal aktivitesini daha yüksek bir şekilde etkilemektedir. Vermikompost komposta kıyasla daha etkili ve hızlı bir besin kaynağıdır. Vermikompost parçalanma süresi olarak daha kısa sürede olgunlaşmaktadır. Vermikompost üretiminde teknik bilgi ve kontrollü üretim yapılması gerekmektedir fakat kompostta daha az teknik donanım yeterlidir.

2.3. Biyochar

Biyochar, organik atıkların oksijensiz ortamda ve yüksek sıcaklıkta (300-1000°C) piroliz edilmesiyle elde edilen karbon(C) açısından zengin bir maddedir. Fiziksel ve kimyasal özellikleri, kullanılan atıklar ve piroliz şartlarına bağlı olarak değişiklik göstermektedir. Biyochar'ın yüzey alanı, piroliz sıcaklığı ve organik atık türüne bağlı olarak değişmektedir. Örneğin, kavak talaşından üretilen biyochar'ın yüzey alanı, 300°C'de 758.3 m^2/g iken, 600°C'de 250.8 m^2/g'ye düştüğü gözlemlenmiştir (27). Biyochar'daki düşük yoğunluk, toprak drenajını iyileştirir ve toprağın havalanmasını sağlar. Biyochar hafif yapılı bir madde olduğu için toprağın yoğunluğunu hafifleterek bitki köklerinin daha iyi gelişmesini teşvik eder.

Biyochar genel olarak alkalin özellik göstermektedir ve düşük pH'lı toprakların pH seviyesini yükseltir bu durum bitki gelişimini desteklemektedir. Piroliz sıcaklık derecesinin artmasıyla, biyocharın pH değerlerinin arttığı kaydedilmiştir. Örneğin, farklı piroliz sıcaklıklarında elde edilen biyocharların pH değerleri 7.72 ile 9.72 arasında değişmektedir. Biyocharın oksijen ve hidrojen oranı düşüktür fakat karbon(C) içeriği yüksektir. Bu durum biyocharın toprakta stabil

olarak daha uzun süre kalmasını sağlamaktadır. Piroliz sıcaklığının artması organik madde elementlerini azaltmaktadır ve kül miktarını artırmaktadır (28).

Biyochar, topraktaki su tutma kapasitesini yükseltir ve toprak yapısını iyileştirmektedir, yapılan bilimsel çalışmalarda bu durumu desteklemektedir. Arzika (2019) tarafından yapılan bir araştırmada, %5 oranında kompost ve biyochar uygulamasının, elektrik iletkenliğini iyileştirdiği, kirlenmiş teknosol topraklarındaki pH seviyesini 1-3 birim artırdığı ve su tutma kapasitesinin arttığı gösterilmiştir. Ek olarak, bu uygulama da toprak içerisinde bulunan kurşun (Pb) hareketliliğini %89-%99 oranında azalttığı gözlemlenmiş. Aynı çalışmada, kompost ve biyochar uygulamalarının topraktaki su tutma kapasitesinin artırdığı bildirilmiştir (29).

Biyochar, mikroorganizmaları için uygun ortam sağlayarak mikrobiyal aktiviteyi teşvik eder. Mikroorganizmalar, topraktaki organik madde döngüsünün daha hızlı olmasını sağlayarak bitkinin besin elementlerini daha kolay ve verimli bir şekilde kullanmasını sağlamaktadır. Biyochar, özellikle toprak mikroflorasını yükselterek toprak sağlığının iyileşmesini sağlar ve bu durum sonucu bitki daha iyi bir şekilde gelişir. Biyocharın ve vermikompostun birlikte kullanılması organik madde döngüsü ve mikrobiyal aktiviteler üzerinde daha olumlu etkiler göstermektedir. Mikrobiyal aktivitenin artması, bitkilerin hastalık ve zararlılara daha güçlü bir şekilde başa çıkmasını sağlamaktadır (30-31).

2.4. Yeşil Gübreler

Yeşil gübreleme, bazı yeşil bitkilerin yetişme ortamlarında, büyüme döneminde iken veya çiçeklenme aşamasından hemen sonra toprakla homojen bir şekilde karıştırılıp sürülmesi işlemidir. Yeşil gübreleme, topraktaki organik madde miktarını artırarak ve topraktaki besin elementlerini artırır. Yeşil gübreleme, toprak yapısını iyileştiren önemli bir gübre çeşididir (32). Bu gübre çeşidinde, belli başlı bitkiler üretilerek toprak yüzeyinde veya içinde parçalanması sonucu toprağın yavaş ve dengeli bir şekilde gübrelenmesini sağlar.

Yeşil gübre, organik madde miktarı yüksek ve hızlı yetişen bitkilerin ürettirilerek toprağa karıştırılmasıyla elde edilir. En yaygın kullanılan yeşil gübre bitkileri hardalgiller (Brassicaceae), baklagiller (Fabaceae) ve bazı tahıl çeşitleridir. Baklagil türleri, köklerinde bulunan *Rhizobium* bakterileri toprağa doğal bir azot kaynağı sağlar (33).

Yeşil Gübre Bitkisi	Azot (N) (%)	Fosfor (P) (%)	Potasyum (K) (%)	Organik Madde (%)	Karbon (C) (%)	Kaynak
Yonca (*Medicago sativa*)	2.5 – 3.5	0.2 – 0.4	1.5 – 2.5	45 – 55	40 – 45	Drinkwater & Snapp, 2007
Fiğ (*Vicia sativa*)	2.0 – 3.2	0.2 – 0.5	1.8 – 2.3	40 – 50	38 – 42	Finney et al., 2016
Soya Fasulyesi (*Glycine max*)	3.0 – 4.0	0.3 – 0.6	2.0 – 3.0	50 – 60	42 – 48	Govaerts et al., 2007
Bezelye (*Pisum sativum*)	2.5 – 3.5	0.3 – 0.5	2.0 – 2.8	45 – 55	39 – 44	Lal, 2004
Çavdar (*Secale cereale*)	1.0 – 1.8	0.2 – 0.4	1.5 – 2.2	35 – 45	35 – 40	Teasdale, 1996
Yulaf (*Avena sativa*)	1.2 – 2.0	0.2 – 0.4	1.4 – 2.0	37 – 47	36 – 41	Uphoff et al., 2006
Hardal (*Sinapis alba*)	1.5 – 2.5	0.3 – 0.6	2.0 – 3.5	40 – 50	37 – 42	Finney et al., 2016
Kaynak:32,33,34,35,36,37						

Yeşil gübreleme; organik madde ve N,P,K,C elementlerini toprağa kazandırdığı bilinmektedir. Yeşil gübreleme verimliliği artırır, su tutma kapasitesini yükseltir, kuraklığa karşı mücadele eder, kök sistemleriyle erozyonu önler, mikrobiyal aktiviteyi artırarak yararlı organizmaların gelişimini destekler, yabancı ot ve zararlıların önüne geçer ve azot(N) bakımından yüksek bitkilerle kimyasal gübre ve herbisit ihtiyacını azaltarak çevresel sürdürülebilirliğe yardımda bulunur. Yeşil gübre bitkileri, toprak yapısı, iklim ve toprağın ihtiyaçlarına göre seçilir. Baklagiller (fiğ, yonca, bezelye, soya fasulyesi) azot bağlayarak toprağın besin maddelerini arttırırken, hardalgiller (hardal, turp) toprak yapısını iyileştirir ve bazı zararlılarla mücadele eder. Tahıllar (çavdar, buğday, yulaf) ise erozyonun önüne geçerek topraktaki organik madde miktarını artırır.

2.5. Alg/Yosun Gübreleri

Algler ve yosunlar, organik tarımda gittikçe daha fazla önem kazanan organik gübre kaynaklarıdır. Alg ve yosun gübreleri, bitki büyümesini teşvik eden makro ve mikro besin elementleri, vitaminler, amino asitler ve büyüme hormonlarını içermektedir. Deniz yosunları,

Azot (N), fosfor (P) ve potasyum (K) gibi makro besinler ve çinko (Zn), demir (Fe), bakır (Cu), bor (B) ve molibden (Mo) gibi mikro besinleri içerisinde barındırır. Bu besin elementleri sayesinde bitki beslenmesini teşvik eder. Toprağın organik madde miktarının artmasını sağlayarak toprak su tutma kapasitesini artırır ve havalanmasını sağlar. İlaveten, alg ve yosun gübreleri pH dengeleme özelliği bakımından topraklarda kireç yerine kullanılabilir.

Deniz yosunu ekstraktları, bitkilerde fotosentez sürecinin ve yaprak ve klorofil içeriğinin de artmasını sağlar. İlaveten, tohumların çimlenme oranını artırarak daha güçlü ve hızlı büyümesini sağlamaktadır. Deniz yosunlarının içerisinde biyoaktif bileşikler bulunur bu sayede bitkiler nematodlara ve fungal hastalıklara karşı daha dirençli hale gelir. Bilhassa Botrytis cinerea gibi fungal enfeksiyonlara karşı önemli derecede direnç gösterir. Virüslere karşı etkin olan alg ve yosun gübreleri zararlılara karşı daha dayanıklı olmaktadırlar. Deniz yosunu gübreleri diğer organik gübreler gibi karbon döngüsüne yardımcı olur ve kimyasal gübrelerin daha az kullanılması sebebiyle ise çevresel sürdürülebilirliğe katkıda bulunmaktadır. Deniz yosunu gübreleri, doğal kaynakların korunmasını sağlarken aynı zamanda organik tarımda sürdürülebilirliğe katkıda da bulunmaktadır (38,39).

Alg ve yosun gübresinin dört farklı kullanımı vardır; Alg ve yosun gübreleri direkt olarak toprağa uygulanabilir. Direkt toprağa uygulama yöntemi bitkilerin kökleri sayesinde hızlıca emilen besin elementlerinin toprakta kolay bir şekilde yayılmasını sağlar. Alg ve yosun gübreleri yaprak gübresi olarak da kullanılabilir. Yaprak gübresi olarak kullanılması sayesinde bitkinin yaprakları vasıtasıyla besin elementlerine hızlı ve kolay bir şekilde ulaşmasını sağlar. Alg ve yosun gübreleri sulama suyuna karıştırılarak da kullanılabilir bu uygulama şekli bitkilerin kök sistemine direkt olarak ulaşmasını sağlar. Alg ve yosun gübreleri, topraksız tarımda besin çözeltisi olarak kullanılabilir. Alg ve yosun gübreleri içerisinde N,P.K besin maddelerini bulunmaktadır. Alg ve yosun gübrelerinin kullanımı topraksız tarımda pestisit ve su ihtiyacını azaltarak çevresel sürdürülebilirliğe katkıda bulunmaktadır (40,41,42).

2.6. Mikrobiyal Gübreler

Mikrobiyal gübreler, bitki yetiştiriciliğinde verim ve kaliteyi artıran mikroorganizma içerikli gübre çeşididir. Mikrobiyal gübrelerde Azot (N), Fosfor (P), Potasyum (K), Kalsiyum (Ca), Magnezyum (Mg), Kükürt (S), Demir (Fe), Çinko (Zn), Bakır (Cu), Mangan (Mn) gibi önemli besin maddeleri bulunmaktadır. Mikrobiyal gübrelerin katı, sıvı ve toz olmak üzeri üç çeşidi vardır (43). Mikrobiyal gübreler uygun dozlarda kullanıldığında bitki gelişimine katkıda bulunmaktadır. Bu gübreler, hastalık ve zararlılara karşı bitkinin direncini artırır ve abiyotik stres koşullarında bitkilerin dayanaklılığını artırmaktadır. Topraktaki yararsız besin maddelerini yararlı hale getirmektedir. Kimyasal gübrelerin bilinçsiz kullanımı sonucu oluşan çevre kirliliği ve ağır metal birikimi sorununa karşılık çevre dostu bir yöntemdir.

Mikrobiyal gübreler, mikorizalar, mantarlar, algler ve bakteriler gibi mikroorganizmaları içerisinde bulundurur. Bu mikroorganizmalar, bitki besin maddelerini serbest bırakmakta, toprak verimliliğini artırmakta ve bitki gelişimini teşvik etmekte kullanılır. Bradyrhizobium ve Rhizobium gibi bakteriler, baklagil bitkileri karşılıklı etkileşime girerek atmosferik azotu bitkilerin kullanabileceği şekle sabitlerler. Azospirillum ve Azotobacter gibi bağımsız hareket

eden bakteriler ise toprakta azot fiksasyonu gerçekleştirerek bitkilerin azot ihtiyacını karşılamaktadırlar. Bacillus, Azotobacter ve Pseudomonas mikroorganizmaları, toprakta bulunan fosfor ve potasyumun çözünürlük kapasitesinin artmasını sağlayarak bitkilerin bu besin elementlerini daha etkin bir şekilde kullanmasını sağlarlar (44,45,46).

Mikrobiyal gübreler uygulanması sonucu topraktaki organik maddelerin ayrışır ve toprağın verimliliğinin desteklenmesini sağlar. Silikat bakterileri, topraktaki potasyum(K) içeriğini artmasını sağlayarak bitki büyümesini teşvik eder. Mikrobiyal gübreler, bitki kök gelişimini, bitki kök gelişimini ve tohum çimlenmesini desteklemektedir. Örneğin, Paenibacillus azotofixans ve Bacillus subtilis bakterileri mısır (Zea mays) bitkisinin protein oranını artırmaktadır (47). Bitkilerin soğukluk, tuzluluk, kuraklık gibi abiyotik stres koşullar altında daha dirençli olmasını sağlayan mikrobiyal gübreler daha verimli ve kaliteli büyümeyi teşvik etmektedir (48). Bununla birlikte, birtakım mikroorganizma türleri hastalık ve zararlılara karşı koruyucu etkiye sahiptir. Örneğin, Bacillus ve Bacillus mikroorganizmaları patojenlere karşı biyopestisit görevi görerek pestisit kullanımının önüne geçmektedir. Mikrobiyal gübreler, bitki gelişiminde verimliliği ve sürdürülebilirliği artıran önemli bir üründür. Bu gübreler, bitki koruma ve bitki besleme amacıyla kullanılmaktadır. Mikrobiyal gübreler hem toprak sağlını koruyarak hem de çevre kirliliğini azaltarak başarılı bir çözüm sunmaktadır.

2.7. Organik Tarım Biliminde Mikorizanın Kullanımı ve Önemi

Organik tarımda yaygın bir kullanım alanına sahip olan mikoriza mantarları, bitkinin kökleriyle simbiyotik ilişkiye girerek besin ve su alınımını artırmaktadır. Fotosentez sürecinde oluşan karbonhidratlar mikoriza mantarları için başlıca enerji kaynaklarından biridir, bu karşılıklı alışveriş sayesinde mantarlar bitkilere su ve besin maddelerini temin etmektedir.

Organik tarımda, mikoriza mantarları kimyasal gübrelere karşı iyi bir alternatiftir çünkü içerdiği başlıca besin maddeleri olan fosfor(P) ve Azot(N) besin elementlerini bitkilere ulaşımını sağlayarak bitkilerin besin ihtiyacını karşılamaktadır. Mikoriza mantar kullanımı toprağın canlı mikroorganizma popülasyonunu artırır ve çevresel kirliliğinde önüne geçer(49).

Mikoriza mantarları bitkilerin hastalık ve zararlılardan korunmasını sağlamaktadır. Bu mantarlar hif ağı oluşturmaktadır ve bu sayede bitki köklerini zararlı patojenlere karşı korur ve su alımını düzenleyerek kuraklık stres koşullarına karşı bitkilerin daha dirençli olmasını sağlar. Bu özellikler sayesinde mikoriza uygulaması organik tarımda sürdürülebilir ve verimli ürün elde etmede önemli bir rol oynamaktadır.

Fakat mikoriza mantarlarının etkinliği bitkinin türü, toprak koşulları ve çevresel faktörlere bağlıdır. Mikoriza mantarı uygulamasının yapılması için bilgi ve donanım gerekir, uygulama yapılmadan önce planlama ve yönetiminin önemli bir şekilde yapılması gerekir. Uzun vadede tarım ekosisteminin sağlığını ve verimliliğinin artması için doğal mikoriza ağlarının korunması büyük önem taşımaktadır (50).

3. ORGANİK GÜBRELERİN VERİM VE KALİTEYE ETKİLERİ

3.1. Tarla Bitkilerinde Verim Artışı

YAZİCİ, L., & ERBAY, M. B. (2024), tarafından yürütülen çalışmada ahır gübresi,çay posası ve çay posası-ahır gübresi kombinasyonları kenevir (Cannabis sativa L.) bitkisinin büyüme ve verim parametreleri üzerindeki etkilerini incelemişlerdir. Ahır gübresi uygulamalarında biyolojik verim en iyi sonucu verdiği bildirilmiştir. (4500,75 kg/da)**,** lif verimi (294,88 kg/da) ve tohum verimi (248,31 kg/da), lif verimi (294,88 kg/da) ve tohum verimi (248,31 kg/da) olarak tespit edildiği belirtilmiştir. Çalışma, organik gübrelerin tarla bitkileri üretiminde verimi artırdığını ve ahır gübresinin en verimli seçenek olduğunu kanıtlamıştır (51).

Büyükfiliz, F. (2016), yapılan çalışmada farklı oranlarda vermikompost uygulamalarının mısır (Zea mays L. indentata) üzerindeki etkileri incelemişlerdir. Çalışma sonucuna göre organik gübre olarak kullanılan vermikompost, verim ve bitki gelişimi değişkenleri üzerinde önemli etkiler gösterdiği tespit etmişlerdir. Özellikle 750 kg/da vermikompost uygulaması**,** en yüksek tane verimi (1561 kg/da) sağlayarak ürün miktarını önemli düzeyde artırdığı bildirilmiştir. Aynı zamanda, bin tane ağırlığı, koçanda tane ağırlığı, bitki boyu, yaprak sayısı ve protein oranı olan verim unsurlarında bariz artışlar gözlemlemişlerdir. Daha düşük dozlarda verim artışı gözlenirken, 750 kg/da uygulamasından sonra verim artışının artmadığı bildirilmiştir (52).

Organik gübrelerin uzun vadede topraktaki besin maddelerini koruduğu akademik çalışmalarda ispatlanmıştır. Sönmez ve arkadaşlarının (2019) yaptığı bir araştırmada, farklı organik gübrelerin (çiftlik gübresi, tavuk gübresi, leonardit ve vermikompost) artan dozlarının toprak özellikleri üzerindeki etkileri incelemişlerdir. Sonuç olarak, organik gübre uygulamalarının toprak verimlilik parametrelerini iyileştirdiğini ve bitki kalitesine katkı sağladığını tespit etmişlerdir (53). Benzer şekilde, Cüre (2022) tarafından yapılan çalışmada, Kimyasal ve organik gübrelerin çevre üzerindeki etkileri incelenmiştir. Bu çalışmada, organik gübrelerin ağır metal birikimi, toprak tuzluluğu ve su kaynaklarını ötrofikasyon etkisinin daha az olduğu vurgulanmıştır. Organik gübrelerin besin maddelerini katkı sağladığı da yapılan çalışmada belirtilmiştir. Ayrıca, organik gübrelerin toprağın organik madde içeriğini artırarak besin elementlerinin korunmasına katkı sağladığı vurgulanmıştır (54). Bu sebeple, tarımda organik gübre kullanımının artırılması çevre koruma ve sürdürülebilir tarım açısından büyük önem taşımaktadır.

Okur, N., ve arkadaşlarının (2007)' de yaptığı çalışmada Leonardit, Biofarm ve Hümik asit gibi organik gübrelerin. Biofarm, Leonardit ve Hümik asit gibi organik gübrelerin, soğuk iklim sebzeleri toprakların biyokütle, mikrobiyal ve enzim aktivitesi üzerindeki etkileri incelemişlerdir. Biofarm gübresinin uygulandığı tüm parsellerde mikrobiyal biyokütle ve enzim aktivitesi yükselttiği bildirilmiştir. Biofarm uygulamaları ile mikrobiyal biyokütle miktarı konvansiyonel tarıma oranla ortalama %77, β-glukozidaz %55, dehidrogenaz %175, proteaz %69 ve alkalin fosfataz %44 oranında daha fazla saptandığı belirtişmiştir (55).

3.2. Tarla Bitkilerinde Kalite Artışı

Organik gübreler, tarla bitkilerinde besin değerlerini artırmakta önemle bir yere sahiptir. Organik gübreler toprak yapısını iyileştirerek bitkilerin besin elementlerinden daha iyi bir

şekilde yararlanmasını sağlamaktadır. Bu gübreler, protein, vitamin ve mineral oranlarının artmasında yardımcı olmaktadır. Organik gübreler bitkilerin besin maddelerinin alınımında doğrudan etkisi olduğu için bitkinin protein içeriğini de etkilemektedir. Yapılan çalışmalar sonucu K-humat ve organomineral gübre uygulamaları tane mısırının protein oranını artırmaktadır ve daha verimli bir üretim sağlamaktadır. Farklı organik gübrelerin kullanımı amonyum sülfata uygulamasına kıyasla da benzer bir artış göstermiştir.

Yaldız, Çamlıca ve Özen (2019) tarafından gerçekleştirilen araştırmada, organik gübre uygulamasının tıbbi ve aromatik bitkilerin kalite ve verim değerlerinin üzerindeki etkilerini incelemiştir. Yapılan çalışmada organik gübre uygulamalarının bitki gelişimine katkı sağladığı ve özellikle uçucu yağ ve fenolik bileşiklerinin içeriğini artırdığı tespit etmişlerdir Organik gübre uygulanan bitkilerin vitamin içeriği doğrudan ölçülmemiş olsa da ikincil metabolitlerin pozitif etkilerine dayanarak vitamin sentezini de artırabileceğini göstermektedir. Ayrıca, farklı araştırmalar organik gübre kullanımının C vitamini, E vitamini ve β-karoten üzerinde pozitif yönde etkiler gösterdiğini ortaya koyduğunu belirtmişlerdir. Azot miktarı yüksek olan organik gübreler, bitkilerde askorbik asit (C vitamini) üretiminin artmasını sağlayabilir ve karotenoid sentezini artırarak provitamin A miktarını yükseltebileceği belirtilmiştir.

Rahımı, A., Arslan, N., & Esmzad, S. (2016) tarafından yürütülen çalışmada, çinko (Zn), demir (Fe), mangan (Mn) ve bor (B) elementlerinin şekerpancarında kaliteyi etkileyen bazı özellikler üzerindeki etkileri incelemişlerdir. Araştırmada, mikro elementlerin şeker oranı, potasyum (K), azot (N) ,sodyum (Na) içerikleri, kristalize edilebilen şeker oranı, alkalinite, melastaki şeker randımanı ve şeker oranı üzerindeki etkileri incelenmiştir.

Çalışma sonucunda, şeker oranı %15.48 ile %17.77, kristalize edilebilen şeker oranı %12.32 ile %13.81 ve şeker randımanı %77.72 ile %79.59 arasında değişmiştir. Uygulanan mikro elementler, sodyum, potasyum ve azot içeriklerini azaltmış; bu da şekerin kristalleşme veriminde artış sağladığı bildirilmiştir.

Demir uygulaması, şeker oranını azaltmasına rağmen en yüksek şeker randımanını sağlamıştır. Bor uygulamasında azot içeriği en düşük seviyede tespit edilmiş, alkalinite en yüksek düzeye ulaşmıştır. Genel olarak mikro elementlerin kullanımı, şekerpancarında kaliteyi belirleyen birçok parametreyi pozitif yönde etkilemiş, özellikle kristalize edilebilir şeker miktarını ve şeker randımanını artışını sağladığı belirtilmiştir (56).

3.3. Toprak Verimliliği ve Uzun Vadeli Etkiler

Türkiye topraklarının büyük bölümü organik madde yönünden noksandır ve %70'ten fazlası erozyon riski barındırmaktadır. Organik madde kaybı, toprak canlılığı ve ekosistem sağlığını doğrudan olumsuz yönde etkilemektedir. Toprak organik maddesinin korunması, toprak sağlığının, verimliliğinin ve karbon dengesinin sürdürülebilirliği için gereklidir (57).

Yılmaz, Alagöz ve Öktüren (2008) tarafından yapılan çalışmada, farklı organik materyal uygulamalarının toprak agregat büyüklük dağılımı ve dayanıklılığı üzerine etkileri ile ilgili araştırmasında, değişik kökene sahip üç adet organik materyal, farklı dozlarda uygulamıştır. Yedi aylık bir inkübasyon zamanında elde edilen sonuçlara göre, uygulamaların toprağın agregat büyüklük dağılımı ve direnci üzerine etkisi değişik agregat boyutlarında çeşitli

düzeylerde gerçekleşmiştir. Agregat büyüklük dağılımı üzerine etki bakımından işlenmiş tavuk gübresi 8–4 mm boyutlu agregatlarda %5, 1–0,5 mm boyutlu agregatlarda %1 düzeyinde, çöp kompostu 2–1 mm boyutlu agregatlarda %1 en etkili oran olduğu belirtilmiştir. (58).

Demir ve ark. (2012) tarafından yapılan çalışmada, kumlu yapıya sahip bir toprağa uygulanan ahır gübresi, leonardit ve su tutucu polimerlerin, tarla kapasitesi ve solma noktası düzeyinde içerdiği su miktarı ile toprakların yarayışlı su tutma kapasitesine olan etkisine bakılmıştır. Araştırma sonuçlarına göre, bu toprak iyileştiricileri, toprağın su tutma kapasitesini, su geçirgenliğini ve organik madde düzeyini artırmış, toprak pH'ını düzenlemiş ve besin elementleri metabolizmalarını etkileyerek bitki gelişimine destek olduğu bildirilmiştir(59).

Karapire ve Özgönen (2013) tarafından yapılan çalışmada, rizosfer mikrobiyolojisi üzerine özellikle ortak mikrobiyal etkileşimi tanımlayan birden fazla çalışmasını, funguslar ve bakteriler üzerine yapmıştır. Barea ve arkadaşlarının yaptığı çalışmada, rizosfer mikroorganizmalarının hem bitki zararlılarını hem de daha önemsiz parazitik ve parazitik olmayan organizmaları etkilediği sonucuna varmışlardır. Bu etkileşimler, bitki gelişimi ve toprak sağlığı üzerinde önemli sonuçlar gösterdiği bildirilmiştir(60).

4. ORGANİK VE KİMYASAL GÜBRELERİN KARŞILAŞTIRILMASI

4.1. Verim Karşılaştırması

Ruşen, D. B. (2020). 'nin yapmış olduğu çalışmaya göre şilempenin içeriğinde bulunan organik madde miktarı ile toprağın içerisindeki organik madde kapasitesini yükselttiği için toprak uygulamasının dane verimini pozitif yönde etkilediği sonucuna varmışlardır. Organik maddece fakir olan topraklarda şilempenin topraktan uygulama yapılması sonucunda buğday yetiştiriciliğinde verim ve kaliteyi pozitif yönde artırdığı sonuçlarda belirtilmiştir (61).

4.2. Kalite Karşılaştırması

Mısır Çeşitlerinde Organik ve Kimyasal Gübre Besin İçeriği Farklılıkları

Gübre Türü	Organik Madde (%)	Azot (N) (%)	Fosfor (P_2O_5) (%)	Potasyum (K_2O) (%)	pH	Nem (%)
Tavuk Gübresi	54.3	3.64	1.63	1.38	6.72	8.20
Çiftlik Gübresi	45.2	2.85	1.65	1.35	7.23	9.80
Solucan Gübresi	48.3	2.23	1.18	1.52	6.25	10.5
Kimyasal Gübre	-	20 kg da^{-1} (N)	8 kg da^{-1} (P_2O_5)	-	-	-

(62).

Kimyasal gübrelerin kalıntı etkileri açısından değerlendirildiğinde, bu gübrelerin büyüme düzenleyiciler ve zirai ilaçlarla birlikte toprak, su, hava ve gıda üzerinde olumsuz etkiler yarattığı ifade edilmiştir. Kimyasal gübrelerin üretimi artırmak amacıyla yaygın kullanımı, su ve toprak kirliliğine yol açmakta, ürün çeşitliliğini ve kalitesini düşürmekte ve toprağın biyolojik yapısını bozarak faydalı kullanım özelliklerini olumsuz yönde etkilemektedir (63).

4.3. Organik Gübrelerin Uzun Vadeli Ekonomik Avantajları

- Organik gübreler, uzun vadede toprak verimliliğini artırarak daha yüksek ürün verimi elde edilmesini sağlar (64).

- Kimyasal gübrelerle kıyasla, organik gübreler toprak yapısını iyileştirmektedir ve su tutma kapasitesini artırır, bunun sonucunda sulama maliyetlerini düşürdüğü bilinmektedir.

- Organik gübre kullanımı, kimyasal gübrelerin sebep olduğu toprak bozulmasına karşı uzun vadeli tarımsal sürdürülebilirliğe destek olmaktadır.

- Organik gübre üretimi, yerel üreticiyi destekleyerek ve dışa bağımlılığı azaltarak ve istihdam sağladığı için ekonomik avantaj sağlamaktadır.

- Organik gübreler, toprağın besin elementlerini doğal yollarla artırarak kimyasal gübrelerin sürekli satın alınmasını gerektiren besin maddelerine olan ihtiyacı azaltır ve uzun vadede çiftçiye ekonomik avantaj sağlar.

5. SONUÇ VE ÖNERİLER

Bu materyalin geri kazanımı ile organik madde içeriği düşük olan topraklarımızın hem organik madde içeriği artırılmış olacak hem de bitki besin maddesi yönünden zenginleşeceği için daha az kimyasal gübre kullanılacaktır.

Organik gübre kullanımının yaygınlaştırılması amacıyla, üreticilerin organik gübre kullanımının özellikle insan sağlığı üzerindeki olumlu etkileri konusunda bilinçlendirilmesi ve buna bağlı olarak da organik gübre üretiminin arttırılması için gerekli çalışmaların yapılması gerekmektedir.

Konvansiyonel tarımın çevreye zararı ve maliyeti göz önüne alınırsa organik gübrelemenin maliyetinin uygun olması ile bu farkı kapatacağı belirtilmiştir.

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THE EFFECTS OF SEED SIZE ON GERMINATION AND SEEDLING GROWTH OF SAFFLOWER

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ABSTRACT

The germination and emergence is a very important aspect of crop production, but it also has a significant impact on the subsequent stages of plant growth in the field. One of the most important aspects for safflower production is a uniform emergence and a strong seedling development in the field. Although this is related to seed size, generally large seeds show better germination and seedling development than small seeds. In this research conducted in the analysis laboratory of Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Field Crops in 2025, it was aimed to determine the effects of different seed sizes on germination and seedling growth in safflower. Two safflower cultivars (Dinçer and Olas) were used in the study and three different seed sizes (Small: 30-35 g, Medium: 40-45 g and Large: 50-55 g) were determined according to the 1000 seed weight. The experiment was conducted at room temperature (20 ± 2°C) with 3 replications according to the randomized split-plot design with cultivars as main plots and seed size as sub-plots. In the study, germination rate (GT), mean germination time (MGT), shoot lenght (SL), root length (RL), shoot fresh weight (SFW), shoot dry weight (SDW), root fresh weight (RFW) and root dry weight (RDW) parameters were investigated. According to the results of the analysis, the effect of seed size was found to be statistically significant, while the effect of cultivars was not found to be statistically significant for all characters examined except root dry weight. Germination rate increased with seed size and the highest germination rate was obtained from medium and large seeds (100.00% and 99.17%, respectively). In addition, as the seed size increased, the germination time of the seeds shortened and the earliest germination was obtained from medium and large seeds (3.20 and 3.05 days, respectively). When the results of the study were analyzed as a whole, it was concluded that germination and seedling growth of large seeds may be better than small seeds.

Keywords: Safflower, Germination, Seedling Growth, Seed Size

ASPİRDE TOHUM İRİLİĞİNİN ÇİMLENME VE FİDE GELİŞİMİ ÜZERİNE ETKİLERİ

ÖZET

Bitkisel üretimde çimlenme ve çıkış çok önemli bir husus olmakla birlikte bitki büyümesinin sonraki aşamaları üzerinde önemli etkilere sahiptir. Aspir tarımı için en önemli hususlardan biri üniform bir çıkış ve kuvvetli fide gelişimidir. Bu durum tohum iriliği ile ilgili olmakla birlikte genellikle iri tohumların küçük tohumlara göre daha iyi çimlenme ve fide gelişimi gösterdiği bilinmektedir. Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü analiz laboratuvarında 2025 yılında yürütülen bu araştırmada farklı tohum iriliklerinin aspirde çimlenme ve fide gelişimi üzerine etkilerinin belirlenmesi amaçlanmıştır. Bu amaçla araştırmada iki aspir çeşidi (Dinçer ve Olas) kullanılmış ve tohumların bin tane ağırlığına göre üç farklı tohum iriliği (Küçük: 30-35 g, Orta: 40-45 g ve Büyük: 50-55 g) belirlenmiştir. Deneme Tesadüf Parselleri Deneme Desenine göre çeşitler ana parselde, tohum irilikleri ise alt parselde olacak şekilde 3 tekrarlamalı olarak oda sıcaklığında (20 ± 2°C) yürütülmüştür. Çalışmada çimlenme oranı (ÇO), ortalama çimlenme süresi (OÇS), sürgün boyu (SB), kök boyu (KB), sürgün yaş ağırlığı (SYA), sürgün kuru ağırlığı (SKA), kök yaş ağırlığı (KYA) ve kök kuru ağırlığı (KKA) gibi özellikler incelenmiştir. Araştırmadan elde edilen verilerin varyans analizi sonucuna göre, tohum iriliklerinin etkisi istatistiki olarak önemli bulunurken, çeşitlerin etkisi kök kuru ağırlığı hariç incelenen tüm karakterler bakımından istatistiki olarak önemli bulunmamıştır. Çimlenme oranı tohum iriliğine bağlı olarak artmış ve en yüksek çimlenme oranı orta ve büyük irilikteki tohumlardan elde edilmiştir (sırasıyla %100.00 ve %99.17). Ayrıca tohum iriliği arttıkça tohumların çimlenme süresi kısalmış ve en erken çimlenme yine orta ve büyük irilikteki tohumlardan elde edilmiştir (sırasıyla 3.20 ve 3.05 gün). Çalışmanın sonuçları bir bütün olarak incelendiğinde iri tohumların çimlenme ve fide gelişimleri küçük tohumlara göre daha iyi olabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Aspir, Çimlenme, Fide Gelişimi, Tohum İriliği

1. GİRİŞ

Asteraceae familyasından olan aspir bitkisi (*Carthamus tinctorius* L.) günümüzden 3000 yıl önce kültüre alınmaya başlanmış eski kültür bitkilerinden birisidir. Aspir, tohumlarında %25-45 yağ bulunan, linoleik (omega 6) ve oleik (omega 9) olmak üzere iki ayrı tipi olan, yağı yemeklik olarak kullanılabilen, biyodizel üretimine uygun, küspesi ve karışım halinde ekimi hayvan yemi olarak değerlendirilen, kuraklığa dayanıklı, kışlık ve yazlık formları bulunan, alternatif bir yağ bitkisidir (Arslan ve ark., 2012; Arslan ve Culpan, 2018).

Bitkisel üretimde çimlenme ve çıkış çok önemli bir husus olmakla birlikte bitki büyümesinin sonraki aşamaları üzerinde önemli etkilere sahiptir. Özellikle tek yıllık bitkilerde yüksek verim ve kalite için hızlı ve üniform bir çıkış esastır (Yari ve ark., 2010). Aspir tarımı için en önemli hususlardan birisi üniform bir çıkış ve kuvvetli fide gelişimidir. Bu durum tohum iriliği ile ilgili olmakla birlikte genellikle iri tohumların küçük tohumlara göre daha iyi çimlenme ve fide gelişimi gösterdiği bilinmektedir. Tohum iriliğinin hem arazi hem de laboratuvar denemelerinde birçok karakter üzerinde önemli etkilere sahip olduğu bildirilmiştir (Elliott ve ark., 2007; Siddiqi ve ark., 2007; Sadeghi ve ark., 2011; Alkansaa ve ark., 2019).

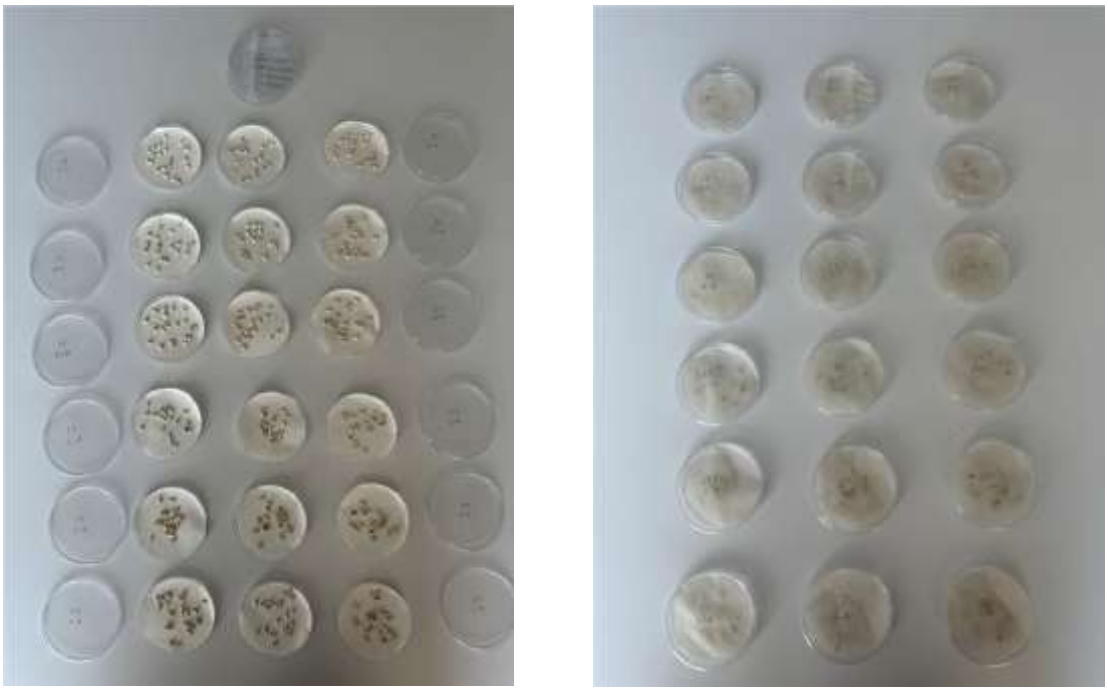
Bu araştırmada farklı tohum iriliklerinin aspirde çimlenme ve fide gelişimi üzerine etkilerinin belirlenmesi amaçlanmıştır.

2. MATERYAL VE METOT

Bu araştırma 2025 yılında Tekirdağ Namık Kemal Üniversitesi Tarla Bitkileri Bölümü Laboratuvarları'nda yürütülmüştür. Araştırmada iki aspir çeşidi (Dinçer ve Olas) kullanılmış ve tohumların bin tane ağırlığına göre üç farklı tohum iriliği (Küçük: 30-35 g, Orta: 40-45 g ve Büyük: 50-55 g) belirlenmiştir. Deneme, "Tesadüf Parselleri Deneme Desenine" göre çeşitler ana parselde, tohum irilikleri ise alt parselde olacak şekilde 3 tekrarlamalı olarak oda sıcaklığında (20 ± 2°C) yürütülmüştür.

Çalışmaya başlamadan önce yüzey sterilizasyonu için tohumlar %5'lik sodyum hipoklorit içerisinde 10 dakika bekletilmişlerdir. Bekletme işleminden sonra birkaç kez saf su ile yıkanmış ve başlangıçtaki ağırlıklarına ulaşıncaya kadar kurutulmuşlardır.

Her tohum iriliği için 20 adet tohum petri kaplarına kurutma kağıtlarının üzerine koyulmuş ve 5 ml sulama yapılmıştır. Filtre kağıtları her iki günde bir değiştirilerek kuruma durumuna göre iki günde bir sulama yapılmıştır (Şekil 1). Tohumlar her gün kontrol edilerek 2 mm kökçük uzunluğuna sahip olanlar çimlenmiş kabul edilmişlerdir (ISTA, 2003).



Şekil 1. Denemeden genel bir görünüm

Ölçümler

- Çimlenme oranı (%)

Çimlenme oranı % = (çimlenmiş tohum sayısı / toplam tohum sayısı) × 100 (Siddiqi ve ark., 2007)

- Ortalama çimlenme süresi (gün)

$$MGT = \sum f.\ x / \sum f$$

f: sayım yapılan gündeki çimlenen tohum sayısı × sayım yapılan gün sayısı (Orchard, 1977).

- Sürgün boyu (cm)

Her bir petrideki bitkilerin kökleri sürgünlerinden ayrılarak sürgünün cetvel ile ölçülmesiyle belirlenmiştir.

- Kök boyu (cm)

Kök ve sürgünleri ayrılmış olan bitkilerin köklerinin cetvel ile ölçülmesiyle belirlenmiştir.

- Sürgün ve kök yaş ağırlığı (g)

Sürgün ve köklerinin hassas terazide tartılmasıyla belirlenmiştir.

- Sürgün ve kök kuru ağırlığı (g)

Sürgün ve kök kuru ağırlıkları ayrı ayrı olarak 48 saat 55 ^{o}C'de kurutulduktan sonra tartılmasıyla belirlenmiştir (Ateş ve Tekeli, 2007).

Denemeden elde edilen sonuçlar TARİST istatistik programı kullanılarak analiz edilmişlerdir. EKÖF testi kullanılarak ortalamalar arasındaki farklılıklar belirlenmiştir ($p \leq 0.05$).

3. BULGULAR VE TARTIŞMA

Araştırmadan elde edilen verilerin varyans analizi sonucuna göre, tohum iriliklerinin etkisi istatistiki olarak önemli bulunurken, çeşitlerin etkisi kök kuru ağırlığı hariç incelenen tüm karakterler bakımından istatistiki olarak önemli bulunmamıştır (Çizelge 1).

Çizelge 1. Çimlenme ve fide özelliklerine ilişkin varyans analizi

VK	sd	ÇO	OÇS	SU	KU	SYA	SKA	KYA	KKA
Çeşit	1	öd	öd	öd	**	öd	öd	öd	öd
Hata$_1$	4								
Tohum İriliği	2	*	*	**	**	**	*	**	**
Çeşit × Tohum İri.	2	öd	öd	*	öd	öd	öd	öd	öd
Hata	8								
Genel	17	--	--	--	--	--	--	--	--
CV (%)		**2.54**	**8.86**	**8.01**	**6.24**	**4.74**	**5.99**	**5.86**	**6.94**

**: $p \leq 0.01$ düzeyinde önemli, *: $p \leq 0.05$ düzeyinde önemli, öd: önemsiz, VK: Varyasyon kaynağı, CV: Varyasyon katsayısı, sd: Serbestlik derecesi, ÇO: Çimlenme Oranı, OÇS: Ortalama Çimlenme Süresi, SU: Sürgün Uzunluğu, KU: Kök Uzunluğu, SYA: Sürgün Yaş Ağırlığı, SKA: Sürgün Kuru Ağırlığı, KYA: Kök Yaş Ağırlığı, KKA: Kök Kuru Ağırlığı

Çimlenme oranı tohum iriliğine bağlı olarak artmış ve en yüksek çimlenme oranı orta ve büyük irilikteki tohumlardan elde edilmiştir (sırasıyla %100.00 ve %99.17). Ayrıca tohum iriliği arttıkça tohumların çimlenme süresi kısalmış ve en erken çimlenme yine orta ve büyük irilikteki tohumlardan elde edilmiştir (sırasıyla 3.20 ve 3.05 gün) (Çizelge 2). Mirshekarnezhad ve ark. (2013) yaptıkları çalışmada aspirde iri tohumların küçük tohumlara göre daha hızlı çimlendiğini ve fide özelliklerinin olumlu yönde etkilendiğini bildirmişlerdir. Lambat ve ark. (2017) yaptıkları çalışmada aspirde iri ve sağlıklı görünüme sahip tohumların %100 oranında çimlendiğini bildirmişlerdir.

Çimlenme oranında oluğu gibi sürgün ve kök uzunlukları da tohum iriliğine bağlı olarak artmış (Şekil 2) ve en uzun sürgün boyu orta ve büyük irilikteki tohumlardan elde edilmiştir (sırasıyla 2.07 ve 2.23 cm) (Çizelge 2). Mirshekarnezhad ve ark. (2013) aspirde iri tohumların küçük tohumlara göre daha uzun sürgün ve kök boyuna sahip olduğunu bildirmişlerdir.

Şekil 2. Farklı tohum iriliklerine göre belirlenen sürgün ve kök uzunlukları

Çizelge 2. Aspirde farklı tohum iriliklerine göre incelenen parametrelere ait ortalama değerler

Karakterler	Çeşit	Tohum İriliği			Ortalamalar
		Küçük	Orta	Büyük	
Çimlenme Oranı (%)	Dinçer	99.67	100.00	98.33	98.33
	Olas	95.00	100.00	100.00	98.33
	Ortalamalar	95.83 **b**	100.00 **a**	99.17 **a**	
	EKÖF (p≤0.05)	Tohum İriliği: 3.328			
Ortalama Çimlenme Süresi (gün)	Dinçer	3.70	3.47	3.07	3.41
	Olas	3.57	2.93	3.03	3.18
	Ortalamalar	3.63 **a**	3.20 **b**	3.05 **b**	
	EKÖF (p≤0.05)	Tohum İriliği: 0.388			
Sürgün Uzunluğu (cm)	Dinçer	1.40 **c**	2.03 **b**	2.43 **a**	1.96
	Olas	1.50 **c**	2.10 **b**	2.03 **b**	1.88
	Ortalamalar	1.45 **b**	2.07 **a**	2.23 **a**	
	EKÖF (p≤0.05)	Tohum İriliği: 0.204		Çeşit × Tohum İriliği: 0.289	
Kök Uzunluğu (cm)	Dinçer	2.20	2.87	4.20	3.09 **a**
	Olas	1.47	2.33	3.50	2.43 **b**
	Ortalamalar	1.83	2.60	3.85	
	EKÖF (p≤0.05)	Çeşit: 0.246			
Sürgün Yaş Ağırlığı (g)	Dinçer	0.918	1.018	1.042	0.993
	Olas	0.984	0.977	1.098	0.120

	Ortalamalar	0.951 **b**	0.998 **b**	1.070 **a**	
	EKÖF (p≤0.05)	Tohum İriliği: 0.063			
Sürgün Kuru Ağırlığı (g)	Dinçer	0.191	0.204	0.223	0.206
	Olas	0.200	0.205	0.215	0.207
	Ortalamalar	0.195 **b**	0.205 **ab**	0.219 **a**	
	EKÖF (p≤0.05)	Tohum İriliği: 0.016			
Kök Yaş Ağırlığı (g)	Dinçer	0.279	0.310	0.316	0.302
	Olas	0.238	0.248	0.305	0.264
	Ortalamalar	0.258 **b**	0.279 **b**	0.311 **a**	
	EKÖF (p≤0.05)	Tohum İriliği: 0.022			
Kök Kuru Ağırlığı (g)	Dinçer	0.046	0.055	0.057	0.053
	Olas	0.045	0.052	0.060	0.052
	Ortalamalar	0.046 **b**	0.054 **a**	0.058 **a**	
	EKÖF (p≤0.05)	Tohum İriliği: 0.005			

Aynı harfle gösterilen ortalamalar arasında istatistiki olarak fark yoktur

Sürgün ve kök yaş ağırlıkları ile kuru ağırlıkları yine tohum iriliğine bağlı olarak artmış ve en fazla sürgün ve kök yaş ağırlıkları ile kuru ağırlıkları orta ve büyük irilikteki tohumlardan elde edilmiştir. Sadeydi ve ark. (2011) aspirde bin tane ağırlıklarına göre yaptıkları tohum iriliği çalışmasında iri tohumların sürgün ve kök yaş ağırlıkları ile kuru ağırlıklarının olumlu yönde etkilendiğini bildirmişlerdir.

4. SONUÇ

Bu araştırmada artan tohum iriliklerinin aspirde incelenen özellikler bakımından olumlu etkiler yaptığı belirlenmiştir. Özellikle orta (40-45 g) ve büyük (50-55 g) irilikteki tohumların fide gelişimlerinin daha iyi olduğu gözlemlenmiştir.

Çalışmanın sonuçları bir bütün olarak incelendiğinde iri tohumların çimlenme ve fide gelişimleri küçük tohumlara göre daha iyi olabileceği sonucuna varılmıştır.

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AN EVALUATION ON KASTAMONU GARLIC

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ABSTRACT

Garlic is widely used in kitchens with its unique aroma and health benefits. It has an important place in nutrition due to its immune system supporting, anti-inflammatory and heart health protective effects. Taşköprü district of Kastamonu stands out with its garlic production and approximately 4000 families make a living from this sector. Kastamonu's market share in Turkey's garlic production has decreased in recent years. Although Kastamonu Taşköprü Garlic is a geographically indicated product, Kastamonu's competitiveness has weakened while other regions (Gaziantep, Kahramanmaraş, Tokat, Aksaray, Konya) have increased their production.

In this study, interviews were held with producers and garlic industrialists in order to evaluate the current situation of the garlic sector in Kastamonu, the main problems encountered in the sector were determined and solution suggestions were presented.

The predominance of traditional methods in production and the inadequacy of technological infrastructure cause costs to remain high. Production is carried out on small parcels with a high workforce, and thousands of tons of garlic are wasted due to ordinary storage. Producers have difficulty in supplying labor and face serious problems in irrigation, storage and marketing. Garlic businesses in the region generally operate as individual or family businesses and the level of institutionalization remains low. Most businesses do not invest in marketing, exports and modern production techniques. One of the biggest problems in the sector is unregistered production and trade, and the marketing of garlic processed without paying attention to hygiene conditions causes unfair competition. In addition, inadequacy of storage facilities, lack of working capital and fluctuating garlic prices, and difficulties in supplying labor force pose great difficulties for companies. Production of value-added products (garlic puree, extract, black garlic, garlic powder, etc.) is very limited or non-existent. The average capacity utilization rate of businesses is 53.2%, and most of them do not consider new investments.

Solution suggestions include establishing a garlic exchange to reduce price fluctuations, preventing imported garlic, reducing product losses and increasing cold storages to ensure 12-month supply, strengthening the organizations of producers and industrialists, and encouraging the production of value-added products. In addition, support mechanisms need to be established for the transition to modern agricultural techniques, the evaluation of garlic waste and the professionalization of the sector. Local governments should allocate more resources to the issue and support it with projects. If these steps are not taken, Kastamonu's leadership in the garlic sector may be in danger.

Keywords: Garlic, Kastamonu, sustainable agriculture, resource efficiency, conscious production

KASTAMONU SARIMSAĞI ÜZERİNE BİR DEĞERLENDİRME

ÖZET

Sarımsak, eşsiz aroması ve sağlık açısından sunduğu faydalarla mutfaklarda yaygın olarak kullanılmaktadır. Bağışıklık sistemini destekleyici, iltihap önleyici ve kalp sağlığını koruyucu etkileri nedeniyle beslenmede önemli bir yer tutmaktadır. Kastamonu'nun Taşköprü ilçesi, sarımsak üretimiyle öne çıkmakta ve yaklaşık 4000 aile bu sektörden geçimini sağlamaktadır. Kastamonu'nun Türkiye'nin sarımsak üretimindeki pazar payı son yıllarda düşüş göstermiştir. Kastamonu Taşköprü Sarımsağı coğrafi işaretli bir ürün olmasına rağmen, diğer bölgeler (Gaziantep, Kahramanmaraş, Tokat, Aksaray, Konya) üretimlerini artırırken Kastamonu'nun rekabet gücü zayıflamıştır.

Bu çalışmada, Kastamonu'daki sarımsak sektörünün mevcut durumunu değerlendirmek amacıyla üreticiler ve sarımsak sanayicileriyle görüşmeler yapılmış, sektörde karşılaşılan temel sorunlar belirlenmiş ve çözüm önerileri sunulmuştur.

Üretimde geleneksel yöntemlerin ağırlıklı olması ve teknolojik altyapının yetersizliği, maliyetlerin yüksek kalmasına yol açmaktadır. Küçük parsellerde yüksek işgücü ile üretim yapılmakta, adi depolama sebebiyle binlerce ton sarımsak heba olmaktadır. Üreticiler işgücü temininde zorluk yaşamakta, sulama, depolama ve pazarlama konusunda ciddi sorunlarla karşılaşmaktadır. Bölgedeki sarımsak işletmeleri genellikle bireysel veya aile işletmeleri şeklinde faaliyet göstermekte ve kurumsallaşma seviyesi düşük kalmaktadır. Çoğu işletme pazarlama, ihracat ve modern üretim tekniklerine yatırım yapmamaktadır. Sektörde en büyük sorunlardan biri kayıt dışı üretim ve ticaret olup, hijyen koşullarına dikkat edilmeden işlenen sarımsakların piyasaya sürülmesi haksız rekabete neden olmaktadır. Ayrıca, depolama imkânlarının yetersizliği, işletme sermayesi eksikliği ve dalgalı sarımsak fiyatları, işgücün temininde yaşanılan zorluklar firmalar için büyük sıkıntılar oluşturmaktadır. Katma değerli ürünlerin (sarımsak püresi, ekstrakt, siyah sarımsak, sarımsak tozu vb.) üretimi oldukça sınırlıdır veya yoktur. İşletmelerin ortalama kapasite kullanım oranı %53,2 olup, büyük bir kısmı yeni yatırım düşünmemektedir.

Çözüm önerileri arasında fiyat dalgalanmalarının azaltılabilmesi için sarımsak borsası kurulması, ithal sarımsağın önlenmesi, ürün kayıpların azaltılması ve 12 ay boyunca tedarik sağlanabilmesi için soğuk hava depolarının artırılması, üretici ve sanayicinin örgütlenmelerinin güçlendirilmesi ve katma değerli ürün üretiminin teşvik edilmesi bulunmaktadır. Ayrıca, modern tarım tekniklerine geçiş, sarımsak atıklarının değerlendirilmesi ve sektörün profesyonelleşmesi için destek mekanizmalarının oluşturulması gerekmektedir. Yerel yönetimler konuya daha fazla kaynak ayırmalı ve projelerle desteklemelidir. Bu adımlar atılmadığı takdirde Kastamonu'nun sarımsak sektöründeki liderliği tehlikeye girebilir.

Anahtar kelimeler: Sarımsak, Kastamonu, sürdürülebilir tarım, kaynak verimliliği, bilinçli üretim

1.GİRİŞ

Sarımsak, hem eşsiz aroması hem de sağlık açısından sunduğu faydalarla mutfaklarda geniş bir kullanım alanı bulmaktadır. Çoğunlukla kuru baş sarımsak şeklinde tüketilse de toz, cips, püre, ekstrakt, tablet, sos ve yağ gibi farklı formlarda da değerlendirilmektedir. Yemeklere doğrudan eklenmesinin yanı sıra sucuk, çemen, pastırma, baharat karışımları, konserve, salamura, turşu, yoğurt ve salça gibi birçok gıda ürününün üretiminde de kullanılmaktadır. Araştırmalar, sarımsağın bağışıklık sistemini destekleyici, iltihap karşıtı, diyabet önleyici, kanser riskini azaltıcı, mikrop kırıcı ve kalp sağlığını koruyucu etkileri olduğunu ortaya koymuştur. Günlük beslenmede sarımsağa yer vermenin sağlık açısından önemli olduğu vurgulanmaktadır. (Kızılaslan ve Tokatlı, 2021)

Kastamonu'nun Taşköprü ilçesi, sarımsak üretimiyle öne çıkmakta olup, bölgedeki tarımsal istihdamın en büyük kısmını oluşturmaktadır. İlçede yaklaşık 4000 aile geçimini sarımsak tarımından sağlamaktadır, bu da nüfusun büyük bir bölümünün bu sektörden gelir elde ettiğini göstermektedir. (Taban vd., 2004). Yoğun iş gücü gerektiren üretim süreci, bölgedeki istihdama doğrudan katkı sağlamakta ve Kastamonu'nun göç veren bir şehir olmasını kısmen önlemektedir. (Koyuncu, 2012; Turfan vd., 2024). Araştırmalar, Kastamonu denildiğinde ilk akla gelen ürünlerden birinin sarımsak olduğunu (Tayfun vd. 2017) ve Taşköprü Sarımsağı'nın Kastamonu'nun en bilinen gıda ürünü olarak tespit edildiğini göstermektedir. (Öner ve Aydoğdu, 2017).

Ancak, Kastamonu Taşköprü sarımsağı, dünya çapında bilinirliğine rağmen modern üretim tekniklerinden yeterince faydalanamamaktadır. Bölgedeki üreticiler, geleneksel yöntemleri sürdürmekte ve yeterli teknolojik altyapıyı sağlayamadıkları için maliyetleri düşürememektedir. Bunun yanı sıra, uygun depolama koşullarının eksikliği ve iş gücüne olan yüksek bağımlılık gibi sorunlar, üretimi ve pazarlamayı zorlaştırmaktadır. Son yıllarda Türkiye'de ve dünyada sarımsak üretimi artarken, Türkiye'nin küresel üretim içindeki payı gerilemiştir. Türkiye'de sarımsak üretiminde Kastamonu'nun payı da zamanla azalmış ve bu durum, rekabet gücünün sorgulanmasına neden olmuştur.

Bu çalışmada, Kastamonu'daki sarımsak sektörünün mevcut durumunu değerlendirmek amacıyla üreticiler ve sarımsak sanayicileriyle görüşmeler yapılmış, sektörde karşılaşılan temel sorunlar belirlenmiş ve çözüm önerileri sunulmuştur.

2. MATERYAL VE METOD

Bu araştırma 2023 yılında Kastamonu'da faaliyet gösteren 17 adet Sarımsak işleme tesisi yöneticisi (K.Ü.ETİK K.K.-7/2-28.04.2023) ve 166 adet sarımsak üreticisi (ETİK K.K.-7/1-28.04.2023) ile yüz yüze anket çalışması yapılarak gerçekleştirilmiştir. Anket verileri MS-Excel programına girilerek istatistiki olarak değerlendirilmiştir.

3.BULGULAR

3.1. Sarımsak üreticileri

Anket sonuçlarının değerlendirilmesiyle, sarımsak üreticilerinin genel profilleri, üretim yöntemleri ve satış alışkanlıklarına dair kapsamlı veriler elde edilmiştir. Ortalama hane halkı büyüklüğünün 5,59 kişi olduğu, eğitim süresinin 8,79 yıl olarak hesaplandığı ve sulanabilir arazi büyüklüğünün 64,18 dekar olduğu belirlenmiştir. Traktörlerin ortalama gücü 68,32 beygir olup, yaşları 11,69 yıl civarındadır.

Tohumluk olarak üreticilerin %60,3'ü iri diş kullanmakta, %41,9'u makineler aracılığıyla dişleyip sınıflandırma yaparken, %62,7'si elle dişleme işlemini gerçekleştirse de boyutlarına göre ayırmaktadır. Kullanılan tohumluk miktarı ortalama 139,4 kg/da olup, verim ise 926,3 kg/da olarak tespit edilmiştir. Üreticilerin %8,9'u makine ve teçhizat alımında proje desteğinden yararlanırken, %9,8'inin dikim makinası, %93,1'inin ise söküm makinası bulunmaktadır. Makine ile söküm yapanların oranı %90,9, makineyle dikim yapanların oranı ise %27,8'dir.

İşgücü ihtiyacını karşılamak için üreticilerin %79,6'sı yevmiyeli işçi çalıştırmakta, ancak %81,8'i ihtiyaç duyduğunda işçi bulmakta zorlanmaktadır. Kimyasal kullanımına bakıldığında, herbisit kullanım oranı %98,7, pestisit kullanımı %83,9, suni gübre kullanımı %79,1, yaprak gübresi kullanımı ise %77,7 seviyesindedir. Üreticilerin tamamı, ürünlerini Taşköprü ve Alatarla sarımsak pazarlarında satışa sunmakta olup, %5,09'u internet üzerinden de satış yapmaktadır. Ürünlerin %10,2'si hasattan önce, %15,9'u ise hasat sonrası tarladan satılmaktadır. Haftada bir kez kurulan sarımsak pazarını yeterli bulan üreticilerin oranı %84,9'dur.

Depolama yöntemlerine bakıldığında, üreticilerin %49,9'u sarımsağını evlerinin altında kısmen serin alanlarda saklamaktadır. Ancak bölgede üreticilerin kullanımına uygun alternatif bir soğuk hava deposu bulunmamaktadır. Üreticiler yılda ortalama 4,3 kez sulama yapmakta olup, %52,8'i sulama hizmetini ücret karşılığında sulama birliklerinden almaktadır. Sulama birliklerinin hizmetlerinden memnun olan üreticilerin oranı %41,5'tir. Tarım sigortası yaptıran üreticilerin oranı %55,7 olup, doğal afetlerden zarar görenlerin tazminat konusunda tatmin düzeyi %59,2'dir. Toprak analizi yaptıran üreticilerin oranı %16,5 olarak belirlenmiştir. Sarımsak üretimiyle ilgili bilgi paylaşımı, dayanışma ve organizasyon sağlayacak bir sivil toplum kuruluşuna ihtiyaç duyan üreticilerin oranı ise %77,3'tür (Ünal 2024a).

3.2. Sarımsak Sanayisi

Kastamonu'daki sarımsak sanayisini oluşturan işletmelerin yapısı incelendiğinde, ortak iş yapma anlayışının yeterince gelişmediği ve çoğunlukla bireysel ya da aile işletmesi şeklinde faaliyet gösterdikleri görülmektedir. Şirket sahipleri, yönetim, pazarlama, satın alma ve AR-GE gibi tüm süreçleri kendileri yürütme eğilimindedir ve bu durum profesyonel yöneticilerin ya da pazarlamacıların istihdam edilmesini sınırlamaktadır. Genel olarak sektörde kurumsallaşmanın yaygın olmadığı gözlemlenmektedir.

Kastamonu'da sarımsak sektörünün sağladığı istihdam yaklaşık 250 kişiyi bulmakta olup, çalışanların büyük bir kısmını kadın işçiler oluşturmaktadır. Özellikle fileleme ve soyma

işlemlerinde vasıfsız kadın işçilerin çalıştığı görülmektedir. Sektör genellikle sarımsak soyma tesislerinden oluşmakta, ardından fileleme tesisleri gelmektedir. Ancak, siyah sarımsak, sarımsak püresi ve sarımsak ekstraktı gibi katma değeri yüksek ürünlerin üretimi oldukça sınırlıdır. Ayrıca, kurutulmuş sarımsak, sarımsak tableti ve sarımsak yağı gibi ürünlerin üretilmediği tespit edilmiştir.

İşletmeler, hammaddeye yakın olabilmek adına genellikle haftalık sarımsak pazarına yakın yerlerde, özellikle Taşköprü-Alatarla-Kastamonu Merkez hattında konumlanmaktadır. Bu durum, hammadde temininde avantaj sağlamaktadır. Kurulan işletmelerin küçük bir kısmı hibe desteği kullanırken, çoğu öz sermaye ile yatırım yapmıştır. Soyulmuş sarımsak üreten işletmelerin, sevkiyat öncesi üretimi muhafaza etmek için küçük ölçekli soğuk hava depolarına sahip olduğu, ancak kısa vadede kullanılacak sarımsağın işletme içindeki kapalı alanlarda saklandığı belirlenmiştir. Üretim sürecinde ortaya çıkan sarımsak atıklarının ise ekonomik olarak değerlendirilmediği, isteyenlere ücretsiz verildiği veya çöpe atıldığı görülmektedir.

İşletmelerin üretim kapasitelerine bakıldığında, soyma tesislerinin günlük ortalama 1305 kg sarımsak işlediği ve %61,2 kapasiteyle çalıştıkları belirlenmiştir. Fileleme tesisleri ise ortalama 1643 kg/gün kapasiteye sahip olup, %54 kapasiteyle faaliyet göstermektedir. Siyah sarımsak üreten işletmelerin günlük ortalama 40 kg üretim yaptığı ve %82,5 kapasiteyle çalıştıkları, ekstrakt üreticilerinin ise 800 kg/gün kapasiteye sahip olup yalnızca %15 kapasiteyle faaliyet gösterdikleri tespit edilmiştir. Genel olarak sektörde ortalama kapasite kullanım oranı %53,2'dir.

Tüm bu veriler doğrultusunda, Kastamonu'da yıllık yaklaşık 4500 ton Taşköprü sarımsağının soyulmuş ve filelenmiş olarak işlendiği tahmin edilmektedir. Buna ek olarak, yıllık yaklaşık 50 ton siyah sarımsak, sarımsak püresi ve sarımsak ekstraktı üretilmekte ve bunun için yaklaşık 60 ton sarımsak kullanılmaktadır. Üretim sürecinde yaklaşık 1100 ton sarımsak atığının oluştuğu hesaplanmaktadır. Soyma tesisleri, daha çok perakende tüketime uygun olmayan, küçük, sapı kopmuş ve görünüm olarak kusurlu sarımsakları işleyerek, piyasada değerlendirilemeyen ürünleri ekonomiye kazandırmaktadır. Fileleme tesisleri ise genellikle orta boy sarımsakları tercih etmektedir.

İşletmelerin öncelikli yatırım ihtiyaçları arasında iş gücünü azaltacak ekipmanlar bulunmaktadır. Soyma tesislerinin bir kısmı, lekeli sarımsakları ayıklamak için renk ayırıcı makineler almayı planlarken, fileleme ve katma değerli ürün üreticileri otomatik tartım, paketleme ve dolum yapabilen makineleri tercih etmektedir. Genel yatırım eğilimleri sorulduğunda, firmaların yaklaşık yarısının üretim kapasitelerini artırmayı düşünmedikleri belirtilmiştir. Pazarlama konusunda işletmelerin yetersiz olduğu gözlemlenmiştir. Reklam, fuar katılımı, online satış ve kalite sertifikasyonu gibi alanlara ilgi göstermemektedirler. İthalat ve ihracat konularında da sınırlı girişimleri bulunmakta, daha çok yerel pazarlarla yetinmektedirler. İşletmeler, hammaddeyi yaklaşık 10 gün vadeli olarak alırken, satışlarını 60 gün vadeli gerçekleştirmektedir. Bu durum, ek sermaye gereksinimini artırmaktadır.

İşletmelerin karşılaştığı en büyük sorunlardan biri işletme sermayesi yetersizliğidir. Firmalar, yatırım için yeterince hibe desteğinden faydalanmadıkları gibi, satış ve alım vadesi arasındaki fark nedeniyle nakit akışı sıkıntısı yaşamaktadır. İşletmeler ayrıca vasıfsız işçi bulmakta zorlanmakta ve özellikle gençlerin sarımsak sektöründe çalışmak istemediği belirtilmektedir.

Dalgalanan sarımsak fiyatları da firmalar için önemli bir sorun teşkil etmektedir. Sermaye yetersizliği ve depolama imkânlarının kısıtlı olması nedeniyle firmalar toplu alım yapamamakta ve bu durum fiyat değişimlerinden daha fazla etkilenmelerine yol açmaktadır. Ayrıca, kayıt dışı faaliyetler sektörde haksız rekabet yaratmaktadır. Ev ortamında hijyen koşullarına dikkat edilmeden işlenen sarımsakların piyasaya sunulması ve vergiye tabi olmadan yapılan satışlar, sektörde ciddi endişelere neden olmaktadır. Kastamonu'daki sarımsak sanayisinin gelişmesi için çeşitli beklentiler bulunmaktadır. İthal sarımsağın önlenmesi, vergi ve SGK primlerinde indirim sağlanması, sarımsak borsasının kurulması, büyük ölçekli soğuk hava depolarının inşa edilmesi ve kayıt dışı ticaretin engellenmesi gibi konular öne çıkmaktadır. Ayrıca, sarımsak atıklarının değerlendirilmesi, sarımsakla ilgili bilimsel araştırmaların artırılması ve sektördeki firmaların iş birliği yaparak ortak pazarlama stratejileri geliştirmesi gerekmektedir. Taşköprü sarımsağının marka değerinin korunması ve katma değerli ürünlerin üretiminin artırılması, sektörün sürdürülebilir büyümesi açısından büyük önem taşımaktadır (Ünal 2024b).

4.SONUÇ ve ÖNERİLER

Sarımsak, hem lezzeti hem de sağlık açısından sunduğu faydalarla dünya genelinde önemli bir gıda maddesi konumundadır. Küresel ölçekte sarımsak üretimi ve tüketimi artış gösterirken, Türkiye'nin üretimdeki payı yıllar içinde azalmıştır. 1994 yılında dünya üretiminin %3,97'sini karşılayan Türkiye, 2008'de %0,8'e, 2023'de ise %0,4'e gerilemiştir (FAO,2025). Türkiye'nin üretim artışı, küresel ölçekte yaşanan gelişmelerle kıyaslandığında yetersiz kalmış ve ülkenin sıralamada geriye düşmesine neden olmuştur. Kastamonu, coğrafi işaretli ve ünlü sarımsağına rağmen üretimini kayda değer ölçüde artırmamış ve marka avantajını yeterince değerlendirememiştir. Buna karşılık, Gaziantep, Kahramanmaraş, Tokat, Aksaray ve Konya gibi iller son on yılda üretimlerini %100 ila %500 oranında artırmayı başarmıştır (TUİK, 2025).

Araştırma sonuçları, Kastamonu'daki sarımsak üreticilerinin ciddi zorluklarla karşı karşıya olduğunu göstermektedir. Küçük ölçekli arazilerde üretim yapılması, iş gücü temininde yaşanan sıkıntılar, sulama sorunları ve yüksek girdi maliyetleri, üreticilerin en büyük sorunları arasında yer almaktadır. Son yıllarda mekanizasyona yönelim sayesinde işçilik maliyetleri bir miktar azalmış olsa da diğer bölgelerdeki üreticilere kıyasla maliyet açısından dezavantaj devam etmektedir. Eğitim seviyesi artsa da toprak analizi, tarım sigortası ve kimyasal kullanım konularında bilinç seviyesi henüz istenen düzeyde değildir. Depolama koşullarının ilkel olması ürün kayıplarına yol açmakta ve bölgede modern soğuk hava depolarına duyulan ihtiyacı artırmaktadır. Pazarlama açısından ise üreticiler yerel piyasa fiyatlarına bağımlıdır ve alternatif pazarlara erişimleri sınırlıdır. Üreticiler genellikle bireysel hareket etmekte, herhangi bir planlama ya da örgütlenme içinde yer almamaktadır. Sarımsak üretimini geliştirmek, üreticilere ekonomik fayda sağlamak ve yeni satış ile ihracat imkânları yaratmak adına bölgede üreticileri destekleyecek bir organizasyona ihtiyaç duyulmaktadır.

Kastamonu'daki sarımsak sanayisi ise iç pazara odaklanmış, kurumsallaşamamış küçük aile işletmesi şeklindedir. İşletme sermayesi yetersizliği, dalgalı Pazar fiyatı, depolama imkânsızlıkları, işgücü temini, yüksek girdi maliyetleri sebebiyle zorluk yaşamaktadırlar. Kurulu kapasitelerinin altında çalışmakta olmalarına rağmen, tanıtım-pazarlama konusunda etkin değillerdir. Çoğunluğu soyulmuş sarımsak ve filelenmiş sarımsak üretmektedir. Katma

değerli ürün yok denecek kadar azdır. Düşük kar marjlarıyla iç piyasada birbirleriyle rekabet ederek ayakta kalmaya çalışmaktadırlar. Son yıllarda 4-5 firma kapanmıştır.

Bu sonuçlar doğrultusunda aşağıdaki önerileri yapmak mümkündür:

*Üreticileri teknik konularda bilinçlendirecek, girdi maliyetlerini düşürecek toplu alım anlaşmaları yapacak, tanıtım ve pazarlama konusunda aktif rol oynayacak yeni sivil toplum örgütleri kurulmalıdır.

*Üretici, kimyasal kullanımı, toprak analizi yaptırması, tarım sigortası yaptırması, depolama koşullarının iyileştirilmesi gibi konularda eğitilmelidir.

*Sarımsak sanayicilerini bir araya getirip, iç pazarda küçük kar marjlarıyla rakip olmaktan öte dış pazarlarda ortak iş yapıp paydaş olmalarını sağlayacak birliktelikler oluşturulmalıdır.

*Gerek üreticilerin gerekse sanayicilerin işgücü maliyetini düşürecek mekanizasyon çözümleri araştırılmalı ve teşvik edilmelidir.

*Sarımsaktan yeni katma değerli ürünler üretilebilmesi için araştırmalar yapılıp, raf ömrünü artırıcı ve sofralarda daha geniş yer bulmasını sağlayacak çözümler üretilmelidir.

*Gerek sanayicinin gerekse üreticinin kullanabileceği büyük soğuk hava depoları yapılmalıdır. Bu sayede adi depolamadan kaynaklı binlerce tonluk zararın önüne geçmek ve Kastamonu sarımsağının 12 ay boyunca bulunabilirliği sağlamak mümkün olacaktır.

*Sarımsak pazarında kayıt dışı alım satım yapan aracı kişiler engellenmelidir. Üretici ve sanayici arasında vergilendirilmemiş 3. şahısların ticareti durdurulmalıdır.

*Kayıt dışı merdiven altı sarımsak işleyicileri engellenmeli, haksız rekabetin önüne geçilmelidir.

* Kastamonu sarımsağının geleceğinde sarımsak işleme tesislerinin de büyük rol oynadığı unutulmamalı, sektör desteklenmeli teşvik edilmelidir.

*Fiyat istikrarının sağlanabilmesi için sarımsak borsası kurulmalıdır. Fiyat belirsizliği azaltılarak sanayicinin önünü görerek güvenli iş bağlantısı yapabilmesinin önü açılmalıdır.

*Sarımsak kabukları ve sapları sebebiyle oluşan atıkların ekonomiye kazandırılması ve çevre kirliliği yaratmaması için gerekli önlemler alınmalıdır.

*Kendi kapasitelerini göz önüne alarak yüksek talepleri geri çevirmek zorunda kalan sanayicilerin bir araya gelerek ortak bir pazarlama ve tedarik sistemi kurması teşvik edilmelidir.

*Sarımsak ithalatı sınırlandırılmalıdır.

*Yerel yönetimler Kastamonu'nun tanıtımında da büyük rol oynayan Taşköprü sarımsağını geliştirmek ve tanıtmak için daha fazla kaynak ayırmalı ve projelerle desteklemelidir.

Mevcut sektör lideri konumunda olan Kastamonu sarımsağı yetiştiriciliğinin ve sanayisinin gerekli önlemlerin alınmaması durumunda yakın gelecekte bu pozisyonunu kaybetmesi kaçınılmazdır.

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STUDIES ON THE EFFECT OF ALLELOPATHIC PLANTS TO WEEDS IN TURKEY

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ABSTRACT

As a result of the intensive and long-term use of herbicides, which are widely used to suppress weeds that are a problem in agriculture and reduce yields, important problems such as herbicide resistance, environmental pollution, residues and reduction in biodiversity have emerged. Therefore, there has been a worldwide search for the development of alternative control methods and the use of natural compounds instead of synthetic herbicides. “Allelopathy”, which is defined as the positive or negative effect of a plant on other plants and organisms, is an important method used for this purpose. The use of allelopathy in weed control is preferred because it is effective as an alternative to herbicides and is not harmful to human and environmental health.

In order to determine the studies on the effect of allelopathic plants to weeds conducted in Türkiye, national and international publications were detected from various printed and internet data sources. After classifying the publications in terms of type of publication, field of science and the geographical regions, the historical change of studies on allelopathy conducted in Türkiye was determined as its subject and scope. In this study, 212 scientific studies conducted in Türkiye between 1980 and 2025 on the effect of allelopathic plants to weeds were compiled.

When the studies were evaluated in general, it was found that the studies on this subject were mostly conducted in the Mediterranean Region and were prepared in the fields of Plant Protection, Field Crops, Horticulture, Biology and Forest Engineering. Also, the studies were focused on the effects of allelopathic plant extracts, essential oils and natural herbicides on weeds that are problematic in agricultural areas. Although the results obtained in the studies are very promising, it was reported that research on new application techniques and formulation types should be emphasized due to some difficulties in their application in greenhouse and field conditions.

Keywords: Allelopathy, Weed, Bibliography, Türkiye.

ALLELOPATİK BİTKİLERİN YABANCI OTLARA ETKİSİ KONUSUNDA TÜRKİYE'DE YÜRÜTÜLEN ÇALIŞMALAR

ÖZET

Tarımda sorun olan ve verimi düşüren yabancı otları, baskı altında tutmak için yaygın olarak kullanılan herbisitlerin yoğun ve uzun süreli kullanımı sonucu herbisitlere dayanıklılık, çevre kirliliği, kalıntı ve biyolojik çeşitlilikte azalma gibi önemli sorunlar ortaya çıkmıştır. Bu nedenle, dünya çapında alternatif mücadele yöntemlerinin geliştirilmesi ve sentetik herbisitlerin yerine doğal bileşiklerin kullanılması arayışına gidilmiştir. Bir bitkinin diğer bitki ve organizmalara olumlu veya olumsuz etki göstermesi olarak tanımlanan "Allelopati" bu amaçla faydalanılan önemli bir yöntemdir. Yabancı ot mücadelesinde allelopatinin kullanımı, herbisitlere alternatif olabilecek düzeyde etkili olması yanında, insan ve çevre sağlığına zararlı olmaması nedeniyle tercih edilmektedir.

Allelopatik bitkilerin yabancı otlara etkisi ile ilgili Türkiye'de yürütülen çalışmaları belirlemek amacıyla, çeşitli basılı ve internet veri kaynaklarından ulusal ve uluslararası yayınlar incelenmiştir. Tespit edilen yayınlar yayın türü, uzmanlık alanı ve yürütüldüğü bölgeler bakımından sınıflandırıldıktan sonra, Türkiye'de bu konuda yürütülen çalışmaların konu ve kapsam olarak tarihsel değişimi belirlenmiştir. Bu çalışmada, Türkiye'de allelopatik bitkilerin yabancı otlara etkisi konusunda 1980–2025 yılları arasında yürütülen 212 adet bilimsel çalışma derlenmiştir.

Çalışmalar genel olarak değerlendirildiğinde, bu konudaki çalışmaların daha çok Akdeniz Bölgesi'nde yapıldığı, alan olarak da Bitki Koruma, Tarla Bitkileri, Bahçe Bitkileri, Biyoloji ve Orman Mühendisliği alanlarında hazırlandığı ortaya çıkmıştır. Ayrıca, araştırmaların allelopatik bitkilerden elde edilen ekstraktların, uçucu yağların ve doğal herbisitlerin tarım alanlarında sorun olan yabancı otlara etkisi konularında ele alındığı belirlenmiştir. Yapılan çalışmalarda elde edilen sonuçlar oldukça ümitvar bulunmakla birlikte, sera ve tarla koşullarında uygulamalarındaki bazı güçlükler nedeniyle yeni uygulama teknikleri ve formulasyon tipleri konusunda araştırılmalara önem verilmesi gerektiği bildirilmiştir.

Anahtar Kelimeler: Allelopati, Yabancı Ot, Bibliyografya, Türkiye.

1. GİRİŞ

Hızla artan dünya nüfusunun gıda ihtiyacının karşılanması en öncelikli konular arasındadır. Bu nedenle tarımsal üretimde verim başta olmak üzere, kalite, ekonomi ve sürdürülebilirlik arzu edilmektedir (FAO 2021; Anonim 2025'ten). Ancak tüm çalışma ve emeklere rağmen, her geçen gün artan dünya nüfusunun ihtiyacını karşılayacak düzeyde tarımsal üretim maalesef ki yapılamamaktadır. Aksine tarımsal üretimde zararlı, hastalık ve yabancı ot sorunlarından dolayı önemli düzeyde kayıplar söz konusudur ve bu kayıplar genellikle kimyasal mücadele yoluyla önlenmeye çalışılmaktadır (Oerke, 2006). Pestisitlerin insan ve çevre sağlığına olan olumsuz etkileri nedeniyle sentetik pestisitlere göre biyolojik olarak çok daha kolay parçalanabilen alternatif çözümler ile ilgili araştırmalar hızlanmıştır (Karaca ve Eren, 2019).

Yabancı otlar kültür bitkilerinin verim ve kalitesini doğrudan veya dolaylı olarak düşürerek tarımsal üretimde önemli sorunlara neden olmaktadır (Zimdahl, 2018). Tarımsal üretimi kısıtlayan yabancı otları baskı altında tutmak için yaygın olarak kullanılan herbisitlere karşı dayanıklılık, çevre kirliliği, kalıntı ve biyolojik çeşitlilikte azalma gibi önemli sorunlar yaşanmaktadır. Bu nedenle, dünya çapında yabancı ot mücadelesinde alternatif mücadele yöntemleri geliştirme ve sentetik herbisitlerin yerine doğal bileşiklerin kullanılması arayışına gidilmiştir. Bu bağlamda, bitkiler arası kimyasal etkileşimleri ifade eden "allelopati" kavramı, son yıllarda sürdürülebilir tarım uygulamaları için dikkat çeken bir araştırma alanı haline gelmiştir. Bu bağlamda, bitkiler arası kimyasal etkileşimleri ifade eden allelopati kavramı, sürdürülebilir tarım uygulamaları açısından dikkat çeken bir araştırma alanı haline gelmiştir (Rice, 1984). Allelopatik etki, bir bitkinin diğer bitki türlerinin büyümesini, gelişmesini veya çimlenmesini engelleyici ya da teşvik edici bileşikler salgılaması yoluyla gerçekleşir. Bu doğal mekanizma, yabancı ot kontrolünde biyolojik temelli stratejilerin geliştirilmesi açısından umut verici bir alternatif sunmaktadır (Macías et al., 2007).

Son yıllarda Türkiye'de yapılan çeşitli araştırmalar, yerli bitki türlerinin allelopatik özelliklerini inceleyerek bu potansiyelin tarımsal mücadelede nasıl değerlendirilebileceği konusunda önemli bilgiler ortaya koymaktadır. Türkiye florası, sahip olduğu yüksek endemizm oranı ve biyolojik çeşitlilik ile allelopatik özellik taşıyan çok sayıda bitki türüne ev sahipliği yapmaktadır (Davis, 1965-1988). Türkiye'de 1980'li yıllardan itibaren hız kazanan botanik ve etnobotanik araştırmalar, birçok yerli bitki türünün geleneksel kullanım alanları yanında, potansiyel allelopatik etkilerini de ortaya koymaya başlamıştır (Baytop, 2021; Sezik et al., 2001). Bu süreçte özellikle tarla denemeleri, laboratuvar analizleri ve literatür taramaları ile bazı bitki türlerinin yabancı otlar üzerindeki bastırıcı etkileri belirlenmiş, bu etkilerin toprak mikrobiyotası, çimlenme oranları ve bitki gelişimi üzerindeki yansımaları bilimsel verilerle desteklenmiştir (Üremiş et al., 2009; Boz, 2016).

2. METOD

Bu çalışmada, Türkiye'de allelopatik bitkilerin yabancı otlara etkisi konusunda yürütülen bilimsel çalışmalar derlenmiştir. Çalışma kapsamında 1980–2025 yılları arasındaki 45 yılda yürütülen 212 adet çalışma değerlendirilmiştir.

Allelopatik bitkilerin yabancı otlara etkisi ile ilgili Türkiye'de yürütülen çalışmaları belirlemek amacıyla, çeşitli basılı ve internet veri kaynaklarından (Anonim 2025a; Anonim 2025b; Google Akademik; Erciş ve ark., 2006) ulusal ve uluslararası literatür gözden geçirilerek konu ile ilgili detaylı bir araştırma yapılmıştır. Konu ile ilgili olarak özellikle YÖK Akademik web sayfasındaki yayınlar ve Türkiye Herboloji Bibliyografyası dikkate alınmıştır. Tespit edilen yayınlar yayın türü, uzmanlık alanı ve yürütüldüğü bölgeler bakımından sınıflandırılmıştır. Daha sonra ilgili yayınların önemli bulguları değerlendirilerek ülkemizde bu konuda yürütülen çalışmaların konu ve kapsam olarak tarihsel gelişimi ve değişimi belirlenmiştir.

3. BULGULAR

Türkiye'de yabancı otlar üzerinde yapılan ilk allelopatik çalışmalar, 1980'li yılların sonları ile 1990'lı yılların başlarına dayanmaktadır. Bu dönemde, özellikle tarım alanlarında yaygın olarak bulunan bazı bitkilerin, diğer bitkilerin gelişmesini engelleyici etkileri olduğu gözlemlenmiş ve bu etkilerin allelopatik mekanizmalarla açıklanabileceği düşünülmüştür. Bu alandaki öncü araştırmalar, özellikle kültür bitkilerinin yabancı otlar üzerindeki baskılayıcı etkilerini incelemiştir. Laboratuvar çalışmalarında, ilk yıllarda çalışmalar genellikle petrilerde yapılan çimlenme denemeleriyle sınırlı kalmıştır. Bitki özlerinin farklı konsantrasyonlarının yabancı ot tohumları üzerindeki etkileri değerlendirilmiştir. İlerleyen dönemlerde yürütülen araştırmalarda, kimyasal analiz yöntemleri ile bitkilerden alınan özütlerdeki fenolik bileşikler gibi allelokimyasal maddelerin tanımlanması yapılmıştır.

Allelopatik bitkilerin yabancı otlara etkisi konusunda Türkiye'de yürütülen çalışmalar yayın türü bakımından değerlendirildiğinde; 58'inin makale, 107'sinin bildiri ve 47'sinin tez olduğu görülmektedir. Yürütülen çalışmaların yayın türü olarak yayınlandığı döneme göre dağılımları Çizelge 1'de sunulmuştur.

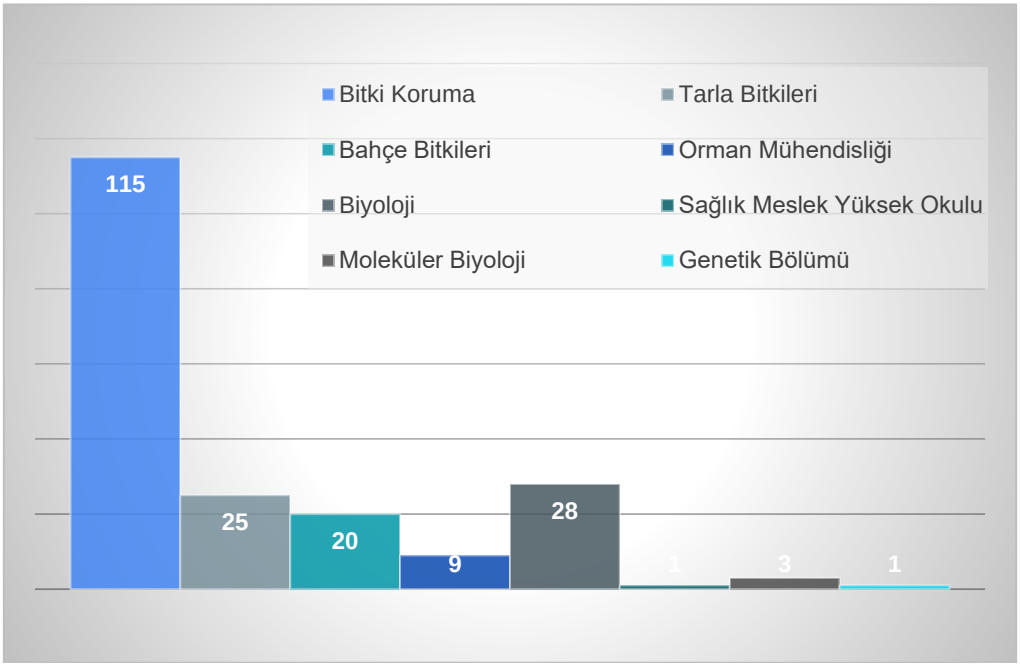
Çizelge 1. Türkiye'de allelopati konusunda yürütülen bilimsel çalışmaların dağılımı

Yıl	Makale	Bildiri	Lisansüstü Tez	Frekans
1980-1990	1	-	-	1
1990-2000	11	1	4	16
2000-2010	10	30	4	44
2010-2020	21	58	22	101
2020-2025	15	18	17	50
Toplam	58	107	47	212

Türkiye'de allelopati konusunda yapılan ilk araştırma, "Kültür turpunun (*Raphanus sativus* L.) Kanyaşa (*Sorghum halepense* (L.) Pers.) olan allelopatik etkisi" konusunda yürütülmüştür (Uygur ve Köseli, 1988). Bu çalışma sonucunda, Kültür turpunun Kanyaş çıkışını önemli ölçüde engellediği belirlenmiştir. Bu konuda Türkiye'de yapılan ilk lisansüstü tez çalışması

"Pamuk kültürü içerisinde Geliçin (*Sorghum halepense* (L.) Pers.) gelişme biyolojisi ve Antep turpunun (*Raphanus sativus* L.) bu biyolojik gelişmeye allelopatik ve biyoherbisit etkisinin araştırılması" konuludur (Köseli, 1991). Bu konuda yayınlanan ilk bildiri ise "Parçalanmış bitki atıklarının mısır kültür bitkisi ile yabancı otların gelişmesine allelopatik ve biyoherbisit etkisi" üzerine olmuştur (Uygur ve ark., 1991). Çalışmalar kronolojik olarak değerlendirildiğinde, allelopati konusundaki çalışmaların süreç içerisinde giderek arttığı, allelopati konusunda özellikle son 10 yılda makale ve bildiriler yayınlandığı dikkat çekmiştir.

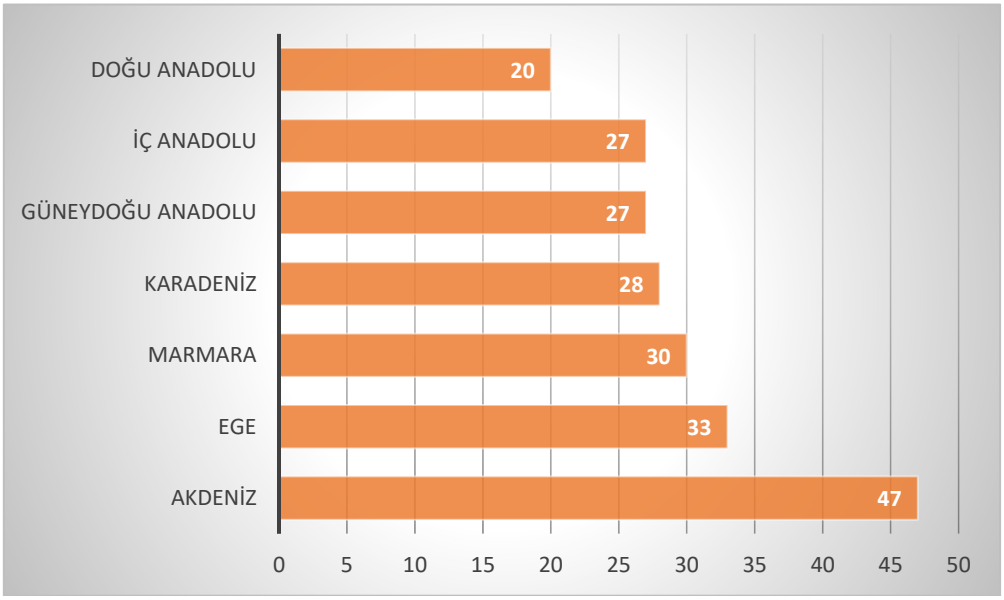
Yürütüldüğü akademik birimler bazında değerlendirildiğinde, ülkemizde yürütülen allelopati konulu çalışmaların 18 farklı akademik birimde yürütüldüğü ortaya çıkmıştır (Şekil 1). Çalışmaların yürütüldüğü Ziraat Fakültelerine bağlı bölümler Bitki Koruma, Tarla Bitkileri, Bahçe Bitkileri, Tarımsal Biyoteknoloji, Tarımsal Yapılar ve Sulama olmuştur. İlgili konuda Fen Fakültesi bünyesindeki Biyoloji, Kimya, Moleküler Biyoloji ve Genetik bölümlerinde, Orman Fakültesinde ise Orman Mühendisliği ve Peyzaj Mimarlığı bölümlerinde çalışmalar yürütülmüştür. Çalışmaların yürütüldüğü Meslek Yüksek Okulları; Bahçe Tarımı, Seracılık, Sağlık, Aşçılık, Turizm ve Otelcilik olmuştur. Çalışmaların büyük çoğunluğunun Bitki Koruma, Biyoloji ve Tarla Bitkileri bölümlerinde yapıldığı, bu bölümleri Bahçe Bitkileri ve Orman Mühendisliği bölümlerinin takip ettiği anlaşılmıştır.



Şekil 1. Türkiye'de allelopatik çalışmaların yürütüldüğü bilimsel alanlar

Türkiye 'de allelopati çalışmalarının yürütüldüğü coğrafik bölgelerin dağılımı incelendiğinde (Şekil 2), en fazla çalışmanın Akdeniz Bölgesi'nde yürütüldüğü ortaya çıkmıştır. Bunun nedeninin, Antep turbu konusunda yürütülen ilk çalışmaların bu bölgede olması, bölgenin fitocoğrafik zenginliği ve tarımsal üretim potansiyelinin yüksek olması nedenlerinden

kaynaklandığı düşünülmektedir. Yürütülen çalışmalar tarımsal üretim potansiyellerine bağlı olarak Akdeniz bölgesinden sonra Ege, Marmara, Karadeniz, Güneydoğu Anadolu, İç Anadolu ve Doğu Anadolu olarak sıralanmıştır. Bu bölgelerde yürütülen çalışmalar kültür bitkileri bazında değerlendirildiğinde; pamuk, şekerpancarı, ayçiçeği, kanola, zeytin, bağ, baklagiller ve tahıl üretim alanlarında sorun olan yabancı otların mücadelesi amacıyla allelopatik çalışmaların yürütüldüğü ortaya çıkmıştır.



Şekil 2. Türkiye'de allelopatik çalışmaların yürütüldüğü coğrafik bölgeler

Türkiye'de 1980–2025 yılları arasında yapılan çalışmalar konu ve kapsam olarak değerlendirildiğinde, daha çok Brassicaceae familyasından bitkilerin veya tıbbi ve aromatik bitkilerin farklı kültür bitkilerinde sorun olan tek yıllık ve çok yıllık pek çok yabancı ot türüne etkinliği konusunda olduğu ortaya çıkmıştır.

Turp (*Raphanus sativus* L.), şalgam (*Brassica rapa* L.), Kekik türleri (*Origanum* spp., *Thymus* spp.) ve Melisa (*Melissa officinalis* L.) gibi bitkilerin güçlü allelopatik etki gösterdiği belirlenmiştir (Karaca ve Eren, 2023; Üremiş ve Efil, 2019). Benzer şekilde, Sarımsak (*Allium sativum* L.), Pelin otu (*Artemisia* spp.), Rezene (*Foeniculum vulgare* Mill.) vd. bazı bitkiler bazı yabancı otların mücadelesinde etkili bulunmuştur (Aydın ve Tursun, 2010; Karaca ve Yurttaş-Kılınç, 2023).

4. SONUÇ ve ÖNERİLER

Yabancı ot mücadelesinde allelopati, insan ve çevre sağlığına zararlı olmaması ile herbisitlere göre daha güvenli olmasından dolayı tercih edilir. Allelokimyasallar bitkilerde sentezlenen doğal bileşikler olduklarından dolayı daha kolay parçalanıp doğada birikmezler çevreye

zararları yoktur. Bu sebeple, yabancı ot mücadelesinde sentetik herbisit yerine allelokimyasalları kullanmak çevre açısından oldukça önemlidir. Allelopatik çalışmalar, çevre sağlığını tehdit eden sentetik herbisitlerin yerine alternatif olabilecek biyoherbisitlere kaynak sağlayabilir.

Türkiye'de allelopati konusunda yürütülen araştırmalar, hem geleneksel bilgilerin modern bilimsel yöntemlerle değerlendirilmesi, hem de doğal kaynaklı herbisitlerin geliştirilmesi açısından bilimsel dayanak oluşturmuştur. Mevcut bulgular ışığında doğal herbisit geliştirme çalışmalarına katkı sunacak bitki türlerinin belirlenmesi ve bu alanda gelecekte yapılabilecek çalışmalara yön verilmesi hedeflenmektedir. Türkiye'de allelopati üzerine yapılan araştırmalar, başlangıçta laboratuvar ortamında yapılan çimlenme denemeleriyle sınırlı kalmıştır. Ancak zamanla, tarla denemeleri ve kimyasal içerik analizleri gibi daha kapsamlı yöntemler kullanılmaya başlanmıştır. Bu alandaki çalışmalar, özellikle organik tarım uygulamalarında doğal mücadele yöntemlerinin geliştirilmesine katkılar sağlayacaktır.

Yapılan çalışmalardan elde edilen sonuçlar oldukça ümitvar bulunmakla birlikte, sera ve tarla koşullarında uygulamalarındaki bazı güçlükler nedeniyle, yürütülecek çalışmalarda yeni uygulama tekniklerinin araştırılmasına önem verilmesi gerekmektedir.

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DETERMINATION of *HSP90AA1* GENE POLYMORPHISM in ILE DE FRANCE X ANATOLIAN MERINO CROSSBRED SHEEP

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ABSTRACT

Climate change driven by global warming is one of the most pressing issues currently affecting the agricultural sector. The development of genotypes resistant to high temperatures, both in plant and animal production, is crucial for ensuring sustainable agricultural practices and a stable food supply. Developed molecular techniques are widely used to identify the genetic basis underlying heat tolerance in farm animals, as in other fields. Heat Shock Protein (HSP) genes are among the most extensively studied genetic regions related to heat tolerance in various livestock species. One of these gene regions is HSP90AA1 (112G>C) gene and it has been reported that the CC genotype is the desired genotype for heat tolerance**.** This study aimed to determine the HSP90AA1 (112G>C) gene polymorphism in Ile de France × Anatolian Crossbred sheep, which are intensively bred in Central Anatolia. For this purpose, DNA samples from 178 individuals were genotyped using Allele-Specific PCR (AS-PCR). In the studied population, the allele frequencies for G and C were 0.62 and 0.38, respectively. The genotype frequencies for GG, GC, and CC were calculated as 0.60, 0.53, and 0.12, respectively. Additionally, it was determined that the population was in Hardy-Weinberg equilibrium with respect to the HSP90AA1 (112G>C) gene polymorphism. In this study, the CC genotype, which is considered favorable for heat tolerance, was detected, albeit at a low frequency. It was also observed that there was sufficient genetic variation within the population. The results suggest that the HSP90AA1 (112G>C) gene polymorphism can be utilized in Marker-Assisted Selection (MAS) programs aimed at improving heat tolerance in Ile de France × Anatolian Crossbred sheep. However, it is important to recognize that polygenic traits, such as heat tolerance, are influenced by multiple genes and environmental factors.

Keywords: HSP, AS-PCR, sheep, heat stress

ILE DE FRANCE X ANADOLU MERINOSU MELEZİ KOYUNLARDA *HSP90AA1* GEN POLİMORFİZMİNİN BELİRLENMESİ

ÖZET

Küresel ısınma kaynaklı iklim değişikliği günümüzde tarım sektörünün üzerinde baskı yaratan en ciddi sorunlardan bir tanesidir. Gerek bitkisel gerekse hayvansal üretim alanında yüksek sıcaklığa dirençli genotiplerin elde edilmesi sürdürülebilir üretim ve gıda arzı bakımından elzemdir. Gelişen moleküler yöntemler çiftlik hayvanlarında diğer alanlarda olduğu gibi ısıya toleransın altında yatan genetik temelin belirlenmesinde yoğun olarak kullanılmaktadır. Farklı çiftlik hayvanı türlerinde ısıya tolerans ile ilişkili çalışılan gen bölgelerinin başında Isı Şok Proteinlerine (HSP) ait genler gelmektedir. Bu gen bölgelerinden bir tanesi de *HSP90AA1* (112G>C) genidir ve bu gen bölgesindeki polimorfizm sonucu oluşan genotiplerden CC genotipinin ısıya tolerans için istenilen genotip olduğu bildirilmiştir. Bu çalışmada Orta Anadolu'da yetiştiriciliği yoğun olarak yapılan Ile de France X Anadolu Melezi koyunlarda *HSP90AA1* (112G>C) gen polimorfizminin belirlenmesi amaçlanmıştır. Bu amaçla 178 örnekten elde edilen DNA'lar Allel Spesifik PCR (AS-PCR) işlemi ile genotiplendirilmiştir. Çalışılan populasyonda G ce C allel frekansları sırasıyla 0.62 ve 0.38 olarak tespit edilmiştir. GG, GC ve CC genotip frekansları ise sırasıyla 0.60, 0.53 ve 0.12 olarak hesaplanmıştır. Ayrıca çalışılan populasyonun *HSP90AA1* (112G>C) gen polimorfizmi bakımından Hardy-Weinberg dengesinde olduğu tespit edilmiştir. Çalışmada ısıya tolerans için istenilen genotip olan CC düşük frekansta da olsa tespit edilmiştir ve populasyonda yeterli genetik varyasyonun olduğu görülmüştür. Bu çalışmadan elde edilen sonuçlar *HSP90AA1* (112G>C) gen polimorfizminin Ile de France X Anadolu Melezi koyunlarda ısıya toleransın iyileştirilmesi için yapılacak Marker Destekli Seleksiyon (MAS) çalışmalarında kullanılabileceğine işaret etmektedir. Ancak ısıya tolerans gibi poligenik kalıtım izleyen özelliklerin çok sayıda gen ve çevresel faktörlerle şekillendiği unutulmamalıdır.

Anahtar Kelimeler: HSP, AS-PCR, koyun, ısı stresi

INTRODUCTION

One of the greatest challenges facing humanity today is climate change, which threatens both ecological balance and economic stability. The increase in global temperatures due to climate change causes a range of environmental problems, including drought, desertification, irregular rainfall, and the reduction of water resources and forests (Brown et al., 2007; Adamo et al., 2022). Agriculture, due to its vast scale and vulnerability to weather conditions, is the industry most at risk from climate change, which is expected to have a significant negative economic impact. Crop yields are greatly affected by variations in meteorological factors such as temperature and rainfall (Malhi et al., 2021). In livestock breeding, global climate change has both direct effects, such as decreased yield and quality, and fertility, as well as indirect effects, including the reduction in the availability and quality of pasture and grassland areas, and a decline in fodder crop production (Cheng et al., 2022).

The stress caused by high ambient temperatures not only leads to yield loss in livestock but also negatively impacts reproductive characteristics and animal welfare. This situation results in significant economic losses for breeders and poses a threat to the sustainable food supply (Demir et al., 2022). Sheep breeding holds considerable potential for sustainable animal husbandry in the face of rising environmental temperatures, which are expected to increase further due to global warming. However, to harness this potential more effectively, it is crucial to identify candidate gene regions related to heat tolerance in sheep and to enhance their frequency in the population through selective breeding (Demir et al., 2022). By incorporating these identified genes into Marker Assisted Selection (MAS) studies, alongside traditional breeding approaches, it is possible to develop animals resistant to heat stress.

Heat shock proteins (HSPs) and their corresponding gene regions have gained significant attention in molecular genetic studies on heat stress and high-temperature tolerance across various livestock species (Singh et al., 2017; Demir et al., 2022; Rawash et al., 2022; Yurdagül et al., 2023; Uzel et al., 2024). Heat shock proteins are chaperone proteins that vary in molecular weight and biological function, and they are induced under heat and other stress conditions. In the event of cellular damage, HSPs circulating in the blood protect cells from toxic effects and thermal damage caused by heat stress. These proteins are classified into five groups based on their molecular weight: HSP100, HSP90, HSP70, HSP60, and small heat shock proteins (17-30 kDa) (sHSP) (Yer, 2017; Çıldır and Özmen, 2019; Şenel et al., 2019).

This study aimed to identify the polymorphism in the *HSP90AA1* (112G>C) gene in Ile de France x Anatolian Merino crossbred sheep raised in Eskisehir province and to explore its potential use in Marker Assisted Selection (MAS) studies.

MATERIAL and METHODS

Material

The material for this study consisted of DNA isolated from blood samples of 10-11-month-old Ile de France x Anatolian Merino crossbred sheep reared on three different farms in the Günyüzü district of Eskişehir province. A total of 180 samples from these three farms were analyzed. DNA was isolated using the GeneJET Genomic DNA Purification Kit (Thermo

K0721) following the manufacturer's instructions. Quality and quantity assessments of the DNA were performed using a spectrophotometer (Allsheng Nano-400A). The DNA concentration was standardized to 50 ng/µL for use in AS-PCR procedures.

Methods

AS-PCR Process and Genotyping

The C and G alleles in the *HSP90AA1* promoter region of the sheep genome were amplified using the AS-PCR technique described by Singh et al. (2017). Some descriptive information about the primers used in PCR is given in Table 1.

Table 1. Primers utilized in AS-PCR process for determination of HSP90AA1 polymorphism

Gene	Locus	Primer Sequences (5'-3')	Genotype Sizes (bp)	Reference
HSP90AA1	(112G>C)	F: TCAGAACCAGCCGAACAGAC R1: AGGTCCATGGTTAGGGGTATC R2: AGGTCCATGGTTAGGGGTATG	254	Singh et al. 2017

Briefly, the 254-base pair (bp) C and G alleles were amplified with two primer sets in the PCR procedure. To optimize the PCR settings, gradient PCR was performed with annealing temperatures ranging from 55 to 65 °C, with the predicted fragments being clearly visible at 60 °C. The PCR reaction mixture consisted of 50 ng of template DNA, 5 µL of 10X reaction buffer, 0.6 mM dNTP, 2.5 mM MgCl2, 10 pM of each primer, 1 U Taq DNA polymerase (GeNet Bio, Korea), and 31.25 µL of nuclease-free water, for a total volume of 50 µL. The amplification process began with an initial denaturation step at 94 °C for 10 minutes, followed by 31 cycles of denaturation at 94 °C for 40 seconds, annealing at 60 °C for 40 seconds, and extension at 72 °C for 40 seconds. The amplified C and G alleles were visualized using agarose gel electrophoresis for genotyping. Individuals with a single amplification product were genotyped as homozygous (CC or GG), while those with both amplification products were classified as heterozygous (GC).

Statistical Analysis

Gene and genotype frequencies and whether the population was in Hardy-Weinberg equilibrium in terms of the relevant gene region were determined using POPGENE 1.31 (Yeh et al. 1997).

RESULTS

All three genotypes were detected with varying frequencies for *HSP90AA1* (112G>C) gene in Ile de France x Anatolian Merino crossbred sheep (Figure 1). The studied population is polymorphic for the related gene.

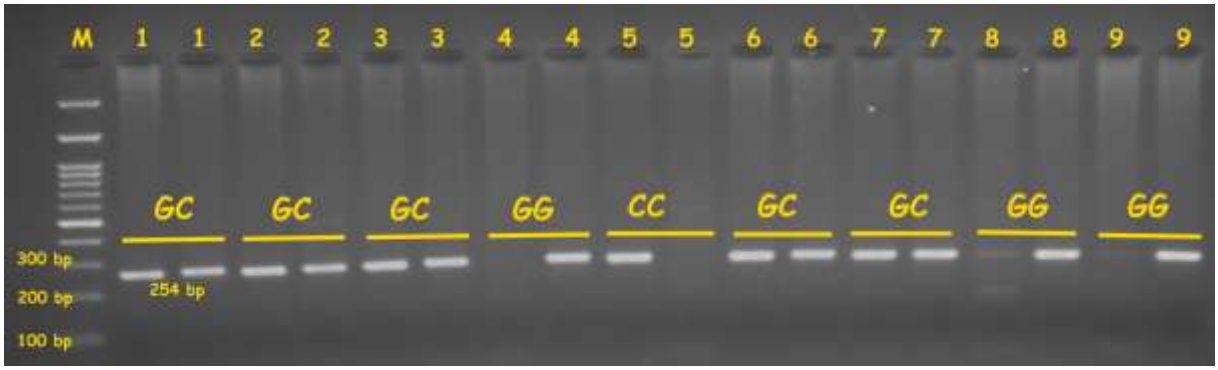

Figure 1. Agarose 2% agarose gel image of *HSP90AA1* (112G>C) polymorphism in studied population

M: Marker (softec, Cat. No: ZT-100BP-1); **1-9:** genotypes obtained

The obtained gene and genotype frequencies, as well as the Hardy-Weinberg equilibrium for the respective genotypes, are provided in Table 2. In the studied population, genotype frequencies ranged from 0.12 (CC) to 0.53 (GC), while the frequencies of the G and C alleles were calculated to be 0.62 and 0.38, respectively. It was determined that the studied population was in Hardy-Weinberg equilibrium ($p < 0.05$) for the relevant gene

Table 2. *HSP90AA1* (112G>C) gene, genotype frequencies, and chi-square values

		Allele frequencies		Genotype frequencies			χ^2
Breed	**n**	**G**	**C**	**GG**	**GC**	**CC**	
Ile de France x Anatolian Merino Crossbred	178	0.62	0.38	0.35 (62)	0.53 (95)	0.12 (21)	2.88[a]

$\chi^2$0.05;1: 3.84; a: Deviation from Hardy Weinberg Equilibrium is non-significant

DISCUSSION

Identifying and breeding animals with high tolerance to temperature stress is crucial for sustainable animal husbandry, especially under the changing environmental conditions brought about by global warming, which affects food supply. Consequently, in recent years, numerous studies have been conducted to explore the genetic mechanisms underlying adaptation to heat

stress in various livestock species or breeds (Tang et al. 2022; Sheraz et al. 2023; Demir 2024; Karsli 2024; Sabzizadeh et al. 2024). Singh et al. (2017) investigated the relationship between mutations in the *HSP70* and *HSP90* gene regions and heat stress in Chokla, Magra, Marwari, and Madras Red sheep breeds in India. The researchers reported that a polymorphism resulting from a point mutation (112G>C) in the *HSP90AA1* gene was directly associated with thermo-tolerance parameters. Furthermore, they found that the C allele and the CC genotype in this gene region are favorable alleles and genotypes for heat tolerance.

Singh et al. (2017) reported that for the *HSP90AA1* (112G>C) gene, the frequency of the GG genotype ranged from 0.48 (Madras Red) to 0.80 (Marwari) and was commonly observed in Chokla, Magra, Marwari, and Madras Red sheep breeds. The GC genotype frequency ranged from 0.19 (Marwari) to 0.35 (Madras Red). It was also noted that the CC genotype was not detected in the Chokla, Magra, and Marwari breeds, with its frequency being 0.16 in the Madras Red breed. The frequency of the C allele ranged from 0.09 (Marwari) to 0.34 (Madras Red), while the G allele frequency ranged from 0.10 (Madras Red) to 0.90 (Marwari) across the four Indian sheep breeds. In our study, the C allele frequency (0.38) and CC genotype frequency (0.12) in the Ile de France × Anatolian Merino crossbred sheep were relatively higher than those reported in the four Indian sheep breeds. This difference is likely attributable to the origin of the sheep. The Ile de France and Anatolian Merino (Akkaraman and German Mutton Merino crossbred) (Karsli, 2025) sheep used in this study are crossbred and primarily of European origin.

Yurdagül (2023) reported G and C allele frequencies of 0.61 and 0.39, respectively, and the frequencies of CC, CG, and GG genotypes as 0.183, 0.404, and 0.413, respectively, in the Pırlak sheep breed. Demir (2024) reported C allele frequencies of 0.33, 0.45, and 0.25, and CC genotype frequencies of 0.25, 0.16, and 0.10 in the Ivesi, Güney Karaman, and Karakaş sheep breeds, respectively. Bilginer et al. (2024) reported a C allele frequency of 0.50 and a CC genotype frequency of 0.25 in the Hamdani sheep breed. When comparing the C allele frequency (0.38) and CC genotype frequency (0.12) observed in the Ile de France × Anatolian Merino crossbred sheep in this study with the aforementioned studies, it is evident that the values are similar to those found in the Pırlak sheep by Yurdagül et al. (2023), but lower than those reported by Demir (2024) for the Ivesi and Güney Karaman breeds and by Bilginer et al. (2024) for the Hamdani breed.

The İvesi sheep breed is raised in the Gaziantep, Şanlıurfa, and Hatay provinces, which border Syria in southern Türkiye (Çebel, 2023), while the Güney Karaman breed is raised in the Antalya and Mersin provinces (Karsli et al., 2020). Both breeds are known for their ability to adapt to high temperatures and are well-adopted to the hot climatic conditions of the regions where they are bred. Similarly, the Hamdani breed, originally from Iraq and Iran, has become increasingly popular among breeders in Eastern and Southeastern Anatolia due to its excellent adaptability and high dual-purpose yield. Therefore, the C allele and CC genotype may be more prevalent in the HSP90AA1 (112G>C) gene in İvesi, Güney Karaman, and Hamdani breeds. As mentioned earlier, the sheep used in this study are primarily of European origin, which may account for the slightly lower frequency of the CC genotype.

CONCLUSION

The CC genotype, previously reported as a desirable genotype in the HSP90AA1 (112G>C) gene for heat tolerance in sheep (Singh et al., 2017), was detected in the Ile de France × Anatolian Merino crossbred sheep in this study, albeit at a low frequency. Additionally, it was determined that the population was in Hardy-Weinberg equilibrium with respect to the related gene. The findings from this study suggest that the HSP90AA1 (112G>C) gene region could be utilized in future MAS studies to enhance heat adaptation in this breed. However, it is important to recognize that heat stress adaptation follows polygenic inheritance and is influenced by numerous genes and environmental factors. Furthermore, analyzing the relationship between the gene region and thermo-physiological phenotypic parameters is crucial. Evaluation of these and similar gene regions together in MAS studies after being associated with thermos-physiological properties will increase the success.

Thanks and Information Note

This study is based on a section of the first author's master's thesis, titled " *Determination of the Relationships Between Parameters Associated with Heat Stress Tolerance and Some Candidate Genes in Ile de France x Anatolian Merino Crossbred Sheep* ".

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A HARMLESS METHOD IN AGRICULTURAL PRODUCTION: ALLELOPATHY

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ABSTRACT

Allelopathy is defined as the positive or negative effect of a plant on other plants or organisms. The allelopathic effect, whose first definition dates back to the 20th century, has always existed in nature and came to light with the beginning of agriculture. Plants with allelopathic effect interact with other plants or organisms with the compounds in their structure. These compounds secreted by plants and causing positive or negative effects are called allelochemicals. Allelochemicals directly or indirectly affect plants or organisms and affect the yield and quality. Chemical control against diseases, pests and weeds has become an indispensable option, especially in order to meet the basic need of the increasing world population and to obtain maximum yield from unit area. The intensive and prolonged use of these chemicals causes problems for humans and the environment and causes difficulties in control. Long-term use of pesticides with the same site of action result in the development of resistant weed populations and organisms, and therefore the control of resistant pests in agricultural areas becomes more difficult. However, plant-based allelochemicals have many advantages over chemical control, such as low or no potential for harm to humans and the environment, easy biodegradability, and low residue risk. Apart from this, they are also used for different purposes in agricultural areas with applications such as rotation, mixed cultivation, green manuring, preplant, cover crop, and mulching.

This research was carried out in order to reveal the current usage areas of allelopathy in agricultural areas for the control of plant protection agents. For this purpose, a comprehensive literature review on the concept of allelopathy and its use in agricultural areas was conducted and the information was compiled. Increasing research on allelopathy and biopesticide applications will play a major role in creating healthier, more efficient and sustainable agricultural systems in the future.

Keywords: Allelopathy, Allelochemical, Biopesticide, Sustainable Agriculture.

TARIMSAL ÜRETİMDE MASUM BİR YÖNTEM: ALLELOPATİ

ÖZET

Allelopati, bir bitkinin diğer bitki veya organizmalar üzerinde oluşturduğu olumlu veya olumsuz etki olarak tanımlanmaktadır. İlk tanımlaması 20. yüzyıla dayanan allelopatik etki, doğada hep var olmuş ve tarımın yapılmaya başlanmasıyla birlikte de gün yüzüne çıkmıştır. Allelopatik etkiye sahip olan bitkiler yapılarında bulunan bileşikler ile, diğer bitki veya organizmalarla etkileşim kurar. Bitkilerden salgılanan ve olumlu-olumsuz etkilere neden olan bu bileşiklere ise allelokimyasal denir. Allelokimyasallar doğrudan veya dolaylı olarak bitki veya organizmalara etki ederek verim ve kaliteye etki etmektedir. Özellikle artan dünya nüfusunun temel ihtiyacı olan gıdayı karşılamak ve birim alandan maksimum verim alınması için hastalık, zararlı ve yabancı otlara karşı kimyasal mücadele vazgeçilemez bir seçenek olmuştur. Bu kimyasalların yoğun ve uzun süreli kullanımı, insan ve çevre açısından sorunlara yol açmakta ve mücadelede zorluklara sebebiyet vermektedir. Etki mekanizması aynı pestisitlerin uzun süreli kullanımı, dayanıklı yabancı ot popülasyonlarının ve organizmaların gelişmesine neden olur ve bu nedenle tarımsal olanlarda dayanıklı zararlıların mücadelesi zorlaşır. Ancak bitkisel kökenli olan allelokimyasallar, insan ve çevreye zarar verme potansiyelinin düşük olması veya hiç olmaması, doğada kolayca çözünmesi, kalıntı riskinin düşük olması gibi kimyasal mücadeleye göre pekçok avantaja sahiptir. Bunun dışında münavebe, karışık ekim, yeşil gübreleme, ön bitki, örtücü bitki, malçlama şeklindeki uygulamalar ile tarımsal alanlarda farklı amaçlarla da kullanılmaktadır.

Bu araştırma, allelopatinin bitki koruma etmenleriyle mücadele ile tarımsal alanlardaki mevcut kullanım alanlarını ortaya çıkarmak amacıyla yapılmıştır. Bu amaçla allelopati kavramı ve tarımsal alanlarda kullanımı konusunda kapsamlı literatür taraması yapılarak elde edilen bilgiler derlenmiştir. Allelopati konusundaki araştırmaların ve biyopestisit uygulamalarının arttırılması, gelecekte daha sağlıklı, verimli ve sürdürülebilir tarım sistemlerinin oluşturulmasında büyük bir rol alacaktır.

Anahtar Kelimeler: Allelopati, Allelokimyasal, Biyopestisit, Sürdürülebilir Tarım.

GİRİŞ

İnsanoğlunun avcılık ve toplayıcılıktan yerleşik hayata geçmesiyle tarım yapılmaya başlanmıştır. Günümümüzden binlerce yıl öncesine dayanan tarım ile günümüzde yapılan tarım arasında çok büyük farklılıklar olsa da, temelde ikisi de insan hayatının devam edebilmesi için şart olan beslenme ihtiyacını karşılamayı hedeflemiştir. Sağlıklı ve temiz gıdaya erişim her yüzyılda insanların en öncelikli hedeflerinden biri olmuştur. Bu hedef gelecek yüzyıllar için de aynı şekilde devam edecektir. Eski çağlarda tarımın kısıtlı imkanlarla yapılması bile az olan nüfusa yetecek gıda tedariğini belli bir oranda karşılayabildiği bilinmektedir. Ulusal Demografik Araştırmalar Enstitüsü (INED) 2024 verilerine göre dünya nüfusu 8 milyar kişiyi aşmış ve giderek artmaktadır **(INED, 2024).** Dünyada tarım yapılan alanlarda herhangi bir değişiklik söz konusu değildir. Dolayısıyla, nüfusun her geçen gün artmasına karşılık gıda ihtiyacını karşılayacak yeni tarım alanları bulunmamaktadır. Dünya nufüsunun her geçen gün artması sağlıklı ve temiz gıdaya olan erişimin zorlaşmasına neden olacaktır. Bu durumda yeni tarım alanları olamayacağı için var olan tarım alanlarınında birim alandan maksimum verim ve kaliteninde alınması gerekmektedir. Birim alandan maksimum verim alınmasını sınırlayıcı biyotik ve abiyotik etmenler bulunmaktadır. Tarımsal alanlarda ürün miktarını sınırlayan biyotik etmenler hastalık, zararlı ve yabancı otlardır **(Bükün, 2012).** Biyotik etmenlerden kaynaklanan verim kaybının %30 civarında olduğu belirtilmektedir **(Karaca, 2022).** Bu etmenlerden birinin veya birkaçının aynı zamanda olması tarımda %100'e varan oranlarda verim ve kalite kayıplarına yol açmaktadır. Abiyotik etmenlerden kaynaklanan kayıpların önüne geçmek için uygulanabilecek bazı mücadele yöntemleri mevcuttur. Bu yöntemlerden kimyasal mücadele kısa sürede etki göstermesi, işçilik maaliyetinin olmaması veya daha düşük olması, kolay uygulanabilirliği gibi nedenlerden dolayı mücadelede en çok tercih edilen yöntemdir. Tarımda hastalık, zararlı ve yabancı otların mücadelesinde farklı kimyasal maddelerin kullanımı eski çağlarda başlamıştır. Kükürdün insektisit ve fungisit özelliğinin M.Ö. 1000 yılında keşfedildiği **(Öztürk ve Özge, 1978: Ağar ve ark. 1991'dan)** "Hellobore" (*Helleborus niger, Helleborus orientalis* ve *Veratrum album*) adlı bitkilerin fare, sıçan ve böceklerin kontrolü için M.Ö. 100 yılında kullanıldığı bilinmektedir. Ancak sanayinin gelişmesi ve teknolojinin ilerlemesiyle birlikte organik/inorganik kaynaklı maddelerin yerini sentetik kimyasallar almaya başlamıştır. 20. yüzyılla birlikte ilk insektisit, fungisit, herbisit gibi terimler kullanılmaya başlanmıştır. Kısa sürede etki göstermesi, diğer mücadele yöntemlerini göre işçilik maaliyetinin düşük olması gibi nedenlerden dolayı pestisit kullanımı hızla artış göstermiştir. Ancak, sentetik kimyasalların yoğun şekilde ve uzun süreli kullanımı sonucu insan, hayvan ve çevre sağlığına olan etkileri fark edilmiş, pestisit kullanımını kontrol altına alabilmek için yasal düzenlemeler getirilmiştir ve uluslararası faaliyet gösteren kuruluşlara eğitimler verilmiştir. Günümüzde EPPO, FAO, WHO, EEC, EPA gibi kuruluşlar pestisit kullanımı konusunda faaliyet göstermektedir **(Ağar ve ark., 1991).** Sentetik kimyasalların kullanımı sonucunda karşılaşılan en önemli sorunlardan biri de çevrede bıraktığı kalıntı ve kullanıldığı organizmada oluşturduğu dayanıklılıktır. Bu karşılaşılan olumsuzluklardan sonra, 1970'li yıllarda çevre koruma hareketleri hızlanmış ve daha kontrollü kimyasal kullanımı ön plana çıkmıştır **(Ağar ve ark, 1991).** Bitki koruma hareketleriyle başlayan bu süreç, yıllar içinde daha da ilerleyerek diğer mücadele yöntemlerinin de gelişmesine olanak sağlamıştır. Entegre mücadele sistemlerininde tarımsal savaşımda daha fazla paydaya sahip olmasını sağlamıştır. Biyoteknik, biyolojik mücadele yöntemlerinin yanısıra, doğal kaynaklı maddelerinde fark edilmesini ve geliştirilmesi hız kazanmıştır. Sentetik kaynaklı pestisitlerin

yerine kulanılabilecek doğal kaynakların varlığı tarımsal açısından önemli bir gelişme olarak nitelendirilebilir.

"Allelon" (birbiri ile ilgili) ve "Pathos" (zarara girmek) kelimelerinin birleşimi ile "Allopathy" olarak tanımlanan allelopati "Bitkiler veya mikroorganizmalar arasındaki olumlu veya olumsuz etkileşimler" olarak 1937 yılında Molich tarafından ilk kez tanımlanmıştır. Bu kavram, daha sonraki yıllarda "Çevreye saldığı kimyasal bileşiklerle bir bitkinin veya bir mikroorganizmanın diğerini dolaylı veya doğrudan zararlı veya yararlı olarak etkilemesi" olarak daha da genişletilerek ifade edilmiştir **(Rice, 1984).** 20. yüzyılın başlarında dünyada başlayan allelopati çalışmalarına Türkiye ise 1980 yılında dahil olmuş ve günümüze kadar çalışmalar ilerleyerek devam etmektedir **(Karaca ve Eren, 2023)**. Doğada allelopatik etki gösteren çok sayıda bitki bulunmaktadır. Allelopatik etkiye sahip böylesi bitkilere ise allelopatik bitkiler denilmektedir. Allelopatik bitkilerin çeşitli kısımlarından salgıladıkları ve bitkiler üzerinde olumlu veya olumsuz etkiler oluşturan bileşiklere allelokimyasal denir. Bitkiler tarafından üretilen sekonder bileşikler, bitkilerin cins ve türüne göre farklılıklar gösterebilmektedir. Farklı sayıda ve miktarlarda bulunan sekonder bileşikler; toksik gazlar, organik asit ve aldehitler, aromatik asitler, doymamış basit laktonlar, kumarinler, kininler, flavanoidler, taninler, alkoloidler, terpeneoidler ve streroidlerdir **(Özer ve ark., 1997).** Allelokimyasal maddeler bitkilerin tohum, çiçek, polen, yaprak, gövde, rizom, meyve ve kök bölgelerinin birinde veya birkaç bölgesinde bulunur **(Yılmaz ve Köse, 2021).** Bitkilerin farklı noktalarında bulunan bu allelokimyasallar bitkiden buharlaşma (volatilizasyon), kök salgıları, toprak üstü organlardan yıkanma ve bitki artıkların ayrışmasıyla etki edeceği organizmaya ulaşır **(Yılmaz ve Köse, 2021).** Bitkilere ulaşan allelokimyasallar tohumun çimlenmesini engelleyerek, büyüme ve gelişmeyi yavaşlatarak veya besin maddelerinin alımında sorunlar oluşturarak allelopatik etkilerini gösterirler **(Yılmaz ve Köse; Kamal, 2020).** Etki ettiği organizmalarda farklı fizyolojik ve morfolojik etkiler sonucu yaşamsal faaliyetler engellenir. Allelokimyasalların bitkilerde üretimini sınırlayan çeşitli etmenler de bulunmaktadır. Güneş ışınları, bitki besin mineral yetersizliği, bitki organlarının yaşı, stres, nem, sıcaklık gibi abiyotik ve fizyolojik faktörlerin yanı sıra, hastalık, zararlı, yabancı otlar gibi biyotik faktörler deallelokimyasal üretimini sınırlayabilmektedir. **(Rice, 1984)**. Allelopatik bitkilerin etkileri değerlendirildiğinde, bazı durumlarda olumsuz sonuçlar doğurabileceği düşünülse de, muhtemel olumsuz durumları doğru yöntemler kullanarak ortadan kaldırmak mümkündür. Allelokimyasallar biyoherbisit olarak tarımsal savaşta kimyasal mücadeleye alternatif olarak uygulayabildiğimiz, aynı zamanda tarımsal alanlarda münavebe, karışık ekim, yeşil gübreleme, ön bitki, örtücü bitki ve malçlama gibi farklı uygulamalarda da etkisinden faydalandığımız doğal bileşikler olarak önemini korumaktadır.

1. ALLELOPATİNİN TARIMDA KULLANIMI

1.1. Biyopestisit

Allelopati, sentetik kimyasalların uzun yıllar kullanılması sonucu ortaya çıkan çevreye olumsuz etkiler, tarımsal ürünlerde kalıntı ve organizmalarda dayanıklılık sorunlarını minimuma indirebilecek veya tamamen ortadan kaldırabilecek bir yöntem olarak görülmektedir. Bazı alleleopatik bitkilerin böcek kovucu oldukları veya yabancı otları çıkışlarını etkiledikleri eski çağlardan günümüze kadar bilinmektedir. *Helleborus niger* (Noel gülü), *Helleborus orientalis*

(Mercimek gülü) ve *Veratrum album* (Beyaz çöpleme) bitkilerinin M.Ö. 100 yılında haşere ve böcekleri kontrol etmede kullanıldığı bilinmektedir **(Öztürk ve Özge, 1978: Ağar ve ark. 1991'dan)**. Allelopatik bitkilerden salgılanan maddeler doğal kaynaklı olduklarından tabiatta bunları tanıyan ve parçalayan enzimler ve mikroorganizmalar bulunmaktadır. Dolayısıyla, tabiatta birikim yapmadıklarından pestisitlere kıyasla çevreye dost bileşiklerdir **(Dukat et al., 2002; Vyvyan 2002; Bhowmik and Inderjit 2003; Yazlık, 2009'dan).** Bu sebeple tarım alanlarında hastalık, zararlı ve yabancı ot mücadelesinde allelopatik bitkilerden sentezlenen allelokimyasalların biyopestisit olarak kullanılması sentetik pestisitlerin uzun yıllar boyunca ve yoğun biçimde kullanılması sonucunda sebep olduğu çevre kirliliği, biyolojik çeşitlilikte azalma, hedef dışı organizmalarda dayanıklılık gelişimi ve insan sağlığına olumsuz etkiler gibi pek çok sorunun çözümünde etkili olacağı düşülmektedir. Bu olumsuzlukların giderek artması, çevre dostu ve sürdürülebilir alternatif arayışları gündeme getirmiştir. Bu bağlamda, bitkilerin kendi savunma mekanizmaları çerçevesinde sentezlediği doğal bileşikler olan allelokimyasallar, son yıllarda özellikle biyopestisit olarak kullanımları ile dikkat çekmektedir. Allelokimyasalların etkilerinin tespit edildiği pek çok laboratuvar çalışmaları mevcuttur. Çoban kirpiği (*Achillea tenuifolia*) bitkisinden elde edilen aseton ekstraktının Tarla akça çiçeği (*Thlaspi arvense*) ve Yabani marul (*Lactuca serriola*) çimlenmesine ve gelişmesine allelopatik etkileri araştırılmış ve sonuç olarak *A. tenuifolia* bitkisinden elde edilen aseton ekstraktının yabancı ot tohumlarının çimlenme, kök ve sürgün gelişmesini engellediği, doz artışıyla beraber engelleme oranlarının da arttığı ve fide ölümlerine neden olduğu saptanmıştır. Sonuç olarak, Çoban kirpiği ekstraktının allelopatik etkisinin olduğu belirlenmiştir **(Bozhüyük-Usanmaz ve Aslan, 2024).** Yapılan başka bir çalışmada ise Pelin otunun (*Artemisia annua*) yaprak özütleri farklı dozlarda üç farklı kültür bitkisine (ayçiçeği, marul, mısır) ve Horozibiği (*Amaranthus* spp.), Darıcan (*Echinochloa crus-galli*) ve Delice (*Lolium perene*) yabancı otlarına allelopatik etkisi araştırılmış ve Pelin özütlerinin, çalışmadaki tüm kültür bitkilerinin ve yabancı ot türlerinin çimlenmesini azalttığı saptanılmıştır **(Kolören, 2006; Güney ve ark., 2019'dan).** Benzer bir araştırmada, Isırgan otu (*Urtica dioica*) etanol ekstraktları hazırlanmış ve Sarı taş yoncası (*Melilotus officinalis*) ve Kıvırcık labada (*Rumex crispus*) tohum çimlenmesine ve fide gelişimine olan etkisi değerlendirilmiştir. Çalışma sonucunda özellikle 15 mg petri^{-1}'lik konsantrasyonun çimlenme, kök ve sürgün gelişimi bakımından önemli düzeyde başarılı sonuçlar verdiği belirlenmiştir. Saksı denemelerinde, en iyi sonuçlar ilk 24 saatte elde edilmiştir. Yapılan bu çalışmayla ısırgan otu ekstraktının bu yabancı otlara etkili bir biyoherbisit olma potansiyelinin var olabileceği tespit edilmiştir **(Bozhüyük-Usanmaz ve Karaçöl, 2024).**

Bu kapsamda yürütülen araştırmalar, özellikle tarımda kimyasal girdilerin azaltılması, biyolojik çeşitliliğin korunması ve sürdürülebilir üretim sistemlerinin geliştirilmesi açısından büyük önem taşımaktadır. Doğal kökenli olmaları nedeniyle toksisitelerinin düşüklüğü, hedef dışı canlılara zarar vermeme potansiyelleri ve çevresel kalıcılıklarının sınırlı olması gibi avantajlar, bu bileşiklerin gelecekte konvansiyonel pestisitlerin yerini alabilecek güçlü adaylar olduğunu göstermektedir.

Sonuç olarak, allelokimyasallar; doğaya uyumlu yapıları, çevrede kalıntı bırakmama özellikleri ve çok yönlü biyolojik aktiviteleri sayesinde, tarımsal üretimde sentetik pestisitlerin neden olduğu çevresel ve sağlık temelli sorunların azaltılmasında önemli bir rol oynayabilir. Bu doğrultuda yapılacak kapsamlı araştırmalar ve saha çalışmaları, bu doğal bileşiklerin

biyopestisit olarak ticarileştirilmesi ve sürdürülebilir tarım uygulamalarında yaygınlaştırılması açısından büyük önem arz etmektedir.

1.2. Canlı veya Cansız Bitkisel Materyallerle Malçlama

Malçlama, toprağın yüzeyini örtücü bir materyalle kaplama işlemidir ve bu uygulama, özellikle güneş ışığının toprakla doğrudan temasını engelleyerek yabancı ot tohumlarının çimlenmesini büyük ölçüde önler. Fotosentez için gerekli ışığın yokluğu, yabancı otların gelişimini baskı altına alarak kültür bitkilerinin rekabet gücünü artırır. Tarımda verimliliği artırmak ve sürdürülebilir üretimi desteklemek amacıyla geliştirilen çeşitli yöntemlerden biri olan malçlama, kültür bitkilerinin yetiştirileceği alanlarda ekim öncesi veya sonrası dönemde uygulanarak hem yabancı otların kontrolü, hem de toprak yapısının korunması açısından önemli katkılar sağlar.

Malç materyalleri organik ya da inorganik kökenli olabilir. Ancak özellikle allelopatik özellik gösteren bitkilerden elde edilen organik malçların kullanımı, yabancı ot yönetiminde çok daha etkili sonuçlar doğurmaktadır. Allelopatik bitkilerin malç materyali olarak tercih edilmesi, malçlamanın etkisini artırarak yabancı otların çimlenme kabiliyetlerini düşürür ve daha etkin bir mücadele sağlar. Allelopatik bitkiler, salgıladıkları kimyasal bileşiklerle çevrelerindeki diğer bitkilerin çimlenmesini ve gelişmesini baskılayıcı etki gösterirler. Bunlara ek olarak, çok yıllık kültür bitkilerinde örtücü bitkilerin doğadaki predator ve parazitoitlere doğal ortam sağlandığı belirlenmiştir **(Temel ve Torun, 2020).** Bu bitkilerden elde edilen malçlar, yalnızca fiziksel bir engel görevi görmekle kalmaz, aynı zamanda kimyasal yollarla yabancı otların çimlenme ve büyüme süreçlerini engeller. Böylece yabancı ot baskısı minimuma indirilerek hem kültür bitkilerinin gelişimi teşvik edilir, hem de pestisit kullanımına olan ihtiyaç azaltılmış olur. Bitkisel materyallerin kullanıldığı canlı malçlar zamanla ayrışıp toprağın organik madde miktarını artırır. Su tutma kapasitesini yükseltir ve biyoçeşitliliğe de katkı sağlamış olur **(Arıkan ve Elibüyük, 2015).** Malç materyalleri, toprak sıcaklığının düzenlenmesine yardımcı olarak bitki köklerinin daha stabil bir ortamda gelişmesini destekler. Aynı zamanda topraktaki buharlaşmayı azaltarak suyun daha verimli kullanılmasını sağlar. Bu durum özellikle su kaynaklarının kısıtlı olduğu bölgelerde su tasarrufu açısından büyük önem taşımaktadır. Toprak yapısınının iyileştirilmesinde, organik maddenin, karbon dinamiğinin ve mikrobiyal yaşamın canlandırılması gibi noktalarda örtücü bitkilerin önemli faydaları bulunur **(Temel ve Torun, 2020).**

Sonuç olarak, malçlama uygulamaları, modern tarımda hem çevresel, hem de ekonomik açıdan önemli avantajlar sunmaktadır. Yabancı otlarla mücadelede çevre dostu bir alternatif olarak öne çıkan bu yöntem, aynı zamanda toprak sağlığının korunması ve iyileştirilmesi, su verimliliğinin artırılması ve tarımsal biyoçeşitliliğin desteklenmesi gibi birçok olumlu etkiyi beraberinde getirmektedir. Bu bağlamda, özellikle sürdürülebilir tarım ve çevre için allelopatik bitkilerle malçlama uygulamalarının daha geniş alanlarda uygulanması gerekmektedir.

1.2.1. Canlı Bitki Materyalleri ile Malçlama (Örtücü Bitki)

Tek ya da çok yıllık otsu bitkilerden oluşan, hızlı gelişim gösteren ve yüzeyde oluşturduğu sık bitki dokusuyla toprağı örten bitkilere örtücü bitkiler denir **(Kitiş, 2010).** Örtücü bitki uygulamaları tüm yıl yada belirli dönemlerde, tek başına veya karışık olarak tek yada çok yıllık otsu bitkilerle toprağın örtülmesi esasına dayanır. Tarımsal arazilerin sürdürülebilirliği ve işleyişinin korunması bakış açısıyla örtücü bitkilerin kullanımı giderek daha fazla önem

kazanmaktadır. Örtücü bitkiler, toprak yüzeyini kaplayarak hem fiziksel, hem de biyolojik olarak pek çok işlevin yerine geçen bitkilerdir. Özellikle ekim nöbeti uygulamalarının benimsendiği tarım sistemlerinde allelopatik özellik gösteren örtücü bitkiler, yabancı otların çimlenmesini ve gelişmesini engelleyerek etkili bir biyolojik kontrol aracı olarak görev yapar **(Arıkan ve Elibüyük, 2015).** Bu bitkiler, kök salgıları veya ayrışan bitki kalıntıları aracılığıyla çevrelerine allelokimyasal bitkiler salgılayarak yabancı otların toprakta tutunmasını veya çimlenmesini baskılar. Yabancı ot kontrolünün yanında, örtücü bitkilerin toprak koruma açısından da birçok olumlu etkisi bulunmaktadır. Toprağın yüzeyini tamamen kaplayan bu bitkiler, yüzeylerin silinmesi ve rüzgar parçalarına karşı doğal bir bariyer oluşturur. Özellikle eğimli arazilerde ve organik madde açısından fakir topraklarda bu işlev son derece kritiktir. Özellikle yapraklı allelopatik bitkilerin örtücü bitki olarak kullanılmasında pek çok avantajlar bulunmaktadır. Yağmur damlalarının hızını keserek toprağa sert çapmasını, agregatlarının dağılmasını ve kaymak tabakasının oluşumunu engellemektedir. Çim ve baklagil gibi tek yıllık olan örtücü bitkiler bu bağlamda yaygın kullanılmaktadır **(Acar ve ark., 2006).** Bu tür bitkiler, kök sistemleri sayesinde havanın fiziksel olarak stabilize edilmesini sağlar, üst aksamları ile yüzeyin korunmasını sağlar. Ayrıca bu programların ayrı ayrı organik madde miktarının artırılması ve toprak biyotasını destekleyerek agroekosisteme katkısı bulunmaktadır. Dünyada ve ülkemizde örtücü bitki olarak yaygın kullanılan birçok bitki türü bulunmaktadır. Örneğin, tarım alanlarında sorun yaratan Tarla sarmaşığı (*Convolvulus arvensis*) ve Sarı topalak (*Cyperus esculentus*) mücadelesinde Tüylü fiğ (*Vicia villosa*), Yabani hardal (*Sinapis arvensis*) ve İtalyan çimi (*Lolium multiflorum*) mücadelesinde ise Kırmızı üçgül (*Trifolium incarnatum*) örtücü bitki olarak kullanılmaktadır **(Özeker ve Ulutürk, 2006).** Ülkemizde kullanılan Adi fiğ (*Vicia sativa*), Macar fiğ (*Vicia narbonensis*), Börülce (*Vigna sinensis*), Karabuğday (*Fagopyrum esculentum*), Sarı acı bakla (*Lupinus luteus*) da örtücü bitkilere örnek olarak verilebilir **(Kitiş, 2010).**

Sonuç olarak, allelopatik örtücü bitkiler, entegre yabancı ot yönetimi stratejilerinde etkili ve çevre dostu bir yöntem olarak değerlendirilmektedir. Aynı zamanda bunların kesilmesi, toprak yapısının yönetimi açısından da önemlidir. Örtücü bitki uygulamalarının yaygınlaştırılması, sürdürülebilir tarıma erişilebilmesinde temel uygulamalardan biri olarak öne çıkmaktadır.

1.2.2. Cansız Bitki Materyalleri ile Malçlama

Toprak yüzeyinin ışık geçirmeyecek şekilde bitkisel bir materyalle örtülmesi işlemidir. Bu materyaller arasında saman, kuru otlar, odun parçaları, talaş ve çeşitli allelopatik içerikli tarımsal atıklar olabilmektedir. Çimlenen yabancı ot tohumları toprak yüzeyine çıksa bile, ışık alamadıkları için ölürler **(Kolören ve Uygur, 2015, Çil ve ark 2022'den).** Böylelikle toprak nemi korunurken aynı zamanda yabancı otlarla mücadele edilmiş olunur. Malçlama uygulamalarının yabancı ot mücadelesinde başarılı olabilmesi için erken dönemde uygulanması gerekir. Böylelikle hem yabancı ot tohumlarının çimlenmek ve gelişmek için ihtiyaç duydukları ışık engellenmiş olur hem de allelopatik özellik sayesinde çimlenme uzun süreli baskılanır.

1.3. Münavebe

Ekim nöbeti diğer ismiyle münavebe, toprak ve iklim istekleri dikkate alınarak kültür bitkilerinin aynı yerde dönüşümlü olarak ekilmesi olarak tanımlanabilir. Aynı zamanda ekim nöbetinde yetiştirilecek bitki seçimi yapılırken kültür bitkilerinin özelliklerine (allelopatik etki, repellent etki, topraktaki fauna ve floraya etki, bitki besleme ve gübre özellikleri, çapalama vb.)

göre planlı bir şekilde yetiştirilmesini ifade eder **(Uygur ve ark., 1984; Liebman ve Dyck, 1993; Wibberley, 1996, Torun ve Uygur 2019'dan).** Ekim nöbeti, tarımda verimliliğin ve kalitenin artırılması için kullanılan entegre mücadele yöntemlerinden biridir. Monokültür tarımda aynı bitki örtüsünün sürekli olarak ekilmesi sonucu toprak koşulları olumsuz etkilenir ve bunun sonucu olarak toprak yorgunluğu oluşur. Monokültür tarım, bazı yabancı ot türlerinin popülasyonlarını artırarak bu türlerin ana zararlı türler haline gelmesine neden olur. Ancak ekim nöbeti, toprak yorgunluğunun giderilmesine, bununla beraber farklı yabancı otların yetişmesine ve floranın zenginleşmesine, kültür bitkilerinin rekabet gücünün artmasına olanak sağlar **(Melander ve Rasmussen, 2001, Torun ve Uygur2019'dan,)**.

Ekim nöbetinde allelopatik bitkilerin tercih edilmesi mücadeledeki etkinliği artırmaktadır. Örneğin tarım alanlarında verim ve kalite kayıplarına neden olan Pelin otu (*Artemisia vulgaris*)'nun mücadelesinde güçlü allelopatik etkisi bulunan Yonca (*Medicago sativa*) bitkisinin ekim nöbeti sistemine dahil edilmesi, Pelin otu popülasyonunu baskılamıştır **(Önen, 1999).** Sonuç olarak, ekim nöbeti sürdürülebilir tarım için hem yabancı ot yönetimini sağlayarak hem de toprak güvenliğini koruyarak faydalı olmaktadır. Bu sisteme allelopatik bitkiler dahil edilerek agroekosistem yönetiminin daha sürdürülebilir olması sağlanabilmektedir.

1.4. Ön Bitki

Ön bitkiler, tarımda ana kültür bitkileri ekilmeden önce, toprak sağlığını iyileştirmek, yabancı otları kontrol etmek, toprak erozyonunu engellemek ve ekosistem dengesini sağlamak amacıyla ekilen bitkilerdir. Bu bitkiler genellikle geçici bir süreyle ekilir ve bu süreç boyunca çeşitli ekolojik faydalar sağlar. Ön bitkiler, tarımsal üretimin sürdürülebilirliğini artıran, toprak yapısını güçlendiren, organik madde kazandıran ve çevresel etkileri en aza indiren bitkilerdir. Özellikle baklagiller, toprakta azot fiksasyonu yaparak atmosferdeki azotu toprakta kullanılabilir hale getirir. Bu özellik, ekilecek diğer kültür bitkilerinin azot ihtiyacını karşılar ve kimyasal gübre kullanımını azaltarak sürdürülebilir tarımı destekler. Yulaf ve çim bitkileri de, toprak yüzeyini kaplayarak erozyonu engeller ve toprağın su tutma kapasitesini artırır. Çim bitkileri özellikle eğimli tarım alanlarında suyun toprakla etkileşimini düzenler ve toprak kaymalarını önler. Ayrıca, kök yapıları sayesinde toprağın havalanmasına katkı sağlar ve bu da toprak yapısının iyileşmesine yardımcı olur. Ön bitkiler, ekim nöbetinin başlangıcında yer alarak, toprağın besin dengesini sağlar, zararlılarla biyolojik mücadele yapar, toprakta yabancı otları kontrol eder ve toprağın yapısının bozulmasını engeller. Bir başka önemli avantaj ise bu bitkilerin allelopatik etkileridir. Allelopatik bitkiler, çevrelerine kimyasal bileşikler salarak, diğer bitkilerin büyümesini inhibe eder. Bu kimyasal bileşikler, özellikle yabancı otların çimlenmesini engelleyerek, ana kültür bitkilerinin sağlıklı bir şekilde büyümesine olanak tanır. Bu durum, kimyasal herbisitlere olan bağımlılığı azaltarak, çevre dostu bir çözüm sunar. Örneğin Kanyaş (*Sorghum halepense*) pamukta önemli verim ve kalite kayıplarına neden olan bir yabancı ottur. Pamuk ekiminden önce Antep turbunun (*Raphanus sativus*) yetiştirilip bir kısmının hasat edilip bir kısmının toprağa karıştırılması sonrasında tekrar pamuk yetiştirildiğinde, Antep turbundan salgılanan allelopatik maddelerin kanyaşın çıkısını önemli oranda baskıladığı tespit edilmiştir **(Kayandan ve ark., 2002; Kitiş 2011'den).**

Sonuç olarak, ön bitkiler tarımda çok önemli bir rol oynamaktadır. Hem toprak sağlığını iyileştirir, hem de çevre dostu ve sürdürülebilir tarım uygulamalarına katkı sağlar. Bu bitkiler,

toprağa organik madde kazandırır, suyun toprakta tutulmasına yardımcı olur ve erozyon riskini azaltır. Ayrıca, allelopatik bitkiler kullanılarak yapılan yabancı ot kontrolü, kimyasal ilaçlara olan bağımlılığı azaltır ve doğal kaynakların korunmasına yardımcı olur. Tarımsal üretimde verimliliği artıran ön bitkiler, hem çevresel hem de ekonomik açıdan faydalı bir strateji sunar. Bu yüzden, ön bitkilerin kullanımı, modern tarım uygulamalarının vazgeçilmez bir parçası olup ekosistemin sağlıklı bir şekilde işlemesine katkı sağlar.

1.5. Karışık Ekim

Tarımsal üretimde verim düşüklüğü üretimin sürdürülebilirliği açısından çok önemli sorunlardan bir tanesidir. Yoğun monokültür uygulamalarının neden olduğu toprak verimliliğinde azalma, hastalık ve zararlıların baskısı ve diğer etmenlerin etkisiyle beraber verimi etkileyen bir çok faktör bulunmaktadır. Karışık ekim sistemi, verim kayıplarının azaltılması amacıyla kullanılabilecek bir yöntem olarak karşımıza çıkmaktadır.

Karışık ekim, iki veya daha fazla bitkinin aynı periyotta yetiştirilmesi olarak tanımlanabilir. Bu ekim sisteminde kültür bitkileri birbirlerinin verimini arttırırken aynı zamanda yapılarındaki allelokimyasallar sayesinde yabancı otları da baskılayabilmektedir. Özellikle tek başına yetiştirilen bitkilerde geniş alanların bulunması yabancı otların yaşamasına imkan sunmaktadır. Karışık ekim yapıldığında ise birlikte yetiştirilen bitkiler daha yoğun bitki örtüsü oluştururken, fiziksel olarak gölgeleme ve allelopatik maddelerin kimyasal salınımı yoluyla yabancı otların olgunlaşmasını da sınırlandırabilmektedir.

Karışık ekim sistemlerinde kullanılan bitkilerden bazılarının güçlü allelopatik özellikler taşıması, önemli etkiler gerçekleşmesini sağlamaktadır. Yabancı otların çimlenmesini baskılamasının yanında, zararlı böcekleri uzaklaştırıcı ya da topraktaki mikrobiyal dengenin korunmasında da oldukça önemlidir. Mısır ve fasulye kültür bitkisiyle yapılan karışık ekim araştırmalarında sık ekilmeleri durumunda her iki bitkinin tane verimleri daha yüksek olmuştur. Nedeni ise birim alanda daha fazla bitki sayısının olması ve fotosentetik aktivite ile daha fazla kuru madde üretilmesidir **(Takıl ve Kayan, 2020).**

Karışık ekim sistemlerinde allelopatik etkileşimler yalnızca yabancı otların değil, zararlı organizmaların da dayanıklılığını artırmaktadır. Örneğin, Kekik (*Thymus vulgaris*), Fesleğen *(*Ocimum basilicum*) ve Nane (*Mentha* spp.) gibi organik yağ içeriği yüksek aromatik bitkilerle yapılan karışık ekimler, domates ve biber gibi sebze türlerinde yaprak biti, beyaz sinek gibi zararlılara karşı doğal bir engelleyici olabilmektedir. Bu ekim sistemine yem bitkileride dahil edilmelidir. Böylelikle bir yandan yabancı otlarla mücadele edilirken bir yandan da yem bitkisi kullanılarak birim alandan daha fazla ve dengeli ürün alınmış olunur **(Acar ve ark., 2006).**

Sonuç olarak, tarımsal üretimde karışık ekim sisteminin uygulanması sürdürülebilirlik ve ekosistemin korunması açısından büyük bir önem içermektedir. Bu bağlamda, allelopatinin daha iyi anlaşılması ve karışık ekim uygulamalarına uygun bitkilerin belirlenmesine yönelik araştırmaların yapılması önemli bir rol oynayacaktır. Karışık ekim alanlarında allelopatik etkileşimlerin incelenmesi, sürdürülebilir tarım uygulamaları açısından büyük önem arz etmektedir.

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ONLINE FOOD PURCHASING TRENDS IN TURKEY AFTER THE PANDEMIC: AN EVALUATION BASED ON SOCIO-DEMOGRAPHIC FACTORS

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ABSTRACT

Developing digital technologies, increasing prevalence of the internet and the pandemic process have significantly affected traditional food purchasing habits and online food shopping has become an increasingly widespread form of consumption. Especially the COVID-19 pandemic, together with mandatory conditions such as social distancing and isolation, has made online food shopping an inevitable choice for many consumers. However, this transformation is closely related not only to technological developments but also to the socio-demographic characteristics of individuals. Based on face-to-face survey data conducted with 1,016 consumers across Turkey, this study analyzes the effects of basic socio-demographic variables such as age, gender, education level, income status, marital status and household size on online food purchasing behavior. The ordered probit model was used in the empirical analyses and variables such as social media use and nutritional preferences were also evaluated. The findings reveal that online food shopping has not yet become widespread, but especially the fact that consumers are young, highly educated, female and live in small households increases the likelihood of online food purchasing behavior. While social media use positively affects online shopping, age and household size have negative effects. It has also been found that consumption tendencies towards certain product groups such as fast food, junk food and supplements increase the probability of online shopping. In contrast, the tendency towards local foods is negatively related to online shopping, indicating consumers' attachment to the physical experience in traditional food supply. In conclusion, online food shopping is a multidimensional phenomenon and is shaped not only by digitalization but also by the socio-cultural structure of the consumer. This study contributes to both academic literature and provides guiding findings in shaping digital retail strategies and public policies.

Keywords: Online Food Shopping, Consumer Behavior, Socio-Demographic Factors, Ordered Probit Model

TÜRKİYE'DE PANDEMİ SONRASI ÇEVRİM İÇİ GIDA SATIN ALMA EĞİLİMLERİ: SOSYO-DEMOGRAFİK FAKTÖRLER EKSENİNDE BİR DEĞERLENDİRME

ÖZET

Gelişen dijital teknolojiler, internetin artan yaygınlığı ve pandemi süreci geleneksel gıda satın alma alışkanlıklarını önemli ölçüde etkilemiş ve çevrim içi gıda alışverişi giderek yaygınlaşan bir satın alma yöntemi haline gelmiştir. Özellikle COVID-19 pandemisi sosyal mesafe ve izolasyon gibi zorunlu koşullarla birlikte çevrim içi gıda alışverişini birçok tüketici için kaçınılmaz bir tercih haline getirmiştir. Ancak bu dönüşüm yalnızca teknolojik gelişmelerle değil, aynı zamanda bireylerin sosyo-demografik özellikleriyle de yakından ilişkilidir. Bu çalışma, Türkiye genelinde 1.016 tüketiciyle yapılan yüz yüze anket verilerine dayanarak, yaş, cinsiyet, eğitim düzeyi, gelir durumu, medeni durum ve hane büyüklüğü gibi temel sosyo-demografik değişkenlerin çevrim içi gıda satın alma davranışı üzerindeki etkilerini analiz etmektedir. Ampirik analizlerde sıralı probit modeli kullanılmış ve sosyal medya kullanımı ile beslenme tercihleri gibi değişkenler de değerlendirilmiştir. Bulgular çevrim içi gıda alışverişinin henüz geleneksel kanallar kadar yaygınlaşmadığını ancak özellikle tüketicilerin genç, eğitim seviyesi yüksek ve kadın olmalarının çevrim içi gıda satın alma davranışını gerçekleştirme olasılığını arttırdığını ortaya koymaktadır. Sosyal medya kullanımı çevrim içi alışverişi pozitif etkilerken, yaş ve hane büyüklüğü negatif etkiler üretmiştir. Ayrıca fast-food, abur cubur ve takviye edici ürünler gibi belirli ürün gruplarına yönelik tüketim eğilimlerinin çevrim içi alışveriş yapma olasılığını artırdığı da tespit edilmiştir. Buna karşılık yerel gıdalara yönelim çevrim içi alışverişle negatif ilişkilidir ve bu da tüketicilerin geleneksel gıda temininde fiziksel deneyime olan bağlılığını göstermektedir. Sonuç olarak, çevrim içi gıda alışverişi çok boyutlu bir olgu olup yalnızca dijitalleşme ile değil, tüketicinin sosyo-kültürel yapısıyla da şekillenmektedir. Bu çalışma, hem akademik literatüre katkı sunmakta hem de dijital perakendecilik stratejileri ve kamu politikalarının şekillendirilmesinde yol gösterici nitelikte bulgular ortaya koymaktadır.

Anahtar Kelimeler: Çevrim İçi Gıda Alışverişi, Tüketici Davranışları, Sosyo-Demografik Faktörler, Sıralı Probit Modeli

1. GİRİŞ

Gelişen dijital teknolojiler ve internet altyapısındaki ilerlemeler geleneksel alışveriş davranışlarını önemli ölçüde etkilemiş ve dönüştürmüştür. Bu dönüşüm özellikle e-ticaret uygulamaları aracılığıyla yapılan gıda alışverişlerinde giderek daha belirgin hale gelmektedir. Çevrim içi gıda alışverişi başlangıçta sınırlı bir kullanıcı grubuna hitap ederken zamanla kolaylık, erişilebilirlik ve zaman tasarrufu gibi avantajları nedeniyle yaygınlaşmıştır. Bununla birlikte küresel COVID-19 pandemisi de bu değişimin hızını ciddi ölçüde artırmış ve çevrim içi gıda alışverişini birçok tüketici için zorunlu bir tercih haline getirmiştir (Jilcott Pitts ve ark., 2018; Lu ve ark., 2022; Karaoğlan ve Hamşioğlu, 2022).

Geleneksel olarak fiziksel temasa dayalı olan gıda satın alımı ürünlerin tazelik, kalite, görünüm ve güvenilirlik gibi niteliklerinin doğrudan gözlemlenmesi ihtiyacı nedeniyle çevrim içi platformlarda diğer ürünlerle karşılaştırıldığında daha sınırlı bir yer edinmiştir (Alaimo ve ark., 2020). Bununla birlikte pandemi süreci sosyal mesafe, izolasyon önlemleri ve sağlık endişeleri gibi nedenlerle tüketicilerin alışveriş davranışlarını yeniden şekillendirmiş ve bu sürçte birçok kişi ilk kez çevrim içi gıda alışverişi deneyimi yaşamıştır. Bu süreçte gelişen kullanıcı deneyimleri, teknolojik adaptasyon ve dijital platformların sunduğu yeni hizmetler (örneğin hızlı teslimat, taze ürün garantisi, kullanıcı yorumları vb.) sayesinde çevrim içi gıda alışverişi kalıcı bir tüketim biçimi haline gelmeye başlamıştır (Gao ve ark., 2020; Gomes ve Lopes, 2022).

Tüketicilerin gıda satın alma kararları yalnızca ürünün içsel özelliklerine veya besleyici değerine değil aynı zamanda bireysel, toplumsal ve çevresel faktörlerin etkileşimine de dayanmaktadır. Sosyo-demografik değişkenler bu kararların arkasındaki temel belirleyiciler arasında yer almakta ve yaş, cinsiyet, medeni durum, gelir ve eğitim düzeyi gibi etmenler bireylerin algı, motivasyon ve tercihlerinde farklılaşmalara yol açmaktadır (Chen ve Antonelli, 2020; Kaya, 2016). Örneğin, genç bireylerde hızlı yaşam tarzı ve zamandan tasarruf arzusu, kolay ulaşılabilir ve pratik gıdalara yönelimi artırırken yaşlı bireyler daha çok sağlık, alışkanlık ve aşinalık temelli seçimlerde bulunma eğilimindedirler (Jáuregui-Lobera ve Bolaños Ríos, 2011). Cinsiyet temelli farklılıklar da ise kadınlar gıda tercihinde daha çok duyusal çekicilik ve sağlık unsurlarına daha fazla önem verirken, erkekler ise fiyat ve tokluk hissine daha çok odaklanmaktadırlar (Phan ve Chambers, 2016; Antin ve Hunt, 2012). Gelir düzeyi açısından değerlendirildiğinde düşük gelirli bireyler için fiyat hassasiyeti ve ürünün ulaşılabilirliği ön planda olurken, yüksek gelir grubundaki bireyler için organik ve doğal içerik gibi nitelikler daha belirleyici olmaktadır (Caswell ve Yaktine, 2013; Kaya, 2016).

Çevrim içi gıda alışverişi davranışlarının belirleyicileri üzerine yapılan çok sayıda araştırma, bu davranışların yalnızca teknolojik gelişmelerle açıklanamayacağını ortaya koymaktadır. Tüketicilerin yaş, cinsiyet, medeni durum, hane yapısı, meslek, eğitim ve gelir düzeyi gibi sosyo-demografik özellikleri alışveriş tercihleri üzerinde doğrudan etkili olmaktadır (Bryła, 2018; Piroth ve ark., 2020; Nguyen ve ark., 2021).

Tüm bu bulgular, çevrim içi gıda alışverişi davranışının yalnızca teknolojik bir dönüşüm olmadığını; aynı zamanda toplumsal yapı, bireysel tercihler, sağlık algısı ve kriz dönemlerine verilen tepkilerle şekillenen çok boyutlu bir olgu olduğunu göstermektedir. Bu nedenle, tüketicilerin sosyo-demografik profillerine dayalı olarak bu davranışın nasıl farklılaştığını incelemek, hem akademik literatür açısından hem de pazarlama ve kamu politikaları açısından

önemli katkılar sağlayacaktır (Piroth ve ark., 2020; Nguyen ve ark., 2021; Bryła, 2018; Vedovato ve ark., 2020; Alaimo ve ark., 2020). Lu ve ark., 2022 çalışmalarının sonuçları da Covid 19 döneminde çevrimiçi taze gıda alışverişinin tedarik sisteminde önemli bir rol oynadığını göstermektedir.

Bu çalışma, COVID-19 pandemisi sonrasında çevrim içi gıda alışverişine yönelik eğilimleri sosyo-demografik değişkenler ekseninde analiz etmeyi amaçlamaktadır. Özellikle yaş, cinsiyet, eğitim düzeyi, gelir, medeni durum, aile yapısı gibi temel demografik faktörlerin çevrimiçi gıda alışverişi sıklığı ve ürün grubu seçimi üzerindeki etkileri incelenerek çevrim içi alışveriş davranışının sosyal boyutları ortaya konulacaktır. Araştırmanın bulguları, hem akademik çalışmalara kuramsal katkı sunmakta hem de dijital gıda perakendecilerine ve politika yapıcılara stratejik planlama açısından önemli veriler sağlayacaktır. Böylece farklı tüketici gruplarının ihtiyaç ve beklentilerine uygun, kapsayıcı ve sürdürülebilir e-ticaret politikalarının geliştirilmesine katkı sağlanabilecektir.

2. MATERYAL VE YÖNTEM

Materyal

Bu araştırmada, tüketicilerin sosyo-demografik özelliklerinin gıda satın alma tercihleri üzerindeki etkisini incelemek amacıyla yüz yüze anket yöntemi kullanılmıştır. Veri toplama süreci, Türkiye'nin yedi coğrafi bölgesini temsilen seçilen İstanbul, Ankara, İzmir, Trabzon, Adana, Van ve Gaziantep illerinde, Nisan-Temmuz 2023 tarihleri arasında gerçekleştirilmiştir. Her bir şehir için belirlenen örneklem büyüklüğü, ilgili ilin ülke nüfusu içindeki payı esas alınarak oluşturulmuştur. Anketler, ticari bir araştırma şirketi olan Ayna Araştırma tarafından toplam 1.016 tüketiciyle gerçekleştirilmiştir. Örneklem büyüklüğü, %95 güven düzeyi ($p = 0,05$) esas alınarak ve sonsuz ana kütle varsayımıyla hesaplanmıştır.

Katılımcıların sosyo-demografik özelliklerine ilişkin bulgular Tablo 1'de sunulmuştur. Bu değişkenler, araştırmada bağımsız değişkenler olarak ele alınmakta olup, tüketicilerin gıda tercih davranışlarının açıklanmasında analitik bir temel sağlamaktadır.

Tablo 1. Örnekleme katılan tüketiclierin sosyo-demografik özellikleri

	f	%		*f*	%
Cinsiyet			*Gelir (₺)*		
Erkek	457	45	Sabit gelir yok	258	25,4
Kadın	559	55	<5500	177	17,4
Yaş			5501–7500	248	24,4
15–24	247	24,3	7501–9000	153	15,1
25–34	334	32,9	9001–11500	95	9,4
35–44	213	21	>11501	85	8,4
45–54	139	13,7	*Eğitim*		
55–65	68	6,7	Okuma yazma yok	15	1,5
≥65	15	1,5	İlk-ortaokul	232	22,8
Hane kişi sayısı			Lise	263	25,9
1	87	8,6	Univerite	449	44,2
2	141	13,9	Lisan üstü	57	5,6
3	271	26,7	*Medeni durum*		
4 ve üzeri	252	24,8	Bekâr	501	49,3
			Evli	515	50.7

Yöntem

Tüketicilerin çevrim içi gıda satın alma sıklıkları ile sosyo-demografik özellikleri arasındaki ilişki, sıralı probit modeli kullanılarak analiz edilmiştir. Sıralı probit modeli, doğal bir sıralamaya sahip kategorik bağımlı değişkenlerin incelenmesinde kullanılan bir regresyon tekniğidir. Özellikle ekonometrik ve sosyal bilimler alanlarında yaygın biçimde uygulanan bu yöntem, araştırmada kullanılan anket sorularının (bağımlı ve bağımsız değişkenler) Likert ölçeğine dayalı olarak düşükten yükseğe doğru sıralanması nedeniyle tercih edilmiştir (Greene, 2018). Lojistik dağılıma dayalı olasılık oranları yerine probit analizi olayların olasılıklarını kümülatif standart normal dağılım değerlerine dönüştürmektedir (Harrell, 2015). Sıralı probit modeli aşağıda gösterilmektedir.

$$y_i^* = x_i'\beta + \varepsilon_i \quad (1)$$

Burada, x_i' tüketicileri ifade etmektedir, β bağımsız açıklayıcı değişkenler vektörüdür ve bilinmeyen eğim parametreleri vektörünü temsil eder ve ε_i standart lojistik dağılıma sahip gözlemlenemeyen bireysel hata terimidir. Kısaca, sıralı probit modelinde, bağımlı değişken (yani bireylerin tüketim sıklığı), gözlemlenemeyen gizli değişken tarafından belirli eşik aralıkları içinde aldığı değerlere göre sınıflandırılır.

$= 0$ eğer $y* \leq 0$ (2)

$= 1$ eğer $0 < y* \leq \mu 1$

$= 2$ eğer $\mu 1 < y* \leq \mu 2$

.

$= J$ eğer $\mu J-1 \leq y*$,

Burada μ değeri ile birlikte tahmin edilmesi gereken bilinmeyen parametrelerdir (Greene, 2012).

Ampirik analiz için, veri analizi kapsamında tanımlayıcı istatistikler SPSS 21 programı kullanılarak hesaplanmış, sıralı probit regresyon modeli ise STATA programı ile analiz edilmiştir.

3. BULGULAR VE TARTIŞMA

Tablo 1. Tüketicilerin gıda satın alımlarında internet kullanımı (%).

Hiçbir zaman	Yılda 1-6	Ayda 1-3	Haftada 1-5	Haftada 5'den fazla
64.5	11.2	12.8	8.9	2.7

Araştırma bulgularına göre çevrim içi gıda alışverişi davranışı Türkiye'de tüketiciler arasında henüz yaygınlaşmamış bir tüketim biçimi olarak öne çıkmaktadır. Örneklem grubunun %64,5'i internetten hiçbir zaman gıda satın almadığını belirtmiş olup bu oran çevrim içi platformların gıda perakendeciliği açısından henüz sınırlı bir kullanım düzeyine sahip olduğunu göstermektedir. Gıda ürünlerini çevrim içi platformlar aracılığı ile haftalık olarak satın alan bireylerin oranı ise %11,6'dır. Bu sonuç, özellikle gıda ürünlerinin doğrudan görsel ve fiziksel değerlendirme ihtiyacı nedeniyle diğer ürün kategorilerine göre çevrim içi kanallarda daha az tercih edildiğini düşündürmektedir. Dominici ve ark. 2021 çalışmaları da çevrim içi gıda satın alan tüketicilerin toplam nüfusun yalnızca küçük bir bölümünü oluşturduğunu ifade etmektedir. Araştırmaya katılan bireylerin yalnızca %2'si çevrim içi gıda satın alımı gerçekleştirmiştir. Bu durum kıyafet veya ev eşyası gibi diğer tüketim mallarının çevrim içi satışlarındaki yüksek pazar paylarıyla çelişmektedir. Brenna Ellison ve ark. 2021 ise COVID-19 pandemisi süresince ABD'de çevrimiçi market alışverişlerinde artışlar olduğunu ortaya koymaktadır.

Tablo 2. Sosyal medya kullanımının ve internetten gıda satın alım davranışına etkisi

Değişken	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Sosyal medya kullanımı	.1264081	.0303911	0.000***	.0668426	.1859736

*** $p < 0.010\%$; Prob > $\chi 2 = 0.0000$

Tablo 2'de sosyal medya kullanımının çevrim içi gıda alışverişi davranışı üzerindeki etkisi analiz edilmiş ve bu değişkenin istatistiksel olarak anlamlı ve pozitif yönde etkili olduğu saptanmıştır ($p<0.001$). Elde edilen sonuç sosyal medya kullanımının artmasının, internetten gıda satın alma olasılığını artırdığını göstermektedir. Bu bulgu, sosyal medyanın dijital tüketici davranışları üzerindeki etkisini açıkça ortaya koymakta özellikle ürün tanıtımları, kullanıcı yorumları, fenomen etkisi ve algoritmik reklamların tüketici karar mekanizmalarını etkileyebileceğini göstermektedir. Sosyal medyanın yalnızca iletişim aracı değil aynı zamanda bir pazarlama kanalı olarak da güçlü bir etki yarattığı bu sonuçla doğrulanmaktadır. Liang ve ark. 2011 bulguları da bireylerin interneti kullanma konusunda daha yetkin olmaları durumunda çevrimiçi gıda satın alma isteklerinin arttığını göstermektedir.

Tablo 3. Tüketicilerin gıda satın alımında internet kullanımı ve sosyo-demografik özelliklerin ilişkisi

Değişkenler	**Katsayı**	**Std. Hata**	**P > |z|**	**[95% Güven Aralığı]**	
Cinsiyet	-.00856	.07934	0.914	-.16407	.14693
Medeni durum	-.23850	.09553	0.013**	-.42574	-.0512
Yaş	-.14475	.04013	0.000***	-.22342	-.0660
Eğitim	.20559	.04757	0.000***	.11234	.29884
Gelir	.02686	.02665	0.314	-.02537	.07909
Hane kişi sayısı	-.11290	.03090	0.000***	-.17347	-.05232

** $p < 0.05$, *** $p < 0.010\%$; Prob > $\chi 2 = 0.0000$

Tablo 3'de gösterilen sıralı probit analiz sonuçlarına göre bazı sosyo-demografik değişkenler çevrim içi gıda alışverişi üzerinde anlamlı etkilere sahiptir. Hasanov ve Khalid 2015 demografik faktörlerin çevrimiçi satın alma niyeti üzerinde anlamlı etkisi olduğunu bulunmamıştır. Benzer biçimde Gomes ve Lopes 2022 sosyo-demografik özelliklerin (yaş, eğitim, gelir), pandemi sürecinde çevrimiçi market alışveriş eğiliminde belirleyici olduğunu tespit etmişlerdir.

Bu bağlamda, yaş değişkeni negatif ve anlamlı bir katsayıya sahip olup bu durum yaş ilerledikçe çevrim içi gıda alışverişi yapma olasılığının azaldığını göstermektedir. Bu sonuç yaşlı bireylerin dijital platformlara erişim ve kullanım konusunda daha temkinli ya da isteksiz olduklarını yansıtmaktadır. Wang ve ark. 2020 göre de yaşlı bireylerin yeni teknolojilere uyum sağlama yeteneklerinin daha düşük olması gençlere kıyasla çevrim içi gıda satın alımını daha az benimsemelerine neden olmaktadır. Benzer sonuçlara Rasoli ve ark. 2021 da ulaşmıştır. Buna göre, yaş çevrimiçi gıda alışverişini ile negatif yönde anlamlı ilişki içerisinde olan bir değişkendir. Gao ve ark. 2020 de genç bireylerin teknolojiye daha yatkın olmaları, mobil uygulamalara hâkimiyetleri ve dijital güvenlik konusunda daha az endişe duymaları onları gıda alışverişlerinde çevrim içi yöntemleri kullanmalarını daha belirgin yapmaktadır.

Eğitim düzeyinin ise pozitif ve anlamlı etkisi bulunmuştur bu da yüksek eğitim seviyesine sahip bireylerin teknolojik adaptasyonunun daha güçlü olduğunu ve çevrim içi alışverişe daha yatkın

olduklarını göstermektedir. Alaimo ve ark. 2020 çalışmaları daha yüksek eğitim düzeyine sahip bireylerin çevrimiçi gıda alışverişi deneyiminden daha yüksek düzeyde memnuniyet duyduklarını göstermektedir. Dominici ve ark. 2021 araştırmaları da çevrim içi gıda alışverişi yapma olasılığı ile bireylerin genç ve iyi eğitimli olması arasında anlamlı ilişkiler ortaya koymuştur. Benzer biçimde Gomes ve Lopes 2022 sonuçları da yüksek eğitim seviyesine sahip genç tüketicilerin, pandemi dönemindeki çevrimiçi market alışverişi deneyiminden daha olumlu etkilendiğini göstermektedir.

Medeni durum değişkeni de çevrim içi gıda satın alma davranışı ile anlamlı ilişkiye sahip olup, evli bireylerin evli olmayanlara kıyasla daha yüksek çevrim içi gıda satın alma olasılığına sahip olduğu tespit edilmiştir. Wang ve ark. 2020 da araştırmalarında evli kişilerin çevrimiçi gıda alıcıları olma olasılıklarının bekârlara göre daha yüksek olduğunu sonucuna ulaşmışlardır.

Son olarak da hane halkı kişi sayısı arttıkça çevrim içi gıda alışverişi yapma olasılığı azalmaktadır. Bu durum geniş ailelerin toplu ve fiziksel alışverişi tercih etme eğiliminde olabileceğini göstermektedir. Rasoli ve ark. 2021 çalışmaları da aile üyesi sayısının artmasının çevrimiçi gıda alışverişini anlamlı düzeyde etkilediğini ortaya koymuştur.

Tablo 4. Beslenme paterni ve çevrim içi gıda satın alma ilişkisi

Değişkenler	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Yerel gıdalar	-.1572036	.0373803	0.000***	-.2304676	-.08393
Fast-food	.158342	.0415558	0.000***	.0768942	.2397898
Tüketime hazır gıdalar	.0060999	.0346498	0.860	-.0618126	.0740123
Sokak yemekleri	.0223165	.0394684	0.572	-.0550401	.0996732
Diyet gıda	.0662526	.0375395	0.078*	-.0073235	.1398287
Hayvansal gıda	.1114292	.0426844	0.009**	.0277694	.1950891
Bitkisel gıda	-.0644611	.0456069	0.158	-.153849	.0249268
Karbonhidrat	.004102	.0421634	0.922	-.0785366	.0867407
Vejetaryen gıdalar	.0049889	.0372579	0.893	-.0680352	.0780131
Abur cubur	.1953167	.036511	0.000***	.1237564	.266877
Takviye edici	.1394982	.0375344	0.000***	.065932	.2130643

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; Prob > $\chi 2 = 0.0000$

Tablo 4 beslenme alışkanlıklarının çevrim içi gıda satın alma davranışı üzerindeki etkilerini göstermekte olup bazı gıda kategorilerinin çevrim içi alışveriş davranışını anlamlı şekilde etkilediğini göstermektedir. Bu bağlamda fast-food, hayvansal gıdalar, abur cubur, diyet ve takviye edici ürünler gibi kolay erişilebilir ve paketlenebilir ürün gruplarını tercih etme sıklığının artması çevrim içi gıda alışveriş yapma olasılığını yükseltmektedir. Buna karşın, yerel gıdalarla çevrim içi alışveriş arasında negatif ve anlamlı bir ilişki bulunmuştur. Bu durum, yerel ürünlerin tüketiciler açısından geleneksel ve doğrudan temin edilme gereksinimi taşıdığına işaret etmektedir.

4. SONUÇ

Bu çalışma, COVID-19 pandemisi sonrasında Türkiye'de çevrim içi gıda alışverişi eğilimlerini sosyo-demografik faktörler bağlamında incelemiş ve çevrim içi alışveriş davranışının çok boyutlu yapısını ortaya koymuştur. Elde edilen bulgular, çevrim içi gıda alışverişinin henüz yaygınlaşmamış bir tüketim biçimi olduğunu, ancak belirli değişkenlerin bu davranışı anlamlı şekilde etkilediğini göstermektedir.

Çalışmanın en dikkat çekici bulgularından biri sosyal medya kullanımının çevrim içi gıda alışverişi üzerindeki güçlü ve pozitif etkisidir. Sosyal medya kullanan bireylerin internetten gıda satın alma olasılıklarının anlamlı şekilde daha yüksek olduğu tespit edilmiştir. Bu durum, sosyal medyanın yalnızca bir iletişim platformu değil, aynı zamanda kullanıcı yorumları, ürün tanıtımları ve dijital reklamlar aracılığıyla tüketici davranışlarını etkileyen güçlü bir pazarlama kanalı olduğunu ortaya koymaktadır.

Sosyo-demografik özellikler de çevrim içi gıda alışverişi davranışında belirleyici rol oynamaktadır. Bu bağlamda, yaş ilerledikçe çevrim içi gıda alışverişi yapma olasılığı anlamlı şekilde azalmaktadır. Bu durum yaşlı bireylerin dijital platformlara erişim ve kullanım konusundaki sınırlılıklarını yansıtmaktadır. Buna karşılık, eğitim düzeyi çevrim içi alışveriş davranışını pozitif yönde etkilemektedir ve yüksek eğitim seviyesine sahip bireylerin bu alışkanlığa daha açıktır. Medeni durum da anlamlı bir faktör olup, evli bireyler bekârlara kıyasla daha fazla çevrim içi alışveriş yapmaktadır. Hane halkı büyüklüğü arttıkça çevrim içi alışveriş yapma olasılığı azalmaktadır. Bu durum büyük ailelerin birlikte fiziksel alışverişi tercih etme eğiliminde olabileceğini düşündürmektedir.

Beslenme tercihlerine bakıldığında ise fast-food, abur cubur, diyet ve takviye edici ürünler gibi hazır ve paketlenmiş gıdalara yönelik yüksek eğilim, çevrim içi gıda alışverişi yapma olasılığını artırmaktadır. Buna karşılık, yerel gıdalara yönelik eğilim çevrim içi alışveriş davranışını negatif etkilemekte bu da geleneksel gıda temininde fiziksel temas ve doğrudan deneyimin halen önemini koruduğunu göstermektedir. Hayvansal gıda tüketimine yatkın bireylerin de çevrim içi gıda satın alma olasılıkları daha yüksek tespit edilmiştir.

Sonuç olarak çevrim içi gıda alışverişi yalnızca teknolojik gelişmelerle değil; bireylerin sosyo-demografik özellikleri, medya kullanım alışkanlıkları ve gıda tercihleriyle birlikte şekillenen çok yönlü bir tüketim pratiğidir. Bu çalışma, dijital perakendecilik stratejileri ve kamu politikalarının şekillendirilmesinde dikkate alınması gereken önemli veriler sunmakta; kapsayıcı ve veri temelli e-ticaret politikalarının oluşturulmasına katkı sağlamaktadır.

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A STUDY ON SOCIAL DETERMINANTS OF FOOD CONSUMPTION BEHAVIOR

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ABSTRACT

Food consumption is not only a physiological need, but also a cultural form of action in which individuals construct their social identities, develop social belonging, and adapt to normative behaviors. This study examines the role of social influences in food consumption within a multi-layered framework and examines how basic factors such as social norms, family and peer relationships, and digital media shape individuals' food consumption behaviors. According to the research findings, individuals frequently make changes in their consumption preferences according to the eating habits of others around them, and this situation remains valid both in physical environments (e.g. family meals, school cafeterias) and digital environments (e.g. social media content). While descriptive norms affect how much and what individuals consume, imperative norms define the social approval or pressure for these behaviors. Parental and peer influences are decisive in the formation of eating habits, especially in childhood and adolescence, and social media plays a reinforcing or guiding role in these processes. In this context, the study goes beyond traditional approaches that evaluate food consumption only within the framework of individual preferences or economic conditions and argues that eating behavior gains meaning within a social structure. Food preferences are directly related to the social groups, cultural affiliations and social identities to which individuals belong. What we eat, how we eat and with whom we eat are transformed into symbolic actions that reflect the individual's social status, values and affiliation relations. Therefore, any analysis to be conducted on eating behaviors should take into account the multi-layered structure of the social context and should include a wide range from normative regulations to cultural transmission forms. By adopting this multi-dimensional approach, the study aims to examine the social determinants affecting eating behaviors on a conceptual and empirical level. In addition, the study offers important suggestions for food industry managers, policy makers and public health experts.

Keywords: Food Consumption Behavior, Social Norms, Family and Peer Influence, Media

GIDA TÜKETİM DAVRANIŞININ SOSYAL BELİRLEYİCİLERİ ÜZERİNE BİR İNCELEME

ÖZET

Gıda tüketimi yalnızca fizyolojik bir gereksinimin karşılanması değil aynı zamanda bireylerin sosyal kimliklerini inşa ettikleri, toplumsal aidiyet geliştirdikleri ve normatif davranışlara uyum sağladıkları kültürel bir eylem biçimidir. Bu çalışma gıda tüketiminde sosyal etkilerin rolünü çok katmanlı bir çerçeveyle ele alarak sosyal normlar, aile ve akran ilişkileri ile dijital medya gibi temel faktörlerin bireylerin gıda tüketim davranışlarını nasıl şekillendirdiğini incelemektedir. Araştırma bulgularına göre, bireyler sıklıkla çevrelerindeki diğer bireylerin yeme alışkanlıklarına göre kendi tüketim tercihlerinde değişiklik yapmakta bu durum hem fiziksel ortamlarda hem de dijital ortamlarda geçerliliğini korumaktadır. Tanımlayıcı normlar, bireylerin ne kadar ve ne tüketeceğini etkilerken, emredici normlar bu davranışlara yönelik toplumsal onay ya da baskıyı tanımlamaktadır. Ebeveyn ve akran etkileri, özellikle çocukluk ve ergenlik döneminde beslenme alışkanlıklarının şekillenmesinde belirleyici olmakta, sosyal medya ise bu süreçleri pekiştirici ya da yönlendirici bir rol üstlenmektedir. Bu bağlamda çalışma, gıda tüketimini yalnızca bireysel tercihler veya ekonomik koşullar çerçevesinde değerlendiren geleneksel yaklaşımların ötesine geçerek, beslenme davranışının toplumsal bir yapı içerisinde anlam kazandığını savunmaktadır. Gıda tercihleri, bireylerin ait oldukları sosyal gruplar, kültürel aidiyetler ve toplumsal kimliklerle doğrudan ilişkilidir. Ne yediğimiz, nasıl yediğimiz ve kiminle yediğimiz, bireyin sosyal statüsünü, değerlerini ve aidiyet ilişkilerini yansıtan sembolik eylemlere dönüşmektedir. Bu nedenle gıda tüketim davranışları üzerine yapılacak her türlü analiz sosyal bağlamın çok katmanlı yapısını göz önünde bulundurmalı ve normatif düzenlemelerden kültürel aktarım biçimlerine kadar geniş bir yelpazeyi içermelidir. Çalışma, bu çok boyutlu yaklaşımı benimseyerek beslenme davranışlarını etkileyen sosyal belirleyicileri kavramsal ve ampirik düzlemde irdelemeyi amaçlamaktadır. Ayrıca çalışma gıda endüstrisi yöneticileri, politika yapıcılar ve halk sağlığı uzmanları açısından önemli öneriler de sunmaktadır.

Anahtar Kelimeler: Gıda Tüketim Davranışı, Sosyal Normlar, Aile ve Akran Etkisi, Medya

1. GİRİŞ

Beslenmek temelde sosyal bir eylemdir. Beslenme ihtiyacının karşılanması gıda tüketiminin temel itici gücü olsa da tüketimin gerçekleştiği sosyal çevre, insanların hem ne tükettiği hem de ne kadar tükettiği üzerinde güçlü bir etkiye sahiptir. Giderek artan disiplinler arası araştırmalar beslenme davranışını şekillendirmede sosyal normların, kültürel geleneklerin, kişilerarası dinamiklerin ve daha geniş toplumsal yapıların rolünü ortaya koymaktadır (Higgs ve ark., 2019; Pliner ve Mann, 2004; Cruwys ve ark., 2015).

Gıda tüketiminde sosyal etki algılanan normlara uyum ve kimliğe dayalı yeme gibi çeşitli yollarla gıda tüketim sürecini etkilemektedir. Deneysel çalışmalar, bireylerin gıda alımlarını çevrelerinde bulunan diğer bireylerin ne yediğine göre ayarladıklarını tutarlı bir şekilde göstermektedir ve bu duruma sosyal modelleme denilmektedir (Cruwys ve ark., 2015). Bu durum bireyler tarafından doğrudan veya çevresel ipuçları gibi dolaylı olarak meydana gelmektedir (Higgs ve Thomas, 2016).

Sosyal normların etkisi sadece akran etkileşimleriyle sınırlı olmayıp aynı zamanda daha geniş kültürel beklentilere ve değerlere de dayanır. Örneğin, ebeveynler ve akranlar özellikle yetkili aile ortamlarında ergenlerin yiyecek tercihlerini ve tüketim kalıplarını önemli ölçüde şekillendirmektedir (Guidetti ve ark., 2016). Benzer şekilde, göçmen topluluklar arasında gözlemlenenler gibi kültürel gelenekler ve beklentiler, kültürleşme ve yaşam tarzı geçişleri bağlamında da yiyecek seçimleri etkilenmektedir (Nicolaou ve ark., 2009).

Bu noktada sosyal etki her zaman sağlıklı beslenme davranışını desteklemez. Bazı durumlarda, sosyal normlar obeziteye yol açan aşırı yemeyi güçlendirebilir veya aşırı kalori alımı gibi uyumsuz durumlara katkıda bulunabilir (Mathieu-Bolh, 2020; Shah ve Asghar, 2023). Akran grupları veya medya etkisiyle daha büyük porsiyon boyutlarının ve yüksek kalorili yiyeceklerin normalleştirilmesi bireylerin sağlıklı beslenme hedeflerini zayıflatabilmektedir (Pliner ve Mann, 2004; Lazaric ve ark., 2020).

Dahası gıda tüketimi giderek küresel ve dijital ağlar tarafından şekillendirilmektedir. Dholakia ve Talukdar 2004, küresel tüketici kültürüne özellikle de Amerikan tüketim normlarına maruz kalmanın, gelişmekte olan pazarlardaki gıda tüketim modellerinde değişimlere yol açtığını göstermektedir. Bu bulgu küreselleşme ve medya yayılımı gibi makro düzeydeki sosyal süreçlerin zaman içinde bireysel beslenme davranışlarını şekillendiren etkili güçler olarak nasıl hareket ettiğini vurgulamaktadır.

Psikolojik mekanizmalar da sosyal yeme davranışına aracılık eder. Bireyler, sosyal onay kazanmak, istenen bir grupla ilişki kurmak veya belirsiz yeme bağlamlarında belirsizliği azaltmak için başkalarının gıda tüketim paternlerini modelleyebilmektedir (Higgs, 2015; Cruwys ve ark., 2015). Bu anlamda, yemek yeme hem bir sosyal performans hem de kimlik oluşturma veya sürdürme aracı haline gelir (Vassallo ve ark., 2016; Goldsmith, 2015; Higgs ve Thomas, 2016).

Bahsi geçen açıklamalar gıda tüketiminin derinden sosyal bir durum ve ilişkisel, kültürel ve yapısal bağlamlara da bağlı olduğunu göstermektedir. Bu çalışmada sosyal etkinin toplumun gıda tüketim davranışını nasıl şekillendirdiği araştırılarak normların, kimliğin, kültürün ve medyanın gıda tüketimimiz için ne anlama geldiğini araştırmaktadır.

2. TEMEL SOSYAL ETKİLER

Sosyal Normlar

Sosyal normlar (sosyal gruplar içindeki davranışları yöneten örtük veya açık kurallar) yeme davranışının en etkili ancak sıklıkla hafife alınan itici güçleri arasındadır. Sosyal varlıklar olarak bireyler, özellikle yiyecek seçimi veya porsiyon büyüklüğü gibi belirsiz durumlarda neyin uygun veya kabul edilebilir olduğu konusunda rehberlik için başkalarından etkilenirler (Cialdini ve ark., 2006; Higgs ve ark. 2019). Yiyecek tüketimi bağlamında sosyal normlar yalnızca insanların ne yediğini değil aynı zamanda ne kadar, ne zaman ve neden yediğini de şekillendirmektedir (Higgs ve Thomas, 2016).

Literatürdeki kritik bir ayrım, çoğu insanın gerçekte ne yaptığına ilişkin algıları ifade eden tanımlayıcı normlar ile başkalarının neyi onayladığı veya onaylamadığına ilişkin algıları ifade eden emredici normlar arasındadır. Tanımlayıcı normlar, belirli bir bağlamda neyin tipik veya beklenen olduğunu işaret ederek davranış üzerinde genellikle daha doğrudan ve acil bir etki uygular (Lally ve ark., 2011; Pedersen ve ark., 2015). Örneğin, bireyler açlık veya tercihten bağımsız olarak yiyecek alımlarını akranlarınınkiyle eşleşecek şekilde ayarlama eğilimindedir ve başkaları daha fazla yediğinde daha fazla, başkaları daha az yediğinde daha az yerler (Pliner ve Mann, 2004; Higgs ve ark. 2019). Bu etkiler, doğrudan etkileşimin olmadığı durumlarda bile devam eder, çünkü restoranlar, kafeteryalar veya sosyal medya gibi ortamlardaki normatif ipuçları uyum davranışlarını harekete geçirebilir (Hawkins ve ark., 2020; Cialdini ve ark., 2006).

Genellikle uzun vadeli niyetler ve tutumlarla ilişkilendirilen emredici normlar ise yeme davranışlarını değiştirmede karışık bir etkinlik göstermiştir. Örneğin çoğu insan sağlıklı beslenme fikrini zaten desteklemektedir ve bu nedenle sağlıklı beslenmenin sosyal olarak onaylandığını vurgulayan mesajlar yeni bir motivasyonel değer sağlamayabilir (Higgs ve ark., 2019). Ancak, tanımlayıcı normlarla eşleştirildiğinde (özellikle aile yemekleri veya akran grupları gibi yüksek bağlılık ortamlarında) emredici normlar belirli davranışların algılanan meşruiyetini ve önemini güçlendirmektedir (Pedersen ve ark., 2015).

Normatif etki yalnızca pasif bir süreç değildir. Bireyler ayrıca sosyal kimlik ve aidiyet ihtiyaçlarına göre yeme normlarını içselleştirir ve yeniden üretebilirler. Cialdini ve ark. 2006 nın Normatif Davranış Odak Teorisine göre normların davranışı etkileme olasılığı en yüksek düzeyde bireylerin norm belirleyen grupla özdeşleştiğinde ortaya çıkmaktadır (Cialdini ve ark., 2006). Örneğin, çalışmalar bir üniversite topluluğuyla güçlü bir şekilde özdeşleşen katılımcıların kampüs arkadaşlarının yeme alışkanlıkları hakkında tanımlayıcı norm mesajlarına maruz kaldıktan sonra sebze alımlarını ayarlama olasılıklarının daha yüksek olduğunu göstermiştir (Higgs ve ark., 2019). Aile ve akran ağları sosyal normların iletilmesinde önemli kanallar olarak işlev görür. Pedersen ve ark. 2015, ergen popülasyonlarında ebeveynlerin tanımlayıcı normlarının (aslında ne yaptıkları) emir normlarından (ne yapılması gerektiğini söyledikleri) daha fazla etkiye sahip olduğunu göstermiştir.

Sonuç olarak, sosyal normlar yaşam boyu yiyecek seçimlerini ve yeme davranışlarını şekillendiren güçlü, çok boyutlu kuvvetler olarak işlev görür. Hem tanımlayıcı hem de emredici normlar davranışı etkilerken, ilki genellikle daha güçlü ve daha tutarlı bir etki uygular - özellikle norm referans grubu belirgin ve sosyal olarak anlamlı olduğunda. Bu nedenle etkili diyet müdahaleleri bireysel eğitimin ötesine geçmeli ve daha geniş sosyal bağlamla etkileşime

girmeli, yanlış algıları düzeltmeli, olumlu normları güçlendirmeli ve güvenilen akranların ve aile üyelerinin etkisinden yararlanmalıdır.

Akran Ve Aile Etkisi

Aile ve akran ilişkileri özellikle çocukluk ve ergenlik döneminde yeme davranışlarını şekillendiren en etkili sosyal ortamlardan ikisidir. Bu ilişkiler yalnızca yiyeceklerin bulunabilirliğini ve öğünlerin yapısını belirlemekle kalmaz aynı zamanda diyet seçimleri, tercihleri ve alışkanlıkları için güçlü kaynaklar olarak da hizmet eder. Çocuklar ergenliğe doğru geçtikçe etki dengesi aileden akranlara doğru kademeli olarak değişir ancak her ikisi de yaşam boyu yeme davranışlarını şekillendirmede önemli olmaya devam eder.

Ebeveynler genellikle yiyecek sosyalleşmesinin en erken ve en tutarlı aracılarıdır ve çocukların yiyecek tercihleri, zamanlaması ve gıdaya yönelik diğer tutumlarla tanışmasına vesile olurlar. Ebeveyn modellemesi yani çocukların ebeveynlerinin yeme davranışlarını gözlemleyip taklit etmesi, diyet tercihlerinin oluşumu üzerinde güçlü bir etkiye sahiptir. Sürekli olarak meyve, sebze ve dengeli öğünler yiyen ebeveynler benzer alışkanlıklara sahip çocuklar yetiştirme eğilimindedirler (Story ve ark., 2002; Chung ve ark., 2017). Ayrıca yemek saatlerinde ebeveyn varlığı, ergenler arasında daha sağlıklı beslenme kalıplarıyla ilişkilendirilmektedir. Videon ve Manning 2003, en az bir ebeveyniyle düzenli olarak yemek paylaşan ergenlerin daha fazla meyve, sebze ve süt ürünü tükettiğini ve kahvaltıyı tek başına veya akranlarıyla yiyenlere kıyasla daha az atlama olasılıklarının olduğunu tespit etmişlerdir.

Gıda tüketim davranışının şekillenmesinde aile yemeklerinin yapısı ve sıklığı önemlidir. Tutarlı yemek zamanı rutinleri sürdüren ailelerden gelen ergenler daha fazla besin yoğunluğuna sahip yiyecekler tüketme eğilimindedir ve işlenmiş atıştırmalıklar ile şekerli içecekleri daha az tüketirler (Xu, 2022). Ebeveyn eğitimi ve denetimi bu etkiyi daha da artırır ve daha eğitimli ebeveynler ergenlerde daha iyi beslenme sonuçlarıyla ilişkilendirilir ve yiyecek seçimleri konusunda daha az özerkliğe sahip ergenlerin yemek atlama veya sağlıksız yiyecekleri tercih etme olasılıkları daha düşüktür (Liu ve ark., 2021; Finnerty ve ark., 2009; Videon ve Manning, 2003).

Çocuklar ergenliğe girdikçe, akran etkisi daha baskın bir rol üstlenmeye başlar. Ev dışında arkadaşlarla sosyal etkileşimler artar ve yemek yeme, akran bağları, kabul ve kimlik oluşumu içinde yer alır. Akran grupları, yeme davranışlarını hem doğrudan (modelleme ve sözlü teşvik yoluyla) hem de dolaylı olarak (grup normlarının oluşturulması yoluyla) etkiler. Çalışmalar, ergenlerin okul kafeteryaları gibi yapılandırılmış ortamlarda veya planlanmamış sosyal yemek yeme etkinliklerinde arkadaşlarının yiyecek seçimlerini ve porsiyon boyutlarını sıklıkla taklit ettiğini göstermektedir (Salvy ve ark., 2012; Ragelienė ve Grønhøj, 2021).

Akranların varlığının yalnızca tüketilen gıdanın türünü değil, aynı zamanda ne kadar tüketileceğine de etkilede bulunduğu tespit edilmiştir. Örneğin, Salvy ve ark. 2011, ergenlerin arkadaşlarıyla yemek yediklerinde, tek başlarına veya tanımadıkları akranlarıyla yemek yediklerinden önemli ölçüde daha fazla yiyecek tükettiğini ortaya koymuştur. Yiyecekle ilgili akran normları, tüketimi hem sağlıklı hem de sağlıksız yönlere de kaydırabilmektedir (Ragelienė ve Grønhøj; 2021)

Akran etkisinin gücü ve yönü cinsiyet, yaş ve arkadaşlık yakınlığı gibi faktörlere bağlı olarak değişebilmektedir. Chung ve ark., 2017, akran etkilerinin yakın, duygusal olarak destekleyici arkadaşlıkları olan ergenler arasında daha güçlü ve kızlar arasında daha belirgin olduğunu vurgulamışlardır.

Kardeşler de yeme alışkanlıklarını şekillendirmede benzersiz, ancak daha az sıklıkla incelenen bir rol oynarlar. Ebeveynler veya akranlar kadar baskın olmasalar da kardeşler, paylaşılan deneyimler ve ince pekiştirme yoluyla diyet davranışlarına katkıda bulunurlar. Ragelienė ve Grønhøj 2021, kardeşleriyle sık sık yemek yiyen ve onlardan sağlıklı beslenme konusunda destek alan çocukların meyve ve sebze tüketiminin önemli ölçüde daha yüksek olduğunu tespit etmişlerdir. Ancak kardeşler olumsuz etkiler olarak da hareket edebilirler. Özellikle rekabetçi veya çatışmalı kardeş dinamiklerinde sağlıklı beslenmeyi engelleyen sağlıksız davranışları alay konusu yapabilir veya modelleyebilirler.

Medya ve Dijital Etki

Son yıllarda medya, özellikle dijital ve sosyal medya yiyecek tercihlerini ve yeme davranışlarını şekillendirmede güçlü bir sosyalleşme aracı olarak ortaya çıkmıştır. Bu etki, Instagram, YouTube, TikTok ve Facebook gibi platformların en sık kullanıcıları olan ergenler ve genç yetişkinler arasında özellikle daha güçlüdür. Bu platformlar yalnızca eğlence veya iletişim kaynakları olarak hizmet etmeyip aynı zamanda yiyecekle ilgili seçimleri ve tutumları etkileyen ortamlar olarak işlev görmektedirler (Qutteina ve ark., 2021; Wu ve ark., 2023; Tan ve ark., 2024).

Sosyal medya platformları kullanıcılarını reklamlar, tanıtımlar ve akranlar tarafından oluşturulan yiyecek gönderileri aracılığı ile sürekli olarak bir içerik akışına maruz bırakmaktadır. Bu maruz kalma, yiyecekle ilgili tutumların, tercihlerin ve davranışların şekillendirilmesiyle tutarlı bir şekilde ilişkilendirilmektedir (Qutteina ve ark., 2021).

Günümüzde yiyecek pazarlamasının dijital platformlardaki etkisi geleneksel reklamcılığın çok daha ötesine uzanmaktadır. Medyada yer alan yiyecek pazarlaması faaliyetleri özellikle ergenler arasında sağlıksız yeme davranışlarına önemli ölçüde katkıda bulunakta ve burada dijital platformlar çok daha büyük etki göstermektedir. Reklamlar, fenomenler ve kullanıcı tarafından oluşturulan promosyonlar gibi teknikler özellikle sağlıksız yiyecekleri sosyal olarak arzu edilir ve normatif hale getirebilmektedir (Qutteina ve ark., 2019).

Yemekle ilgili sosyal medya içeriklerine maruz kalmanın düzensiz beslenme, beden memnuniyetsizliği ve çarpık yiyecek tercihleri gibi çok çeşitli sonuçlarla bağlantılı olduğu görülmüştür. Özellikle, duygusal olarak ilgi çekici anlatılar veya görsel çekicilik içermediği sürece sağlıklı yiyecek içeriklerinin bile sınırlı bir etkisi vardır (Wu ve ark., 2023).

Günümüzün dijital platformları aşırı tüketimi (örneğin, yiyecek meydan okuması veya şımartma videolarında) ve idealize edilmiş vücut imajlarını aynı anda sunarak daha karmaşık bir çelişki de sunmaktadırlar (Harrison ve Cantor, 1997; Wu ve ark, 2023).

Daha geniş bir toplumsal perspektiften bakıldığında, medya aynı zamanda çevresel olarak sürdürülemez gıda seçimlerini de pekiştirmektedir. Dijital estetik ve pazarlama yoluyla ultra

işlenmiş ve aşırı paketlenmiş gıdaların normalleştirilmesi yalnızca yetersiz beslenmeye değil aynı zamanda ekolojik bozulmaya da katkıda bulunmaktadır (Simeone ve Scarpato, 2020).

Tüm bu bulgular bir arada ele alındığında, dijital medyanın yalnızca pasif bir arka plan değil, aynı zamanda modern gıda kültürünü şekillendirmede aktif ve ikna edici bir güç olduğunu göstermektedir. Ergenler ve genç yetişkinler, özellikle etkileyiciler, akranlar ve sosyal eğilimler tarafından güçlendirildiğinde, medya odaklı mesajları içselleştirirler ve bu da estetik çekiciliği, kolaylığı ve bir şeyi önceliklendiren yiyecek tercihlerine yol açar ve popülerlik sağlıktan daha önemlidir. Bu sorunun ele alınması, medya okuryazarlığı eğitimi, gıda pazarlaması konusunda daha güçlü politikalar ve daha sağlıklı, daha sürdürülebilir beslenme normlarını teşvik etmek için sosyal platformlardan yararlanan kamu sağlığı kampanyaları gerektirir (Qutteina ve ark, 2019; Wu ve ark, 2023).

3. SONUÇ

Bu çalışma, gıda tüketim davranışlarının yalnızca bireysel tercihler ya da ekonomik şartların bir yansıması olmadığını; aynı zamanda sosyal normlar, aile ve akran etkisiyle birlikte dijital medyanın da dahil olduğu çok katmanlı sosyal faktörler tarafından şekillendirildiğini ortaya koymaktadır. Sosyal normlar, bireylerin neyi, ne kadar ve nasıl tükettikleri üzerinde hem doğrudan hem de dolaylı yollarla etkili olmakta; özellikle tanımlayıcı normların, emredici normlara kıyasla daha güçlü bir etki yarattığı görülmektedir. Bu normatif etkiler, bireyin sosyal kimliği ve ait olduğu grupla kurduğu bağla da yakından ilişkilidir.

Araştırmanın bulguları, bireylerin beslenme alışkanlıklarının gelişiminde aile ve akran çevresinin zamanla değişen roller üstlendiğini göstermektedir. Çocukluk döneminde aile, özellikle de ebeveynlerin rol model olması, evdeki yemek düzeni ve ebeveyn gözetimi, sağlıklı beslenme davranışlarının kazanılmasında belirleyici olmaktadır. Öte yandan, ergenlik ve genç yetişkinlik döneminde akranlar devreye girmekte; bu dönemde arkadaş çevresinden gelen etkiler hem sağlıklı hem de sağlıksız yeme alışkanlıklarının pekişmesine yol açabilmektedir. Ayrıca kardeş ilişkilerinin de, bu süreçte daha arka planda kalsa da özgün ve dikkat çekici etkiler taşıdığı gözlemlenmiştir.

Günümüzde dijital medya, özellikle gençler arasında önemli bir sosyalleşme alanı haline gelmiş durumdadır. Sosyal medya içerikleri, yiyecek tercihlerinde hem doğrudan hem de dolaylı etkiler yaratmakta; özellikle sağlıksız gıdaları normalleştirme ve çekici kılma potansiyeli taşımaktadır. Bu durum, bireylerin beden algısı, düzensiz yeme davranışları ve sürdürülebilir olmayan beslenme tercihleriyle ilişkili riskleri artırmaktadır. Medyada sıkça karşılaşılan estetik ve cazibe odaklı mesajlar, sağlıklı beslenme davranışlarının yaygınlaşması konusunda yetersiz kalmakta; bu da medya okuryazarlığının geliştirilmesini ve düzenleyici politikaların güçlendirilmesini gerekli kılmaktadır.

Sonuç olarak, bireylerin gıda tüketim alışkanlıkları, çok boyutlu ve iç içe geçmiş sosyal dinamiklerin etkisiyle şekillenmektedir. Bu nedenle sadece bireye odaklanan müdahaleler yetersiz kalmakta; sosyal normların dönüştürülmesini hedefleyen, aile ve akran ilişkilerini kapsayan ve dijital medya etkisini gözeten bütüncül stratejilere ihtiyaç duyulmaktadır. Politika yapıcılar, halk sağlığı uzmanları ve gıda sektöründeki paydaşlar için geliştirilecek uygulamaların, bu sosyal belirleyicileri merkeze alan bir yaklaşımla tasarlanması büyük önem

taşımaktadır. Bu tür sosyal etkileri odağına alan yaklaşımlar, hem sağlıklı hem de sürdürülebilir beslenme davranışlarının toplum genelinde benimsenmesine katkı sağlayacaktır.

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TRENDS AND GROWTH RATES IN FISH IMPORT AND EXPORT IN NIGERIA FOR THE PERIOD 1970 – 2022

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ABSTRACT

The study examined the growth rates and trends in fish import and export in Nigeria for the period 1970 – 2022 using time series data. The Secondary data were obtained from National Bureau of Statistics (NBS), Central Bank of Nigeria (CBN) and Federal Inland Revenue Services (FIRS) annual reports. used for this study. Data collected were analyzed using descriptive statistics, graphical charts and exponential growth model. The empirical findings based on the summary statistics revealed that the time series data used were normally distributed but became stationary after first differencing. The minimum fish import (4,230,000) and export (680,000) was recorded in the year 1970, while the maximum fish import (8,590,000,000) and export (386,000,000) was recorded in the year 2022, implying a gradual and consistent upward trend in fish export and import. Also, the trend co-efficient of the fish import (0.0102) and fish export (0.0193) were positive and revealed an exponential growth rate of 1.01% and 1.92%, respectively. Johansen's trace statistics value of 43.8075 and maximum statistics value of 29.7702 at r = 0 was higher than the critical value of 15.41 at 5% probability level, while both the trace and maximum statistics values of 14.0374 at r = 1 was also higher than the critical value of 3.76 at 5% probability level indicating that significant relationship exist between fish import and export in Nigeria. It is recommended therefore that Government should provide enabling environment for fish production in Nigeria and make policy on fish importation in order to protect local production.

Keywords: Growth Rates, Trend, Fish, Export, Import

INTRODUCTION

Fish is one of the most valuable commodities among the various agricultural products (Muhammed *et al.*, 2015). In 2016, about 35 percent of global fish production entered into the international trade in various forms either for human consumption or non-edible purposes (Food and Agriculture Organization (FAO), 2018). The rapid rate of expansion of international trade in fish and fish products over recent decades has taken place in the context of a broader process of globalization, a large-scale transformation of the world economy driven by trade liberalization and technological advancements (FAO, 2018). According to Cocker (2014), fish is Africa's leading agricultural export commodity (in terms of quantity), but the continent is a net importer of low value fish and fish products. As a result, African domestic and regional markets continue to be the main destination of locally produced fish as demand expands. Meanwhile, the growth rate of exports from developing countries has increased faster than from developed ones (United Nations (UN), 2019).

The fishery sub-sector plays an important role in Nigeria's economy, directly contributing about 5.4% of the gross domestic product (GDP) and employing over one million people (Federal Department of Fisheries, 2016). In spite of the unstable macroeconomic indices, there is an increasing trend in its international trade and has grown rapidly over the last two decades, with fish trade values rising from US$15 billion in 1980 to US$140 billion in 2017 (FAO, 2018). A significant share of total fish production in Nigeria (about 36 percent, live-weight equivalent) is exported (FAO, 2018). Contrastingly, the total demand for fish in the country is 3.32 million metric tons and Nigeria is producing about 1.12 million metric tons locally, while the deficit of 2.2 million metric tons is met by imports (Federal Ministry of Agriculture and Rural Development (FMARD), 2022). According to the National Bureau of Statistics (NBS) (2024), Nigeria spent ₦50.8 billion on fish importation in the third quarter of 2023.

Meanwhile, Nigeria exported 117 shipments of fish in 2023 marking a growth rate of 89.0% as compared to the preceding year (NBS, 2024). According to FAO (2020), Nigeria exported approximately 5 tons of smoked fish per month as airfreight or 60 tons per annum mostly for United Kingdom and other countries like Ghana, the Ivory Coast and Cameroon among others. Nigeria's fish export has significant potentials with her vast water resources and growing aquaculture industry. There are opportunities to export fish products such as shrimps, prawns, catfish, tilapia, dried and smoked fish. Despite the opportunity, the sub-sector is faced with numerous challenges not limited to infrastructural gap, quality standard, over-fishing and regulatory bottleneck on the part of Government. However, to overcome these challenges and improve the fish sub-sector of Nigeria, adequate measures need to be taken among which include investment in infrastructure, adherence to quality standard, suitable monetary policies that is strategic for market penetration and adequate research which is the basis for this study.

Therefore, this study was undertaken to provide the needed information to guide policy on the development of fish export and import in Nigeria by examining the growths and trends. The specific objectives of this study were to examine the growths and trends of fish export and import in Nigeria for the period 1970 – 2022 and evaluate the relationship between fish export and import in Nigeria for the period 1970 -2022).

METHODOLOGY

Study Area

This study was conducted in Nigeria which lies between Latitudes 4° and 14°N and Longitudes 3° and 14°E of the equator. The country operates Federal system of government with 36 States, Federal Capital Territory and 774 Local Government Areas (LGAs). Nigeria is located in West Africa on the Gulf of Guinea and It is bounded by the Atlantic Ocean to the South and by the Sahelian countries of Niger and Chad to the North. It is one of the largest and populous countries in Africa occupying a geographical area of about 923,770 square kilometers including 13,000 square kilometers of inland water ways with an estimated population of 223,804,632 using population growth rate of 2.4% (United Nation, 2022). Nigeria enjoys a warm tropical climate with relatively high temperatures throughout the year, and two seasons; the rainy or wet season that lasts from mid-March to November in the South and from May to October in the North, and the dry season that occupies the rest of the year. Larger percentage of the people reside in the rural area where they are engaged in agriculture such farming, livestock and fishing activities as primary occupation.

Method of data collection and analysis

The empirical analysis covers the period between 1970 and 2022. Secondary data (time series) used for the analysis were obtained from National Bureau of Statistics (NBS), Central Bank of Nigeria (CBN) and Federal Inland Revenue Services (FIRS) annual reports, publications and other statistical bulletin. The information obtained were on the export and import of fish and fish products, and other relevant parameters over the period under review. Meanwhile, the time series data collected were analyzed using descriptive statistics to ascertain the normality of the series, exponential growth model, Augmented Dickey-Fuller (ADF) stationarity test and Johansen co-integration test.

Model Specification

The exponential growth rate model is expressed as the difference between two values in time in terms of a percentage of the first value (Ammani, 2012). The growth model is therefore expressed in equation (1):

$$Y_t = Y_o(1+r)t(1) \quad (1)$$

Where:

Y_t = Quantity of fish export / import in a year t (tons);

r = Compound rate of growth of Y (%);

Y_o = Quantity of fish import in a base year (tons);

t = Time (year); and

1 = Constant.

Meanwhile, by linearizing the equation (1), the resulting outcome is expressed in equation (2):

$$LnY_t = LnY_o + Ln(1+r)t \quad (2)$$

Substituting LnY_o with β_1 and $Ln(1+r)$ with β_2 in equation (2), it transforms to equation (3).

$$LnY_t = \beta_1 + \beta_2 t \quad (3)$$

Adding the error term to equation (3), it gave rise to equation (4):

$$LnY_t = \beta_1 + \beta_2 t + \mu \quad (4)$$

Where:

Y_t = Quantity of fish export / import in year t (tons);

β_1, β_2 = Parameters to be estimated;

μ = Error term; and

t = Time

The trends in Nigeria's fish trade flow (export and import) were estimated using exponential regression model as employed by Adamu (2021). The exponential trend for fish trade flow was specified in equation (5):

$$Y_t = \beta_o + \beta_1 t_i + U_t \quad (5)$$

Finding the natural log of both sides gave the linear form of the equation (6):

$$Ln\, Y_t = \beta_o + \beta_1 t_i + U_t \quad (6)$$

Where:

Ln = natural log of fish trade flow (export and import);

Y_t = Qty of fish export or import (tons);

β_o = Constant (intercept of the equation);

t = Time trend (years);

β_1 = Trend coefficient; and

Ut = Error term.

The ADF test is the modified and improved version of the Dickey-Fuller (DF) test. The ADF stationarity test is specified in equation (7).

$$\Delta Z_t = \beta_1 + \beta_1^t + \partial Z_{t-1} + \Sigma_{i-1}^{m} \alpha_1 \Delta_{t-1} + \varepsilon_t \quad (7)$$

Where:

t = Time series variable (estimated parameters);

ΔZt = The change operator;

$\Delta Zt - 1 = (Z_{t-1}-Z_{t-2})$, $\Delta Z_{t-2} = (Z_{t-1}-Z_{t-2})$;

Z_{t-1} = Past values of variables;

β = Estimated parameters of the differenced values of the lagged variables; and

ε_t = White noise error term.

The null hypothesis that the time series data has no unit root or not stationary was tested.

Johansen co-integration was used to test for relationship between export and import time series variables. The study adopted the Johansen Maximum Likelihood procedure because it allowed for all feasible co-integration relationship and the number of co-integrating vectors to be verified practically. Thus, Johansen co-integration model was expressed in equation (8):

$$Z_t = \phi + A_1 Z_{t-1} + \cdots . + A_p Z_{t-p} + \varepsilon_t \quad (8)$$

The equation (8) can be rewritten as in equation (9):

$$\Delta Z_t = \phi + \sum_{i=1}^{n} \Gamma_i \Delta Z_{t-1} + \Pi Z_{t-1} + \varepsilon_t \quad (9)$$

Where;

$\Pi = \sum_{i=1}^{n} A_t - I, \Gamma_i = -\sum_{j=i+1}^{p} A_j$ and Z_t(EP and IP) was n x 1 vector of all the non-stationary I (1) variables in the study.

ϕ is a n x 1 vector of parameter (intercept),

ε_t is an k x 1 vector of innovations or random shocks.

Γ and Π are n x n matrices of parameters, were Γ is a n x 1 vector of coefficients of lagged Z_t variables. The Π is a *n x 1* long-run impact matrix which is product of two *(n x 1)* matrices of Exp (Export) and Imp (Import).

RESULTS AND DISCUSSION

Trend of fish import and export in Nigeria for the period from 1970 – 2022

Figure 1. shows the graphical trends of fish import and export in Nigeria from the period from 1970 to 2022 before differencing. As shown in Figure, there was a gradual and consistent increase in fish import and export over the period under review. Meanwhile, slight downward trend was recorded in rice production in 1990 and 1994 which thereafter gradually rise upward. The minimum fish import (4,230,000) and export (680,000) was recorded in the year 1970, while the maximum fish import (8,590,000,000) and export (386,000,000) was recorded in the year 2022. This implies a gradual and consistent upward trend in fish export and import over the period under review which could be attributed to several factors among which includes demand – supply, government policies and programmes which appears to be the most important factors. This finding is in corroboration with work of Ibrahim (2020) who reported a gradual and consistent increase in importation of most agricultural produce in Nigeria.

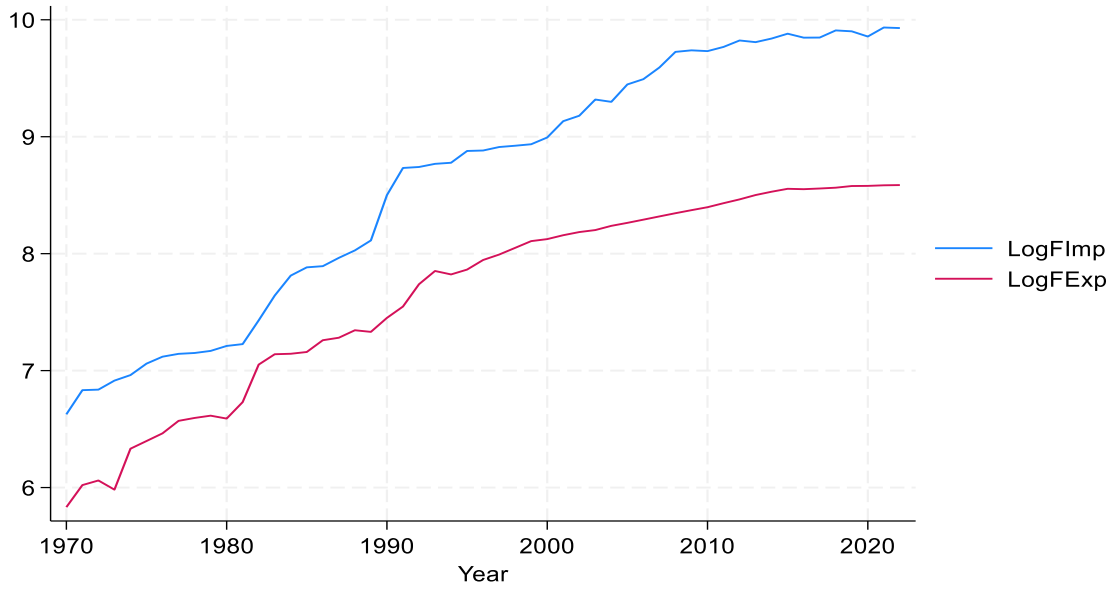

Figure 1: Trend of fish import and export in Nigeria from 1970 – 2022 before difference

More so, Figure 2 shows the graphical trends of fish import and export in Nigeria from the period from 1970 to 2022 after the differencing. The trends became stationary after the differencing at zero implying that the fish import and export has no unit root. This is expected of every time series data before it can be subjected to further analysis. Although, the fish import and export trends revealed the expected pattern of variability as it gives an idea of the past experience and also helps to predict for the future.

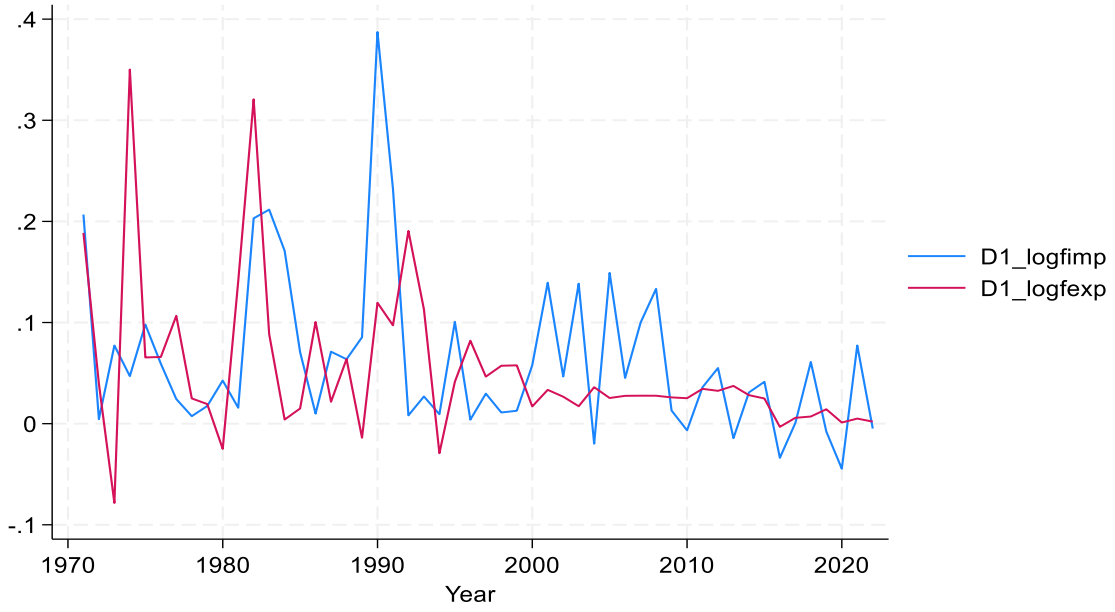

Figure 2: Trend of fish import and export in Nigeria from 1970 – 2022 after difference

Growth Rate of Fish Import and Export in Nigeria from 1970 – 2022

The results of exponential growth rate for fish import and export over the period of 1970 – 2022 are presented in Table 1. The F-statistic value of 10.059 and 37.488 revealed that the time trend was significant in the specified model. This was statistically significant at 5% and 1% level of probability and the time trend was relevant in explaining the variation in the fish import and export, respectively. Meanwhile, the trend co-efficient of the fish import (0.0102) and fish export (0.0193) were positive and revealed an exponential growth rate of 1.01% and 1.92%, respectively, implying a positive and increasing trend in fish import and export over the period under review. Therefore, the null hypotheses that there is no positive trend in the growth rate of fish import and export was rejected, while the accepting the alternate hypotheses.

Table 1: Growth rate of fish import and export in Nigeria from 1970 – 2022

Parameters	Fish Import	Fish Export
F – statistic	10.059**	37.488***
Trend Coefficient	0.0102	0.0193
t – statistic	5.603***	7.593***
Growth rate (%)	1.01	1.92

Source: Time series data from 1970 – 2022 computed using Stata 18

Note: ** and * implies significant at 5% and 1% level of significance**

Relationship between Fish Import and Export in Nigeria for the period from 1970 – 2022

Summary statistics of fish import and export time series

The summary of the basic features in respect to time series data used in the study is presented in Table 2. As revealed in the Table, the mean value of fish import and export for the period under review (1970 – 2022) was ₦2,440,000,000 and ₦135,000,000, respectively. The skewness results of 1.045 and 2.249 respectively, was less than the acceptable bench mark value of ±3.0, implying that the data set were normally distributed. Meanwhile, the kurtosis results of 7.374 and 10.149 respectively, was greater than the acceptable bench mark value of ±7.0, implying that the datasets were not peaked and flattened. However, Although, the Jarque – Bera value of 10.9747 was statistically significant at $p<0.01$ level of probability. However, the Jarque – Bera value of 48.959 and 148.609 respectively, was statistically significant at $p<0.01$ level of probability, hence the hypothesis that the data sets were not normally distributed was rejected. This finding is in corroboration with the study of Hair *et al.* (2022) who reported that skewness value between -2 to +2 is generally acceptable.

Table 2: summary statistics of the time series data

Description	Obs.	Min.	Max.	Mean	Std. Dev.	S	K	JB
ΔF_Imp.	53	4,230,000	8.59e+09	2.44e+09	3.02e+09	1.045	7.374	48.959
ΔF_Exp.	53	680,000	3.86e+08	1.35e+08	1.37e+08	2.249	10.149	148.609

Source: Time series data from 1970 – 2022 computed using Stata 18

Note: Obs. = Observation, Std. Dev. = Standard Deviation, S = Skewness, K = Kurtosis, JB = Jarque-Bera, Imp = Import and Exp = Exp.

Unit root test of fish import and export time series

Result of the unit root test is revealed in Table 3. The application of most time series models requires data to be stationary (Almuammar and Fasli, 2019). To test for the stationarity of the data set, the lags selection determined was guided by the Akaike Information Criterion (AIC) which ensure absent of serial correlation and loss of degree of freedom in the series. The ADF test values for the fish import (-5.411; -5.603) and fish export (-6.679; -7.593) without trend and with trend were greater than the critical values of 2.929 and 3.499, respectively. This implies that the ADF values for all the variables were higher than the critical values at $p < 0.05$ probability level, thus the variables had no unit root and were stationary around zero at first difference I (1).

Table 3: Estimate of unit root of the ARIMA

Variables	Order	Exogenous	ADF test (P-value)	Critical value at 5%
$\Delta FImp_t$	1(1)	Constant	-5.411 (0.0000)	-2.929
		Trend and Constant	-5.603 (0.0000)	-3.499
$\Delta FExp_t$	1(1)	Constant	-6.679 (0.0000)	-2.929
		Trend and Constant	-7.593 (0.0000)	-3.499

Source: Time series data from 1970 – 2022 computed using Stata 18

Johansen co-integration test of fish import and export time series

After ensuring that the time series data were stationary, the relationship between fish import and export in the period under review was estimated using the Johansen co-integration test. The Johansen co–integration test result of the null hypothesis that there is no relationship or co-integration between fish import and export is presented in Table 4. The results revealed that Johansen's trace statistics value of 43.8075 and maximum statistics value of 29.7702 at r = 0 was higher than the critical value of 15.41 at 5% probability level, while both the trace and maximum statistics values of 14.0374 at r = 1 was also higher than the critical value of 3.76 at 5% probability level. Therefore, the null hypothesis that there is no relationship or co-integration between fish import and export was rejected, while accepting the alternative hypothesis that there is relationship or co-integration between fish import and export with at least one of the co-integrating vectors. This implies that the fish import and export datasets vary independently in the short–run but could be interconnected in the long–run. The is evident from the fact that fish products are critical protein need for human consumption.

Table 4: Johansen co–integration test of fish import and export

Rank	Eigen value	Trace statistic	Critical value	Maximum statistic	Critical value
0	0.0000	43.8075*	15.41	29.7702*	14.07
1	0.4487	14.0374*	3.76	14.0374*	3.76
2	0.24478				

Source: Time series data from 1970 – 2022 computed using Stata 18

Note: * implies significant at p<0.05 critical value

CONCLUSION AND RECOMMENDATIONS

Based on the evidence emanating from the result of the data analysis, it can be concluded that the fish import and export datasets exhibits an upward and consistent trend. More so, there was a positive and increasing growth of fish import and export over the period under review. The datasets were normally distributed but not peaked and has no unit root as it become stationary after differencing. There is a positive relationship between fish import and export but vary independently in the short–run but could be interconnected in the long–run. However, the following recommendations were put forward among others. Fish production should be enhanced and improved by the producers to meet the domestic demand and boost export that will generate foreign exchange for the country. Government should provide enabling environment for fish production in Nigeria and make policy on fish importation in order to protect local production. Time series data used were normally distributed indicating significance of keeping reliable data, thus relevant government agency should ensure sustainable record keeping on fish import and export that will be useful for future research.

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INVESTIGATION OF EXTRACTION METHOD AND PHYSICOCHEMICAL PROPERTIES OF *EMILIA SONCHIFOLIA*

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ABSTRACT

Emilia sonchifolia's potential bioactive properties were assessed through physicochemical analysis and extraction. Petroleum ether, chloroform, ethyl acetate , methanol and aqueous solvents with increasing polarity have been utilised in a gradually solvent extraction process. A rotary evaporator was used to concentrate the extracts after every sixteen hours extraction, which was agitated periodically. To ensure the plant materials quality and purity, physicochemical characteristics were evaluated. Moisture content and volatile components were determined by drying loss evaluation, while total ash and solvent-soluble ash values were evaluated to identify inorganic elements and impurities. These characteristics provide knowledge of the stability and composition of crude plant extracts and are essential quality control measures for herbal formulations. The findings of this study contribute to standardizing extracts of *Emilia sonchifolia*, making it easier to conduct more phytochemical and pharmacological studies for potential therapeutic uses.

Keywords: *Emilia Sonchifolia*, bioactive properties, methanol extracts, ash value

INTRODUCTION

Medicinal plants are a source of great economic value in the Indian subcontinent. Nature has been bestowed on us a very rich botanical wealth and a large number of diverse type of plants grow in different parts of the country. India is rich in all the 3 levels of biodiversity, namely species diversity, genetic diversity and habitat diversity. In India thousands of species are known to have medicinal value and the use of different parts of several medicinal plants to cure specific ailments has been in vogue since ancient times.

Herbal medicines are complex mixtures of plants, animal parts or products, mineral and metals. However, plants and plant products form the dominant part of Materia Medica of traditional medicine practiced in different parts of the world and in particular in Asia, especially China, India, Korea, Philippines, Indonesia and Tibet. In India, for example, the Charaka Samhita (treatise), dating back to 900 BC, lists 341 plants and plant products for medicinal use. Susruta, who practiced surgery about 600 BC, described 395 medicinal plants. Herbal medicine is still mainstay of about 75-80% of the whole population, mainly in developing countries, for primary health care because of better cultural acceptability, better compatibility with the human body and fewer side effects. However, the last few years have seen a major increase in their use in the developed world (Rana and Jain, 2011).

Even though pharmacological industries have produced a number of new antibiotics in the last three decades, resistance to these drugs by microorganisms has increased. In general, bacteria have the genetic ability to transmit and acquire resistance to drugs, which are utilized as therapeutic agents. Such a fact is cause for concern, because of the number of patients in hospitals who have suppressed immunity, and due to new bacterial strains, which are multi-resistant. Consequently, new infections can occur in hospitals resulting in high mortality (Gislene *et al.,* 2000).

Medicinal plants are of great importance to the health of individuals and communities. The medicinal value of these plants lies in some chemical substances that produce a definite physiological action on the human body and these chemical substances are called phytochemicals. These are non-nutritive chemicals that have protective or disease preventive property. The most important of these phytochemicals are alkaloids, flavonoids, tannins and phenolic compounds. Many of these indigenous plants are used as spices and food plants (Subhashini *et al.,* 2010)

Considering the aforesaid, it is assumed that the need of the hour is to search for new antimicrobials. With this in mind, in the present work, some selected plants are screened for their potential antimicrobial activity. A number of such studies have been done in various places of the world (Sudharameshwari and Radhika, 2007). There are several reports on the antimicrobial activity of different herbal extracts (Parekh and Chanda, 2007).

MATERIALS AND METHODS

Herbal medicines derived from plant extracts are being increasingly utilized to treat a wide variety of clinical disease, relatively little knowledge about their mode of action is available. There is a growing interest in the pharmacological evaluation of various plants used in Indian

traditional system of medicine. Such an attempt was made in "*Emilia sonchifolia*" Which is suspected to have the antimicrobial activity.

Successive Solvent Extraction

'Emilia sonchifolia' shoots were washed well with water. They were air dried at 25°C For 5 days in shade and ground well using a mixer grinder (Singh *et al .,* 2025). The powdered medicinal plant material was taken and subjected to successive solvent extraction. The extraction was carried out for 16 hours with the following solvents in the increasing order of Polarity.

- Petroleum ether
- Chloroform
- Ethyl acetate
- Methanol
- Aqueous

PREPARATION OF DIFFERENT PLANT EXTRACTS

Preparation of Petroleum ether extract:

About 25g of powered plant material was extracted with 125ml petroleum. By using a separate funnel with occasional shaking for 16 hours. The extract was concentrated by Rotary flask evaporator. Each time before extracting the next solvent the residue was dried thoroughly to remove the solvent used.

Preparation of Chloroform extract:

After complete drying, the above said residue was extracted with 125ml Chloroform by occasional shaking for 16 hours.

Preparation of Ethyl acetate extract:

The above said residue was extracted with 125ml Ethyl acetate by occasional shaking for 16 hours.

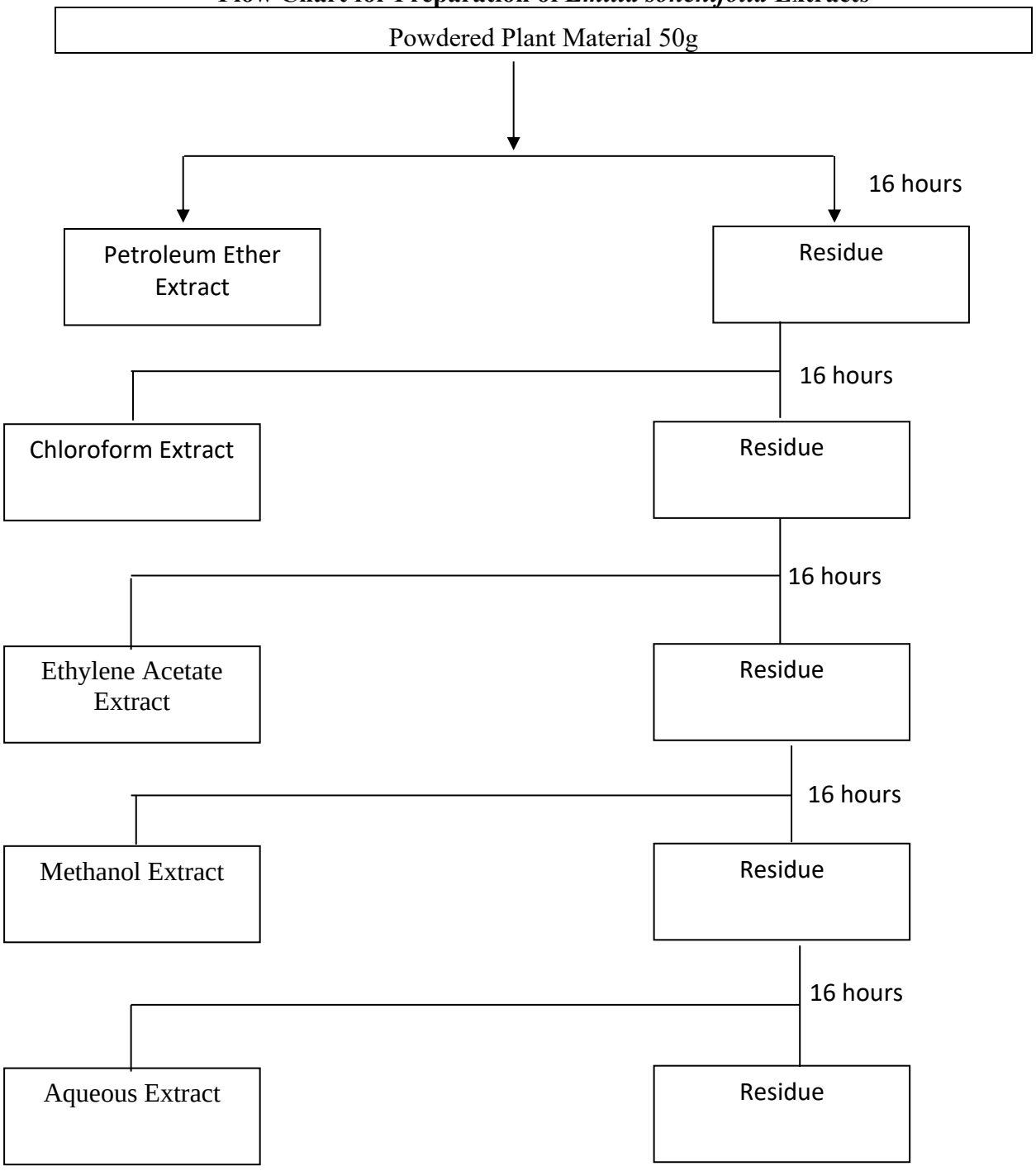
Preparation of Methanol extract:

The above said residue was extracted with 125ml ethanol by occasional shaking for 16 hours

Preparation of Aqueous extract:

The above said residue was extracted with 125ml aqueous by occasional shaking for 16 hours. The flow chart for extraction procedure is given below.

Flow Chart for Preparation of *Emilia sonchifolia* Extracts



DETERMINATION OF PHYSICAL CONSTANTS (Ross *et al.*, 2002)

1) Loss on drying at 110^{0}C

Loss on drying is the loss of mass expressed as per cent w/w. The test for loss on drying determines both water and volatile matter in the crude drug. Moisture is an inevitable component of crude drug, which must be eliminated as far as possible.

An accurately weighed quantity of about 5 g of powdered drug was taken in a tared porcelain dish. The powder was distributed evenly. The porcelain dish kept open in vacuum oven and the sample was dried at a temperature 110°C for 2 h until a constant weight was recorded. Then it was cooled in a desiccator to room temperature, weighed and recorded. % Loss on drying was calculated using the following formula.

$$\% \text{ Loss on Drying} = \frac{\text{Loss in weight of the sample}}{\text{Weight of the Sample}} \times 100$$

2) Ash values

Ash values are helpful in determining the quality and purity of a crude drug, especially in the powdered form. The objective of ashing vegetable drugs is to remove all traces of organic matter, which may otherwise interfere in an analytical determination on incineration, crude drugs normally leave an ash usually consisting of carbonates, phosphates and silicates of sodium, potassium, calcium and magnesium. The total ash of a crude drug reflects the care taken in its preparation

i) Total ash value

Weighed accurately about 2 to 3 g of the powdered drug in a tared silica crucible. Incinerated at a temperature not exceeding 450^{0}C for 4 h, until free from carbon, cooled and weighed. Calculated the percentage of ash with reference to air-dried drug using following formula,

$$\% \text{ Total ash value} = \frac{\text{Wt. of total ash}}{\text{Wt. of crude drug taken}} \times 100$$

ii) Petroleum Ether soluble ash value

Petroleum ether by occasional shaking after 16 hours residue (insoluble matter) tared silica crucible. Incinerated at a temperature not exceeding 450^{0}C for 4 h. Cooled ina desiccator and weighed. The difference in weight represented weight of petroleum ether in soluble ash. Calculated the percentage of petroleum ether insoluble ash with reference to the air-dried drug using the following formula,

Wt. of total ash – Wt.of pet.ether insoluble ash

$$\% \text{ pet.ether insoluble ash value} = \frac{\text{Wt. of total ash – Wt.of pet.ether insoluble ash}}{\text{Wt. of crude drug taken}} \times 100$$

iii) Chloroform soluble ash value

Chloroform by occasional shaking after 16 hours residue (insoluble matter) tared silica crucible. Incinerated at a temperature not exceeding 450^{0}C for 4 h . Cooled in a desiccator and weighed. The difference in weight represented weight of chloroform insoluble ash. Calculated the percentage of chloroform insoluble ash with reference to the air-dried drug using the following formula,

$$\%\text{Chloroform insoluble ash value} = \frac{\text{Wt. of total ash – Wt.of chloroform insoluble ash}}{\text{Wt. of crude drug taken}} \times 100$$

iv) Ethyl acetate soluble ash value

Ethyl acetate by occasional shaking after 16 hours residue (insoluble matter) tared silica crucible. Incinerated at a temperature not exceeding 450^{0}C for 4 h . Cooled in a desiccator and weighed. The difference in weight represented weight of ethyl acetate insoluble ash. Calculated the percentage of ethyl acetate insoluble ash with reference to the air-dried drug using the following formula,

$$\% \text{ ethyl acetate insoluble ash value} = \frac{\text{Wt. of total ash – Wt.of ethyl acetate insoluble ash}}{\text{Wt. of crude drug taken}} \times 100$$

v) Methanol soluble ash value

Methanol by occasional shaking after 16 hours residue (insoluble matter) tared silica crucible. Incinerated at a temperature not exceeding 450^{0}C for 4 h. Cooled in a desiccator and weighed. The difference in weight represented weight of methanol insoluble ash. Calculated the percentage of methanol insoluble ash with reference to the air-dried drug using the following formula,

$$\% \text{ Water insoluble ash value} = \frac{\text{Wt. of total ash – Wt.of water insoluble ash}}{\text{Wt. of crude drug taken}} \times 100$$

vi) Water soluble ash value

Water by occasional shaking after 16 hours residue (insoluble matter) tared silica crucible. Incinerated at a temperature not exceeding 450^{0}C for 4 h. Cooled in a desiccator and weighed. The difference in weight represented weight of water insoluble ash. Calculated the percentage of water insoluble ash with reference to the air-dried drug using the following formula,

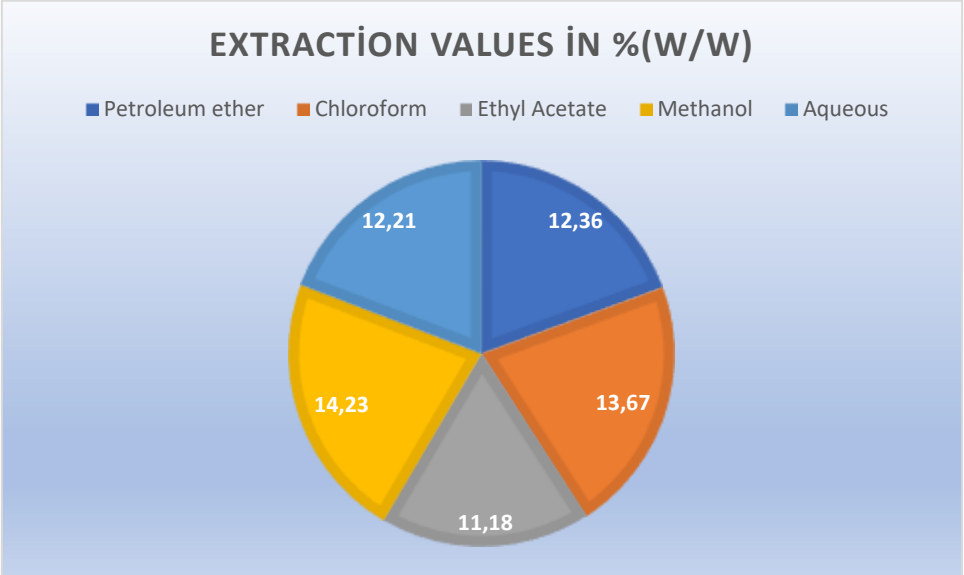
$$\% \text{ Water insoluble ash value} = \frac{\text{Wt. of total ash} - \text{Wt.of water insoluble ash}}{\text{Wt. of crude drug taken}} \times 100$$

RESULTS AND DISCUSSION

Extraction Value

Emilia sonchifolia's extraction yield varied significantly depending on the solvent; methanol obtained the highest extraction value (14.23% W/W) and ethyl acetate obtained the lowest (11.18% W/W). Petroleum ether, chloroform, and aqueous solvents exhibited extraction values of 12.36%, 13.67%, and 12.21% W/W, respectively. The polarity of the solvents and their capacity to dissolve various phytochemical elements are the reasons for the variance in extraction yield between them. Methanol had the highest extraction yield, most likely due to its strong polarity, which allows it to extract a diverse spectrum of polar and semi-polar chemicals such as flavonoids, alkaloids, and phenolics. A comparatively high extraction yield (13.67% W/W) was also demonstrated by the moderately polar solvent chloroform, suggesting that it is useful for extracting specific non-polar and semi-polar molecules.

Figure 1. Extraction Value of *Emilia sonchifolia* in different solvents



Petroleum ether yielded 12.36% W/W, which suggests that non-polar compounds including lipids and terpenoids were present, but in less amounts than more polar components. Ethyl acetate showed the lowest extraction yield (11.18% W/W) due to its intermediate polarity, which would have prevented it from efficiently extracting a wide range of phytochemicals. The aqueous extract (12.21% W/W) showed a moderate extraction efficiency, most likely extracting highly polar components such polysaccharides, glycosides, and tannins. For instance, a study on *Datura metel* leaves found that methanol extraction resulted in a 39.0% yield, while choloroform and petroleum ether yielded 18.9% and 11.2 % respectively (Dixon and Jeena, 2017).

DETERMINATION OF PHYSICAL CONSTANTS

In the present study, plant sample of *Emilia sonchifolia* was investigated for the Physical constants. The observations were tabulated in Table no. 1

Extraction Value

Table 1. Physical constants of *Emilia sonchifolia*

Sl. No	Physico-chemical parameter	Value
1	Loss on drying at 110^0C	2.2 %
2. i)	Ash values- Total ash value	8.1 %
ii	Petroleum ether insoluble ash value	76 %
iii	Chloroform insoluble ash value insoluble ash value	89.8 %
iv	Ethyl acetate insoluble ash value	86.5 %
v	Methanol insoluble ash value	87.2 %
vi	Water insoluble ash value	39.8 %

Emilia sonchifolia physico-chemical investigation revealed the following parameters. 2.2% was lost when drying at 110°C, suggesting a low moisture content. In contrast to the solvent-insoluble ash values, which differed significantly, the total ash value was 8.1%. The insoluble ash content was determined as follows: 76% for petroleum ether, 89.8% for chloroform, 86.5% for ethyl acetate, 87.2% for methanol, and 39.8% for water. The drying loss (2.2%) shows that *Emilia sonchifolia* includes considerable amounts of moisture, which is necessary to keep microorganisms out and ensure the long-term stability of the medicinal ingredients. The presence of inorganic residues, including mineral content and possible interaction with extraneous materials, can be determined by the total ash value of 8.1%. When assessing the quality and purity of botanical products, ash values are essential. In along with assessments of fat, ash, protein, fiber, and carbohydrate content, a study on the nutritional analysis and mineral content of *Emilia sonchifolia* revealed a moisture content of 83.18% (Morshed *et al.,* 2021).

The high solvent-insoluble ash measurements, particularly for methanol (87.2%), ethyl acetate (86.5%), and chloroform (89.8%), indicate that a significant portion of the ash is made up of inorganic substances that are difficult to dissolve in organic solvents. Because petroleum ether dissolves non-polar substances like lipids, its insoluble ash content (76%) is somewhat lower. The lowest water-insoluble ash score of all, 39.8%, indicates that a sizable portion of the ash is water-soluble, possibly including water-soluble minerals and inorganic salts. Water-soluble ash is the percentage of total ash that dissolves in water, indicating the presence of water-soluble minerals and helping to determine the purity of medicinal plant materials. This is consistent with typical pharmacognostic evaluations (Renjini *et al.,* 2024).

SUMMARY AND CONCLUSION

Methanol provided the maximum extraction yield of *Emilia sonchifolia*, whereas ethyl acetate produced the lowest, as a result of variations in phytochemical solubility. According to physico-chemical examination, the total ash content varied, with the lowest water-insoluble ash indicating a considerable presence of water-soluble minerals and the highest insoluble ash in methanol, ethyl acetate, and chloroform. The study shows that the extraction yield of *Emilia sonchifolia* is significantly affected by the solvent selection, with methanol being the most efficient because it can extract a wide variety of bioactive chemicals. The plant's mineral

stability and composition are further highlighted by physico-chemical examination; high solvent-insoluble ash values indicate a strong inorganic content. The low moisture content enhances the plant's potential for long-term therapeutic use. It is suggested to conduct additional qualitative research on the composition of the ash with the goal to investigate its particular mineral content and its pharmacological uses.

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PLASMID CURING POTENTIAL OF *NIGELLA SATIVA* ON MULTIDRUG RESISTANT *STAPHYLOCOCCUS AUREUS*

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ABSTRACT

Multidrug resistant (MDR) bacterial infections pose significant challenges to the public health especially the hospital environment. The study investigate the plasmid curing potential of *Nigella sativa* on multidrug resistant *Staphylococcus aureus* isolated from hospitalized patients. The seed extract of *N sativa* was screened for plasmid curing potential by exposing the isolates to standard antibiotics and subjecting them back to the standard antibiotics after exposure to the extract for reassessment. The *Nigella sativa* post curing treatment of *S aureus* to Levofloxacin 11(91.67%), Amoxicillin 4(33.33%) and *P aeruginosa* to Ofloxacin (87.5%) and Amoxicillin 8(100%). The finding of this study provide insight into the role of plasmid in MDR pathogens and the potential of plant based agents in combating plasmid mediated resistance

Introduction

Resistance to antibiotic may come from parent bacteria however they can as well pick up resistance trait from their competitors (Ringel *et al.*, 2016). Some bacteria have the capacity to inject toxic cocktail into their competitors causing cell lysis and death by genetic materials integration. These organisms may be carrying drug resistance genes that may be transferred into predator by uptake of DNA fragment taken up which has been released by the prey as such signifies that the gene for such resistance can be transferred from one bacterium to another (Barrow & Feltham, 2003; Ringel *et al.*, 2016; Zaman & Chawdhury, 2024).

Plasmid targeting for curing is a promising novel drug if success is recorded because the most essential principal feature of a drug target is for the site not to be analogous to eukaryotic cell, of which only yeast cell is a eukaryote that acquires plasmid and no multicellular organism has that feature of plasmid being in its cell. This paper focus on curing plasmid in multidrug resistant clinical isolates of *Staphylococcus aureus* using organic extracts of *Nigella sativa (*Black seed).

Statement of the Problem

Considering the natural accidental detection of antibiotic, bacterial infections should be treatable with antibiotics but resistance has become a common phenomenon preventing the cure of infections which have varying mechanism in their actions against antibiotics and therefore remain a problem. The antibiotics of different structure, form, mode of action have been developed in curing bacterial diseases but all are almost exhausted due to bacteria resistance which are mostly as a result of alterations in either cellular, physiological or genetic makeup leaving the infection to persist (Sekhi *et al.*, 2021). Such line of drugs have targeted many cellular organelles and other components of the cell but a non-chromosomal DNA known as plasmid contribute to such resistance and render a sensitive bacteria cell to drug resistance by empowering such bacteria host with the ability to resist drugs using such code of genes conferring resistance on the plasmid (Zaman & Chawdhury, 2024).

Justification

Since plasmid has been identified as a problem in the course of AMR, there is need for curing plasmid and reassessment of sensitivity following curing of the plasmid as an identified problem in order to improve the sensitivity of bacteria to antibiotics. The known curing agents like ethidium bromide that have been commonly used cannot be transcribed to human use because of its ability to cause gene mutation since they are known intercalating agents that are dangerous for human use. Therefore there is need to explore organic compounds with minimum health risk as replacement to the chemical like the aforementioned such as acrydine orange and bromide. It will also be a great model to blocking the activity of such plasmid genes capable of rendering antibiotics non active or non-effective (Rithanya & Ezhilarasan, 2021).

The aim of the study is to carry out Plasmid Curing on Multi-drug Resistant *Staphylococcus aureus* with the specific objectives of plasmid curing of MDR *S aureus* using *Nigella sativa*

extracts as curing agents and reassess for sensitivity to the antibiotics the isolates were previously displaying resistance to.

Materials and Methods

Collection of Plants for Plasmid Curing

The seeds of *Nigella sativa* (Black seed, Abbatu sauda) was purchased from herbal store in Sokoto Metropolis and authentication was done in Usmanu Danfodiyo University, Sokoto Biological Science Herbarium with accession number UDU/ANS/0106.

Screening of Extracts of *N sativa* for Antibacterial Activity

Prior to MIC, the screening of extracts of *N sativa* for antimicrobial activity were confirmed using an agar well diffusion with crude extract according to the method of Oyeleke & Manga (2008). For the zone of inhibition, *Nigella sativa* crude of 0.2ml was dispensed in dished borrow of solidified Mueller Hinton Agar.

Determination of Minimum Inhibitory Concentration (MIC) of the Plant Extract

The Minimum Inhibitory Concentration (MIC) of the extract against *S. aureus* were determined using the broth dilution method (Wiegand *et al*., 2008; Cheesbrough, 2006). The MIC is defined as the lowest concentration of extract that inhibited visible growth. Tube dilution method was employed, the N sativa oil extract was serially diluted to obtain varying concentration of 100mg/ml, 50mg/ml, 25 mg/ml and 12.5 mg/ml in Mueller-Hinton Broth containing twin 80.

Standardized suspension of the *S. aureus* was prepared to Mcfarland, typically 10^8 CFU/mL standard. Aliquots 2ml of the prepared Mueller-Hinton broth was introduced into test tubes which was sterilized and cooled before been inoculated with 5µl of the mcfarland standardized bacterial suspension. A series of tubes containing different concentrations of the extracts, (*N sativa*) typically in a doubling dilution series was made. The isolates of *Staphylococcus aureus* (039SA/181SA) suspensions were inoculated into different concentrations prepared in the test tubes. The tubes were incubated at 37^0C for 24hr. The growth was observed, looking for turbidity. The MIC was the lowest concentration of the antimicrobial agent that inhibits growth (Levine, 2018).

Plasmid curing

The plasmid curing was performed as described by Gunjal *et al.* (2020). This process was modified for design of the research plants. The cultures of *S aureus* was grown in Mueller-Hinton broth in the presence of plant extracts *Nigella sativa* at sub-inhibitory concentration of 200, 100 and 50ul/ml for 24 h at 37^0C. The growth were recovered into Nutrient agar to obtain well isolated colonies of cured isolates. Inoculated Acridine orange of (10µg/mL) in Mueller Hinton Broth was used as a positive control and untreated bacteria culture in MHB as a negative control. The bacteria grown in the extract were sub-cultured after 24 hours for reevaluation of their antimicrobial sensitivity. The strain which failed to grow in the presence of an antibiotic,

was considered as putative cured derivatives. The yielded rate of curing response was subjected to sensitivity reevaluation for record of curing efficiency of the plant extracts.

Antimicrobial Activity Test after Curing

Curing require growing the resistant bacteria in the subminimum inhibitory concentration of each extract and then subculture in a freshly prepared nutrient agar before preparing for antibacterial activity of the previously resisted antibiotics. Aliquots of 0.1 mL of inoculum suspension with reference to mcfarland standard of the cured isolates were lawn grown on Mueller Hinton agar plates using the disc diffusion method as previously applied in the initial antibiogram testing. The plates were kept for 30 min for diffusion. Antibiotic discs were impregnated in to the MHA plates. The plates were incubated at 37^0C for 24 hours and the zones of inhibition were measured for Post curing sensitivity in mm as zone of inhibition (Muscara *et al.*, 2021).

Bio-centrifugation for Plasmid DNA Extraction

Plasmid extraction according to Altamirano *et al.* (2021) was slightly modified in accordance with the manufacturer's instruction of Hi yield. Bacteria cells were grown for 24hours, washed in nuclease free water then centrifuged. The supernatant was discarded living the cell pellets. The Hiyield reagents for plasmid DNA extraction was employed and conducted according to Laguerre *et al* (1992). The plasmid curing capacity of *N sativa* was assessed on agarose gel electrophoretic machine showing bands of DNA. This was done according to the protocol of Adeyemo & Onilude, (2015) with little modification. Buffer preparations of Hi yield plus plasmid mini kit protocol was used for spin column. Prior to extraction, kit were optimized as follows; RNase was centrifuged and was entirely added to PD1 Buffer. The mixture were shaken for few seconds and stored at 4°C. Absolute ethanol was added to wash buffer and mixture well shake PD2 was checked for precipitation and observed precipitates were heaped to warm at 37°C. Bacteria colony was harvested with sterile applicator sticks into 1.5ml centrifuged tube containing nuclease free water micro centrifugation for proper harvest yield. In the re-suspension, aliquot (200µl) of PD1 Buffer (RNase A) was added to the 1.5ml centrifuge tube containing cell pellet Two microliter (2µl) of blue mix lysis buffer was added to the same 1.5ml micro centrifuge tube and well mixed by shaking. That is 1:100 mix of Blue mix buffer and PD1. The mixture was continuously pipetted until cells were noticed lysed and dissolved. Then 200µl of PD2 buffer was added and then mixed by inverting the tube 10 times. The mixture were allowed to stand incubated for 2 minutes at room temperature. All precipitates became dissolved after adding PD2 buffer. Then 300µl PD3 buffer was added and mixed by inverting the tube 10 times.

It was centrifuged at 16000kg for 3 minutes. After adding PD3 buffer QPD column was placed in a 2ml collection tube. For DNA binding, all supernatants were transferred to QPD column using a narrow tip pipette. The supernatant was completely centrifuged for 30 seconds at room temperature. The flow through was discarded and QPD column was placed back to the 2ml collection tube. Six hundred microliter (600µl) of buffer was added in the QPD column and centrifuged at 16000kg for 3 minutes at room temperature in order for the column matrix to be

dry. The QPD was transfered to new 1.5ml micro centrifuge tube and second wash was performed.

The elution buffer of 50µl TE was added into the center of the column matrix and allowed to stand for 2 minutes for proper complete absorption of TE. Then followed by centrifugation at 16000xg for 2 minutes to elute all plasmid DNA.

Agarose Gel Electrophoresis of the Plasmid DNA

Agarose powder of 1.0g was dissolved in 100ml of 1× Tris Borate Ethylene di-tetra acetate buffer in a 500mL Erlen Meyer Conical flask. The flask was swirled to dissolve the agarose powder and heated microwave oven until clear solution of the molten agarose was achieved. The molten agarose was allowed to stand before cooling on bench and 5µL of ethidium bromide (intercalating agent) was added into the gel for visual clarity of DNA fragments in the course of imaging. Comb was placed in cast to form well in loading the amplicons. Gel was submerged with 1× Tris EDTA running buffer in the electrophoretic chamber, PCR products was mixed with the loading dye (0.25% bromophenol blue, 0.25% xylene cyanol and 30% glycerol). The first and last well was loaded with 1kb molecular weight marker of DNA ladder as an estimate of resulting DNA fragment. Electrophoretic chamber was connected to source of power and run at 100Volts (6v/cm) for 40minutes. The bands of DNA was viewed by UV light illuminated images (Lee *et al.*, 2012).

The descriptive and Analysis of variance (ANOVA) was used to calculate the differences in the response to antibiotics and response to curing by *C procera* and *N sativa* extracts respectively using Excel Package with degree of confidence gazette at 95% of 0.05 pvalue.

Results

Table 1 shows the zone of inhibition exhibited by *S aureus* to standard antibiotics before subjecting them to plasmid curing indicating over 90% been resistant to amoxicillin and rifampin. Table 2 presents the zone of inhibition for antimicrobial screening of crude extracts of *N sativa*. The crude concentration of the extract was screened on isolate 39SA, 181SA for antimicrobial activities. *N sativa* yielded a zone of inhibition of 15mm on 39SA, 14mm on. Table 3 show the minimum inhibitory concentration of *N sativa* extract at 0.25ml/ml on *S aureus* 39SA/181SA.

Table 1 Plasmid Positive *Staphylococcus aureus* Pre Curing Antibiogram Pattern

Staphylococcus Aureus	**E**	**LEV**	**CPX**	**CN**	**AML**	**S**	**RD**
003SA	0	0	0	20	0	15	0
12SA	0	0	0	20	0	16	0
14SA	0	25	22	20	0	0	0
31SA	0	0	0	0	0	20	0
37SA	20	21	0	29	0	18	0
39SA	20	0	18	23	0	0	0
96SA	20	0	30	25	0	20	0
97SA	0	0	0	0	0	18	0
120SA	0	0	0	0	0	0	0
127SA	0	0	0	0	0	15	15
129SA	0	0	11	0	0	0	0
181SA	15	15	17	13	13	0	0

Table 2 Extracts Antimicrobial Screening based on Zone of Inhibition

Strains	MIC Values
181	0.25ml/ml
39	0.25ml/ml

Table 3: Minimum Inhibitory Concentration (MIC) of *Nigella sativa* extract Against *S aureus* (SA) and *P aeruginosa* (PA)

Tested Isolates	*N sativa*
039SA	15mm
181SA	14mm

Tables 4 is a presentation of the sensitivity pattern as an outcome of plasmids curing with *N sativa* at concentration of 50µl, 100µl and 200µl on multidrug resistant plasmid positive of *S aureus*. The analysis confirmed a variability in the efficacy of antibiotics and the impact of concentration of *Nigella sativa* on *S aureus* susceptibility. Two way ANOVA was conducted with the P-value 1.000 for the effect of antibiotic not been significant however concentration

of *N sativa* gave a significant value of 0.016. This implies that concentration variation has significant effect on the response of the cured *S aureus* isolates to the drugs they were previously resisted to.

Table 4: Antibiogram profile of *Staphylococcus aureus* Post-Plasmid Curing with *Nigella sativa* Against Standard Antibiotics

Staphylococcus aureus		**E**	**LEV**	**CPX**	**CN**	**AML**	**S**	**RD**
003SA	50ul	0	0	0	0	0	0	0
	100ul	0	0	0	0	0	0	0
	200ul	0	0	0	0	0	0	0
12SA	50ul	22	26	24	20	0	20	14
	100ul	0	26	24	0	0	0	0
	200ul	0	0	0	0	0	0	0
14SA	50ul	0	26	23	18	0	13	0
	100ul	0	0	0	0	0	0	0
	200ul	0	0	0	0	0	0	0
31SA	50ug	20	0	0	0	14	0	0
	100ug	0	30	34	20	0	22	0
	200ug	0	0	0	25	17	22	0
37SA	50ug	16	30	30	22	0	20	14
	100ug	24	30	0	22	0	17	0
	200ug	16	19	30	25	0	22	0
39SA	50ug	17	28	30	24	0	21	17
	100ug	24	34	32	20	0	18	0
	200ug	18	0	14	21	0	22	0
	50ug	0	0	0	25	0	18	14

96SA								
	100ug	0	0	0	22	0	20	0
	200ug	22	40	38	0	21	0	18
97SA	50ug	0	21	0	23	0	22	0
	100ug	0	22	24	21	0	20	16
	200ug	0	26	25	24	0	21	14
120SA	50ug	13	23	24	25	0	23	14
	100ug	0	23	22	20	0	20	15
	200ug	22	20	22	22	0	0	13
127SA	50ug	0	0	0	0	0	20	0
	100ug	0	0	0	30	20	20	0
	200ug	25	30	26	28	0	15	13
129SA	50ug	0	30	27	18	0	20	13
	100ug	0	21	22	19	0	21	15
	200ug	0	28	29	20	0	20	15
181SA	50ug	0	0	18	0	0	22	17
	100ug	0	0	0	0	0	15	0
	200ug	15	28	30	0	25	12	0

DISCUSSION

Effective plasmid curing serve as a means of restoring bacteria susceptibility reinstating antibiotics integrity for effective treatment options rather than closing door at some antibiotics of choice. With the increment of multiple drug resistant bacteria worldwide *P aeruginosa* and *Staphylococcus aureus* pose great danger to the society (Okoye *et al*., 2022). The two bacteria are always disseminated with plasmid mediated resistance (Almuhayawi *et al.*, 2023). Ciprofloxacin resistance pattern is similar in the *S aureus* strain as found against levofloxacin hence similar success of plasmid curing was also achieved with 11(90.9%) of the isolates however 50µl of the oil extract outperformed the 200µl concentration of *N sativa* as 6 and 5

strains were cured respectively. However *Pseudomonas aeruginosa* was 100% sensitive to Ciprofloxacin.

Gentamicin resistance were cured at 100µl and 200µl concentration of the oil extract as 4 of the strains resistant became cured. Among the amoxicillin resistant strain which is most common in this study among the MDR *S aureus* were intermediate resistant however, the effect of *N sativa* was not so pronounced as many do change from their initial status hence only 4(33.33%) reverted sensitive while *P aeruginosa* had only 196PA uncured as 7(87.5%) became cure. In fact, the 33.33% curing affirm the reported output from Yogini *et al.* (2015) with similar curing percentage of *Cuminum sativum* on Acinetobacter sp, and Klebsiella sp. Speaking from this study, one may conclude that specific antibiotics is favored at one concentration of extract to the other as established from the post curing experiments. Streptomycin resistant among the MDR *S aureus* were 100% cured with *N sativa* oil extract while Rifampicin resistance is upheld except for 4(33.33%) that change in zone of inhibition ranging between 16mm to 18mm classifying them as intermediate of sensitive and resistant. This may be that more concentration is required or variation of concentration is needed. The level of plasmid curing of *Nigella sativa* N-Hexane extract is between 33.33%-90.9% on *S aureus* at varying concentrations of 50µl, 100µl and 200µl per milliliter. The result from this study is similar to the report of Maryam *et al*. (2016) who reported 100% cured of MDR bacteria in their study.

Conclusion

The curing electrophoretic gel image revealed a positive outcome from extracts of reversing the resistance of *S aureus* and *P aeruginosa*. Following treatment with *C procera* the reassessment antibiogram indicated *S aureus* resistance reversal to Levofloxacin (100%) and Amoxicillin 5(47.67%) while *P aeruginosa* has resistant reversal to Ofloxacin 8(100%) and Amoxicillin 8(100%) indicating high response. The *Nigella sativa* post curing treatment of *S aureus* to Levofloxacin 11(91.67%), Amoxicillin 4(33.33%) and *P aeruginosa* to Ofloxacin (87.5%) and Amoxicillin 8(100%). The finding of this study provide insight into the role of plasmid and resistant genes in MDR pathogens and the exploration potential of plant based agents in combating plasmid mediated resistance.

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EVALUATION OF THE RELATIONSHIP BETWEEN BLOOD PH, ANION GAP AND BLOOD ELECTROLYTE CONCENTRATION IN CALVES WITH HYPOGLYCEMIC DIARRHEA

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ABSTRACT

Early detection of acidemia in calves is important in preventing complications and organ and tissue damage. Therefore, this study aimed to evaluate the relationship between hypoglycemia in calves and blood pH, anion gap and electrolyte concentration. In this study, 30 Simmental calves of different sexes, aged 1-28 days, were used. The hypoglycemic group consisted of 20 calves, while the healthy group consisted of 10 calves. Calves with diarrhea, weakness, no sucking reflex, and glucose concentrations <4.4 mmol/L were included in the hypoglycemic group. Blood samples were taken from the jugular vena of the calves in the study into 1 ml lithium heparin syringes for blood gases and into 2 ml anticoagulant tubes for hematological analyses. Blood gas analysis was performed using a portable automatic device, while leukocyte count was analyzed using a hematology device. There was no statistically significant difference between hypoglycemic and healthy calves in terms of respiratory frequency ($p>0.396$), body temperature ($p>0.279$), sodium ($p>0.691$), potassium ($p>0.152$) and chloride ($p>0.986$). However, heart frequency ($p<0.046$) of hypoglycemic calves was found to be statistically significantly higher than healthy calves. Glucose ($p<0.001$), blood pH ($p<0.001$) and bicarbonate concentration ($p<0.001$) of hypoglycemic calves were found to be significantly lower than healthy calves. In contrast, it was determined that the anion gap ($p<0.001$), WBC ($P<0.005$) and HCT values ($p<0.002$) of hypoglycemic calves were significantly higher than those of healthy calves. In conclusion, this study evaluated blood pH, anion gap and electrolyte concentrations in hypoglycemic calves and revealed a significant relationship between glucose concentration and anion gap, blood pH and bicarbonate levels. In the future, it is necessary to evaluate blood electrolyte concentrations and other variables in large populations and hypoglycemic calves of different severities and to evaluate their effects on mortality.

Keywords: Calf, Diarrhea, Electrolyte, Blood Ph, Anion gap

INTRODUCTION

The first 3-4 weeks of life, referred to as the "neonatal period" in calves, are a critical phase in the survival of calves. It is stated that calf diarrhea in this phase constitutes 86% of the total costs in a farm (Cho and Yoon, 2014; Lewis and Phillips, 2017). Among the problems seen in livestock farms, calf diarrhea is the most common and most common disease in our country and in the world (Berchtold, 2009; Cho and Yoon, 2014). Despite many preventive and therapeutic developments to prevent losses due to calf diarrhea, losses due to calf diarrhea are still serious (Roussel and Brumbaugh, 1991; Lorenz and Trefz, 2024). While an average of at least 15% of calf deaths occur annually in Turkey, the cost of these deaths to the country is quite high (Sahal et al., 2018).

Metabolic acidosis, hyperlactatemia, hypovolemic shock, cardiac and hepatic failure, azotemia, hyponatremia and hypoglycemia are common complications that develop due to diarrhea in calves (Trefz et al., 2016). Among these, hypoglycemia has recently been given careful attention due to its effect on mortality (Trefz et al., 2016; Trefz et al., 2017). Since calves have sufficient energy reserves, maternal factors, congenital disorders and neonatal diseases can potentially lead to disruption of blood glucose homeostasis, as any condition that disrupts energy intake (Carlson, 1996). Trefz et al. (2017) reported in their study that hypoglycemia has an important place in predicting mortality.

Metabolic acidosis is defined as a condition characterized by a decrease in blood pH and blood bicarbonate concentration (Lorenz and Trefz, 2024). Disturbance of blood acid-base balance leads to serious damage to tissues and organs (Adrogue and Madias, 1998). As the severity of acidosis increases, decreases in liver blood flow, glomerular filtration rate, cardiac contractility and cardiac output are common complications (Adrogue and Madias, 1998; Trefz et al., 2017). Early detection of acidemia in calves is important in preventing complications and organ and tissue damage. Therefore, this study aimed to evaluate the relationship between hypoglycemia in calves and blood pH, anion gap and bicarbonate concentration.

MATERIAL AND METHODS

This study was initiated after the approval of the Bingöl University Animal Experiments Local Ethics Committee (Meeting Number: 2025/02, Decision Number: 02/02).

Animal Selection

In this study, 30 Simmental calves of different sexes, aged 1-28 days, were used. The hypoglycemic group consisted of 20 calves, while the healthy group consisted of 10 calves. Calves with diarrhea, weakness, no sucking reflex, and glucose concentrations <4.4 mmol/L were included in the hypoglycemic group (Trefz et al., 2016; Smith et al., 2015). After routine clinical examinations of the calves, the rectum of the calves was stimulated by rectal stimulation in order to determine infectious agents in both healthy and hypoglycemic calves, and their stools were collected in sterile feces containers. Etiological screening was performed using rapid immunochromatographic commercial diarrhea test kits (Anigen Rapid BoviD-5 Ag Test Kit, Bionote, Inc. Korea) for Rotavirus, Coranavirus, Escherichia coli K99, Cryptosporidium

parvum and Giardia lamblia from fecal samples. In addition, calves with prematurity, congenital anomalies and surgical problems were excluded from the study in both groups.

Blood Collection and Laboratory Analysis

Blood samples were taken from the jugular veins of the calves in the study into 1 ml lithium heparin syringes for blood gas and into 2 ml anticoagulant tubes for hematological analyses. Blood gas analyses were performed using a portable automatic device, while leukocyte counts were analyzed using a hematology device.

Statistical analysis

Data were analyzed using software [SPSS 26 (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) and Graph Pad Prism (Prism 9 for Windows, version 9)]. Data are presented as mean ± standard deviation. Shapiro-Wilk test was used to assess the normal distribution of the data. When analyzing the distinctions between hypoglycemic and healthy calves groups, Mann-Whitney U test was used for data that did not meet the criteria for normal distribution. Conversely, Independent Samples T-test was applied to data showing normal distribution. Correlation between variables was examined by Spearman's rank correlation test. Statistical significance level was determined as $p<0.005$.

RESULTS

Table 1 shows the mean-standard error and statistical significance between groups for clinical examination findings of healthy and hypoglycemic groups. No statistically significant difference was found between hypoglycemic and healthy calves in terms of respiratory frequency ($p>0.396$) and body temperature ($p>0.279$). However, it was determined that the heart rate of hypoglycemic calves ($p<0.046$) was statistically significantly higher than healthy calves.

Table 2 shows the mean-standard error and statistical significance between groups for biochemical values of healthy and hypoglycemic groups. Glucose ($p<0.001$), blood pH ($p<0.001$) and bicarbonate concentration ($p<0.001$) of hypoglycemic calves were found to be significantly lower than healthy calves. In contrast, anion gap ($p<0.001$), WBC ($p<0.005$) and HCT ($p<0.002$) of hypoglycemic calves were found to be significantly higher than healthy calves.

Table 1. Mean-standard error and statistical significance between groups of clinical examination findings of healthy and hypoglycemic groups.

Parameters	Hypoglycemic Group	Healthy Group	P value
Heart rate (Number of heart beats per minute)	122±36.51	102±18.61	0.046
Respiratory Frequency (Respiratory rate per minute)	35.45±11.42	35±0.9	0.396
Body Temperature (oC)	37.54±1.58	36.59±1.31	0.279

The data are given as mean ± standard deviation. a, b: The differences between the groups with different letters on the same line are significant. $p < 0.05$.

Table 2. Mean-standard error and statistical significance between groups of biochemical values of healthy and hypoglycemic groups.

Parameters	Hypoglycemic Group	Healthy Group	P value
Glucose (mmol/L)	$3.1±1.04^a$	$4.85±0.65^b$	0.001
Anion Gap (mmol/L)	$21.8±6.78^a$	$3.6±3.62^b$	0.001
Blood Ph	$7.03±0.3^a$	$7.42±0.12^b$	0.001
Bicarbonate (mmol/L)	$15.64±7.63^a$	$30.51±1.13^b$	0.001
WBC ($x10^9$)	$18.16±10.67^a$	$12.18±1.10^b$	0.005
Sodium (mmol/L)	133.95±7.07	134.2±1.26	0.691
Potassium (mmol/L)	5.78±1.75	5.69±0.31	0.152
Chlorine (mmol/L)	101.75±8.8	102.5±1.75	0.986
HCT (%)	$36.6±7.63^a$	$25.7±4.5^b$	0.002

The data are given as mean ± standard deviation. a, b: The differences between the groups with different letters on the same line are significant. $p < 0.05$.

DISCUSSION

As a result of the limited energy reserves of calves in the neonatal period, the development of diarrhea, pneumonia and other neonatal diseases leads to the deterioration of glucose metabolism in animals. In addition, blood pH, bicarbonate and anion gap variables contribute significantly to the formation of mortality by causing acidemia (Trefz et al., 2017; Trefz et al., 2016; Kiran et al., 2015). However, no study has been found evaluating the relationship between blood pH, bicarbonate and anion gap concentrations of hypoglycemic calves . Therefore, the aim of this study is to evaluate the relationship between hypoglycemia in calves and blood pH, bicarbonate and anion gap.

Blood pH is an important blood gas parameter used in the evaluation of acid and base load in the blood. A blood pH of less than 7.35 is called acidemia, and a blood pH of more than 7.45 is called alkalemia (Trefz et al., 2017). Metabolic acidosis occurs when blood pH is low or bicarbonate loss occurs (Trefz et al., 2017; Trefz et al., 2016). Many studies on critically ill people have reported that blood pH <7.20 indicates high intensive care mortality and poor prognosis (Jung et al., 2011; Kiran et al., 2015). In parallel with studies in human medicine, a study on calves with neonatal diarrhea reported that blood pH <6.85 has a significant effect on mortality in calves and is important in predicting diarrhea (Trefz et al., 2017). Similarly, in a study conducted by Ekinci et al. (2024) on diarrheic calves, it was determined that blood pH was significantly low and was a parameter that had a serious effect on mortality. The reason why blood pH is so effective on mortality is related to the fact that it causes serious damage to many different tissues and organs (Androgue and Madias, 1998). Since the evaluation of the effects of blood pH, bicarbonate and anion gap on mortality in hypoglycemic calves in this study was not included in the scope of this study, it was not evaluated. In this study, the blood pH of the calves in the hypoglycemic group (7.03±0.3) was significantly lower than the calves in the healthy group (7.46±0.05). In addition, it was determined that there was a high correlation between hypoglycemia and blood pH. Therefore, this result should be considered that metabolic acidosis may have developed in diarrheic calves with hypoglycemic blood glucose concentration under field conditions.

The anion gap is a value obtained from the difference between measurable anions and cations and shows the acid-base status of the organism well. This value is calculated according to the electroneutrality principle and presented (Ewaschuk et al., 2003; Ekinci et al., 2024). The anion gap value is an important parameter that cannot be easily measured under field conditions such as D-lactate and L-lactate, but has clinical use because it correlates well with the anion gap value (Trefz et al., 2017; Ekinci et al., 2024). In a study conducted by Gomez et al. (2013) on 264 diarrheic calves, they reported that the anion gap value was significantly correlated with sucking reflex, body posture (sternal, lateral and standing) and poor animal behavior. In a study conducted on cattle with different diseases, it was reported that the anion gap value showed a moderate correlation with L-lactate, but had a limited effect in predicting blood L-lactate concentration (Constable et al., 1997). In a study conducted on 52 diarrhoeic calves by Ewaschuk et al. (2003), it was reported that there was no correlation between the anion gap value and L-lactate concentration, but there was a significant correlation between the anion gap and D-lactate and DL-lactate. The author attributed this difference between the studies to obtaining data from a clinical population and stated that it was related to the experimental nature of diarrhoea in the calves in the previous study (Ewaschuk et al., 2003). In a study conducted

on 89 diarrheal calves with neonatal diarrhea, it was reported that the anion gap concentration was significantly higher in non-survivors than in survivors (Ekinci et al., 2024). Another study conducted by Lee et al. (2020) reported that the anion gap concentration was significantly higher in non-survivors and also that the anion gap level was correlated with the degree of dehydration and worsening of the clinical condition. In line with previous studies, in this study, the anion gap concentration in hypoglycemic calves was significantly higher than in healthy calves and also that the anion gap level was significantly negatively correlated with blood glucose concentration.

Electrolyte levels in the blood are measured through analysis and the condition in which their levels are high or low is called electrolyte imbalance. Imbalances in calcium, magnesium, chloride, phosphorus, sodium and potassium levels cause significant problems that can threaten the lives of animals (Constable, 2003). With the widespread use of blood gas analyzers, the measurement of electrolytes such as sodium, potassium and chloride has become easier. This has allowed the accurate knowledge of the blood electrolyte concentration of diseased cattle and the appropriate treatment (Kim et al., 2015). In some studies, it has been reported that sodium, potassium and chloride have an important effect on the evaluation of mortality in calves and the treatment of the disease (Constable, 2003; Trefz et al., 2017; Ekinci et al., 2024). In a study conducted by Lee et al. (2020), it was determined that sodium, potassium and chloride concentrations had no effect on mortality. In contrast, in a study conducted by Trefz et al. (2017) on 1400 diarrheal neonatal calves, it was determined that sodium and potassium concentrations were significantly higher in non-survivors and that sodium level was a predictor of mortality. In a study conducted by Ekinci et al. (2024) on diarrheal neonatal calves, it was reported that chloride and sodium concentrations were significantly higher in non-survivors than in survivors, but only chloride level had a significant effect on mortality. In this study, no statistically significant difference was determined between hypoglycemic and healthy calves in terms of sodium, potassium and chloride concentrations. The possible reason for this may be related to the degree of dehydration, severity of diarrhea, etiological differences and analytical conditions of the analyses.

In conclusion, this study evaluated blood pH, anion gap and electrolyte concentrations in hypoglycemic calves and revealed a significant relationship between glucose concentration and anion gap, blood pH and bicarbonate levels. In the future, it is necessary to evaluate blood electrolyte concentrations and other variables in large populations and hypoglycemic calves of different severities and to evaluate their effects on mortality.

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IN VITRO COMPATIBILITY OF THE ENTOMOPATHOGENIC FUNGI BEAUVERIA BASSIANA (BALS.) VUILL. AND METARHIZIUM BRUNEUMU WITH DIFFERENT FUNGICIDES

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ABSTRACT

Chemical pesticides are widely used in agriculture to control disease and pest populations. However, these chemicals cause significant problems such as environmental pollution, damage to non-target organisms and the development of insect resistance. Therefore, biological control methods are gaining more and more importance. Entomopathogenic fungi, especially *Beauveria bassiana* and *Metarhizium bruneum*, stand out as effective agents in biological control of insect pests. These fungi infect host insects, causing their death and controlling their populations naturally. Entomopathogenic fungi also exert antagonistic effects against pathogenic fungi in the phyllosphere and rhizosphere or in plant tissues as endophytes through parasitism, competition and antibiosis. However, some fungicides used in agriculture may adversely affect the growth of entomopathogenic fungi. Determination of the interactions of fungicides with biological control agents is of great importance for sustainable agricultural practices. The main objective of this study was to evaluate the compatibility of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium bruneum* isolates with different fungicides in *invitro*. Within the scope of the study, it was aimed to determine the effects of the fungicides on the mycelial growth of the entomopathogenic fungi. Thus, it is aimed to contribute to environmental sustainability in agricultural production by reducing the fungicide use.

ENTOMOPATOJENİK FUNGUS *BEAUVERİA BASSİANA* (BALS.) VUILL.'İ VE *METARHİZİUM BRUNEUMU*'UN FARKLI FUNGİSİTLERLE *İN VİTRO* UYUMLULUĞU

ÖZET

Tarımda hastalık ve zararlı böcek popülasyonlarını kontrol altına almak amacıyla yaygın olarak kimyasal pestisitler kullanılmaktadır. Ancak, bu kimyasallar çevresel kirlilik, hedef dışı organizmaların zarar görmesi ve böceklerin direnç geliştirmesi gibi önemli sorunlara yol açmaktadır. Bu nedenle, biyolojik mücadele yöntemleri giderek daha fazla önem kazanmaktadır. Entomopatojen funguslar, özellikle *Beauveria bassiana* ve *Metarhizium bruneum*, zararlı böceklerle biyolojik mücadelede etkili ajanlar olarak öne çıkmaktadır. Bu funguslar, konukçu böcekleri enfekte ederek onların ölümüne neden olmakta ve popülasyonlarını doğal yollarla kontrol altına almaktadır. Entomopatojen funguslar, filosfer ve rizosferde ya da endofit olarak bitki dokuları içinde patojenlere karşı parazitizm, rekabet ve antibiyosis yoluyla antagonistik etki göstermektedirler. Bununla birlikte, tarımsal üretimde kullanılan bazı fungisitler, entomopatojenik fungusların gelişimini olumsuz etkileyebilir. Fungisitlerin biyolojik mücadele ajanlarıyla olan etkileşimlerinin belirlenmesi, sürdürülebilir tarım uygulamaları açısından büyük önem taşımaktadır. Bu çalışmanın temel amacı, entomopatojen fungus *Beauveria bassiana* ve *Metarhizium bruneum* izolatlarının farklı fungisitlerle *in vitro* ortamda uyumluluğunu değerlendirmektir. Çalışma kapsamında, kullanılan fungisitlerin fungusların misel gelişimi üzerindeki etkilerini belirlemek amaçlanmıştır. Böylece, fungusit kullanımını azaltarak tarımsal üretimde çevresel sürdürülebilirliğe katkı sağlanması amaçlanmaktadır.

1.GİRİŞ

Tarımda kimyasal yöntemlerle mücadele, zararlı organizmaların kontrol altına alınması amacıyla insektisit, fungisit, herbisit gibi pestisitlerin kullanılmasıdır. Bu yaklaşım, kısa sürede yüksek ürün elde etmeyi sağladığı için özellikle modern tarımda sıkça tercih edilmektedir. Ancak pestisitlerin bilinçsiz ve yoğun kullanımı; çevre kirliliğine, yararlı ve hedef dışı canlıların zarar görmesine, ürünlerde kalıntı oluşumuna ve zararlı organizmaların bu kimyasallara karşı direnç kazanmasına yol açmaktadır. Bu sorunlar, bütünleşik zararlı yönetimi ve biyolojik mücadele gibi çevre dostu ve sürdürülebilir yöntemlerin gerekliliğini daha da ön plana çıkarmıştır (Aktar, Sengupta, & Chowdhury, 2009; Pimentel, 2005).

Bitki hastalıklarına karşı biyolojik mücadele yöntemleri, 1920'li yıllarda dikkat çekmeye başlamıştır. Bu alandaki ilk önemli gelişmelerden biri, yeşil gübre uygulamalarıyla patates uyuzu hastalığı etmeni olan *Streptomyces scabies* (Thaxter) Lambert and Loria'nın kontrol altına alınması olmuştur (Özaktan, 2010).

Biyolojik mücadele genel bir ifade ile bitkilere zarar veren mikroorganizmaların faydalı olarak adlandırılan mikroorganizmalar tarafından doğrudan engellenmesi veya zarar seviyelerinin minimuma indirgenmesi olarak ifade edilmekte olup, son yıllarda üzerinde yoğun biçimde çalışılan çevre dostu bir mücadele yaklaşımıdır (Sülü ve ark., 2016).

Biyolojik mücadelede etkili olan doğal düşmanlar predatörler, parazitoidler ve patojenler olarak üç ana grupta toplanmıştır. Predatörler, zararlılar üzerinde doğrudan beslenerek etkili olan faydalı böceklerdir. Parazitoidler, yumurtalarını diğer bir böceğin ergin ya da ergin öncesi dönemleri dediğimiz yumurta, larva ve pupa gibi gelişme dönemleri içerisine bırakarak etkili olan genellikle arı grubundan faydalılardır. Patojenler ise diğer canlılarda olduğu gibi zararlılarda da hastalık yapan etmenlerdir. Hastalık yapan patojenler funguslar, bakteriler ve virüsler gibi etmenlerdir (Weeden et al., 2007). Bu kapsamda mikrobiyal mücadele etmenleri içerisinde yer alan entomopatojen funguslar (EPF) pek çok zararlının doğal yollarla baskı altına alınmasında etkili olan mikroorganizmalardır (Kılıçarslan, 2024). Bu organizmalar, doğrudan böceklerin dış kütikulasına tutunarak enfeksiyon başlatır ve konağın iç dokularında çoğalarak ölümüne neden olurlar. Bu özellikleri sayesinde, özellikle bitki özsuyu ile beslenen zararlılarla mücadelede etkili olmaktadırlar (Sevim ve ark., 2014).

Bakteri ve virüslerden farklı olarak, entomopatojen funguslar konaklarını yalnızca bağırsaktan değil, aynı zamanda solunum deliklerinden ve integumentin yüzeyinden de enfekte edebilmektedir. Bu özellik sayesinde konağı tarafından yenilmesine gerek yoktur ve konak aralığı çiğneme yapan böcekler ile sınırlı kalmamaktadır (Yıldız, 2015).

EPF'ler, sadece zararlı böceklerle mücadelede değil, aynı zamanda bitki gelişimini destekleme ve bitki hastalıklarına karşı direnç kazandırma gibi faydalı etkilere de sahiptir. Örneğin, *Beauveria bassiana* ve *Metarhizium robertsii* gibi türler, bitkilerle endofitik ilişkiler kurarak bitki büyümesini teşvik eder ve patojenlere karşı savunma mekanizmalarını aktive ederbilirler (Mertoğlu, 2022).

2. MATERYAL VE YÖNTEM

2.1 MATERYAL

Çalışmanın ana materyalini Tokat ilinde farklı tarımsal alanlardan izole edilmiş olan Tokat Gaziosmanpaşa Üniversitesi Bitki Koruma Bölümü Fitopatoloji laboratuvarında bulunan Entomopatojen Fungus stok kültüründen steril ortamda çoğaltılmış olan funguslar (Çizelge 2.1) ve %50 Captan Islanabilir Toz (WP), %80 Thiram Suda Islanabilir Toz (WP) oluşturmuştur.

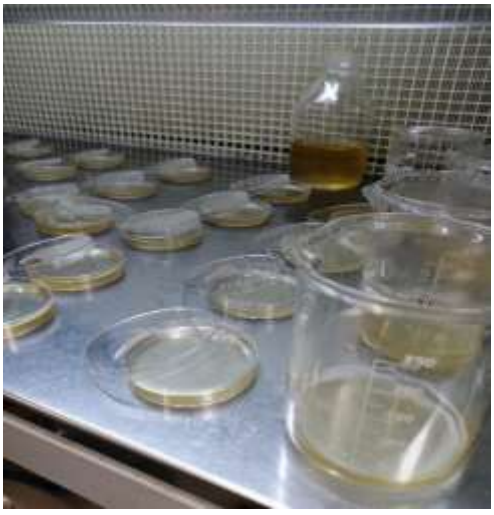
Çizelge 2.1 Çalışmada kullanılan Entomopatojen Funguslar

İZOLAT NUMARASI	BİLİMSEL ADI	KAYNAKLAR	ACCESSION NUMARASI
SİVAS-10	*Beauveria bassiana*	Şeker pancarı	MW07711
BEE2	*Beauveria bassiana*	Biber	MW07712
ORP-13	*Metarhizium brunneum*	Toprak	MW410195
ORP-18	*Metarhizium brunneum*	Toprak	MW410200

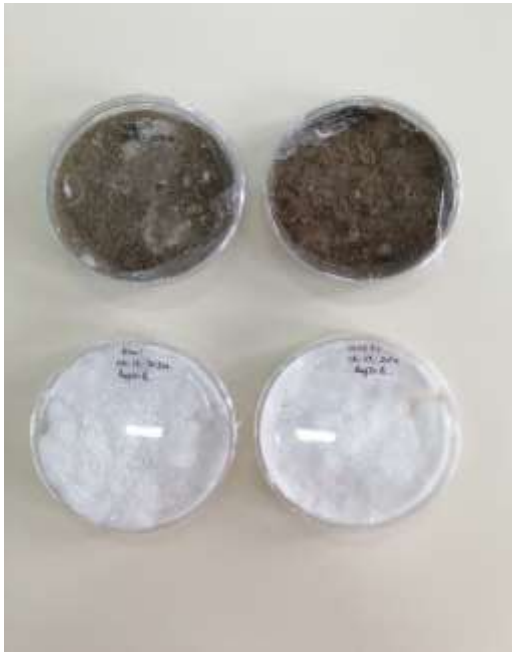
2.2 YÖNTEM

2.2.1 ENTOMOPATOJEN FUNGUS ÜRETİMİ

Steril ortamda hazırlanan Potato Dekstroz Agar (PDA) steril kabin içerisine 90 mm petrilere dökülmüş ve katılaşması beklenmiştir (Şekil 3.1). Besi yeri EPF aktarımına hazır hale geldiğinde fungus diskleri besi ortamı içeren petri kaplarına aktarılarak 25±2 °C de inkübasyona bırakılmıştır (Şekil 3.2).



Şekil 2.1 Steril kabinde PDA hazırlanması



Şekil 2.2 Entomopatojen Fungus

2.2.2 ENTOMOPATOJEN FUNGUSLARIN FUNGUSİTLERE REAKSİYON TESTLERİ

Öncelikle çalışmada kullanılan Thiram ve Captan etkili maddeli fungusitlerin önerilen dozunun 1/8, 1/16 ve 1/32'si otoklovda steril edilen PDA besi ortamları 45-50 ^{0}C'ye eklenerek manyetik karıştırıcıda homojen bir dağılım sağlanana kadar karıştırılmıştır. Daha sonra 60 mm'lik petri kaplarına 10 ml/petri olacak şekilde aktarılmıştır. Geliştirilen taze EPF izolatlarına ait kültürlerin aktif olarak gelişen (ORP13, ORP18, Sivas10 ve BBE2) uç kısımlarından alınan 5 mm'lik misel diskleri ilaçlı PDA ortamlarına aktarılmıştır. Deneme 4 tekerrürlü olacak şekilde kurulmuştur. Fungusit içermeyen PDA ortamları negatif kontrol olarak kullanılmıştır. Parafilm ile kapatılan petriler, 25±1 °C'de karanlıkta 14 gün boyunca (kontrolde fungus ortamı tamamen kaplayana kadar) inkübe edilmiştir. İnkübasyon süresi sonunda radial miselyum büyümeleri hesaplanmıştır.

3. BULGULAR ve TARTIŞMA

On dört günlük inkübasyon süresi sonunda, kontrol grubundaki misel gelişimi ortalama 15.55 mm olarak ölçülmüştür. Çalışmada kullanılan 1/8, 1/16 ve 1/32 oranlarındaki Thiram uygulamaları sonucunda elde edilen misel gelişimleri sırasıyla 15.03 mm, 15.18 mm ve 15.20 mm olarak belirlenmiş olup, bu değerler kontrol grubuyla karşılaştırıldığında istatistiksel olarak anlamlı bir fark gözlenmemiştir. Benzer şekilde, 1/8, 1/16 ve 1/32 oranlarındaki Kaptan

uygulamaları sonucunda misel gelişimleri sırasıyla 12.77 mm, 12.20 mm ve 12.45 mm olarak kaydedilmiş; ancak bu gruplar ile kontrol grubu arasında da anlamlı bir fark tespit edilmemiştir.

Çizelge 3.1 Thiram ve kaptanın farklı dozlarının Beauveria bassiana BBE2 izolatının miselyum gelişimi üzerine etkisi.

Uygulamalar	**Misel Uzunluğu (mm)**
BBE2 Kontrol	15.55bc
%6.25 Kaptan+BBE2 Kombinasyon	12.20a
%3.125 Kaptan+BBE2 Kombinasyon	12.45a
%12.5 Kaptan+BBE2 Kombinasyon	12.77ab
%12.5 Thiram+BBE2 Kombinasyon	15.03c
%6.25 Thiram+BBE2 Kombinasyon	15.18c
%3.125 Thiram+BBE2 Kombinasyon	15.20c

Şekil 3.1 BBE2 Misel Gelişimi

Çalışmada kullanılan bir diğer entomopatojen fungus olan Sivas 10 izolatında, kontrol grubunda misel gelişimi ortalama 14.96 mm olarak belirlenmiştir. Thiramın 1/8, 1/16 ve 1/32 dozlarında ise sırasıyla 14.80 mm, 14.39 mm ve 14.34 mm misel gelişimi ölçülmüştür. Diğer taraftan Kaptanın 1/8, 1/16 ve 1/32 dozlarında misel uzunluğu sırasıyla 14.04 mm, 14.27 mm ve 13.34 mm olmuştur. Bu sonuçlar, hem Thiram hem de Kaptan uygulamalarının, Sivas 10 izolatının misel gelişimi üzerinde önemli bir engelleyici etki göstermediğini ortaya koymuştur.

Çizelge 3.2 Thiram ve kaptanın farklı dozlarının Beauveria bassiana Sivas10 izolatının miselyum gelişimi üzerine etkisi.

Uygulamalar	**Misel Gelişimi**
Kontrol Sivas10	14.96a
%3.125 Kaptan	13.34a
%12.5 Kaptan	14.04a
%6.25Kaptan	14.27a
%3.125 Thiram	14.34a
%6.25 Thiram	14.39a
%12.5 Thiram	14.80a

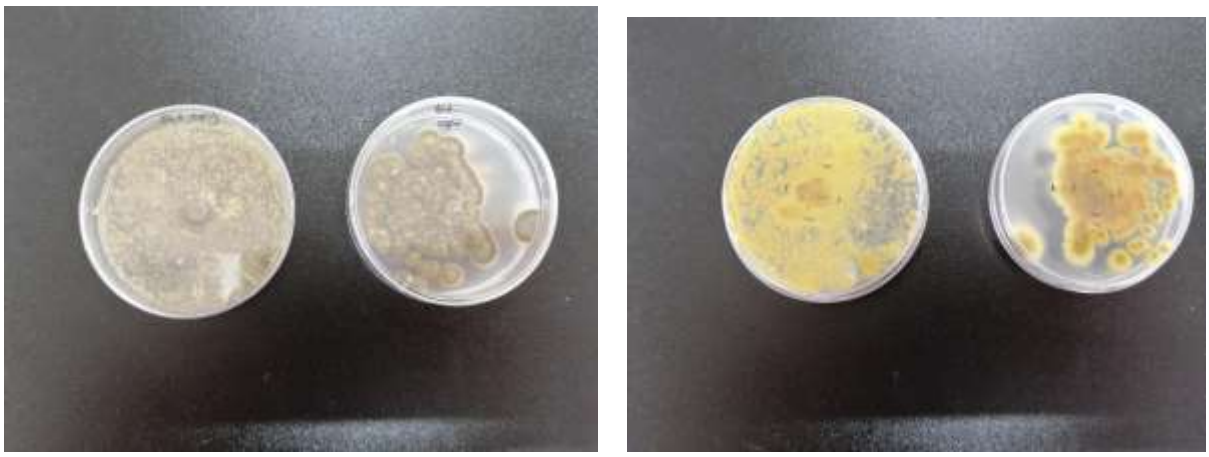
Şekil 3.2 Sivas 10 Misel Gelişimi

Mevcut çalışma bulgularına benzer şekilde Usha ve ark.,(2014) yapmış olduğu çalışmada *Beauveria bassiana*'nın B57 dışındaki izolatlarının uygulanan kükürt dozlarında (0.1X, 0.5X ve 1X) normal gelişim sergilediğini diğer taraftan bakır oksiklorür düşük dozlarında (0,1X) normal gelişirken, yüksek dozlarının (1X) toksik etki gösterdiği belirlenmiştir(1X tavsiye edilen doz, 0.5X tavsiye edilen dozun yarısı, 0,1X tavsiye edilen dozun 1/10).

Yapılan bir diğer çalışmada Fungusit olarak Mankozeb ve Entomopatojen Fungus *(Metarhizium anisopliae, Hirsutella sp., Beauveria bassiana, Paecilomyces sp.)*kullanılmıştır.Çalışmada kullanılan fungusit dozları; önerilen dozun 0.25 katı, 1 katı, 2 katı ve kontrol grubu olarak belirlenmiştir. Çalışmanın sonucunda Mankozeb fungisiti tüm Entomopatojen Fungus izolatlarının gelişimi üzerinde olumsuz bir etki gösterdiği belirtilmiştir.

Çizelge3.3 Thiram ve kaptanın farklı dozlarının Metarhizium brunneum ORP13 izolatının miselyum gelişimi üzerine etkisi.

Uygulamalar	**Misel Gelişimi**
%6.25 Thiram	14.77a
%3.125 Thiram	14.78a
%12.5 Thiram	14.93a
%12.5 Kaptan	15.00a
Kontrol Thiram	15.16a
%6.25 Kaptan	15.22a
%3.125 Kaptan	15.72a

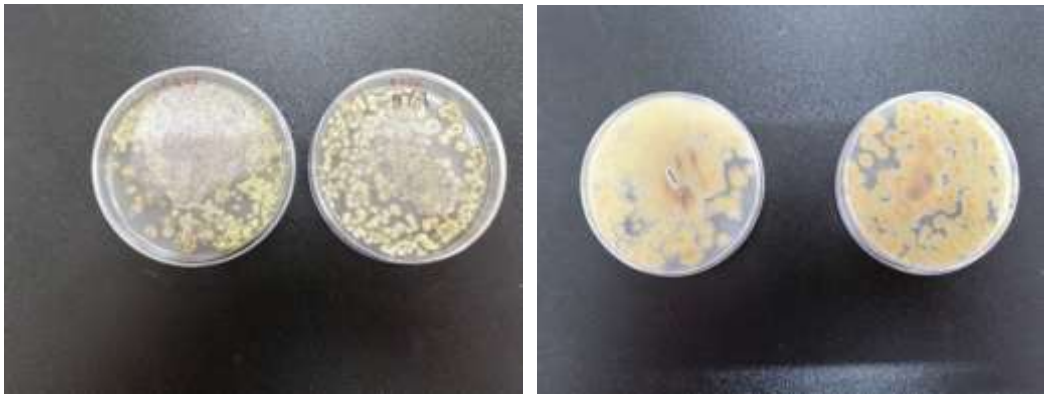


Şekil 3.3 ORP 13 Misel Gelişimi

Çalışmada, 14 günlük inkübasyon süresi sonunda kontrol grubunda ortalama misel gelişimi 15.16 mm olarak ölçülmüştür. Thiram uygulamasında 1/8, 1/16 ve 1/32 oranlarında sırasıyla 14.93 mm, 14.77 mm ve 14.78 mm misel gelişimi kaydedilmiştir.

Çizelge 3.4 Thiram ve kaptanın farklı dozlarının Metarhizium brunneum ORP18 izolatının miselyum gelişimi üzerine etkisi.

Uygulamalar	**Misel Gelişimi**
%3.125 Thiram	14.62
%6.25 Kaptan	14.63
%6.25 Thiram	14.75
Kontrol	14.91
%3.125 Kaptan	14.92
%12.5 Thiram	15.03
%12.5 Kaptan	15.33



Şekil 3.4 ORP 18 Misel Gelişimi

Diğer fungusit olan Kaptan uygulamalarında ise 1/8 oranında 15.00 mm, 1/16 oranında 15.22 mm ve 1/32 oranında 15.72 mm'lik misel gelişimleri gözlemlenmiştir.

Elde edilen veriler, her iki fungusitin de uygulanan oranlarına bağlı olarak misel gelişimini belirgin şekilde etkilemediğini, özellikle düşük konsantrasyonlarda misel gelişiminin kontrol grubuna yakın seyrettiğini ortaya koymaktadır.

On dört günlük inkübasyon süresi sonunda yapılan ölçümlere göre, kontrol grubunda misel gelişimi ortalama 14.91 mm olarak kaydedilmiştir. %12.5 Thiram + ORP18 uygulamasında misel gelişimi 15.03 mm, %12.5 Captan + ORP18 uygulamasında ise 15.33 mm olarak ölçülmüştür. %3.125 Thiram, %6.25 Captan ve %6.25 Thiram uygulamalarında elde edilen misel gelişimi sırasıyla 14.62 mm, 14.63 mm ve 14.75 mm olarak belirlenmiş olup, bu uygulamaların kontrol grubuna kıyasla anlamlı bir fark oluşturmadığı gözlemlenmiştir.

4.SONUÇ

Bu çalışmada, Captan %50 WP ve Thiram %80 WP fungisitlerinin önerilen dozlarının 1/8, 1/16 ve 1/32'lik konsantrasyonlarının entomopatojen fungus izolatlarının (Beauveria bassiana ve Metarhizium bruneum) misel gelişimleri üzerindeki etkileri değerlendirilmiştir. Yapılan in vitro analizler sonucunda, bu düşük dozların entomopatojen fungusların misel gelişimini anlamlı düzeyde baskılamadığı gözlemlenmiştir. Elde edilen bulgular, entomopatojenik fungusların, azaltılmış fungisit dozları ile birlikte uyumlu bir şekilde kullanılabileceğini göstermektedir. Bu durum, özellikle çevre dostu ve sürdürülebilir tarım uygulamaları kapsamında, toprak kaynaklı patojenlere karşı biyolojik mücadelede entegre yöntemlerin geliştirilmesi açısından umut vericidir. Sonuç olarak, entomopatojen funguslar, hem fungal hastalıklara karşı biyolojik kontrol ajanı olarak hem de kimyasal girdilerin azaltılmasına katkı sağlayarak toprak sağlığının korunmasında önemli bir rol üstlenebilir.

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A CRITICAL REVIEW OF SYMPTOMATOLOGY AND ISOLATION TECHNIQUES OF *ALTERNARIA* SPP. IN SOLANACEOUS CROPS

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ABSTRACT

Accurate sampling and the establishment of pure cultures remain essential for the advanced study of fungal pathogens in plant protection, particularly for genera with complex ecological roles such as *Alternaria*. This genus comprises not only saprophytic and endophytic species but also numerous phytopathogens that affect a wide range of agricultural crops. In Solanaceae family plants—such as tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum*), pepper (*Capsicum spp.*), eggplant (*Solanum melongena*), and tobacco (*Nicotiana tabacum*)—*Alternaria* spp. are predominantly recognized as necrotrophic pathogens responsible for diseases like early blight, brown spot, leaf and fruit lesions, and necrosis of various plant parts, including underground storage organs. These pathogens, which are mostly anamorphic members of the Ascomycota phylum, exhibit a wide geographical distribution and substantial host diversity. Despite similarities in symptom expression—such as concentric ring patterns on leaves and necrotic lesions—there is considerable variation among *Alternaria* species in terms of symptomatology and isolation efficiency. Different species may produce similar symptoms on different host plants, while a single species may induce distinct symptom patterns depending on the host and developmental stage. Critical analysis of the literature reveals that foliar symptoms are more frequently observed and characterized compared to other plant organs. These symptoms often vary subtly among hosts and developmental stages. In terms of isolation protocols, surface sterilization with sodium hypochlorite remains the most common practice, followed by culture on Potato Dextrose Agar (PDA). Optimal incubation temperatures typically range between 20–28 °C, with lighting conditions alternating between day/night cycles or continuous darkness, depending on the study design. Although PDA is the most commonly used medium, other media and environmental conditions are occasionally utilized, albeit less frequently.

Keywords: *Alternaria* spp., Solanaceae, early blight, fungal pathogens, isolation techniques, disease symptoms

1. INTRODUCTION

Fungal pathogens are prevalent across diverse agricultural environments including fields, greenhouses, storage facilities, and natural ecosystems. Given their high diversity and ecological complexity, reliable identification of these pathogens requires the establishment of pure cultures through precise isolation techniques. Accurate sampling, recognition of disease symptoms, and appropriate culture practices constitute the foundational steps for successful pathogen characterization (Narayanasamy, 2011).

Among fungal plant pathogens, species belonging to the genus *Alternaria* hold particular importance due to their wide host range and capacity to cause significant economic and ecological damage. These pathogens can induce diseases such as leaf blight, stem cankers, fruit rot, seed necrosis, and tuber decay in a variety of crop species (Goetz & Dugan, 2006; Adongo et al., 2015; Matić et al., 2020). Moreover, their ability to persist as saprophytes or endophytes complicates their detection and diagnosis (Thomma, 2003; DeMers, 2022).

The Solanaceae family—comprising key crops such as tomato (*Solanum lycopersicum*), potato (*S. tuberosum*), pepper (*Capsicum* spp.), eggplant (*S. melongena*), and tobacco (*Nicotiana tabacum*)—represents a major group affected by *Alternaria* spp. These crops occupy large global cultivation areas and contribute significantly to global food security (FAOSTAT, 2025). Consequently, understanding *Alternaria* infections in Solanaceae is of critical importance for plant protection efforts worldwide.

Infection by *Alternaria* spp. may remain latent, leading to unnoticed contamination of seeds and fruits. Such latent infections can result in damping-off in seedlings or post-harvest decay in fruits, highlighting the importance of sensitive and specific detection strategies. The variation in symptom expression among host plants—woody or herbaceous, tuberous or non-tuberous—demands careful symptom documentation and methodological standardization.

Traditional pathogen detection approaches—such as visual assessment, culturing, and isozyme analysis—remain useful, though modern techniques including polymerase chain reaction (PCR), immunoassays, stress-based detection, and biomarker-based diagnostics offer greater precision (Ray et al., 2017). This review critically examines studies related to the symptom expression and isolation methods of *Alternaria* spp. in solanaceous crops, aiming to outline key methodological insights and highlight areas requiring further refinement.

2. SYMPTOMS OF *ALTERNARIA* SPP. IN SOLANACEAE

Symptom observation is the initial and most crucial step in identifying plant diseases caused by fungal pathogens such as *Alternaria* spp. Foliar symptoms are the most commonly reported manifestations, often preceding infections in other plant parts such as stems, fruits, and roots. Across solanaceous crops, *Alternaria* species are known to induce a range of visible effects—primarily necrotic lesions exhibiting concentric ring patterns, chlorosis, and tissue collapse—although these may vary depending on host species, cultivar, environmental conditions, and pathogen strain.

In tomato (*Solanum lycopersicum*), *Alternaria alternata* has been widely documented as a causal agent of early blight. Typical symptoms begin with yellowing and browning of lower leaves, followed by necrosis extending to the petiole. Under high humidity, lesions often enlarge

and coalesce, forming characteristic concentric rings with dark sporulation, ultimately leading to premature defoliation and yield loss (Akhtar et al., 2004).

Tobacco (*Nicotiana tabacum*) plants have been reported to host both *A. alternata* and *A. longipes*. Comparative symptom analyses revealed that *A. alternata* typically produces larger brown lesions than *A. longipes*. These lesions are often sunken and appear more prominently on sunburned leaves, suggesting interaction between environmental stress and disease expression (Hou et al., 2016).

In *Solanum muricatum* (pepino), *A. alternata* causes elongated, elliptical or V-shaped lesions on foliage, often surrounded by a chlorotic halo and concentric zones. Postharvest fruit symptoms include small brown lesions that expand over time, developing grayish-white mycelial growth in lesion centers, indicative of secondary sporulation (Li et al., 2016; Chen et al., 2022).

Alternaria alternata has also been identified in wild Solanaceae species such as *Solanum rostratum* and *Datura stramonium*. In *S. rostratum*, foliar symptoms initiate as yellowish spots on the abaxial surface, which then develop into dark, necrotic patches under moist conditions. In severe cases, lesions coalesce and lead to complete leaf drop (Guo et al., 2019). In *D. stramonium*, *A. crassa* produces irregular necrotic lesions with concentric rings and chlorotic halos, affecting not only leaves but also petioles, stems, and veins (Bozoğlu et al., 2022).

Potato (*Solanum tuberosum*) is affected by both *A. solani* and *A. alternata*. In some cases, *A. alternata* causes small, brown-black lesions with or without halos, distributed across leaf surfaces. In contrast, *A. solani* infections are distinguished by larger, target-shaped spots exhibiting concentric rings, often beginning on lower leaves and progressing upwards, causing significant foliage damage (Lingwal et al., 2022; Ganie et al., 2013; Schmey et al., 2024).

These findings collectively underscore that *Alternaria* symptoms in Solanaceae exhibit both consistency and variability. While concentric necrotic lesions and chlorosis are commonly observed across hosts, lesion size, distribution, and secondary effects (such as defoliation) differ depending on the host-pathogen interaction. Environmental conditions such as humidity and temperature further modulate symptom severity and appearance, necessitating standardized observational protocols for effective diagnosis and comparison among studies.

3. ISOLATION METHODS OF *ALTERNARIA* SPP. IN SOLANACEAE

Effective isolation of *Alternaria* species from symptomatic solanaceous tissues is fundamental for accurate pathogen identification, pathogenicity assays, and further molecular or morphological analyses. Although the general workflow involves surface sterilization of diseased tissues, culturing on nutrient-rich media, and incubation under defined environmental conditions, significant methodological variations exist among studies.

3.1. Sample Selection and Surface Sterilization:

Diseased plant tissues—commonly leaves, stems, fruits, and occasionally flowers or tubers—are excised at the lesion margins to maximize the chance of recovering viable fungal material. Surface sterilization is typically performed using sodium hypochlorite (ranging from 0.1% to

5%) or ethanol (70–75%) for periods between 30 seconds and 3 minutes, followed by thorough rinsing with sterile distilled water to remove chemical residues (Martinko et al., 2022; Guo et al., 2019; Chen et al., 2022). The choice of sterilizing agent and exposure duration depends on the tissue type and sensitivity to chemical damage.

3.2. Culturing Media and Conditions:

Potato Dextrose Agar (PDA) is the most frequently used medium for initial fungal growth due to its richness and compatibility with sporulation. However, alternative or supplementary media such as Potato Carrot Agar (PCA), Potato Sucrose Agar (PSA), and V8 juice agar have also been employed to enhance sporulation or conidial morphology (Bessadat et al., 2020; Nasehi et al., 2014). Some studies further transfer initial colonies to host extract media to preserve virulence or mimic in planta conditions.

3.3. Incubation Parameters:

Optimal incubation conditions vary, but most studies report growth at 25–28°C under a 12–16 hour photoperiod (white light) or complete darkness, depending on the intended sporulation or mycelial expansion. For recalcitrant isolates that fail to sporulate readily, exposure to direct sunlight, mechanical wounding, or nutrient stress has been reported to enhance sporulation (Bessadat et al., 2017).

3.4. Single-Spore or Pure Culture Isolation:

To obtain genetically uniform isolates, some protocols emphasize single-spore isolation using a stereomicroscope, particularly when morphological or molecular studies are intended. This step minimizes contamination and genetic variation, which may otherwise confound downstream analyses (Nasehi et al., 2014).

3.5. Host-Specific Approaches:

The type of tissue and host plant often dictate protocol modifications. For instance:

- In *Capsicum annuum*, *A. capsicicola* was isolated using single conidium extraction directly from necrotic lesions.
- In *S. muricatum*, fruit tissues required dual sterilization with ethanol and hypochlorite due to higher microbial load.
- In potatoes, lesion margins were first disinfected with ethanol before transfer to modified PDA for incubation under continuous light (Tymon et al., 2016; Lingwal et al., 2022).

3.6. Antibiotic Supplementation:

To reduce bacterial contamination, some protocols incorporate antibiotics such as streptomycin or chloramphenicol into water agar or PDA media during the initial stages of isolation, particularly from highly decomposed or field-collected materials (Park et al., 2024).

Overall, while sodium hypochlorite and PDA remain the gold standards for surface sterilization and culturing respectively, variations in sterilization intensity, media supplementation, and environmental parameters are often tailored to the host species and study objectives. Notably, standardization and molecular confirmation of isolates (e.g., ITS or TEF1-α sequencing) are increasingly necessary to resolve taxonomic ambiguities within the *Alternaria* genus.

4. CONCLUSION AND FUTURE PERSPECTIVE

A critical examination of current literature on *Alternaria* spp. affecting solanaceous crops reveals both commonalities and inconsistencies in symptom expression and pathogen isolation methods. Leaf symptoms—characterized by concentric necrotic lesions, chlorosis, and defoliation—are consistently the most documented, while symptoms on fruits, stems, or roots are reported less frequently and with greater variability. These differences are likely influenced by host species, plant developmental stages, and environmental factors such as humidity and temperature.

In terms of isolation, the majority of protocols employ sodium hypochlorite for surface sterilization and culture the pathogen on nutrient-rich media such as PDA or PCA under moderate temperatures (20–28 °C). However, despite their widespread use, these methods are often adapted to specific host-pathogen systems without standardization. Such variability can hinder reproducibility and inter-study comparisons. Additionally, while traditional methods based on morphology and sporulation remain valuable, the incorporation of molecular tools—such as ITS or TEF1-α sequencing—is becoming increasingly critical for accurate species identification within the *Alternaria* genus.

Future research should aim to:

- Expand symptom characterization beyond foliar tissues to include underground storage organs, reproductive structures, and postharvest conditions.
- Develop standardized isolation protocols that balance effectiveness with reproducibility across host systems.
- Integrate molecular diagnostic techniques into routine isolation pipelines to resolve taxonomic ambiguities.
- Investigate the influence of host physiology, pathogen diversity, and environmental stressors on symptom variability and pathogen aggressiveness.
- Explore the potential of advanced culture-independent techniques, such as metagenomics and environmental DNA (eDNA) analyses, for detecting *Alternaria* spp. in complex plant-microbe communities.

Such integrative approaches will not only improve disease diagnostics and pathogen surveillance in solanaceous crops but also contribute to more sustainable plant protection strategies.

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NEW ERA OF RURAL DEVELOPMENT IN TÜRKİYE: DIGITALISATION

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ABSTRACT

The transformation of rural development policies in Türkiye represents an evolutionary shift from traditional modernization approaches to digital integration. This study explores the historical progression and paradigm shifts in Türkiye's rural development policies, emphasizing the transition from conventional modernization strategies to contemporary digital solutions. A mixed-method approach, incorporating historical document analysis and policy evaluation, is employed to examine this transformation. The study categorizes the evolution into three key phases: the revitalization and modernization period (1923-1980), the structural adjustment period (1980-2000), and the digital transformation period (2000-present). Findings indicate that Türkiye's rural development policies have undergone significant changes in response to both global trends and local needs. The initial phase focused on state-led industrialization and agricultural mechanization, aiming to modernize rural structures through technological advancements and infrastructure improvements. The structural adjustment period marked a transition toward market-oriented policies, fostering rural entrepreneurship and private sector involvement. In the contemporary phase, digital transformation has taken center stage, exemplified by initiatives such as the Digital Agriculture Market, smart village applications, and e-agriculture platforms. This digitalization process has introduced new dimensions to rural development, including precision agriculture, digital literacy programs, and ICT-based rural services. However, the digital divide between urban and rural areas remains a significant challenge. Considering the ongoing difficulties in accessing essential resources in rural areas compared to urban regions, it is evident that the full realization of these transformations in rural Türkiye will require time. While digitalization is expected to enhance productivity in rural areas, the extent to which the rural population can adapt to this transition remains an open question. This study is significant in shedding light on the transformation of rural development policies in Türkiye.

Keywords: Rural Development, Digital Transformation, Development Paradigm, Türkiye

1. INTRODUCTION

Rural development policy plays a central role in Türkiye's economic and social development. Historically, Türkiye has focused on the economic development and social welfare of rural areas and has developed various strategies in this context. The modernization process that began in the 1950s led to various reforms aimed at increasing agricultural productivity and improving living standards in rural areas. However, these processes often followed a top-down approach that ignored local dynamics and community needs. As a result, social and economic inequalities in rural areas deepened and the migration of the rural population to the cities increased. From the 1950s onwards, a modernization policy was implemented in Türkiye to promote rural development. In this process, efforts were made to increase agricultural productivity and the loans provided to farmers by Ziraat Bank and agricultural credit cooperatives played an important role in this modernization process. The loans extended to farmers by Ziraat Bank and the institutions it financed increased significantly after 1950. This increase in agricultural loans served to increase production in economic terms (İnci, 2022). Although practices such as the Land Acquisition Law for Farmers enacted in 1947 and the Land and Agrarian Reform Law enacted in 1973 aimed to increase agricultural productivity and capital accumulation and to benefit from support services to a greater extent (Andersen, 1971), they failed to achieve the expected effects because they did not take into account the social structure of local communities (Börtücene, 1978). In the course of the modernization process that began in the 1950s with the mechanization of agriculture, especially through Marshall Aid after the Second World War, there was a considerable expansion of agricultural production areas, and the volume of agricultural production increased accordingly. At the same time, the number of stores and services in the mechanized regions increased and contacts with the outside world continued to develop (Aktan, 1954; Kazgan, 1966). However, mechanization also had a significant social and demographic impact on the countryside. Contact between peasants and urbanites increased thanks to tractors. Peasants became better informed about the opportunities offered by the city. Farmers and workers who had lost their land and jobs due to mechanization began to migrate to the cities, which they believed would offer them a better life (Tütengil, 1969). This situation has shown the need to restructure policies in terms of both rural and urban sociology and development.

Today, digitalization, which is one of the current issues for rural areas, has become an important element in the transformation of rural development policies. The potential of digital technologies to increase agricultural productivity (Bi et al., 2022) has a positive impact on the quality of life in rural areas. Mobile applications and data analysis for farmers enable them to optimize their production processes. Digital agricultural applications contribute to environmental sustainability by promoting the adoption of sustainable agriculture (Beck et al., 2020).

Digitalization also holds significant potential for greater social and economic participation of rural communities. Local people can help to make rural development processes more participatory by identifying their problems and developing solutions using digital tools. It is expected that this situation will contribute to strengthening social capital and increasing social solidarity. The widespread use of digital technology is changing the way interpersonal interactions take place and social relationships are built. It promotes the formation of online communities and provides new opportunities for shaping collective identity and consciousness

(Zhao and Wang, 2023). In addition, the flow of information through digital platforms has the potential to increase the resilience of rural communities. LaRose et al. (2007) state that the problem of physical distance and inadequate provision of services in rural areas can be largely solved by promoting digital connectivity instead of many of these services. However, remote rural areas in particular lack the necessary digital connectivity, which increases the risk of rural areas falling further behind in terms of accessibility to services. In Türkiye, the integration of rural development policy with digitalization is an innovative approach that is compatible with the Sustainable Development Goals in both economic and social terms. This change enables local communities to discover their potential and achieve sustainable development goals. In addition, the opportunities offered by digitalization increase economic diversity by promoting social innovation and entrepreneurship in rural areas. In this context, it should be noted that digitalization has found its way into rural development policy documents (TOB, 2019; TOB, 2021, TOB, 2025). With this study, rural development in Türkiye. This study was an assessment of the transition from modernization to digitalization in rural development policy in Türkiye.

2. MATERIAL AND METHODS

This study was conducted by adopting a qualitative research approach in order to address the change in rural development processes in Turkey from a historical perspective. Qualitative research provides a methodological framework that allows for in-depth analyses aimed at making sense of social phenomena (Yıldırım and Şimşek, 2018). In this context, the main purpose of the study is to understand and interpret the transformation of rural development policies in Turkey over time and the effects of digitalization at this point.

The data used in the study is based on secondary sources. In this context, relevant academic literature, reports published by public institutions (especially the Ministry of Agriculture and Forestry, TÜİK and Development Agencies), strategy documents, legal regulations, project outputs and statistical data were examined. In addition, digital transformation-themed rural development projects, national development plans and technology-focused applications for rural regions were also included in the analysis.

A purposeful sampling method was adopted in the data collection process and sources directly related to the concept of digitalization in the context of rural development were selected. Descriptive analysis technique was used in the analysis of the data. The information obtained through this technique was classified under thematic headings, and the structural and technological changes that occurred in rural development over time were presented in a descriptive manner. With this method, how rural development in Turkey interacted with the digitalization process, the breaking points of this interaction and the transformation it created at the policy level were evaluated from a holistic perspective.

3. RURAL AREA IN TÜRKİYE

In order to talk about rural development policy, it is necessary to define rural areas first. In Türkiye, there have been different approaches to the definition of rural areas since the time of the Republic. Türkiye experienced a problem-free period in terms of defining rural areas from the beginning of the planned period until the 2000s. During this period, definitions were made

according to threshold values based on administrative boundaries of settlements and population sizes. The last threshold was set at 20 thousand in all National Rural Development Strategies published since 2007 (Yardımcı, 2023). However, in the 2000s, the functionality of this definition was eroded due to rapid population growth in Türkiye, internal migration, overcrowded settlements and unplanned urbanization. The necessity of conducting studies within this framework began to be mentioned in high-level policy documents, especially in development plans. However, before a new definition could be made, regulations were made in 2012 with Law No. 6360, Law No. 5216 on Metropolitan Municipality, Law No. 5302 on Provincial Special Administration and Law No. 5393 on Municipality, which fundamentally changed the local administration system in urban and rural areas. As a result of these changes, the population threshold of 20,000 inhabitants and the calculation method referred to in rural policy documents have been significantly affected. The number of provinces with metropolitan municipalities in Türkiye increased to 30, and provincial special administrations, town and village community administrations were closed in the provinces with metropolitan municipalities. A total of 1,582 town municipalities and 16,082 villages, which constitute the core of rural policy in the 30 affected provinces, were transformed into neighborhoods (Yardımcı, 2023). This situation led to a confusion between the neighborhoods that already existed in urban settlement areas and the settlements that were converted from towns and villages to neighborhoods. Soon, in the provinces with metropolitan communities, the term "rural neighborhood" began to be used to distinguish villages and towns that were transformed into neighborhoods from neighborhoods in urban areas (Yardımcı, 2017, 2024). Over time, the concept of rural neighborhood has been incorporated into legislation (Resmi Gazete, 2020a; Resmi Gazete, 2020b). As a result of the changes in the local administrative system, the calculation method became dysfunctional, and the rural population ratio, which was 27.6 percent in 2012 according to the 20,000 population threshold, decreased to 13.3 percent in 2013 and 10.8 in 2022; according to the village-town definition, the village population ratio, which was 22.7 percent in 2012, decreased to 8.7 percent in 2013 and 6.7 percent in 2022 (Figure 1). "There has been a statistical transfer from the rural population to the urban population that does not reflect reality; due to the change in the administrative affiliation of villages and towns, the data calculation method no longer provides reliable results" (Doğan and Yardımcı, 2019).

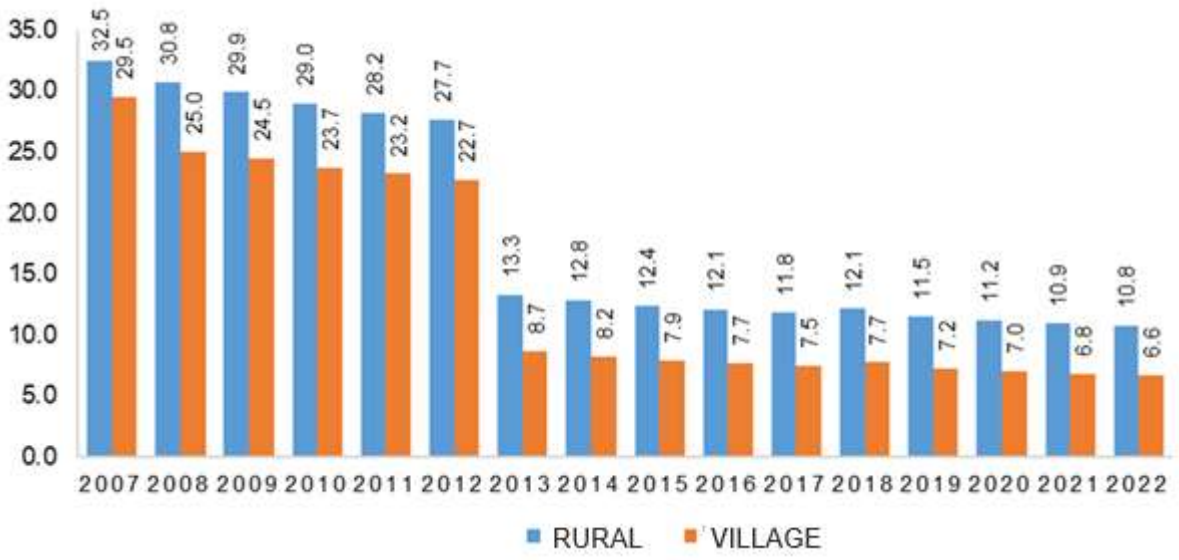

Figure 1. Rural and Village Population Rates According to Urban-Rural and Village-City Definitions (%) (Yardımcı, 2023).

In order to obtain accurate and up-to-date information at the national level and to implement a data-driven rural policy, as well as to harmonize with the EU and various definitions of rural areas of international organizations such as the OECD, it was deemed necessary to update the definition of rural areas in Türkiye. This issue, which was first raised in the 2006 Development Program (DPT, 2005), was also addressed in the National Rural Development Strategy-1 (UKKS-1) (2007-2013) (DPT, 2008) and the 2007 and 2008 Development Programs (DPT, 2006; DPT, 2007). The emphasis on the need to update the definition of rural areas was reinforced in the development plans and other rural development policy documents published during the period of the 2012 Act (Resmi Gazete, 2012) and the 10th Development Plan (2014-2018) (KB, 2014). With the 11th Development Plan (SBB, 2019) prepared by the Presidency for the years 2019-2023, Türkish Statistical Institute (TÜİK) was given the responsibility to revise the urban-rural definitions in a way that takes into account both national and international needs. The new rural definition study, which will reflect the real situation and enable international comparisons, was included in the Official Statistics Program in 2014 (KAGM, 2024). In this context, with the introduction of the Spatial Address Registration System (MAKS), which is the responsibility of the Ministry of Interior, a classification that more accurately reflects the actual urban-rural structure was made by TÜİK in order to produce statistics. In this new classification, which was created in the distinction of “dense urban, medium dense urban and rural”, the "Degree of Urbanization (DEGURBA)" developed by the European Statistical Office was taken as a basis and MAKS and the Address-Based Population Registration System (ADNKS) were used as data sources. In this context, statistics distinguishing between urban and rural areas were compiled again for the first time from 2022 (TÜİK, 2023a). Accordingly, the population distribution in Türkiye according to the new definition is shown in Figure 2. According to the new definition of TÜİK (2023a), the share of rural population in the total population is 17.26%, while according to the data of TÜİK (2023b)

ADNKS 2022, the share of urban and village population in the total population is 6.64%. It can be said that a more accurate approach to determining the rural population has been proposed with the new system.

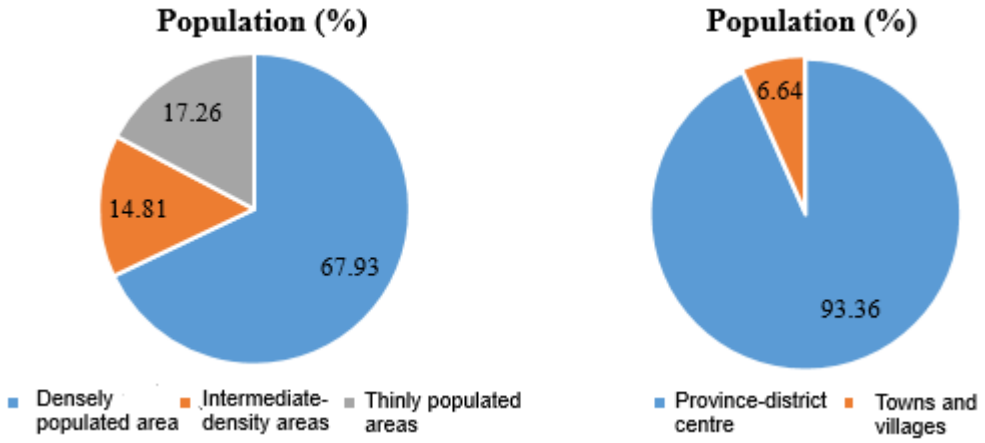

Figure 2. Distribution of population by urban-rural and province-district centres, town and villages classifications (2022) (TÜİK, 2023a)

According to TÜİK's calculations, the dense urban population, which constitutes 67.9 percent of the total population, lives in settlements that constitute only 1.6 percent of the total area; the rural population, which constitutes 17.3 percent of the total population, lives in settlements that constitute 93.5 percent of the total area; and the medium-density urban population, which constitutes 14.8 percent of the total population, lives in settlements that constitute 4.9 percent of the total area (Figure 3).

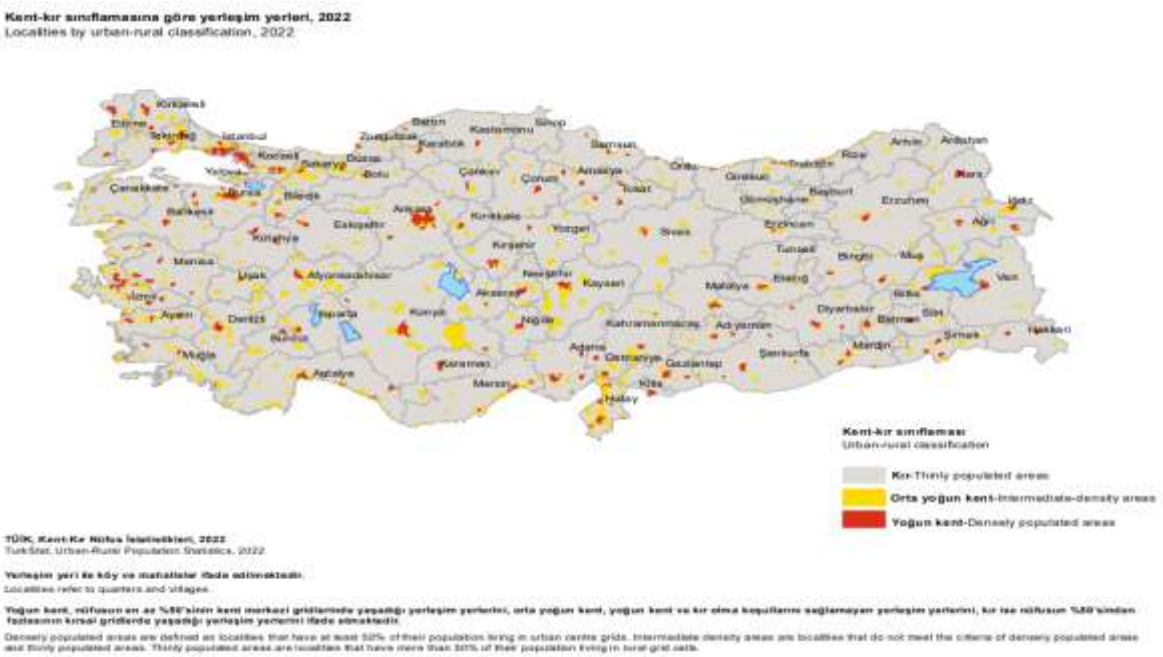

Figure 3. Distribution of Urban-Rural Population by Surface Area in Türkiye (TÜİK, 2023a)

4. TRANSFORMATIONS IN RURAL DEVELOPMENT POLICY OF TÜRKİYE

It is known that rural development efforts in Türkiye started after the proclamation of the Republic in 1923. Immediately after the foundation of the Republic, development efforts in agriculture and rural areas emerged throughout the country. On the other hand, since a large part of the population lives in rural areas and the economy is based on agriculture, it is possible to say that the importance attributed to rural areas has increased. From the proclamation of the Republic until the transition to the planned period in 1963, development efforts in Türkiye were generally made and put into practice in the field of industry. In these periods, when the agriculture-based industry was prioritised and the logic that developments in rural areas and agriculture would follow the processing of raw materials into high value-added goods, agricultural and rural development policies were intertwined and rural development was considered under the umbrella of agricultural development.

In the post-Republican period, the village has an important place in the realisation of Atatürk's ideas on the new Türkiye. The greatest contribution to increasing production through the correct and efficient use of resources comes from the villages. The phrase *"The Peasant is the Master of the Nation"* is also important in terms of showing the value Atatürk attached to the village and the peasant. Atatürk's statement to İsmet İnönü in one of the conversations after a dinner in Çankaya that *"...Development starts from the village, first of all, we have to develop the peasants of our Anatolia; we have to start development from the villages"* is also important in terms of revealing Atatürk's village vision in the agriculture and rural development move in Türkiye. With this perspective, the Village Law No. 442 was enacted on 18 March 1924. The Village Law, which is still in force, is one of the first milestones of the rural development move in Türkiye with its provisions on many issues such as duties related to the village, job

descriptions, legal administrative functioning, and the work to be done by the villagers. The ***"Ideal Republican Village Project"***, which was put forward by experts and with the great contributions of Atatürk in 1937 in the rural development move that started with the village development move in the Republican period, is an important village project of the time. Atatürk supported the implementation of the project, but with his early death, the project could not become widespread.

Increasing industrialisation in Türkiye triggered rural-urban migration in the 1950s (Güreşçi 2010). This situation weakened production in villages. At this point, the aim of village-oriented projects and studies is to transform the village into the basis of education, culture and industry, and to ensure that the villagers become educated, social, cultured, productive people who use modern methods in agriculture and animal husbandry. At the same time, another aim is to remove the differences between rural and urban areas by increasing income and welfare and to make rural settlements more livable (Doğanay 1993, Çolakoğlu 2007). Villages are settlements where national culture, customs and traditions, which should be preserved and made the basis of society, are fully experienced and protected (Dicle 2012). For this reason, another important project put forward before the planned period was the **"Village Institutes"** model. This model, which brought groundbreaking developments in education and training in its period, provided important services in the formation of human capital, which was the most important deficiency of rural development. The Village Institutes, which were the enlightenment and development project of Anatolia, were accepted in 1940 and terminated in 1954.

With the transition of the Turkish economy to the planned period after 1963, a rapid increase in the level of development has been observed with the implementation of the determined plans. Since 1963, a total of twelve development plans have been put into practice. When Türkiye's rural development is analysed within the framework of development plans, it can be said that Türkiye's approaches to rural development have been shaped by the paradigmatic changes in the field of rural development in the world. The rural development approaches, which date back to the beginning of the 19th century, have differentiated over time with the impact of technological and socio-economic factors and the changes that emerged. Popular ideas and terminologies that came to the fore during this differentiation, which can be characterised by **"modernization"** in the 1960s, **"state interventions"** in the 1970s, **"free market-liberilisation"** in the 1980s, "**participation and empowerment"** in the 1990s, **"integration with the environment-green development"** in the 2000s and **"integration with technology-Rural 3.0"** today, have also been remarkable. However, the changes in rural areas in Türkiye can be categorised as modernisation between 1923-1980, structural changes between 1980-2000, and technological adaptation and digitalisation after 2000.

It is understood that the five-year development plans put forward since the beginning of the planned development period contain a traditional regional development approach. The common concept in all the plans put forward in the planned period has been determined as objectives and tools. The main objective of these five-year development plans is to eliminate the imbalance between regions and to ensure balanced regional development. In the first five-year development plan, the structures in the rural areas were negatively affected by the fact that they were scattered and small. For the first time, **"Model Village"** project was implemented. In the third five-year development plan, due to the dispersed structure of the villages, services such as electricity, roads and water to be brought from the centre could not be provided on time and

there were not enough resources, the **"Central Village"** approach was adopted, which aims to determine one of the villages close to each other as a service unit and to provide services to all villages forming the centre established from here. In the fourth five-year development plan, settlements with the characteristics of central villages were identified and efforts were made to provide services to all villages from the identified centre. However, the desired success could not be achieved due to the dispersed and large number of villages. In this plan, the central village approach was replaced by the **"Village City"** model. In the sixth five-year development plan, for the first time, the practices of other countries started to be taken as an example in the theory and practice of regional development policies. It can be said that the first signs of transformation in regional development policies started to be seen in the 1990s. In the seventh five-year development plan, for the first time in Türkiye, the concepts of "regional planning" and "regional development" were replaced by the concept of "sustainable development". In the eighth five-year development plan, the regionalism approach found a wide application area. Administrative functioning in rural areas could not be brought to the desired level and could not fulfil the expectations. Within the framework of sustainable development approach, it is aimed to increase the income level of people living in rural areas by increasing employment and production.

In the Ninth Development Plan, it is planned that Türkiye, which is growing steadily within the framework of the EU membership processes in which our country is going through, has a development that has international competitiveness, provides fair income distribution and has realised all structural arrangements. With this Plan, it can be said that Türkiye has entered into a planned period in the field of rural development. Both the limitation of agricultural supports that distort competition and the market as required by the World Trade Organisation Agreement on Agriculture in the international arena and Türkiye's efforts to harmonise with the European Union (EU) have made the supports for rural development both more visible and more felt in the 2000s. Increasing disparities between rural and urban areas, efforts to improve the welfare of those living in rural areas and the process of harmonisation with the EU are among the most important reasons for Türkiye's transition to the planned rural development period since 2007. Since 2002, Türkiye, which became a candidate country after the Helsinki Summit in 1999, has been benefiting from EU funds for accession to the Union. The EU provides assistance to countries in the process of preparing for membership through pre-accession funds to support their political, institutional, social and economic reforms towards membership and to help them achieve Union standards. These funds, which were initially provided through different Union programmes and financial instruments, were gathered under a single instrument and legal framework called Instrument for Pre-Accession Assistance (IPA) in 2007. IPA funds are planned to cover 7-year periods in accordance with the European Union budget period. In this framework, IPA I, the first IPA implementation, was implemented during the budget period of the European Union covering the years 2007-2013 (IPA, n.d.).

In terms of rural development, Türkiye utilises the Rural Development (RD) instrument of IPA funds. In this context, National Rural Development Strategy (UKKS) documents have been prepared in Türkiye and for the first time, Türkiye has stepped into the planned period of rural development. UKKS-I (2007-2013), UKKS-II (2014-2020), UKKS-III (2021-2023) and most recently UKKS-IV (2024-2028) were prepared and put into effect (Resmi Gazete, 2006; Resmi Gazete, 2015; TOB, 2021, TOB, 2025). At the same time, the reports of the Special Expertise

Commission on Rural Development (ÖİK) prepared within the framework of the Development Plans, which are prepared and activated every five years, are also important in terms of both revealing the current situation and determining the five-year development plan in Türkiye. The most recently completed XIth Development Plan (2019-2023) and the Rural Development ÖİK report prepared within this framework have now been replaced by the XIIth Development Plan (2024-2028) and the Rural Development ÖİK report. When the UKKS documents are analysed in general, the strategic objectives of these documents are presented in Table 1. When the table is examined, it can be seen that the most recent strategy document has a separate heading for technological transformation and digitalisation.

Table 1. Türkiye's National Rural Development Strategies by Periods

UKKS I (2007-2013)	UKKS II (2014-2020)	UKKS III (2021-2023)	UKKS IV (2024-2028)
Strategic Objective 1: Developing the Economy and Increasing Job Opportunities	**Strategic Objective 1:** Developing Rural Economy and Increasing Employment Opportunities,	**Strategic Objective 1:** Developing Rural Economy and Increasing Employment Opportunities	**Strategic Objective 1:** Ensuring Economic Sustainability of Agricultural Production and Long-Term Food Security
Strategic Objective 2: Improving Human Resources, Level of Cooperation and Local Development Capacity	**Strategic Objective 2:** Improvement of Rural Environment and Ensuring Sustainability of Natural Resources,	**Strategic Objective 2:** Improvement of Rural Environment and Ensuring Sustainability of Natural Resources	**Strategic Objective 2:** Developing and Managing Sustainable Use of Natural Resources against Climate and Environmental Change
Strategic Objective 3: Improving Rural Physical Infrastructure Services and Increasing the Quality of Life	**Strategic Objective 3:** Improving the Social and Physical Infrastructure of Rural Settlements,	**Strategic Objective 3:** Improvement of Social and Physical Infrastructure of Rural Settlements	**Strategic Objective 3:** Mitigating the Effects of Natural Disasters on Rural Development
Strategic Objective 4: Protection and Development of Rural Environment	**Strategic Objective 4:** Improving the Human Capital of Rural Communities and Reducing Poverty,	**Strategic Objective 4:** Developing Human and Social Capital of Rural Communities and Reducing Poverty	**Strategic Objective 4:** Dissemination of Technological Transformation and Digitalisation
	Strategic Objective 5: Improving Institutional Capacity for Local Development	**Strategic Objective 5:** Improving Institutional Capacity for Local and Rural Development	**Strategic Objective 5:** Ensuring Rural Livability, Improving Physical Infrastructure and Social Capital
			Strategic Objective 6: Increasing the Effectiveness of Public Institutions for the Development of New Rural Development Models in Local Areas

Sources: Resmi Gazete, 2006; Resmi Gazete, 2015; TOB, 2021a, TOB, 2025

Considering both UKKS documents and Development Plans and related Special Expertise Commission (ÖİK) Reports, the change in rural development strategies in Türkiye can be analysed under the following headings. These are;

Development of social and human capital; Conceptually, the concept of social capital, which constitutes the fourth component along with physical, financial and human capital, constitutes a structure that is more difficult to explain and measure than other capital concepts. However, its impact on social structure and its relationship with development theory is one of the issues that increase the importance of social capital. Studies on social capital, which is so important for development, are important in terms of revealing the role of different variables in terms of community development. Rural development has an important place in the concept of development. In rural areas, it is important to investigate the changes in social capital in today's society 5.0. In the National Rural Development Strategy (UKKS) (2021-2023), the main objective of Türkiye's rural development policy is "*increasing the production capacity of producer associations and family enterprises and the employability of rural labour force, improving the quality of life, reducing poverty, increasing the welfare level of the rural community by providing regular and sufficient income opportunities, ensuring the retention of the population in rural areas, developing and sustaining it with a sustainable rural development approach*". One of the sub-objectives taken into account in achieving these objectives is stated as "*Strengthening human and social capital and activating social policy practices within the scope of poverty reduction*". The addition of the statement on the development of social capital as well as human capital with the UKKS III shows that the targets for social and societal structure are prioritised in Türkiye's rural development strategies. In this context, it can be said that social policies for the rural population have gained key importance in the improvement of Türkiye's basic development indicators. Studies on this subject also indicate that there is significant weakening in norms, social networks and trust, which are the components of social capital in rural areas (Kan et al. 2021; Kan and Özdemir, 2022). This situation shows that the problems in social capital in rural society are gradually increasing, which negatively affects the success of rural development efforts.

Resilient society to climate change, natural disasters and crises; "SDG 11 - Sustainable Cities and Communities" and "SDG 13 - Climate Action", two of the United Nations Sustainable Development Goals, aim both to realise the capacity to adapt to climate change and to support positive economic, social and environmental relations between rural and urban areas and to create a resilient society, including disasters, especially for poor and vulnerable groups. In order to realise these objectives, it is essential to increase the resilience of rural dwellers to climate change and the disasters such as drought, flood, fire, etc. and natural disasters such as earthquakes, and to create a sustainable rural society that is resilient to the effects of economic crises caused by conflicts such as war, embargo, economic sanctions, etc. in national and international arena. The basic approach in the Eleventh Development Plan (SBB, 2019), especially in the Eleventh Development Plan Rural Development Special Expertise Commission Report, is shaped within the framework of "Sustainable Society" (SBB, 2018). Climate change, which has made itself felt more and more in recent years, creates negative pressure on natural resources with its negative effects on rural areas, especially on livelihoods (especially agriculture), water resources due to drought, forests due to excessive heat and fires, and settlements due to floods caused by excessive rainfall. The high dependence of rural life on

natural resources and agriculture makes life more difficult in rural settlements. For this reason, people living in rural areas are among the communities most affected by disasters and crises. On 06 February and 20 February 2023, the earthquakes in Kahramanmaraş and Hatay caused severe damage to rural areas and the agricultural sector. It is stated that approximately 9.1 million people were affected by the earthquakes and 35% of these people were people living in rural areas, and the cost of the earthquakes in the agricultural sector was approximately 6.3 billion USD (FAO, 2023a). As a result of another study conducted in the earthquake region, it is stated that the construction of a society resistant to earthquakes and other natural disasters, especially in rural areas, is one of the most important things to be done. In this context, the Turkey Earthquake Response and Recovery Plan (ERRP) was developed in partnership with the Republic of Türkiye to address the devastating impact of the earthquakes that occurred in February 2023 on the agricultural and rural sectors. The ERRP's three result-oriented plans summarize the situation in rural areas in the earthquake zone. These are; "*Renewing agricultural food systems, including supply and value chains*", "*Revitalizing the agricultural labor market*", *"Strengthening rural communities for sustainable development*" (FAO, 2023b). In the light of these results, the Twelfth Development Plan under the title of rural development, policies and measures in Article 896.1. In Article 899, the protection of the environment and natural resources and increasing the adaptation capacity to climate change are mentioned (SBB, 2023).

The sustainability-based rural development approach integrated with the environment; Environmental issues, especially in relation to agriculture and rural development, have been consistently addressed in Turkish politics since the 1990s. Considering that both agricultural and rural development policies have been significantly shaped within the framework of EU harmonization strategies, approaches in this direction have also begun to gain priority in Türkiye with the significant strengthening of the environment and agriculture relationship in the EU Common Agricultural Policy in 2003. For this reason, rural development strategy documents, agricultural and agricultural forest council results and development plans particularly focus on the environment. In this context, Article 708.2 of the Eleventh Development Plan foresees increasing environmental support and incentives, and Article 899.1 of the Twelfth Development Plan foresees carrying out environmentally focused rural development projects and programs. Strategic objective 4 in UKKS I, and strategic objective 2 in UKKS II and UKKS III indicate an environment-focused rural development policy (Resmi Gazete, 2006; Resmi Gazete, 2015; TOB, 2021). The prioritization of the environment in strategy documents, the support of investments with the 201 measure "Agriculture-Environment Climate and Organic Agriculture" within the IPARD supports, and the inclusion of worm compost production investments in the IPARD III program indicate that policy studies that take into account circularity, especially in agriculture, will continue in rural areas in Türkiye. In addition, the investment logic that prioritizes renewable energy sources in production systems is another example of sustainability and circularity.

The development approach with good bottom-up governance; There have been significant changes in the rural development approach in Türkiye, especially with the introduction of IPARD supports. The best example of these changes in approach is the LEADER approach "Preparation and Implementation of Local Rural Development Strategies". This measure was included in the 2007-2013 Türkiye Program for the implementation of the European Union

Common Agricultural Policy and Rural Development Policy, and Türkiye became acquainted with LEADER thanks to the IPARD I Program. The characteristic of the LEADER approach is that it encourages the establishment of partnerships called local action groups (LAGs) by bringing together representatives of the public, private sector and civil society organizations. Within the scope of this approach, which is important in terms of both a bottom-up development approach and being a good governance model, 50 LAGs are supported in Türkiye. In Türkiye, where new approaches have come to the fore instead of traditional development models, 27 provinces were determined in the IPARD II program, which was called for in 2022, where the Local Development Strategy would be implemented (TKDK, 2022). Within the scope of IPARD III, the LEADER measure is planned to be implemented in 42 provinces where TKDK has a provincial coordinatorship.

Studies on more effective implementation of rural development activities and increasing the effectiveness of rural development supports; One of the important policies and measures included in the Eleventh Development Plan is stated in article 707 as "*Rural development supports will be programmed with a focus on farmers and the environment; arrangements will be made to eliminate the existing multi-headedness in the implementation of supports, complementarity and efficiency will be ensured in implementation*", while in article 898 of the Twelfth Development Plan it is stated as "*Rural development supports will be programmed with a focus on farmers and productivity, and complementarity and efficiency will be increased in implementation by ensuring coordination between the different supports implemented*" (SBB, 2023). It can be said that in the last two development plans, the issues of coordination of supports, their complementarity and increasing their effectiveness came to the forefront in rural development policies in Türkiye. In this context, the process of establishing a National Rural Network (NRN) in Türkiye, in accordance with the European Network for Rural Development (ENRD) approach that emerged with the LEADER approach that was practically initiated in the EU in the period of 1991-1993, was officially launched with a broad participation meeting organized by the Managing Authority on 28 November 2017. The establishment of a rural network aims to implement rural development policies in a more effective and participatory manner, to develop close relations with other networks, to establish and develop experience sharing and cross-border collaborations, and to disseminate good practice examples in this way (NRN, 2021a). As of May 2021, the National Rural Network Communication Strategy document has defined the communication principles and approach, target audiences, methods to be used in the process and communication tools for the National Rural Network (NRN, 2021b).

Prioritization of data-based rural development policy approach; One of the most important issues included in both the 11th Plan and the Rural Development Special Development Board Report, as well as the Twelfth Development Plan, is the strengthening of the infrastructure for collecting statistical information for rural areas and the establishment of rural databases (SBB, 2018, 2019, 2023). It is understood that the process that started with the definition of rural areas will continue with the preparation of village inventory, more active use of geographic information systems, as well as the determination and monitoring of indicators related to socioeconomic and cultural development of rural areas.

Technological transformation and digitalization in rural areas; One of the most important issues that distinguishes it from other rural development documents, especially in both the 12th

Development Plans and UKKS IV (2024-2028), is the issue of technological transformation and digitalization in rural areas. Two priority areas and eight measures have been determined in UKKS IV (TOB, 2025). With the increasing penetration of artificial intelligence into our lives, it is planned to further disseminate digitalization and smart technologies, especially in agriculture. In addition, it is envisaged that internet services will be made more widespread, as well as that technological opportunities will be used more in basic services such as education, which need to be brought to rural areas.

5. DIGITAL TRANSFORMATION IN RURAL AREAS OF TÜRKİYE

Since 2000, which is considered the beginning of the digital age, digitalization has gained an important place in social life. Especially with the impact of the pandemic, remote working and education experiences have brought digitalization to the forefront. However, there is a strong connection between cities and digital culture for digitalization to be sustainable. While information and communication technologies are needed for cities to grow and develop, this situation makes it possible to provide internet access and digital opportunities more easily in urban areas. On the other hand, it is observed that rural settlements do not benefit sufficiently from digitalization. The majority of fiber internet subscriptions in Türkiye are concentrated in large cities in the western regions. These cities are characterized by high education levels and income groups, as well as developed service sectors. In the eastern and southeastern provinces with low income levels, fixed broadband internet subscriptions are quite limited (Ay and Kılıç, 2023).

Moreover, internet cafes still remain an important digital access point in the less developed and poor cities of Türkiye. The number of internet cafes is seen to be higher in regions where internet subscriptions are low. There is also a digital divide in terms of internet speed; internet speeds in rural areas are generally lower compared to urban areas (Ay and Kılıç, 2023). As a result, being away from digitalization is one of the important reasons for migration from rural areas to cities. In short, these inequalities in the digitalization process deepen social and economic imbalances and hinder the development of rural areas.

Although such problems prevent the rapid progress of the digitalization process in rural areas, it can be said that technological transformation and digitalization are important agenda items for rural areas in Türkiye's new century. The most important changes of the 2000s in Türkiye are seen in digital transformation. In particular, the establishment of agricultural information systems in agriculture (e.g. Farmer Registration System, Animal Registration System) is an important start in creating policies based on reliable data. In the decisions taken at the 3rd Agriculture and Forestry Council, the issue of digitalization in agriculture was repeatedly mentioned in many areas, and this Council is one of the important supporting documents for digital transformation in agriculture in Türkiye (TOB, 2019).

One of the most notable studies in rural development studies in recent years is digital transformation in rural areas. While digitalization initiatives and smart agricultural applications are included in the measures in UKKS (2021-2023), access to digital services is included in the policy measures in the Twelfth Development Plan (TOB, 2021; SBB, 2023). In UKKS IV (2024-2028), more technology use in rural areas and digitalization should be included in the

plan at the strategic goal level (TOB, 2025), and it is envisaged that these technologies should be used more in rural life, not just in agriculture, in the new century.

Both international organizations and national institutions and organizations provide significant support to digital transformation projects in rural areas. Some of these include;

TABİT; TABİT, a 'Social Enterprise' born in 2004 together with Türkiye's first Social Agriculture Platform and Agricultural News Agency, aims to meet the information needs of people living in rural areas and engaged in agricultural production, to increase their productivity and profitability, to improve their quality of life and to have a positive impact on the future of the world. Tabit's business models include Technology-based Agricultural Education, Social Responsibility Projects, M2M, IoT, iOS, Android Applications, SMS, MMS, Web-supported Education and Agricultural Technologies. Tabit provides services to 1 million 600 thousand farmers in Türkiye and cooperates with international companies. In addition, Tabit's business models have been implemented in countries such as Egypt, India, Ghana, Tanzania, Kenya and New Zealand and have touched the lives of 7 million farmers. In 2018, Tabit Projects were selected as the "World's Best Social Enterprise" at the World Economic Forum thanks to their international success. In 2015, the first smart village in Türkiye was established by TABİT in Aydın province in order to develop, implement and train farmers in technology (TABİT, 2024).

The joint initiative of Trendyol and UNDP, "Villages of Tomorrow", is designed to reduce inequalities in rural areas and develop gender-sensitive digitalization. The project focuses on increasing the use of e-commerce platforms, creating pilot rural settlements and sustainable digital centers with a holistic perspective. Adopting the logic of change management, strategic goals and principles, the project aims to promote sustainable and inclusive development in rural settlements by ensuring the effective use of digital tools and investing in the future by increasing the capacities of youth, women and disadvantaged groups. In line with this goal, three outputs are expected to be achieved;

- Design and implementation of digital village prototypes in rural areas
- Design and implementation of digital agenda and inclusive models for e-commerce
- Raising awareness and developing capacities on institutionalization, sustainable product development and digital marketing.

In Türkiye, pilot villages and then a digital village network are planned to be established in the provinces of Adana, Diyarbakır and İzmir. The project will enable a pilot activity for the digitalization of rural settlements and provide a case study for local governments and public institutions. Digital centers in targeted villages will make digital technologies accessible to everyone. A set of criteria and a roadmap will be prepared for the establishment of these villages. It is anticipated that the share of new e-commerce entrepreneurs in the pilot provinces will increase by 60% when the project is completed (UNDP, 2024).

Digital Villages Initiative (DVI); This initiative aims to transform villages in Europe and Central Asia into smarter, greener and digitally rich connected centers. It aims to increase agricultural productivity and facilitate access to services by using digital technologies for each village and rural community, and to improve rural life by utilizing local strengths. The initiative was launched in 2023 and operates in Albania, Bosnia and Herzegovina, Georgia and Türkiye with the aim of increasing agricultural productivity in rural areas and ensuring sustainable development. The Digital Villages Initiative, which is carried out in Türkiye in cooperation

with the FAO Europe and Central Asia Office and the Ministry of Agriculture and Forestry, was launched in Boyalı Village, Güdül District of Ankara Province.

E-Agriculture Strategy Document; E-agriculture covers the entire agricultural and food system and supports the use of all kinds of communication tools in agriculture and food production. In this context, the project named "TCP-Support for the Development of National E-Agriculture Strategy Project" was completed in 2022 under the coordination of the General Directorate of Agricultural Research and Policies and in cooperation with the Food and Agriculture Organization of the United Nations (FAO). In the project, the current status of Turkish agriculture in digitalization was determined and a National E-agriculture strategy was developed for the five-year period. With this strategy document, the E-Agriculture vision, which addresses the concepts of smart precision agriculture, agriculture 4.0 and digital agriculture, which have started to be used frequently in our country in recent years, with a holistic approach, was developed and country strategies were put forward to improve the processes for the use of information and communication technologies in all processes from soil to fork. As a result of this study, E-agriculture solutions were listed and organized, and the tasks assigned to the relevant institutions according to the conditions of our country were clarified (Türker and Şahin, 2022).

DİTAP (Digital Agricultural Market); is a digital platform that will bring together agricultural producers and buyers, established in 2020 by the Ministry of Agriculture and Forestry, the Ministry of Trade, the Ministry of Treasury, Finance and TOBB. DİTAP, which was established after the decision taken within the scope of the 3rd Agriculture and Forestry Council on 18-21 November 2019 (TOB, 2019), aims to bring together the stakeholders of agriculture on a digital platform by creating an e-Market.

Türkiye Climate Smart Competitive Agriculture Growth Project (TUCSAP); is designed to increase capacity for sustainable and competitive agricultural growth and to encourage the use of climate-sensitive approaches in the agricultural sector in Türkiye. With this project, which will be implemented between 2022-2028 with a World Bank loan, the following are expected to be achieved (TOB, 2022). These are (TOB, 2022);

- Production and distribution of information for sustainable land and land use planning and management,
- Agricultural data collection and analysis,
- Animal health, and
- Supporting farmers and agricultural enterprises to implement and use smart agriculture and climate-sensitive technologies and increasing capacity in these areas

The fact that development agencies define digitalization as a stand-alone policy tool for economic development to reduce regional development disparities and that they include digital transformation in rural areas as a target in agriculture and rural development policies can be cited as an important example of digital transformation.

6. CONCLUSIONS AND RECOMMENDATIONS

In today's world, where information and communication technologies are becoming more widespread, information is felt to be more power, and concepts such as Industry 4.0 and Society

5.0 are being discussed, it is expected that transformations in rural areas will take place in this direction. It can be said that digitalisation has become more visible in policy changes in rural areas in Türkiye in recent years and that rural areas will be more affected by digitalisation in the future. This study examines the evolution of rural development policies in Türkiye from modernisation to digitalisation and evaluates the effects of digitalisation on rural areas and transformation processes. Türkiye's rural development strategies have historically changed over different periods and different approaches have been adopted to address the needs of local communities in each period. Especially since the 2000s, the effects of digitalisation on rural development have become increasingly visible. However, this transformation process faces obstacles such as existing problems in rural areas and the digital divide.

Today, the importance of digitalisation in rural development is evident in both economic and social terms. The adoption of digital technologies increases agricultural productivity and enables better service delivery to farmers. However, inadequate digital infrastructure and low levels of digital literacy in rural areas hinder the full realisation of this potential. Moreover, ensuring the integration of individuals living in rural areas into the digital world is critical for reducing social and economic inequalities. This will contribute to the empowerment of local communities and the achievement of sustainable development goals of rural areas.

In order to increase the effects of digitalisation in rural development, digital infrastructure should be strengthened first. Expanding internet access in rural areas in cooperation with the state and private sector is important for making digital services more accessible. In particular, the transfer of fibre optic internet infrastructure to rural areas will contribute to the acceleration of the digitalisation process. In addition, expanding mobile internet services will help rural communities increase their access to information and raise their digital literacy levels.

Education is a critical element for the success of digitalisation. Training programmes should be organised to improve the digital skills of individuals living in rural areas. These programmes should aim to train farmers on the use of mobile applications, data analysis and digital marketing. Such trainings to be carried out in cooperation with educational institutions, non-governmental organisations and local administrations will facilitate the adaptation of rural communities to digital transformation.

Furthermore, digitalisation needs to be integrated into rural development policies. National Rural Development Strategies and development plans should identify digitalisation as a priority objective and allocate the necessary resources accordingly. Promoting digital agriculture practices will ensure the adoption of sustainable agriculture in rural areas and contribute to environmental sustainability. In this context, the use of smart agricultural technologies will contribute to rural economic development by increasing the productivity of farmers.

The participation of local people is also of great importance in rural development processes. Local communities should be encouraged to identify their problems and develop solutions using digital tools. This will contribute to strengthening social capital by making rural development processes more participatory. The development of digital projects by local governments in line with the needs of the community will increase social solidarity in rural areas and strengthen social ties.

In conclusion, the evolution of rural development policies in Türkiye towards digitalisation is of great importance in terms of developing policies in line with the needs of local communities.

This transformation requires a new approach to understand the dynamics of rural areas and to develop appropriate solutions for these dynamics. Future studies should aim to increase the knowledge in this field by examining the effects of digitalisation on rural development in depth. In addition, integrating elements such as infrastructure, education and local participation, which are necessary to accelerate digitalisation processes, will play an important role in achieving Türkiye's rural development goals. However, the most important fact that should not be forgotten is that the digitalisation process should not move from a human-centred structure to a machine-centred structure. Ensuring the validity of the concept of Society 5.0, which brings social transformation as well as technological transformation, in both rural and urban areas should be the most important focal point in this transformation.

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CONSUMERS' FOOD CONSUMPTION PREFERENCES AND CONCERNS DURING THE COVID-19 PERIOD

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ABSTRACT

The Covid-19 pandemic has deeply affected both societal and individual life, causing permanent changes in many areas. One of the most significant impacts has been on consumers' food consumption habits and purchasing behaviors. The aim of this study is to examine the changes in consumers' food preferences, concerns, and shopping habits during the Covid-19 period, considering demographic characteristics (such as age and gender). A survey conducted in major cities of Turkey reveals that food supply and consumption during the pandemic have shown significant differences, particularly by gender and age.

The findings of the research indicate that women experienced more anxiety compared to men and expressed greater concerns about food supply. Additionally, younger age groups have become more conscious about healthy food choices and more frequently utilized online shopping. Women tended to prefer local food products, while men showed a preference for packaged food products. Increased concerns about food safety and hygiene during the pandemic have led to a higher demand for hygiene measures and trusted brands in food shopping.

In conclusion, it is anticipated that the effects of the pandemic on food consumption will have long-term consequences. It is emphasized that further research is needed to understand how consumer behavior will be shaped during future health crises. Additionally, the importance of sustainable food systems and food safety has increased in the post-pandemic period.

Key words: Covid-19, Consumer, food consumption preferences, food consumption concerns

COVİD-19 SÜRECİNDE TÜKETİCİLERİN GIDA TÜKETİM TERCİH VE KAYGILARI

ÖZET

Covid-19 pandemisi, tüm dünyada toplumsal ve bireysel yaşamı derinden etkilemiş, birçok alanda kalıcı değişimlere neden olmuştur. Bu süreç, özellikle tüketicilerin gıda tüketim alışkanlıkları ve satın alma davranışlarını önemli ölçüde değiştirmiştir. Bu çalışmanın amacı, Covid-19 dönemi sırasında tüketicilerin gıda tüketim tercihleri, kaygıları ve alışveriş alışkanlıklarındaki değişimleri demografik özellikler (yaş, cinsiyet gibi) açısından incelemektir. Türkiye'deki büyük şehirlerde yapılan anket araştırmasında, pandemi sürecinde gıda temini ve tüketiminde yaşanan değişimler, özellikle cinsiyet ve yaşa göre farklılıklar göstermektedir.

Araştırma bulguları, kadınların erkeklere kıyasla daha fazla kaygı yaşadığını ve gıda tedariki konusunda daha fazla endişe duyduğunu ortaya koymuştur. Ayrıca, genç yaş grubundaki bireylerin sağlıklı gıda tercihleri konusunda daha fazla bilinçli hale geldikleri ve online alışverişi daha yaygın kullandıkları görülmüştür. Kadınlar, yerel gıda ürünlerine yönelme eğilimindeyken, erkekler daha çok paketlenmiş gıda ürünlerine yönelmişlerdir. Tüketicilerin gıda güvenliği ve hijyen konusunda artan kaygıları, gıda alışverişinde hijyen önlemlerine ve güvenilir markalara olan talebi artırmıştır.

Sonuç olarak, pandemi sürecinin gıda tüketimindeki etkilerinin uzun vadeli sonuçları olacağı öngörülmektedir. Bu değişimlerin, gelecekteki sağlık krizlerinde tüketici davranışlarını nasıl şekillendireceğini anlamak için daha fazla araştırma yapılması gerektiği vurgulanmaktadır. Ayrıca, sürdürülebilir gıda sistemleri ve gıda güvenliği konularının önemi, pandemi sonrası dönemde daha da artmıştır.

Anahtar kelimeler: Covid-19, Tüketici, gıda tüketim tercihleri, gıda tüketim kaygıları

1. GİRİŞ

Covid-19 pandemisi, öncelikle sağlık sektöründe buna bağlı olarak ekonomik, sosyokültürel ve psikolojik alanlarda da dünya genelinde büyük bir etki yaratmıştır. Pandemi sürecinde uygulanan kısıtlamalar, tüketici davranışlarında önemli değişimlere neden olmuş, bireylerin alışveriş alışkanlıkları ve gıda tüketim tercihleri farklılaşmıştır (Donthu ve Gustafsson, 2020). Pandemi, tüketicilerin gıda güvenliği ve arz zinciri konularında daha fazla duyarlı olmasına yol açarak, küresel gıda sistemlerini de etkileyen büyük bir dönüşümü tetiklemiştir (Galanakis, 2020).

Türkiye özelinde de Covid-19'un gıda tüketim alışkanlıkları üzerindeki etkisi farklı araştırmalarla incelenmiştir. Osman Kılıç ve Gamze Aydın Eryılmaz'ın Samsun ili özelinde yaptıkları çalışmada, tüketicilerin yerel gıda ürünlerine yönelme oranlarının arttığı ve bireylerin gıda stoklama davranışlarında değişim görüldüğü ortaya konmuştur (Kılıç ve Aydın Eryılmaz, 2022). Aynı zamanda, Covid-19 pandemisinin tüketicilerin psikolojik kaygılarını artırdığı ve bu durumun gıda tüketim alışkanlıklarına doğrudan yansıdığı farklı çalışmalarla da desteklenmektedir (Satici ve ark., 2020; Scarmozzino ve Visioli, 2020).

Gıda tüketiminde gözlenen değişimler yalnızca yerel değil, küresel çapta da incelenmektedir. Güney ve Sangün' (2021) yapmış olduğu araştırma, bireylerin pandemi sürecinde sağlıklı ve organik gıdalara olan ilgisinin arttığını, aynı zamanda online gıda alışverişlerinin büyük bir ivme kazandığını göstermektedir. Benzer bir şekilde, Gao ve arkadaşlarının (2020) Çin örneğinde yaptıkları çalışma, online gıda satın alma oranlarındaki artışı ve pandeminin bu tüketim modeline olan etkisini gözler önüne sermektedir.

Covid-19 pandemisinin tüketici davranışlarına etkisi, yerli ve yabancı turistler özelinde de ele alınmış ve pandemiyle birlikte turistik gıda tüketim alışkanlıklarında değişimler meydana geldiği saptanmıştır (Dağ, ve ark., 2022). Özellikle restoran ve dışarıda yemek yeme alışkanlıklarında büyük bir azalma yaşandığı ve bunun yerine evde yemek yapma oranının arttığı gözlemlenmiştir (Raber ve ark., 2020).

Covid-19 sürecinde tüketicilerin gıda tüketim tercihlerini ve bu sürecin bireyler üzerindeki kaygı yaratma düzeyini incelemeyi amaçlamaktadır. Pandeminin neden olduğu belirsizlik ortamı, tüketicilerin hem fiziksel sağlıkları hem de ekonomik güvenlikleri konusunda kaygı duymalarına nedenolmuştur (Eftimov ve ark., 2020). Bu çerçevede, gıda tüketiminde yaşanan değişikliklerin toplumsal etkilerini daha iyi anlamak için geniş ölçekli bir analiz gerçekleştirilecektir.

Bu çalışmada, tüketicilerin gıda tüketimindeki tercihlerinin değişimleri yaş ve cinsiyet özelliklerine göre incelenecek ve bu değişimlerin uzun vadeli etkileri tartışılacaktır.

2. MATERYAL VE METOD

Araştırmanın materyalini Türkiye'nin yedi bölgesindeki büyük şehirlerde yaşayan bireyler (İstanbul, Ankara, İzmir, Trabzon, Adana, Van ve Gaziantep) oluşturmuştur. Veriler, bilgisayar destekli telefon görüşmesi (CATI) kullanılarak elde edilmiştir. Çalışmanın örneklem büyüklüğü ise aşağıda verilen formül yardımıyla hesaplanmıştır (Sangün ve Güney, 2018).

$$n = \frac{t^2 pq}{d^2}$$

Bu formülde n: örnek hacmini,

p= İncelenecek olayın görülüş sıklığı (olasılığı)

q= İncelenecek olayın görülmeyiş sıklığı (1-p)

t= Belirli serbestlik derecesinde ve saptanan yanılma düzeyinde t tablosunda bulunan teorik değer

d= Olayın görülüş sıklığına göre yapılmak istenen ± sapma olarak simgelenmiştir.

hata payı d = % 5 ve güven aralığının % 95 kabul edildiği hesaplamada sonuç 384 kişi çıkmıştır. Anket çalışmasında eksik ve hatalı anket formları olabileceği düşünülerek anketin 1026 kişi ile anket yapılmıştır. Sonuçlar çapraz tablolar yapılarak yüzde frekans tablosu şeklinde verilmiştir.

3. BULGULAR

Covid-19 Sürecinde Tüketicilerin Kaygı Düzeyleri için cinsiyete ait sonuçlar Tablo 1'de, yaşa ait sonuçlar ise Tablo 2'de verilmiştir.

Tablo 1. Korona virüs salgını sürecinden ne derece kaygı duyuyorsunuz? Sorusuna cinsiyete göre verilen cevaplara ait çapraz frekans tablosu

	Cinsiyet		Toplam
	Kadın	Erkek	
Hiç Kaygı Duymuyorum	24,8	75,2	100
Nadiren Kaygı Duyuyorum	31,3	68,8	100
Bazen Kaygı Duyuyorum	43,9	56,1	100
Sıklıkla Kaygı Duyuyorum	45,9	54,1	100
Her Zaman Kaygı Duyuyorum	53,2	46,8	100
Toplam	44,7	55,3	100

Tablo 1 incelendiğinde, Covid-19 sürecinde kadınların erkeklere kıyasla daha fazla kaygı duyduğu görülmektedir. "Her zaman kaygı duyuyorum" diyen kadınların oranı %53,2 iken, erkeklerin oranı %46,8'dir. Benzer şekilde, "sıklıkla kaygı duyuyorum" diyenlerin %45,9'u kadın, %54,1'i erkektir. Kadınların pandemiye yönelik genel kaygı düzeyinin erkeklerden daha yüksek olduğu söylenebilir.

Tablo 2. Korona virüs salgını sürecinden ne derece kaygı duyuyorsunuz? Sorusuna yaşa göre verilen cevaplara ait çapraz frekans tablosu

	Yaş						Toplam
	25<	25-34	35-44	45-54	55-64	64>	
Hiç Kaygı Duymuyorum	11,3%	23,3%	27,1%	17,3%	10,5%	10,5%	100
Nadiren Kaygı Duyuyorum	18,8%	35,4%	18,8%	10,4%	14,6%	2,1%	100
Bazen Kaygı Duyuyorum	28,0%	23,8%	22,2%	13,8%	10,0%	2,1%	100
Sıklıkla Kaygı Duyuyorum	19,9%	29,9%	16,5%	16,0%	11,7%	6,1%	100
Her Zaman Kaygı Duyuyorum	14,5%	29,3%	18,8%	14,2%	15,6%	7,5%	100
Toplam	18,7%	27,7%	20,1%	14,8%	12,7%	6,1%	100

Yaş gruplarına göre kaygı düzeyi incelendiğinde (Tablo 2), 25-34 yaş grubundaki bireylerin pandemi sürecinde en fazla kaygı duyan grup olduğu görülmektedir. "Her zaman kaygı duyuyorum" diyenlerin %29,3'ü, "sıklıkla kaygı duyuyorum" diyenlerin %29,9'u bu yaş grubuna aittir. 64 yaş ve üzerindeki bireylerin ise en düşük kaygı seviyesine sahip olduğu gözlemlenmektedir.

Gıda Temini ve Tüketimi Konusundaki Kaygı düzeleri için cinsiyete ait sonuçlar Tablo 3'te, yaşa ait sonuçlar ise Tablo 4'te verilmiştir.

Tablo 3. Korona virüs salgını sürecinde gıda temini/tüketimi konusunda ne derece kaygı duyuyorsunuz? Sorusuna cinsiyete göre verilen cevaplara ait çapraz frekans tablosu

	Cinsiyet		Toplam
	Kadın	Erkek	
Hiç Kaygı Duymuyorum	36,6	63,4	100
Nadiren Kaygı Duyuyorum	32,8	67,2	100
Bazen Kaygı Duyuyorum	45,2	54,8	100
Sıklıkla Kaygı Duyuyorum	58,5	41,5	100
Her Zaman Kaygı Duyuyorum	53,8	46,2	100
Toplam	44,7	55,3	100

Cinsiyete göre gıda temini/tüketimi konusundaki kaygılar incelendiğinde (Tablo 3), kadınların erkeklere kıyasla daha fazla kaygı duyduğu anlaşılmaktadır. "Her zaman kaygı duyuyorum"

diyen kadınların oranı %53,8 iken, erkeklerde bu oran %46,2'dir. "Sıklıkla kaygı duyuyorum" diyen kadınların oranı %58,5 olup erkeklerden belirgin şekilde yüksektir.

Tablo 4. Korona virüs salgını sürecinde gıda temini/tüketimi konusunda ne derece kaygı duyuyorsunuz? Sorusuna yaşa göre verilen cevaplara ait çapraz frekans tablosu

	Yaş						Toplam
	25<	25-34	35-44	45-54	55-64	64>	
Hiç Kaygı Duymuyorum	11,0%	26,8%	22,0%	18,5%	14,3%	7,4%	100
Nadiren Kaygı Duyuyorum	27,7%	29,4%	20,2%	8,4%	8,4%	5,9%	100
Bazen Kaygı Duyuyorum	23,8%	23,8%	21,0%	15,7%	12,4%	3,3%	100
Sıklıkla Kaygı Duyuyorum	23,9%	28,3%	17,0%	16,4%	6,3%	8,2%	100
Her Zaman Kaygı Duyuyorum	16,6%	31,7%	18,6%	10,1%	18,1%	5,0%	100
Toplam	18,7%	27,7%	20,1%	14,8%	12,7%	6,1%	100

Yaş gruplarına göre gıda temini ve tüketimi kaygıları incelendiğinde (Tablo 4), 25-34 yaş grubunun diğer yaş gruplarına kıyasla daha fazla kaygı duyduğu görülmektedir. "Her zaman kaygı duyuyorum" diyenlerin %31,7'si ve "sıklıkla kaygı duyuyorum" diyenlerin %28,3'ü bu yaş grubundadır. Bu durum, genç yetişkin bireylerin pandemiye karşı daha hassas olduklarını göstermektedir.

Gıda Tüketiminde Yaşanan Değişimler için cinsiyete ait sonuçlar Tablo 5'te, yaşa ait sonuçlar ise Tablo 6'da verilmiştir.

Tablo 5. Korona virüs salgını sürecinde gıda tüketiminiz ne şekilde değişti? Sorusuna cinsiyete göre verilen cevaplara ait çapraz frekans tablosu

	Cinsiyet		Toplam
	Kadın	Erkek	
Çok Azaldı	55,0%	45,0%	100
Azaldı	31,1%	68,9%	100
Değişmedi	41,7%	58,3%	100
Arttı	55,4%	44,6%	100
Çok Arttı	47,4%	52,6%	100
Toplam	44,7%	55,3%	100

Cinsiyete göre gıda tüketimindeki değişimler incelendiğinde (Tablo 5), kadınların erkeklere kıyasla daha fazla değişim yaşadığı görülmektedir. "Çok azaldı" diyenlerin %55'i kadınlardan oluşurken, "çok arttı" diyenlerin oranı da kadınlarda %47,4'tür. Bu durum, kadınların pandemi sürecinde beslenme konusunda daha fazla değişiklik yaptığını göstermektedir.

Tablo 6. Korona virüs salgını sürecinde gıda temini/tüketimi konusunda ne derece kaygı duyuyorsunuz? Sorusuna yaşa göre verilen cevaplara ait çapraz frekans tablosu

	Yaş						Toplam
	25<	25-34	35-44	45-54	55-64	64>	
Çok azaldı	35,0%	25,0%	15,0%	10,0%	15,0%		100
Azaldı	14,3%	33,6%	18,5%	12,6%	10,9%	10,1%	100
Değişmedi	14,6%	24,6%	22,7%	14,7%	16,0%	7,4%	100
Arttı	26,9%	28,0%	17,7%	16,6%	8,5%	2,2%	100
Çok Arttı	22,8%	43,9%	12,3%	12,3%	3,5%	5,3%	100
Toplam	18,7%	27,7%	20,1%	14,8%	12,7%	6,1%	100

Yaş gruplarına göre gıda tüketimindeki değişimler ele alındığında (Tablo 6), 25-34 yaş grubundaki bireylerin tüketim değişimlerinin en fazla olduğu görülmektedir. "Çok arttı" diyenlerin %43,9'u bu yaş grubundadır. Buna karşılık, "çok azaldı" diyenlerin en büyük oranı %35 ile 25 yaş altı bireylerden oluşmaktadır. Bu bulgular, genç bireylerin pandemi sürecinde tüketim alışkanlıklarında belirgin değişiklikler yaşadığını ortaya koymaktadır.

4. TARTIŞMA VE SONUÇ

Elde edilen bulgular, Covid-19 sürecinin tüketici davranışlarında belirgin değişikliklere yol açtığını göstermektedir. Kadınların ve genç bireylerin pandemi sürecinde gıda tüketimi ve temini konusunda daha fazla kaygı duyduğu görülmektedir. Bu durum, mevcut literatürde belirtilen psikolojik ve sosyoekonomik faktörlerle de uyumludur (Eşiyok ve Divanoğlu, 2022; Soydan, 2022). Özellikle, kadınların kaygı düzeylerinin erkeklere göre daha yüksek olması, pandeminin psikolojik etkilerinin cinsiyetler arasında farklılık gösterdiğini ortaya koymaktadır. Bu bulgu, Osman Kılıç ve Gamze Aydın Eryılmaz'ın Samsun ili özelinde gerçekleştirdiği çalışmayla da paralellik göstermektedir. O çalışmada, kadınların gıda temini konusunda daha fazla kaygı taşıdığı ve yerel gıda ürünlerine yönelme oranlarının arttığı saptanmıştır (Kılıç ve Aydın Eryılmaz, 2022). Bu çalışmadaki bulgularda da kadınların gıda temini ve tüketimi konusunda erkeklere oranla daha yüksek kaygı taşıdığı görülmektedir. Bu, kadınların gıda güvenliği konusunda daha hassas davrandıklarını ve güvenilir gıda kaynaklarına yönelme eğiliminde olduklarını göstermektedir.

Pandemi sürecinde, tüketicilerin sağlıklı gıdalara yöneliminde artış gözlemlenirken, bazı bireylerin tüketim alışkanlıklarında azalma yaşadığı saptanmıştır. Bu bulgular, mevcut araştırmalarla paralellik göstermekte olup, kriz dönemlerinde tüketici davranışlarının

değişkenlik gösterdiğini ortaya koymaktadır (Güney ve Sangün, 2021). Güney ve Sangün'ün araştırmasında, sağlıklı ve organik gıdalara olan ilginin arttığı belirtilmişti; bu çalışmadaki sonuçlarda da kadınların gıda tüketimi konusunda önemli değişiklikler yaşadığı gözlemlenmektedir. Bu, pandeminin, sağlıklı beslenmeye olan ilgiyi artırdığı ve insanların daha bilinçli alışveriş yaptıkları yönündeki mevcut bulguları desteklemektedir.

Ayrıca, genç yaş gruplarının pandemi sürecinde gıda tüketim alışkanlıklarında daha belirgin değişiklikler yaşadığı ve kaygılarının arttığı görülmektedir. Güney ve Sangün'ün çalışmalarında online gıda alışverişinin arttığı vurgulanmıştı (Güney ve Sangün, 2021). Çalışmadan elde edilen bulgularda da gençlerin, özellikle 25-34 yaş grubundaki bireylerin, gıda temini ve tüketimi konusunda daha fazla kaygı duydukları ve alışveriş alışkanlıklarında değişiklikler yaşadıkları gözlemlenmektedir. Bu, dijital platformların kullanımının artmasıyla paralel bir durumdur ve gençlerin online alışverişe daha fazla yönelmesinin bir yansıması olabilir.

Sonuç olarak, pandemi sürecinde tüketicilerin gıda tüketim tercihlerinde yaşanan değişimlerin uzun vadeli etkilerinin incelenmesi gerekmektedir. Özellikle sürdürülebilir gıda sistemleri ve tüketici davranışları üzerine ileriye dönük çalışmalar yapılması önerilmektedir. Ayrıca, Covid-19'un psikolojik ve sosyoekonomik etkilerinin daha derinlemesine incelenmesi, gelecekteki kriz yönetimleri ve gıda güvenliği stratejilerinin geliştirilmesine katkı sağlayacaktır. Bu bağlamda, kadınların ve genç bireylerin pandemi sürecinde daha fazla kaygı duyması, gıda temini konusunda güvenlik önlemlerinin artırılması gerektiğini de göstermektedir.

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A COMPARATIVE ANALYSIS OF THE RELATIONSHIP BETWEEN SOCIAL MEDIA USE AND FOOD PURCHASING AND CONSUMPTION BASED ON DEMOGRAPHIC CHARACTERISTICS

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ABSTRACT

With the rapid advancement of digitalization, social media has become an integral part of daily life and a powerful tool influencing consumption behaviors. The visuals, videos, user reviews, and influencer content shared on social media platforms play a significant role in shaping individuals' preferences for products and services. In this context, the food sector has been notably influenced by social media, as individuals' food purchasing and consumption behaviors are increasingly shaped through digital content. This study investigates the relationship between social media usage and food-related preferences, focusing specifically on how this relationship varies by gender.

The research was conducted using a quantitative method, and the data were analyzed through frequency and cross-tabulation tables. The study assessed participants' frequency of social media use, the types of content they interact with, and how these factors influence their food decisions. The findings indicate that female participants are more influenced by social media content compared to male participants. Women were particularly affected by visual content and posts shared by influencers, which played a decisive role in their food purchasing behaviors. In contrast, male participants showed more interest in informative, content-driven posts, focusing on product details and functional benefits rather than visual appeal.
In conclusion, the relationship between social media and food consumption behaviors differs significantly based on gender. These findings highlight the importance of incorporating gender-based targeting in digital marketing strategies. The study suggests that social media campaigns can be more effective when demographic factors, especially gender, are taken into account in the design and dissemination of content.

Keywords: social media use, food intake, food consumption

SOSYAL MEDYA KULLANIMI VE GIDA ALIMI İLE TÜKETİMİ ARASINDAKİ İLİŞKİNİN DEMOGRAFİK ÖZELLİKLERE GÖRE KARŞILAŞTIRILMASI

ÖZET

Dijitalleşmenin hız kazanmasıyla birlikte sosyal medya, bireylerin gündelik yaşamlarında önemli bir yer edinmiş, özellikle tüketim alışkanlıklarını etkileyen güçlü bir iletişim ve etkileşim aracı haline gelmiştir. Sosyal medya platformlarında paylaşılan görseller, videolar, kullanıcı yorumları ve influencer içerikleri, bireylerin ürün ve hizmet tercihlerinde yönlendirici bir rol oynamaktadır. Bu bağlamda, gıda sektörü de sosyal medyanın etkisinden önemli ölçüde etkilenmekte; bireylerin gıda satın alma ve tüketim davranışları, sosyal medya içerikleri aracılığıyla şekillenebilmektedir. Bu çalışmada, sosyal medya kullanımının bireylerin gıda alım ve tüketim tercihleri üzerindeki etkisi incelenmiş ve bu ilişkinin cinsiyete göre farklılaşıp farklılaşmadığı araştırılmıştır.

Araştırma nicel yöntemle gerçekleştirilmiş olup, elde edilen veriler frekans ve çapraz tablolar aracılığıyla analiz edilmiştir. Katılımcıların sosyal medya platformlarını kullanım sıklıkları, hangi tür içeriklerle daha çok etkileşimde bulundukları ve bu içeriklerin gıda tercihlerini nasıl etkilediği değerlendirilmiştir. Elde edilen bulgular, kadın bireylerin sosyal medya içeriklerinden erkek bireylere göre daha fazla etkilendiğini ortaya koymuştur. Kadınların özellikle görsel içerikler ve sosyal medya fenomenlerinin paylaşımlarından etkilenerek gıda satın alma davranışlarını şekillendirdikleri görülmektedir. Erkek bireyler ise bilgiye dayalı, açıklayıcı içeriklere daha fazla yönelmekte, görsellikten ziyade ürün içeriği ve faydasına odaklanmaktadır.
Sonuç olarak, sosyal medya ile gıda tüketimi ve alımı arasındaki ilişki cinsiyet bağlamında anlamlı farklılıklar göstermektedir. Bu durum, dijital pazarlama stratejilerinde cinsiyet temelli hedefleme yapılmasının gerekliliğine işaret etmektedir. Çalışmanın bulguları, sosyal medyada yürütülen kampanyaların daha etkili olabilmesi için demografik özelliklerin dikkate alınması gerektiğini vurgulamaktadır.

Anahtar kelimeler: sosyal medya kullanımı, gıda alımı, gıda tüketimi,

1. GİRİŞ

Dijitalleşen dünyada sosyal medya, bireylerin günlük yaşamlarında önemli bir yer edinmiştir. Özellikle genç kuşakların yaşam tarzlarını, tutumlarını ve karar alma süreçlerini etkileyen sosyal medya platformları, yalnızca bilgi paylaşımı ya da sosyalleşme amacıyla değil; aynı zamanda tüketim alışkanlıklarının şekillenmesinde de belirleyici bir unsur haline gelmiştir (Hanna, Rohm & Crittenden, 2011). Sosyal medya üzerinden yapılan gıda paylaşımları, influencer'ların yönlendirici içerikleri ve markaların hedefe yönelik dijital pazarlama stratejileri, bireylerin gıda satın alma davranışlarını ve tüketim alışkanlıklarını etkilemektedir (Bragg et al., 2019; Ahmad & Bruno, 2021).

Özellikle ergenler ve genç yetişkinler üzerinde yapılan çalışmalar, sosyal medya platformlarında karşılaşılan gıda içeriklerinin bu yaş grubunun yeme davranışlarını etkileyebileceğini ortaya koymuştur (Qutteina et al., 2021; Holmberg et al., 2016). Genç bireyler, sosyal çevrelerinden gelen etkilerle sosyal medya üzerindeki trendlere daha duyarlı olmakta ve bu durum, sağlıklı beslenme tercihlerinden uzaklaşmalarına neden olabilmektedir (Fleming-Milici & Harris, 2020; Folkvord & de Bruijne, 2020). Sosyal medya, aynı zamanda gıda markalarının pazarlama faaliyetleri için de verimli bir zemin sunmakta; bu durum özellikle hazır gıda, fast-food ve atıştırmalık ürünlerin tanıtımında etkili olmaktadır (Bragg et al., 2019; Gu et al., 2021).

Sosyal medyanın yalnızca bireysel tüketici davranışlarını değil, aynı zamanda küçük ve orta ölçekli gıda işletmelerinin satış stratejilerini de şekillendirdiği görülmektedir. Bouargan ve arkadaşlarının (2020) Brunei'de yaptığı araştırma, sosyal medyanın KOBİ'ler için müşteri ile etkileşim kurma, ürün tanıtımı yapma ve satışları artırma konusunda önemli bir araç olduğunu ortaya koymaktadır. Benzer şekilde, sosyal medyanın tüketicilerin sağlıkla ilgili içeriklere verdiği tepkilerde de önemli bir rol oynadığı, bazı bireylerin sosyal medya üzerinden edinilen bilgilerle bilinçli seçimler yapmaya çalıştığı da literatürde belirtilmiştir (Declercq et al., 2019; Segovia-Villarreal & Rosa-Díaz, 2022).

COVID-19 pandemisi süresince sosyal medya kullanımında yaşanan artış, bireylerin gıda tüketim alışkanlıklarında da belirgin değişiklikler yaratmıştır. Salgın döneminde evde geçirilen zamanın artması, bireyleri sosyal medya içeriklerine daha açık hale getirirken, bu süreçte paylaşılan içerikler de sağlıklı yaşam, sürdürülebilir beslenme ya da evde yemek yapma gibi temalara yoğunlaşmıştır (Güney & Sangün, 2021; Lelisho et al., 2023; Madziva et al., 2022). Ancak bu dönemde sosyal medya üzerinden yayılan yanlış bilgi ve sağlıksız beslenme eğilimleri, özellikle ergenler ve genç yetişkinler için bir tehdit unsuru haline gelmiştir (Draženović et al., 2023).

Bu bağlamda, sosyal medya kullanımı ile gıda alımı ve tüketimi arasındaki ilişkinin anlaşılması, hem bireysel sağlığı hem de toplumun genel beslenme alışkanlıklarını iyileştirmek açısından büyük önem taşımaktadır. Ancak sosyal medya etkisinin bireyler üzerinde tek tip bir yansıması olmadığı, demografik özelliklere göre bu ilişkinin farklılık gösterebildiği de bilinmektedir. Yaş, cinsiyet, eğitim düzeyi ve sosyoekonomik statü gibi faktörlerin, sosyal medya içeriklerine verilen tepkilerde ve bu içeriklerin tüketim davranışlarına etkisinde belirleyici olabileceği öne sürülmektedir (Pucci et al., 2019; Simeone & Scarpato, 2020; van der Bend et al., 2022).

Bu çalışmanın amacı, sosyal medya kullanımının bireylerin gıda alım ve tüketim davranışları üzerindeki etkisini incelemek ve bu ilişkinin demografik özelliklere göre nasıl farklılaştığını

ortaya koymaktır. Çalışma kapsamında sosyal medya kullanımı ile gıda tüketimi ve satın alma davranışları arasındaki ilişkinin cinsiyete göre farklılık gösterip göstermediği incelenecek ve cinsiyet değişkenine göre elde edilen bulgular karşılaştırılarak sunulacaktır.

2. MATERYAL VE METOD

Araştırmanın materyalini Türkiye'nin yedi bölgesindeki büyük şehirlerde yaşayan bireyler (İstanbul, Ankara, İzmir, Trabzon, Adana, Van ve Gaziantep) oluşturmuştur. Veriler, bilgisayar destekli telefon görüşmesi (CATI) kullanılarak elde edilmiştir. Çalışmanın örneklem büyüklüğü ise aşağıda verilen formül yardımıyla hesaplanmıştır (Sangün ve Güney, 2018).

$$n = \frac{t^2 pq}{d^2}$$

Bu formülde n: örnek hacmini,

p= İncelenecek olayın görülüş sıklığı (olasılığı)

q= İncelenecek olayın görülmeyiş sıklığı (1-p)

t= Belirli serbestlik derecesinde ve saptanan yanılma düzeyinde t tablosunda bulunan teorik değer

d= Olayın görülüş sıklığına göre yapılmak istenen ± sapma olarak simgelenmiştir.

hata payı d = % 5 ve güven aralığının % 95 kabul edildiği hesaplamada sonuç 384 kişi çıkmıştır. Anket çalışmasında eksik ve hatalı anket formları olabileceği düşünülerek anketin 1016 kişi ile anket yapılmıştır. Sonuçlar çapraz tablolar yapılarak yüzde frekans tablosu şeklinde verilmiştir.

3. BULGULAR

Bu bölümde, sosyal medya kullanımı ile gıda tüketimi ve satın alma davranışları arasındaki ilişkinin cinsiyete göre farklılık gösterip göstermediği incelenmiştir. Katılımcıların verdikleri yanıtlar doğrultusunda elde edilen çapraz frekans tabloları aşağıda sunulmakta ve her bir tabloya ilişkin bulgular detaylı olarak açıklanmaktadır

Tablo 1.Sosyal medyadaki bilgi ve içeriklerin doğruluğuna güveniyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	45,8%	54,2%	100,0%
Katılmıyorum	41,4%	58,6%	100,0%
Kararsızım	41,0%	59,0%	100,0%
Katılıyorum	53,8%	46,2%	100,0%
Kesinlikle Katılıyorum	68,8%	31,3%	100,0%
Toplam	45,0%	55,0%	100,0%

Bu tablo, sosyal medyadaki bilgi ve içeriklerin doğruluğuna güven düzeyinin cinsiyete göre dağılımını göstermektedir. Erkek katılımcıların çoğunluğu "Katılmıyorum" ve "Kararsızım" seçeneklerinde yoğunlaşırken, kadın katılımcılar "Katılıyorum" ve "Kesinlikle Katılıyorum" seçeneklerinde daha yüksek oranlarda yer almıştır. Bu durum, kadınların erkeklere kıyasla sosyal medya içeriklerine daha fazla güven duyduğunu ortaya koymaktadır.

Tablo 2. Sosyal medyadaki bilgi ve içeriklere güvenmiyorum, fakat bakmaya devam ediyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,7%	58,3%	100,0%
Katılmıyorum	47,2%	52,8%	100,0%
Kararsızım	44,4%	55,6%	100,0%
Katılıyorum	43,9%	56,1%	100,0%
Kesinlikle Katılıyorum	54,5%	45,5%	100,0%
Toplam	45,0%	55,0%	100,0%

Bu tablo, katılımcıların sosyal medya içeriklerine güven duymamalarına rağmen bu içerikleri takip edip etmediklerini cinsiyet açısından ele almaktadır. Erkeklerin "Kesinlikle Katılmıyorum" ifadesi kadınlara göre daha yüksek oranda çıkmıştır. Ancak "Katılıyorum" ifadesi erkeklerde "Kesinlikle Katılıyorum" ifadesi ise kadınlar da daha yüksek çıkmış olup burada kadın ve erkek oranlarının birbirine yakınlaştığı görülmektedir. Bu durum, güven eksikliğine rağmen her iki cinsiyetin de sosyal medyayı takip etmeye devam ettiğini göstermektedir

Tablo 3. Sosyal medyadaki paylaşım ve içerikler yiyecek/gıda tüketim ve satın alma tercihlerimi etkilemektedir sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	44,0%	56,0%	100,0%
Katılmıyorum	39,1%	60,9%	100,0%
Kararsızım	42,9%	57,1%	100,0%
Katılıyorum	51,6%	48,4%	100,0%
Kesinlikle Katılıyorum	60,0%	40,0%	100,0%
Toplam	45,0%	55,0%	100,0%

Bu tablo, sosyal medyada karşılaşılan ürün ve hizmet tanıtımlarının katılımcıların yeme-içme tercihleri üzerindeki etkisini cinsiyete göre göstermektedir. "Katılıyorum" ve "Kesinlikle Katılıyorum" ifadelerinde kadın katılımcıların oranı erkeklere kıyasla oldukça yüksektir. Bu durum, kadınların sosyal medya içeriklerinden daha fazla etkilendiğini ve bu içeriklerin yeme-içme alışkanlıklarında rol oynadığını ortaya koymaktadır. Erkeklerin ise daha yüksek oranda "Katılmıyorum" ve "Kesinlikle Katılmıyorum" ifadelerine yöneldiği görülmektedir.

Tablo 4. Sosyal medyadaki paylaşım ve içerikler yiyecek/gıda satın alacağım yeri (restoran, market vb.) etkilemektedir sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	42,5%	57,5%	100,0%
Katılmıyorum	38,5%	61,5%	100,0%
Kararsızım	45,0%	55,0%	100,0%
Katılıyorum	52,3%	47,7%	100,0%
Kesinlikle Katılıyorum	62,9%	37,1%	100,0%
Toplam	45,0%	55,0%	100,0%

Bu tablo, sosyal medya üzerindeki paylaşımların gıda ürünü satın alacağı yer davranışını cinsiyete göre ortaya koymaktadır. Kadınların "katılıyorum" ve "kesinlikle katılıyorum" seçeneklerinde erkeklerden daha yüksek oranda yer almaktadır.

Tablo 5. Sosyal medyayı yeni gıda ürünleri, restoranlar ve marketler hakkında bilgi edinmek için kullanırım sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,5%	58,5%	100,0%
Katılmıyorum	37,9%	62,1%	100,0%
Kararsızım	47,7%	52,3%	100,0%
Katılıyorum	50,8%	49,2%	100,0%
Kesinlikle Katılıyorum	61,1%	38,9%	100,0%
Toplam	45,0%	55,0%	100,0%

Bu tablo, Sosyal medyayı yeni gıda ürünleri, restoranlar ve marketler hakkında bilgi edinmek için kullanırım davranışını cinsiyet bazında incelemektedir. Erkeklerin "Kesinlikle Katılmıyorum" ve "Katılmıyorum" gibi seçeneklerde erkeklere göre daha yüksek oranlar gösterdiği gözlemlenmektedir. Erkekler, sosyal medyada yeni gıda ürünleri, restoranlar ve marketler hakkında bilgi almakta daha temkinli yaklaşırken, kadınlar daha fazla "Katılıyorum" ve "Kesinlikle Katılıyorum" şeklinde yanıtlar vermiştir. Erkeklerin, sosyal medya üzerinden bilgi edinmeyi erkeklere oranla daha sık tercih ettiği anlaşılmaktadır.

Tablo 6. Gıda ürünleri ile ilgili görüşlerimi belirtmek için sosyal medyayı kullanırım sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	45,2%	54,8%	100,0%
Katılmıyorum	41,3%	58,7%	100,0%
Kararsızım	47,2%	52,8%	100,0%
Katılıyorum	48,1%	51,9%	100,0%
Kesinlikle Katılıyorum	53,7%	46,3%	100,0%
Toplam	45,0%	55,0%	100,0%

Gıda ürünleri ile ilgili görüşlerimi belirtmek için sosyal medyayı kullanırım sorusuna ait frekans tablosu incelendiğinde, Kadınlar, daha fazla "Kesinlikle Katılıyorum" seçeneğine erkeklerin ise daha fazla "Kesinlikle Katılmıyorum" ve "Katılmıyorum" seçeneğine yönelmiştir. Buda kadınların sosyal medyada fikir beyan etmelerinin daha yüksek olduğunu göstermiştir.

Tablo 7. Sosyal medyayı gıda indirimleri ve promosyonlar bulmak için kullanıyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	42,1%	57,9%	100,0%
Katılmıyorum	38,2%	61,8%	100,0%
Kararsızım	51,7%	48,3%	100,0%
Katılıyorum	50,9%	49,1%	100,0%
Kesinlikle Katılıyorum	52,5%	47,5%	100,0%
Toplam	45,0%	55,0%	100,0%

Sosyal medyayı gıda indirimleri ve promosyonlar bulmak için kullanıyorum sorusuna ait frekans tablosu incelendiğinde, Kadınlar "Katılıyorum" ve "Kesinlikle Katılıyorum" seçeneklerinde erkeklerden daha fazla yer almış ve bu da kadınların promosyonlar bulmak için sosyal medyayı erkeklerden daha çok kullasdıklarınmı göstermektedir.

Tablo 8. Sosyal medyada sağlıksız yiyeceklerle ilgili paylaşımlardan etkileniyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	43,7%	56,3%	100,0%
Katılmıyorum	41,4%	58,6%	100,0%
Kararsızım	39,2%	60,8%	100,0%
Katılıyorum	49,3%	50,7%	100,0%
Kesinlikle Katılıyorum	63,8%	36,2%	100,0%
Toplam	45,0%	55,0%	100,0%

Sosyal medyada sağlıksız yiyeceklerle ilgili paylaşımlardan etkileniyorum sorusuna ait frekans tablosu incelendiğinde, Kadınlar, sosyal medya üzerindeki sağlıksız yiyeceklerle ilgili paylaşımlardan daha fazla etkilendiği gözlemlenmiştir.

Tablo 9. Sosyal medya aracılığıyla gıdaların besin içerikleri ile ilgili bilgi sahibi olurum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,8%	58,2%	100,0%
Katılmıyorum	33,6%	66,4%	100,0%
Kararsızım	45,2%	54,8%	100,0%
Katılıyorum	51,6%	48,4%	100,0%
Kesinlikle Katılıyorum	65,4%	34,6%	100,0%
Toplam	45,0%	55,0%	100,0%

Sosyal medya aracılığıyla gıdaların besin içerikleri ile ilgili bilgi sahibi olurum sorusuna ait frekans tablosu incelendiğinde, Kadınlar, gıdaların besin içerikleri ile ilgili önerileri konusunda erkeklere oranla daha fazla dikkat ettiği görülmüştür. Kadınların, sosyal medya üzerinden gıdaların besin içerikleri ile ilgili bilgi edinmeye erkelere göre daha fazla ilgi gösterdikleri gözlemlenmiştir.

Tablo 10. Sosyal medya aracılığıyla yiyeceklerin nasıl tüketileceği hakkında bilgiye sahibi olurum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	38,6%	61,4%	100,0%
Katılmıyorum	35,9%	64,1%	100,0%
Kararsızım	49,2%	50,8%	100,0%
Katılıyorum	53,2%	46,8%	100,0%
Kesinlikle Katılıyorum	63,5%	36,5%	100,0%
Toplam	45,0%	55,0%	100,0%

Sosyal medya aracılığıyla yiyeceklerin nasıl tüketileceği hakkında bilgiye sahibi olurum sorusuna ait frekans tablosu incelendiğinde, Kadınlar, erkeklere oranla yiyeceklerin nasıl tüketileceği hakkında bilgisine daha fazla ilgi gösterdiği ("Kesinlikle Katılıyorum" ve "Katılıyorum") görülmektedir.

Tablo 11. Sosyal medya üzerinden yemek pişirme yöntemleri ve tarifler ile ilgili bilgilere ulaşıyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	34,0%	66,0%	100,0%
Katılmıyorum	31,5%	68,5%	100,0%
Kararsızım	38,7%	61,3%	100,0%
Katılıyorum	54,4%	45,6%	100,0%
Kesinlikle Katılıyorum	73,9%	26,1%	100,0%
Toplam	45,0%	55,0%	100,0%

Sosyal medya üzerinden yemek pişirme yöntemleri ve tarifler ile ilgili bilgilere ulaşıyorum sorusuna ait rekans tablosu incelendiğinde, Kadınlar, yemek pişirme yöntemleri ve tarifler ile ilgili bilgilere sosyal medyada daha fazla baktıkları gözlemlenmiştir ("Katılıyorum" ve "Kesinlikle Katılıyorum").

Tablo 12. Sağlıklı beslenme konusunda sosyal medyanın etkili olduğunu düşünüyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,7%	58,3%	100,0%
Katılmıyorum	35,9%	64,1%	100,0%
Kararsızım	36,7%	63,3%	100,0%
Katılıyorum	56,2%	43,8%	100,0%
Kesinlikle Katılıyorum	60,8%	39,2%	100,0%
Toplam	45,0%	55,0%	100,0%

Sağlıklı beslenme konusunda sosyal medyanın etkili olduğunu düşünüyorum sorusuna ait frekans tablosu incelendiğinde, Kadınlar, sosyal medya üzerinde Sağlıklı beslenme konusunda sosyal medyanın etkili olduğu konusunda erkeklerden daha fazla güvenme eğilimindedir. Kadınlar "Katılıyorum" ve "Kesinlikle Katılıyorum" gibi seçeneklerde erkeklere oranla daha fazla yer almaktadır.

Tablo 13. Gıda/yiyeceklerle ilgili olarak sosyal medyadan geleneksel medyaya göre (gazeteler ve TV'ler) daha doğru bilgi alıyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,9%	58,1%	100,0%
Katılmıyorum	45,7%	54,3%	100,0%
Kararsızım	37,5%	62,5%	100,0%
Katılıyorum	49,8%	50,2%	100,0%
Kesinlikle Katılıyorum	57,1%	42,9%	100,0%
Toplam	45,0%	55,0%	100,0%

Gıda/yiyeceklerle ilgili olarak sosyal medyadan geleneksel medyaya göre (gazeteler ve TV'ler) daha doğru bilgi alıyorum sorusuna ait frekans tablosu incelendiğinde, Kadınlar, bu soruya kesinlikle katılıyorum cevabını erkelerden daha fazla vermiş, erkeler ise kesinlikle katılmıyorum cevabını daha yüksek oranda vermiştir.

Tablo 14. Gıda/yiyeceklerle ilgili olarak sosyal medyadan geleneksel medyaya göre (gazete ve TV) daha kolay bilgi edinebilirim sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,4%	58,6%	100,0%
Katılmıyorum	43,3%	56,7%	100,0%
Kararsızım	39,1%	60,9%	100,0%
Katılıyorum	48,5%	51,5%	100,0%
Kesinlikle Katılıyorum	55,6%	44,4%	100,0%
Toplam	45,0%	55,0%	100,0%

Gıda/yiyeceklerle ilgili olarak sosyal medyadan geleneksel medyaya göre (gazete ve TV) daha kolay bilgi edinebilirim sorusuna ait frekans tablosu incelendiğinde, yine Kadınlar, bu soruya kesinlikle katılıyorum cevabını erkelerden daha fazla vermiş, erkeler ise kesinlikle katılmıyorum cevabını daha yüksek oranda vermiştir.

Tablo 15. Gıda/yiyecek markaları hakkında sosyal medyadan bilgi ediniyorum sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	41,2%	58,8%	100,0%
Katılmıyorum	33,8%	66,3%	100,0%
Kararsızım	45,1%	54,9%	100,0%
Katılıyorum	54,6%	45,4%	100,0%
Kesinlikle Katılıyorum	56,1%	43,9%	100,0%
Toplam	45,0%	55,0%	100,0%

Gıda/yiyecek markaları hakkında sosyal medyadan bilgi ediniyorum sorusuna ait frekans tablosu incelendiğinde**,** Kadınlar, "Katılıyorum" ve "Kesinlikle Katılıyorum" gibi seçeneklerde daha yüksek oranlarla yer alırken, erkekler daha düşük oranlar sergilemektedir. Kadınlar sosyal medyadan gıda markaları hakkında erkeklere göre daha fazla bilgi edinmektedir.

Tablo 16. Diğer insanların sosyal medyada yiyecek konusundaki paylaşımları, deneyimleri ve önerilerinden etkilenmekteyim sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	42,5%	57,5%	100,0%
Katılmıyorum	39,2%	60,8%	100,0%
Kararsızım	46,6%	53,4%	100,0%
Katılıyorum	50,4%	49,6%	100,0%
Kesinlikle Katılıyorum	70,6%	29,4%	100,0%
Toplam	45,0%	55,0%	100,0%

Diğer insanların sosyal medyada yiyecek konusundaki paylaşımları, deneyimleri ve önerilerinden etkilenmekteyim sorusuna ait frekans tablosu incelendiğinde, Kadınların Diğer insanların sosyal medyada yiyecek konusundaki paylaşımları, deneyimleri ve önerilerinden etkilenmekteyim sorusuna "Katılıyorum" ve "Kesinlikle Katılıyorum" seçeneklerinde daha fazla yer alması, onların başkalarından önerilerinden daha fazla etkilendiği göz önüne çıkmıştır.

Tablo 17. Ünlü kişilerin sosyal medyadaki gıda/yiyecek tüketimleri ile ilgili paylaşımlarından etkilenirim sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	43,8%	56,2%	100,0%
Katılmıyorum	38,4%	61,6%	100,0%
Kararsızım	46,8%	53,2%	100,0%
Katılıyorum	53,1%	46,9%	100,0%
Kesinlikle Katılıyorum	65,6%	34,4%	100,0%
Toplam	45,0%	55,0%	100,0%

Ünlü kişilerin sosyal medyadaki gıda/yiyecek tüketimleri ile ilgili paylaşımlarından etkilenirim sorusuna ait frekans tablosu incelendiğinde, Kadınlar, Ünlü kişilerin sosyal medyadaki gıda/yiyecek tüketimleri ile ilgili paylaşımlarından erkeklere göre daha fazla etkilendikleri görülmüştür ("Katılıyorum" ve "Kesinlikle Katılıyorum").

Tablo 18. Arkadaşlarımın sosyal medyadaki gıda/yiyecek paylaşımlarından etkilenirim sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	43,7%	56,3%	100,0%
Katılmıyorum	40,1%	59,9%	100,0%
Kararsızım	45,7%	54,3%	100,0%
Katılıyorum	49,8%	50,2%	100,0%
Kesinlikle Katılıyorum	58,8%	41,2%	100,0%
Toplam	45,0%	55,0%	100,0%

Arkadaşlarımın sosyal medyadaki gıda/yiyecek paylaşımlarından etkilenirim sorusuna ait frekans tablosu incelendiğinde**,** Kadınlar, bu soruya kesinlikle katılıyorum cevabını erkelerden daha fazla vermiş, erkeler ise kesinlikle katılmıyorum cevabını daha yüksek oranda vermiştir. Kadınlar arkadaşlarının paylaşımlarından erkeklere göre daha fazla etkilendiği ortaya çıkmıştır.

Tablo 19. Sosyal medyadaki gurme hesaplarındaki gıda/yiyecek paylaşımlarından etkilenirim sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	44,1%	55,9%	100,0%
Katılmıyorum	39,1%	60,9%	100,0%
Kararsızım	46,1%	53,9%	100,0%
Katılıyorum	49,8%	50,2%	100,0%
Kesinlikle Katılıyorum	68,8%	31,3%	100,0%
Toplam	45,0%	55,0%	100,0%

Sosyal medyadaki gurme hesaplarındaki gıda/yiyecek paylaşımlarından etkilenirim sorusuna ait frekans tablosu incelendiğinde**,** Kadınlar, bu soruya kesinlikle katılıyorum cevabını erkelerden daha fazla vermiş, erkeler ise kesinlikle katılmıyorum cevabını daha yüksek oranda vermiştir. Kadınlar sosyal medyadaki gurmelerin paylaşımlarından erkeklere göre daha fazla etkilendiği ortaya çıkmıştır.

Tablo 20. Bir gıda ürünü, gıda markası veya restoran hakkında sosyal medyadaki olumsuz haberlerden etkilenirim sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	42,5%	57,5%	100,0%
Katılmıyorum	38,5%	61,5%	100,0%
Kararsızım	54,5%	45,5%	100,0%
Katılıyorum	47,5%	52,5%	100,0%
Kesinlikle Katılıyorum	50,0%	50,0%	100,0%
Toplam	45,0%	55,0%	100,0%

Bir gıda ürünü, gıda markası veya restoran hakkında sosyal medyadaki olumsuz haberlerden etkilenirim sorusuna ait frekans tablosu incelendiğinde, gıda markası veya restoran hakkında sosyal medyadaki olumsuz haberlerden her iki cinsiyetinde etkilendiği gözlenmiştir.

Tablo 21. Yiyecek-içecekler mobil uygulamalarını kullanırım (kalorisayar, bisu, starbucks, vivino, dominos vb.) sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	48,3%	51,7%	100,0%
Katılmıyorum	39,6%	60,4%	100,0%
Kararsızım	46,9%	53,1%	100,0%
Katılıyorum	44,9%	55,1%	100,0%
Kesinlikle Katılıyorum	31,3%	68,8%	100,0%
Toplam	45,0%	55,0%	100,0%

Yiyecek-içecekler mobil uygulamalarını kullanırım (kalorisayar, bisu, starbucks, vivino, dominos vb. sorusuna ait frekans tablosu incelendiğinde, erkekler "Katılıyorum" ve "Kesinlikle Katılıyorum" seçeneklerinde daha yüksek oranlarda cevap vermiştir.

Tablo 22. Paket yemek servisleri veya marketlerin eve ürün teslimi (sanal market) için internet ve mobil uygulamalar kullanırım sorusuna ait çapraz frekans tablosu

	Cinsiyet		
	Kadın	Erkek	Total
Kesinlikle Katılmıyorum	46,8%	53,2%	100,0%
Katılmıyorum	38,1%	61,9%	100,0%
Kararsızım	55,0%	45,0%	100,0%
Katılıyorum	43,8%	56,2%	100,0%
Kesinlikle Katılıyorum	39,0%	61,0%	100,0%
Toplam	45,0%	55,0%	100,0%

Paket yemek servisleri veya marketlerin eve ürün teslimi (sanal market) için internet ve mobil uygulamalar kullanırım sorusuna ait frekans tablosu incelendiğinde, erkekler "Katılıyorum" ve "Kesinlikle Katılıyorum" seçeneklerinde daha yüksek oranlarda cevap vermiştir.

5. SONUÇ VE ÖNERİLER

Bu çalışmada, sosyal medya kullanımının gıda alımı ve tüketimi üzerindeki etkileri cinsiyet farklılıklarına göre incelenmiştir. Elde edilen bulgular, sosyal medya kullanım alışkanlıklarının ve içerik türlerinin cinsiyetler arasında farklılıklar gösterdiğini ortaya koymuştur.

Kadınlar, sosyal medya üzerinde sağlıklı beslenme, yemek tarifleri ve mutfak önerilerine erkeklerden daha fazla ilgi göstermektedir. Kadınlar, bu içeriklere yönelik daha yüksek katılım oranlarına sahipken, erkekler bu tür içerikleri daha az takip etmektedir. Bu durum, kadınların gıda tüketiminde daha bilinçli bir yaklaşım sergileyebileceğini düşündürmektedir.

Sosyal medya üzerinden gıda alımı ile ilgili reklamlara ve yorumlara dikkat etme konusunda da kadınlar erkeklerden daha fazla eğilim göstermektedir. Bu bulgu, kadınların sosyal medya üzerindeki gıda reklamlarını ve kullanıcı yorumlarını daha fazla dikkate aldığını ve bu bilgileri satın alma kararlarında bir referans noktası olarak kullanma eğiliminde olduklarını göstermektedir.

Cinsiyetler arasındaki farklar, sosyal medya platformları üzerinde kadınların daha etkileşimli ve bilgi arayışı içinde olduklarını, erkeklerin ise daha pasif bir tutum sergilediklerini ortaya koymaktadır. Erkekler genellikle sosyal medya üzerinden yapılan gıda ile ilgili paylaşımlara daha düşük oranda katılım gösterirken, kadınlar bu paylaşımlar üzerinden daha fazla bilgi edinmeye ve bu bilgileri uygulamaya yönelmektedir.

Sosyal medya üzerinden yapılan yorumlar ve içerikler, tüketici davranışlarını yönlendirme potansiyeline sahiptir. Kadınlar, özellikle sağlıklı beslenme ve yemek tarifleri gibi içeriklere daha fazla odaklanırken, erkekler daha çok yemekle ilgili pratik ve basit önerilere ilgi göstermektedir.

Markaların kadınlara yönelik sosyal medya reklamlarını artırmaları gerekmektedir. Kadınlar, gıda alımı ve tüketimi ile ilgili sosyal medya içeriklerine daha fazla ilgi gösterdiği için, markaların sosyal medya stratejilerini bu eğilimlere göre şekillendirmeleri faydalı olacaktır. Sağlıklı beslenme ve yemek tarifleri gibi içeriklerle kadınları hedef alacak kampanyalar daha etkili olabilir.

Erkekler için daha pratik ve işlevsel içerikler geliştirilmelidir. Erkeklerin sosyal medyada genellikle daha az etkileşime girdiği gözlemlenmiştir. Bu nedenle, erkeklere yönelik sosyal medya içeriklerinde pratik yemek tarifleri veya hızlı hazırlık önerileri gibi daha işlevsel ve basit içerikler sunulması, bu grubun dikkatini çekebilir.

Sosyal medya içeriklerinin etkileşimli hale getirilmesi önerilmektedir. Kullanıcıların içeriklerle daha fazla etkileşime girmesini sağlamak amacıyla, sosyal medya platformlarında anketler, soru-cevap etkinlikleri, interaktif yemek tarifleri gibi etkileşimli içerikler sunulabilir. Bu tür içerikler, kullanıcıların daha fazla katılım göstermesini ve içeriklerle bağlantı kurmalarını sağlayabilir.

Sosyal medya yorumları ve geri bildirimler daha fazla dikkate alınmalıdır. Tüketiciler, sosyal medya üzerinden yapılan yorumları satın alma kararlarında referans olarak kullanmaktadır. Markaların bu yorumları dikkatle izlemeleri ve kullanıcıların geri bildirimlerine hızlı bir şekilde yanıt vermeleri, müşteri memnuniyetini artırabilir.

Sağlıklı beslenme konusundaki farkındalık artırılmalıdır. Özellikle kadınlar arasında sağlıklı beslenme ile ilgili içeriklerin daha fazla rağbet gördüğü göz önüne alındığında, sosyal medya üzerinden sağlıklı beslenme konusunda bilgilendirici ve eğitici kampanyalar düzenlenmesi önerilmektedir. Bu, tüketicilerin daha bilinçli alışveriş yapmalarına ve sağlıklı yaşam tarzlarına yönelmelerine yardımcı olabilir.

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EVALUATION OF SOME *Cota* SPECIES IN TERMS OF HERBAGE QUALITY CHARACTERISTICS

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ABSTRACT

This study was carried out to determine some quality characteristics of *Cota* species collected from the Southeastern Anatolia Region, which are important for animal nutrition, and the similarities between the locations where these species were collected. *Cota* species were considered as the subject of the study because of their widespread occurrence in pastures and natural areas of Southeastern Anatolia Region and plants of *Cota* species collected from 10 different locations of the region were used as material. Crude protein (CP), acid detergent protein (ADP), acid detergent fiber (ADF), neutral detergent fiber (NDF), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K) were determined in the dry grasses of *Cota* species. It was observed that there were significant statistical differences among the locations in terms of these traits. In the study, it was determined that *Cota* species were in the third quality class in terms of CP ratio, second quality class in terms of ADF and DDM ratios, and first quality class in terms of NDF and DMI contents and RFV. P, K, Mg and K:(Ca+Mg) ratios of *Cota* species were also found to be at ideal levels, but Ca content was high and Ca:P ratio was above the required limit value (>2). Cluster analysis was performed to reveal the similarity of the locations. As a result of the cluster analysis, it was determined that 10 different locations showed variation to be divided into two main groups. Among these groups, Gaziantep (2) where *Cota altisima* species was taken and Şanlıurfa (2) where *Cota wiedemanniana* species was taken were the closest to each other, while Diyarbakır and Gaziantep (1) where *Cota altissima* species was taken were the farthest from each other.

Keywords: *Cota* species, Quality characteristics, Minerals, Cluster analysis

BAZI *Cota* TÜRLERİNİN OT KALİTE ÖZELLİKLERİ AÇISINDAN DEĞERLENDİRİLMESİ

ÖZET

Güneydoğu Anadolu Bölgesinden toplanan *Cota* türlerinin, hayvan besleme açısından önem arz eden bazı kalite özellikleri ile bu türlerin toplandığı lokasyonların birbirlerine benzerliklerini tespit etmek amacıyla, bu çalışma yürütülmüştür. *Cota* türleri, Güneydoğu Anadolu Bölgesi'nin mera ve doğal alanlarında yaygın olarak bulunmasından dolayı çalışma konusu olarak ele alınmış ve bölgenin 10 değişik lokasyonundan toplanan *Cota* türlerine ait bitkiler, materyal olarak kullanılmıştır. *Cota* türlerine ait bitkilerin kuru otlarında ham protein (HP), asit deterjanda çözünmeyen protein (ADP), asit deterjanda çözünmeyen lif (ADF), nötral deterjanda çözünmeyen lif (NDF), sindirilebilir kuru madde (SKM), kuru madde tüketimi (KMT), nispi yem değeri (NYD), kalsiyum (Ca), magnezyum (Mg), fosfor (P) ve potasyum (K) oranları saptanmıştır. İncelenen bu özellikler açısından lokasyonlar arasında önemli istatistiksel farklılıkların olduğu görülmüştür. Araştırmada, *Cota* türlerinin HP oranı açısından üçüncü, ADF ve SKM oranları açısından ikinci, NDF ve KMT içerikleri ile NYD açısından birinci kalite sınıfında yer aldığı belirlenmiştir. *Cota* türlerinin P, K, Mg ve K:(Ca+Mg) oranlarının da ideal düzeyde olduğu, ancak Ca içeriklerinin yüksek ve buna bağlı olarak Ca:P oranının ise olması gereken sınır değerin (>2) üzerinde olduğu belirlenmiştir. Lokasyonların benzerlik durumlarını ortaya koyma amacıyla kümeleme analizi yapılmıştır. Yapılan kümeleme analizi sonucunda 10 farklı lokasyonun iki ana gruba ayrılacak şekilde varyasyon gösterdiği belirlenmiştir. Bu gruplar arasında *Cota altisima* türünün alındığı Gaziantep (2) ve *Cota wiedemanniana* türünün alındığı Şanlıurfa (2) lokasyonlarının birbirine en yakın, *Cota altissima* türünün alındığı Diyarbakır ve Gaziantep (1) lokasyonlarının da birbirlerine en uzak lokasyonlar olduğu saptanmıştır.

Anahtar Kelimeler: *Cota* türleri, Kalite özellikleri, Mineraller, Kümeleme analizi

1.GİRİŞ

Astraceae familyası dünyanın her yerinde en fazla taksonla temsil edilen familyadır. Antartika hariç dünyanın her yerine dağılmış yaklaşık 1600-1700 cins ve yaklaşık 24000 türe sahiptir (Funk et al., 2005).

Astraceae familyasının bir üyesi olan *Cota* cinsi, dünyada 49 türe ait 63 takson ile temsil edilmektedir. *Cota* cinsi dünya üzerinde Akdeniz ve İran-Turan fitocoğrafik bölgelerinin birbirleriyle çakıştığı alanlarda yayılış göstermektedir. Çoğunlukla Avrupa'nın kuzeyi hariç bütününde, Afrika'nın kuzeyinde, Kafkaslar ve Güney Rusya'nın bir kısmında ve Anadolu'dan Afganistan'a kadar olan kesimde yayılış göstermektedir. *Cota* cinsinin çeşitlilik merkezlerinden birisi de Türkiye'dir. Özellikle Türkiye'nin Akdeniz ve İran-Turan fitocoğrafik bölgelerinde yaygındır. Türkiye'de *Cota* cinsi 22 taksondan (17 tür, 2 alttür, 3 varyete) oluşmakta ve bunların 9 adedi Türkiye için endemiktir. Bu durum *Cota* cinsi için %41'lik bir endemizm oranına tekabül etmektedir (Özbek, 2010; Özbek et al., 2018; Özbek & Vural, 2020; Özbek et al., 2011).

Türkiye'de *Cota* cinsi ile ilgili olarak yapılan çalışmalara bakıldığında, Gazi Üniversitesi Fen Fakültesi öğretim üyelerinden sayın Doç. Dr. Mehmet Ufuk Özbek'in konu ile ilgili çalışmalara hem yurtiçi hem de yurtdışında öncülük ettiği anlaşılmaktadır. Araştırmacı tarafından, *Cota* cinsinin taksonomik revizyonu (Özbek, 2010), *Cota* cinsine ait bazı endemik taksonların kromozom özellikleri (Özbek et al., 2010), *Cota* cinsinin polen morfolojisi (Özbek et al., 2016), aken morfolojisi (Özbek et al., 2018), *Cota* cinsinin sinopsisi (Özbek & Vural, 2020) gibi birçok çalışmanın başarıyla yapıldığı görülmektedir. Ayrıca araştırmacı tarafından Uludağ'da 2011 yılında bulunan yeni bir tür, *Cota hamzaoglui* U.Özbek & Vural (Asteraceae, Anthemideae) ismi ile bilim dünyasına kazandırılmıştır (Özbek et al., 2011).

Özbek dışında diğer araştırmacılar tarafından yapılan diğer çalışmaların ise daha çok flora çalışmalarında tespit edilen *Cota* türleri veya *Cota* türlerinin geleneksel olarak kullanımları ile ilgili olduğu görülmektedir. Örneğin, Göller bölgesinde yayılış gösteren bitkilerin tehdit sınıfları ve endemizm durumlarının incelendiği bir çalışmada *Cota fulvida* türünün tehdit sınıfı kritik olarak belirlenmiştir (Arslan et al., 2015). Düzce bölgesindeki ballarda yapılan polen analizinde *Cota tinctoria* var. *pallida* türünün %3'ten düşük eser düzeyde polene sahip olduğu bildirilmiştir (Atsay & Çakır, 2022). Güneydoğu Anadolu Bölgesi'nde aktarlarda satılan papatya türlerinin tespitine yönelik yapılan bir çalışmada Siirt, Batman, Mardin, Diyarbakır, Şanlıurfa ve Gaziantep illerinde aktarlar tarafından satılan türlerin %95.7 oranı ile *Cota altissima* (köpek papatyası) türü olduğu bildirilmiştir. *Cota altissima* türünün etnobotanik çalışmalarda hazımsızlık, boğaz ağrısı, yara iyileştirici, adet ağrısı, sarılık, mide rahatsızlığı ve öksürük için kullanıldığı bildirilmiş ise de bunu doğrulayan bilimsel çalışmalara rastlanılmadığı belirtilmiştir (Arslan, 2019). Artvin bölgesinde yapılan floristik bir çalışmada tespit edilen bitki taksonlarının geleneksel kullanımları ele alınmıştır. Bu çalışmada *Cota altissima* ve *Cota tinctoria* türlerinin bronşit ve öksürük giderici olarak kullanıldığı bildirilmiştir (Ergül Bozkurt et al., 2019).

Bu çalışmalar dışında *Cota* türlerinin sahip olduğu ve hayvancılık açısından önem arz eden kalite özelliklerinin tespitine yönelik çalışmaların ise yapılmadığı görülmüştür. Bu nedenle bu çalışma, Güneydoğu Anadolu Bölgesinin farklı lokasyonlarından toplanan *Cota* türlerinin

hayvanlar açısından besleme derecesini ortaya koymak ve türlerin toplandığı lokasyonlar arasındaki benzerlik ve farklılıkları incelemek amacıyla yürütülmüştür.

2.MATERYAL VE METOT

Güneydoğu Anadolu Bölgesi'nin 10 farklı lokasyonundan toplanan *Cota* türlerine ait bitki örnekleri, araştırmanın materyalini oluşturmaktadır. *Cota* türlerinin toplandığı lokasyonlara ait bazı bilgiler (enlem, boylam ve rakım) Tablo 1'de, bu türlere ait bazı fotoğraflar da Şekil 1'de verilmiştir. *Cota* türleri, Tablo 1'de verilen lokasyonlardan çiçeklenme döneminde ve 2023 yılının Mayıs ayı içerisinde toplanmıştır. Toplanan bitki örneklerinin teşhisi Dicle Üniversitesi Fen Fakültesi Biyoloji Bölümü öğretim üyelerinden Prof. Dr. A. Selçuk ERTEKİN tarafından yapılmıştır.

Tablo 1'de belirtilen lokasyonlarda ve belirtilen tarihlerde *Cota* türlerine ait bitki örnekleri, tesadüfi ve üç tekerrürlü olacak şekilde yaklaşık 200 g alınmıştır. Bitki örnekleri 65 ºC'de 48 saat kurutulduktan sonra el değirmeni yardımıyla öğütülmüştür. Öğütülen örnekler 1 mm elekte elendikten sonra analize gönderilmiştir. *Cota* türlerinin HP, ADP, ADF, NDF, Ca, Mg, P ve K analizleri NIRS (Near Infrared Spectroscopy, Foss Model 6500) cihazı ile yapılmıştır. Analizde baklagil yem bitkilerine ait kalibrasyon seti kullanılmıştır (Basbag et al., 2023; Başaran et al., 2011; Cacan et al., 2018; Çaçan et al., 2014; Sayar et al., 2022). Tespit edilen ADF ve NDF değerlerinden hareketle SKM, KMT ve NYD hesaplanmıştır (SKM=88.9-(0.779 x %ADF), KMT= (120/NDF), NYD= (SKM x KMT) / 1.29) (Morrison, 2003).

Tablo 1. *Cota* türlerinin toplandığı lokasyonlar ve bu lokasyonların coğrafi konumları

Türler	Lokasyon	Rakım	Enlem (N)	Boylam (E)
1.Cota altissima (L.) J. Gay	Diyarbakır	992	37°53'13.39"	39°48'4.89"
2. Cota altissima (L.) J. Gay	Gaziantep (1)	655	37°23'11.54"	37°33'31.46"
3. Cota altissima (L.) J. Gay	Gaziantep (2)	836	37°10'48.69"	37°26'52.82"
4. Cota coelopoda (Boiss.) Boiss.	Adıyaman (1)	634	37°43'8.82"	37°57'13.04"
5. Cota coelopoda (Boiss.) Boiss.	Adıyaman (2)	821	37°41'28.77"	37°53'02.35"
6. Cota coelopoda (Boiss.) Boiss.	Diyarbakır (1)	722	38°08'08.10"	40°51'52.80"
7. Cota coelopoda (Boiss.) Boiss.	Diyarbakır (2)	930	38°13'31.80"	39°39'50.04"
8. Cota wiedemanniana (Fisch. & C.A.Mey.)	Diyarbakır (1)	887	38°22'10.73"	40°33'10.94"
9. Cota wiedemanniana (Fisch. & C.A.Mey.)	Şanlıurfa (1)	1469	37°46'30.38"	39°47'01.44"
10. Cota wiedemanniana (Fisch. & C.A.Mey.)	Şanlıurfa (2)	773	37°50'34.57"	39° 7'49.64"

Araştırma verileri, tesadüf blokları deneme deseninde üç tekerrürlü olacak şekilde JMP programı vasıtasıyla varyans analizine tabi tutulmuştur. Ortalamalar arasındaki benzerlikler ve farklılıklar Tukey (%5) testi ile karşılaştırılmıştır. Araştırmada türler bir faktör olarak ele alınmış olup, lokasyonların birbirine olan yakınlık ve uzaklıklarını belirlemek için de kümeleme analizi (cluster) yapılmıştır (JMP, 2018).

Şekil 1. *Cota* türlerine ait fotoğraflar (Sırasıyla *Cota altissima*, *Cota coelopoda* ve *Cota wiedemanniana*)

3.BULGULAR VE TARTIŞMA

Farklı lokasyonlarından toplanan *Cota* türlerinin HP, ADP, ADF ve NDF içerikleri Tablo 2'de sunulmuştur. Tablo 2'deki verilere göre, incelenen tüm parametreler açısından *Cota* türleri arasında istatistiksel olarak anlamlı farklılıklar tespit edilmiştir ($P<0.01$).

Cota türlerinin HP oranları %9.2 ile %14.2 arasında değişim göstermiştir. En yüksek HP oranı *Cota coelopoda*'nın Diyarbakır (1) lokasyonundan, en düşük HP oranı ise Gaziantep lokasyonundan alınan *Cota altissima* türünde saptanmıştır. ADP oranı %0.48 ile %0.78 arasında değişim göstermiştir. En yüksek ADP oranı *Cota altissima*'nın Gaziantep (1) ve Gaziantep (2) lokasyonlarından, en düşük ADP oranı *Cota wiedemanniana*'nın Şanlıurfa (1) lokasyonundan alınmıştır. ADF oranı %30.1 ile %41.4, NDF oranı ise %35.8 ile %48.7 arasında değişmiştir. En düşük ADF oranı *Cota wiedemanniana*'nın Diyarbakır (1) ve *Cota coelopoda*'nın Adıyaman (1) lokasyonlarından, en yüksek ADF oranı da *Cota altissima*'nın Diyarbakır, *Cota wiedemanniana*'nın Şanlıurfa (2), *Cota coelopoda*'nın Adıyaman (2) ve *Cota altissima*'nın Gaziantep (2) lokasyonlarından alınmıştır. En düşük NDF oranı da *Cota wiedemanniana*'nın Diyarbakır (1) ve Şanlıurfa (1), *Cota coelopoda*'nın Adıyaman (1) lokasyonlarından, en yüksek NDF oranı da *Cota altissima*'nın Gaziantep (2), Gaziantep (1), Diyarbakır, *Cota coelopoda*'nın Adıyaman (2) ve Diyarbakır (1) ile *Cota wiedemanniana*'nın Şanlıurfa (2) lokasyonlarında saptanmıştır (Tablo 2).

Tablo 2. *Cota* türlerine ait HP, ADP, ADF ve NDF içerikleri

Türler	Lokasyon	HP (%)	ADP (%)	ADF (%)	NDF (%)
1.Cota altissima	Diyarbakır	12.5 bc	0.62 de	41.4 a	45.7 ab
2. Cota altissima	Gaziantep (1)	9.2 e	0.75 ab	36.3 d	46.6 ab
3. Cota altissima	Gaziantep (2)	12.2 bcd	0.78 a	39.7 abc	48.7 a
4. Cota coelopoda	Adıyaman (1)	13.2 b	0.56 e	31.3 e	36.7 c
5. Cota coelopoda	Adıyaman (2)	12.1 cd	0.66 cd	39.8 ab	44.8 ab
6. Cota coelopoda	Diyarbakır (1)	14.2 a	0.66 cd	37.8 bcd	45.2 ab
7. Cota coelopoda	Diyarbakır (2)	12.9 bc	0.57 e	36.4 cd	44.2 b
8. Cota wiedemanniana	Diyarbakır (1)	12.9 bc	0.29 g	30.1 e	35.8 c
9. Cota wiedemanniana	Şanlıurfa (1)	11.4 d	0.48 f	35.2 d	39.6 c
10. Cota wiedemanniana	Şanlıurfa (2)	12.9 bc	0.71 bc	41.2 ab	45.4 ab
	Ortalama	**12.3**	**0.61**	**36.9**	**43.3**
	CV (%)	**2.71****	**3.35****	**3.18****	**3.52****

**: P<0.01 düzeyinde önemli ve tabloda aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark önemsizdir.

Ham protein oranı %19'dan yüksek olunca prime, %17-19 arasında birinci, %14-16 arasında ikinci, %11-13 arasında üçüncü ve %8-10 arasında dördüncü kalite sınıfında yer almaktadır. ADF oranı %31'den düşük olması durumunda prime, %31-35 arasında birinci, %36-40 arasında ikinci ve %41-42 arasında üçüncü, %43-45 arasında dördüncü kalite sınıfında yer almaktadır. NDF oranı %40'dan düşük olması durumunda yem bitkilerinin kalite standardı en iyi kalite olan prime, %40-46 arasında olunca birinci ve 47-53 arasında olunca ikinci kalite sınıfında yer almaktadır (Lacefield, 1988).

Ham protein oranı açısından Diyarbakır (1) lokasyonundan alınan *Cota coelopoda* türü ikinci, Gaziantep (1) lokosyonundan alınan *Cota altissima* dördüncü, geriye kalan diğer türlerin ise üçüncü sınıf kalite grubunda yer aldığı görülmektedir. ADF açısından Adıyaman (1) lokasyonundan alınan *Cota coelopoda* ile Diyarbakır (1) ve Şanlıurfa (1) lokasyonlarından alınan *Cota wiedemanniana* türlerinin birinci, Diyarbakır lokasyonundan alınan *Cota altissima* ve Şanlıurfa (2) lokasyonlarından alınan *Cota wiedemanniana* türlerinin üçüncü, geriye kalan diğer türlerin ise ikinci kalite sınıfında yer aldığı görülmektedir. NDF oranı açısından ise Adıyaman (1) lokasyonundan alınan *Cota coelopoda* ile Diyarbakır (1) ve Şanlıurfa (1) lokasyonlarından alınan *Cota wiedemanniana* türlerinin prime, Gaziantep (2) lokasyonundan alınan *Cota altissima*'nın ikinci ve geriye kalan diğer türlerin de birinci kalite sınıfında yer aldıkları görülmektedir.

Asteraceae familyasına ait türlerin kalite özellikleri ile ilgili daha önce yapılan çalışmalara bakıldığında; *Artemisia* sp. türünün HP oranı %17.63, ADF oranı %24.37 ve NDF oranı 26.39, *Tanacetum densum* türünde HP oranı %14.15, ADF oranı %33.00 ve NDF oranı %34.37 olarak tespit edildiği bildirilmiştir (Başbağ et al., 2018). On iki adet Asteraceae familyasına ait türün

kalite özelliklerinin incelendiği başka bir çalışmada ortalama olarak HP oranı %19.18, ADF oranı %26.28, NDF oranı %32.48 olarak tespit edilmiştir (Basbag & Sayar, 2023). Asteraceae familyasının bir üyesi olan *Crepis* cinsinin on farklı lokasyondan toplanan beş farklı türünde ortalama HP oranı %16.5, ADP oranı %0.66, ADF oranı %25.1 ve NDF oranı %34.1 olarak tespit edilmiştir (Başbağ & Çaçan, 2025). Araştırma konusu olan bitkilerin doğadan ve farklı lokasyonlardan toplanıyor olmaları ve elde edilen sonuçların aynı familyanın farklı türlerinden elde edilen sonuçlar olmalarından dolayı, ortaya çıkan farklılıklar olası kabul edilmektedir.

Farklı lokasyonlarından toplanan *Cota* türlerine ait SKM, KMT ve NYD ile ilgili sonuçlar Tablo 3'te yer almaktadır. Tablo 3 incelendiğinde, tüm özellikler açısından lokasyonlar arasında istatistiksel olarak anlamlı farklılıklar bulunduğu görülmektedir (P<0.01).

SKM oranı %56.6-65.4, KMT oranı %2.46-3.35 ve NYD 111-170 arasında değişim göstermiştir. Ortalama SKM oranı %60.1, KMT oranı %2.80 ve NYD ise 131 olarak belirlenmiştir. En yüksek SKM oranı, Diyarbakır (1) lokasyonundan alınan *Cota wiedemanniana* ile Adıyaman (1) lokasyonundan alınan *Cota coelopoda* türlerinde tespit edilmiştir. En düşük SKM oranı Diyarbakır lokasyonundaki *Cota altissima* türünden alınmıştır. En yüksek KMT oranı ile en yüksek nispi yem değeri ise SKM oranı ile benzer olacak şekilde Diyarbakır (1) lokasyonundaki *Cota wiedemanniana* ile Adıyaman (1) lokasyonundaki *Cota coelopoda* türlerinden alınırken, bu türleri Şanlıurfa (1) lokasyonundan alınan *Cota wiedemanniana* türü takip etmiştir. En düşük KMT oranı ile en düşük nispi yem değerleri de geriye kalan diğer tüm lokasyon ve türlerden alınmıştır (Tablo 3).

Tablo 3. *Cota* türlerine ait SKM ve KMT oranları ile NYD

Türler	Lokasyon	SKM (%)	KMT (%)	NYD
1.Cota altissima	Diyarbakır	56.6 e	2.64 c	116 c
2. Cota altissima	Gaziantep (1)	60.6 b	2.58 c	121 c
3. Cota altissima	Gaziantep (2)	57.9 cde	2.46 c	111 c
4. Cota coelopoda	Adıyaman (1)	64.5 a	3.27 ab	163 a
5. Cota coelopoda	Adıyaman (2)	57.9 de	2.68 c	120 c
6. Cota coelopoda	Diyarbakır (1)	59.4 bcd	2.65 c	122 c
7. Cota coelopoda	Diyarbakır (2)	60.6 bc	2.72 c	128 bc
8. Cota wiedemanniana	Diyarbakır (1)	65.4 a	3.35 a	170 a
9. Cota wiedemanniana	Şanlıurfa (1)	61.5 b	3.04 b	145 b
10. Cota wiedemanniana	Şanlıurfa (2)	56.8 de	2.64 c	116 c
	Ortalama	**60.1**	**2.80**	**131**
	CV (%)	1.52**	3.43**	4.82**

**: P<0.01 düzeyinde önemli ve tabloda aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark önemsizdir.

Lacefield (1988), SKM oranı %65, KMT oranı %3.0 ve NYD 151'den büyük olan kaba yemlerde kalitenin en iyi (prime) olduğunu bildirmiştir. Bu açıdan bakıldığında, SKM, KMT ve NYD açısından Adıyaman (1) lokasyonundan alınan *Cota coelopoda* ile Diyarbakır (1) lokasyonundan alınan *Cota wiedemanniana* türünün en iyi kalite olan prime grubunda yer aldığı görülmüştür. Geriye kalan diğer türlerin ise daha düşük kalite sınıflarında yer aldıkları belirlenmiştir.

Asteraceae familyasına ait türlerin kalite özelliklerine bakıldığında; *Artemisia* sp. türünde SKM oranı %69.9, KMT oranı %4.55, NYD 246, *Tanacetum densum* türünde SKM oranı %63.21, KMT oranı %3.49 ve NYD 171 olarak tespit edildiği bildirilmiştir (Başbağ et al., 2018). On iki adet Asteraceae familyasına ait türün kalite özelliklerinin incelendiği çalışmada ortalama olarak SKM oranı %68.43, KMT oranı %3.75 ve NYD de 200 olarak tespit edilmiştir (Basbag & Sayar, 2023). Asteraceae familyasının bir üyesi olan *Crepis* cinsinin on farklı lokasyondan toplanan beş farklı türünde ortalama SKM oranı %69.3, KMT oranı %3.57 ve NYD ise 192 olarak tespit edilmiştir (Başbağ & Çaçan, 2025). Araştırma konusu olan türlerin ve lokasyonların farklı olmasından dolayı, daha öne yapılan çalışmalar ile elde edilen sonuçlar arasında da kısmen farklılıkların olduğu görülmektedir.

Cota türlerinin Ca, P, Ca:P, K, Mg ve K:(Ca+Mg) değerleri Tablo 4'te sunulmuştur. Bu özellikler açısından türler arasındaki farklılıklar, istatistiksel olarak önemli bulunmuştur ($P<0.01$).

Lokasyonların kalsiyum oranları %1.13-1.62, fosfor oranları %0.17-0.34, Ca:P oranları 3.33-9.28, potasyum oranları %1.97-3.28, magnezyum oranları %0.24-0.47 ve K:(Ca+Mg) değerleri ise 1.21 ile 2.08 arasında değişim göstermiştir. Genel bir değerlendirme yapıldığında; en yüksek kalsiyum oranının alındığı Gaziantep (1) lokasyonundaki *Cota altissima* türünden, aynı zamanda en düşük P, en yüksek Ca:P, en yüksek K ve en yüksek Mg oranının alındığı saptanmıştır. En düşük kalsiyum oranının alındığı Diyarbakır (1) lokasyonundaki *Cota coelopoda* türünden ise en yüksek P, en düşük Ca:P, en düşük Mg ve en yüksek K:(Ca+Mg) oranının alındığı görülmüştür. Benzer şekilde en düşük potasyum değerinin alındığı Diyarbakır lokasyonundaki *Cota altissima* türünden de en düşük K:(Ca+Mg) değerinin alındığı görülmüştür.

Tablo 4. *Cota* türlerine ait Ca, P, Ca:P, K, Mg ve K:(Ca+Mg) değerleri

Türler	Lokasyon	Ca (%)	P (%)	Ca:P	K (%)	Mg (%)	K:(Ca+Mg)
1.Cota altissima	Diyarbakır	1.29 bcd	0.23 g	5.71 c	1.97 g	0.34 cd	1.21 f
2. Cota altissima	Gaziantep (1)	1.62 a	0.17 i	9.28 a	3.28 a	0.47 a	1.57 c
3. Cota altissima	Gaziantep (2)	1.28 cd	0.27 e	4.81 e	2.51 def	0.38 b	1.51 cd
4. Cota coelopoda	Adıyaman (1)	1.39 b	0.29 c	4.87 de	3.06 ab	0.29 e	1.83 b
5. Cota coelopoda	Adıyaman (2)	1.21 de	0.31 b	3.96 f	2.62 c-f	0.28 e	1.76 b
6. Cota coelopoda	Diyarbakır (1)	1.13 e	0.34 a	3.33 g	2.85 bc	0.24 f	2.08 a
7. Cota coelopoda	Diyarbakır (2)	1.37 bc	0.26 f	5.32 cd	2.66 cde	0.29 e	1.61 c
8. Cota wiedemanniana	Diyarbakır (1)	1.53 a	0.19 h	7.94 b	2.80 bcd	0.34 cd	1.50 cde
9. Cota wiedemanniana	Şanlıurfa (1)	1.33 bc	0.27 d	4.87 de	2.29 fg	0.33 d	1.38 de
10. Cota wiedemanniana	Şanlıurfa (2)	1.35 bc	0.28 cd	4.84 e	2.34 ef	0.36 bc	1.37 e
	Ortalama	**1.35**	**0.26**	**5.49**	**2.64**	**0.33**	**1.58**
	CV (%)	2.82**	0.95**	2.98**	4.45**	2.86**	3.12**

**: P<0.01 düzeyinde önemli ve tabloda aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark önemsizdir.

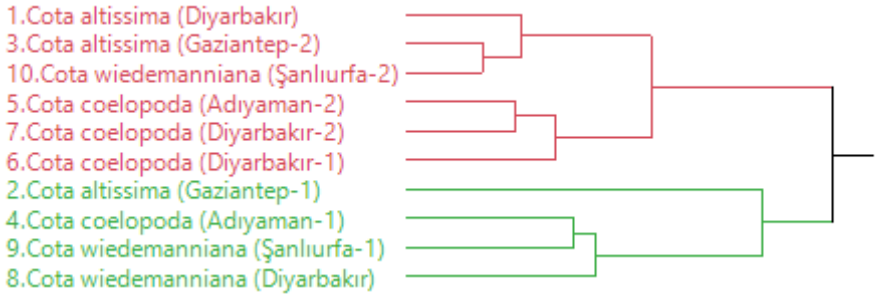
Bitkilerde kalsiyumun %0.10-1.00, fosforun %0.20-0.50, potasyumun %1.00-5.00 ve magnezyumun %0.10-0.40 arasında olması yeterli kabul edilmektedir (Motsara & Roy, 2008). Tablo 4'e göre K oranlarının tüm türler açısından, P ve Mg oranlarının ise Gaziantep (1) lokasyonundaki *Cota altissima* türü dışında kalan diğer türler açısından istenilen düzeyde olduğu görülmüştür. Ancak tüm lokasyonlarda Ca oranlarının olması gereken değerin (%1.00) üzerinde olduğu görülmektedir. Bu durum Ca:P oranının da yüksek olmasına sebebiyet vermektedir. Ca:P oranının 2.0'den fazla olması, hayvanlarda zehirlenmelere yol açabilmektedir (Ayan et al., 2010). Tablo 4'te belirtilen Ca:P dengesizliğin temel nedeninin fosfor eksikliği değil, lokasyonlardan alınan ottaki kalsiyum fazlalığından kaynaklandığı ön görülmektedir.

K:(Ca+Mg) oranının da 2.2'in üzerinde olması, hayvanlarda tetani hastalığı riskini artırmaktadır (Aydın & Uzun, 2002). K:(Ca+Mg) değerinin tüm türler istenilen sınır değerleri içerisinde olduğu, bu türler için böyle bir riskin olmadığı anlaşılmaktadır.

Asteraceae familyasına ait türlerin makro element içeriklerine bakıldığında; *Artemisia* sp. türünde Ca oranı %1.79, P oranı %0.30, Ca:P oranı 5.97, Mg oranı %0.47 ve K oranı %2.66, *Tanacetum densum* türünde Ca oranı %1.59, P oranı %0.30, Ca:P oranı 5.30, Mg oranı %0.49 ve K oranı %2.86 olarak tespit edildiği bildirilmiştir (Başbağ et al., 2018). On iki adet Asteraceae familyasına ait türün makro element içeriklerinin incelendiği çalışmada ortalama olarak P oranı %0.34, K oranı %3.24, Ca oranı %1.41, Mg oranı %0.39, Ca:P oranı 4.25 ve K:(Ca+Mg) oranı da 1.81 olarak tespit edilmiştir (Basbag & Sayar, 2023). Asteraceae familyasının bir üyesi olan *Crepis* cinsinin on farklı lokasyondan toplanan beş farklı türünde

ortalama Ca oranı %1.49, P oranı %0.34, Ca:P oranı 4.46, K oranı %3.42, Mg oranı %0.38 ve K:(Ca+Mg) oranı ise 1.87 olarak tespit edilmiştir (Başbağ & Çaçan, 2025). Daha önce yapılan bu çalışmalar ile mevcut çalışma bulguları arasında büyük oranda benzerlikler olduğu görülmektedir.

Farklı lokasyonlardan toplanan *Cota* türlerinin kümeleme (cluster) analizi sonuçları Şekil 2'de sunulmuştur. Bu analiz, lokasyonlardan elde edilen türlerin benzerlik düzeylerini değerlendirmek amacıyla gerçekleştirilmiştir.



Şekil 2. *Cota* türlerinin toplandığı lokasyonların kümeleme analizi

Şekil 2'de sunulduğu üzere kümeleme analizi neticesinde 2 farklı kümenin oluştuğu ve birinci kümede *Cota altissima* türünün alındığı Diyarbakır ve Gaziantep (2), *Cota wiedemanniana* türünün alındığı Şanlıurfa (2) ile *Cota coelopoda* türünün alındığı Adıyaman (2), Diyarbakır (1) ve Diyarbakır (2) lokasyonlarının, ikinci kümede ise geriye kalan diğer lokasyonların olduğu görülmektedir. Kümelerin benzerlik durumlarına göre birinci kümede *Cota altissima* türünün alındığı Gaziantep (2) ve *Cota wiedemanniana* türünün alındığı Şanlıurfa (2) lokasyonlarının, ikinci kümede *Cota coelopoda* türünün alındığı Adıyaman (1) ve *Cota wiedemanniana* türünün alındığı Şanlıurfa (1) lokasyonlarının benzerlik bakımından birbirlerine en yakın ve benzer lokasyonlar olduğu görülmektedir. İncelenen özellikler bakımından *Cota altissima* türünün alındığı Diyarbakır lokasyonu ile *Cota altissima* türünün alındığı Gaziantep (1) lokasyonunun ise birbirine en uzak olan lokasyonlar olduğu sonucuna varılmıştır.

Kümeleme analizi, lokasyon veya genotiplerin birbirleriyle yakınlıklarını ve uzaklıklarını belirlemek maksadıyla kullanılan analiz yöntemlerinden bir tanesidir. Öten and Albayrak (2016) Batı Akdeniz bölgesinden toplanan yonca popülasyonları arasındaki varyasyon seviyesini belirlemek için kümeleme analizini kullanmışlardır. Yaptıkları kümeleme analizi sonucunda yonca genotiplerinin iki ana ve dört alt gruba ayrıldığını ve birinci grubun %60, ikinci grubun %65 oranında alt gruba ayrıldığını bildirmişlerdir. Yine Öten and Albayrak (2018) 26 yonca popülasyonunun 21 farklı özelliği arasındaki ilişkiyi kümeleme analizi ile incelemişlerdir. Kümeleme analizi neticesinde yonca hatlarının %50 ile %98 arasında benzerlik gösterdiğini ve hatların esasında iki ana gurup altında beş farklı alt guruba ayrıldıklarını tespit etmişlerdir. Başbağ et al. (2019) Güneydoğu Anadolu Bölgesi'nin değişik lokasyonlarından topladıkları *Astragalus hamosus* türünün lokasyonlar arası benzerliklerini tespit etmek için

kümeleme analizini kullanmışlardır. Kümeleme analizi sonucunda 20 farklı lokasyonunun dört grup olacak şekilde varyasyon gösterdiğini bildirmişlerdir. Başbağ and Çaçan (2025) Güneydoğu Anadolu Bölgesinden topladıkları *Crepis* türlerinin lokasyonlar arası benzerliklerini tespit etmek amacıyla da kümeleme analizini kullanmışlardır. Kümeleme analizi sonucunda 10 lokasyonun iki farklı grup olacak şekilde varyasyon gösterdiği bildirilmiştir.

4.SONUÇ

Güneydoğu Anadolu Bölgesinin 10 farklı lokasyonundan toplanan *Cota* türlerinin kalite özellikleri ile bu türlerin toplandığı lokasyonların benzerliklerini belirlemek amacıyla yürütülen bu çalışmada; *Cota* türlerinin HP oranı açısından üçüncü, ADF oranları açısından ikinci, NDF içeriği açısından birinci kalite sınıfında yer aldığı belirlenmiştir. SKM oranı açısından ikinci, KMT oranı ve NYD açısından ise birinci kalite sınıfında yer aldığı belirlenmiştir. *Cota* türlerinin P, K, Mg ve K:(Ca+Mg) oranlarının istenilen seviyede, ancak Ca içeriğinin yüksek ve bundan kaynaklı olarak Ca:P değerinin maksimum seviyenin (>2) üzerinde olduğu görülmüştür. Bu sonuç, *Cota* türlerinden elde edilen otun Ca ve P içerikleri arasında bir dengesizlik olduğunu ve bu dengesizliğin de hayvanlarda zehirlenmelere yol açabileceği anlamını taşımaktadır. Bu şekilde ortaya çıkabilecek olumsuz bir durum, bu türden elde edilen otun ya kurutularak ya da başka otlarla birlikte karıştırılarak hayvanlara yedirilmesi ile engellenebilir. Doğal alanlarda veya meralarda otlayan hayvanlar, karışık beslendikleri için bu şekilde ortaya çıkabilecek bir zehirlenme riski zaten düşük olmaktadır. Yapılan kümeleme analizi neticesinde 10 farklı lokasyonun esasında iki gruba ayrılacak şekilde varyasyon gösterdiği görülmüştür. İncelenen özellikler açısından *Cota altisima* türünün alındığı Gaziantep (2) ve *Cota wiedemanniana* türünün alındığı Şanlıurfa (2) lokasyonlarının birbirine en yakın, *Cota altissima* türünün alındığı Diyarbakır ve Gaziantep (1) lokasyonlarının da birbirlerine en uzak lokasyonlar olduğu görülmüştür.

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DETERMINATION OF SOLAR RADIATION VARIATION IN SOME CENTRAL BLACK SEA REGION PROVINCES BY ŞEN'S INNOVATIVE AND MANN-KENDALL METHODS

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ABSTRACT

Solar radiation is the Earth's primary source of energy. It plays a vital role in many fields and applications, such as the hydrological cycle, evapotranspiration, climate prediction, agricultural and hydrological modeling, solar energy technologies, and terrestrial ecosystems. Any change in the amount of solar radiation significantly impacts life and the environment. Therefore, understanding the trend direction of solar radiation is essential for explaining meteorological and hydrological processes, ecological functions, energy development, and utilization. In this study, the annual and monthly trends of solar radiation values of Tokat, Amasya, and Samsun stations located in the Central Black Sea Region between 1991-2024 were determined. The Innovative Trend Analysis (ITA) test was applied to the trend analysis and the ITA test results were compared with the Mann-Kendall test, the traditional trend analysis method. When the results were analyzed, it was determined that there were increasing and decreasing changes in many months in Tokat and Amasya stations, while in Samsun station, there was an increase only in April, according to the ITA test. It was determined that there was no change in the annual solar radiation values in general.

Keywords: Solar Radiation, Innovative Trend Analysis, Mann-Kendal Test, Trend Analysis

BAZI ORTA KARADENİZ BÖLGESİ İLLERİNDEKİ SOLAR RADYASYON DEĞİŞİMİNİN YENİLİKÇİ ŞEN VE MANN-KENDALL YÖNTEMLERİYLE BELİRLENMESİ

ÖZET

Solar radyasyon yerkürenin temel enerji kaynağıdır. Hidrolojik döngü, evapotranspirasyon, iklim tahmini, tarımsal ve hidrolojik modelleme, güneş enerjisi teknolojileri ve karasal ekosistem gibi birçok alanda ve uygulamada önemli bir rol oynamaktadır. Solar radyasyon miktarında meydana gelen herhangi bir değişiklik, yaşam ve çevre üzerinde büyük etkilere sebep olmaktadır. Bu nedenle solar radyasyonunun eğilim yönünün anlaşılması, meteorolojik ve hidrolojik süreçleri, ekolojik işlevleri, enerji gelişimini ve kullanımını açıklamak için büyük önem taşımaktadır. Bu çalışmada 1991-2024 yılları arasında Orta Karadeniz Bölgesi'nde yer alan Tokat, Amasya ve Samsun istasyonlarının solar radyasyon değerlerinin yıllık ve aylık değişim eğilimleri tespit edilmiştir. Eğilim analizinde Yenilikçi Trend Analizi (ITA) testi uygulanmıştır ve ITA test sonuçları geleneksel trend analiz yöntemi olan Mann-Kendall testi ile karşılaştırılmıştır. Sonuçlar incelendiğinde Tokat ve Amasya istasyonlarında pek çok ayda artan ve azalan yönde değişimler olduğu, Samsun istasyonunda ise sadece ITA testine göre Nisan ayında artan yönde değişim olduğu belirlenmiştir. Yıllık solar radyasyon değerlerinde ise genel olarak değişim olmadığı saptanmıştır.

Anahtar Kelimeler: Solar Radyasyon, Yenilikçi Trend Analizi, Mann-Kendal Testi, Trend Analizi

1. INTRODUCTION

Solar radiation, which has an essential effect on the formation of climate and weather events, is the source of energy required for the continuity of life. Some radiation passing through the atmosphere is scattered, reflected, or absorbed by atmospheric gases, clouds, and dust. The amount of radiation reaching a horizontal surface is called solar radiation (Rs) (Allen et al. 1998). Solar radiation varies depending on atmospheric conditions, seasons, climate, and geographical location (Solanki, 2002). Therefore, understanding solar radiation clearly is important to minimize the negative environmental impacts of fossil fuels and ensure sustainable development through more effective use of renewable energy sources (Zhang et al., 2017).

Solar radiation data is an important meteorological parameter used in many fields, such as solar energy systems (Yadav & Chandel, 2014; Abdoos et al., 2025), evapotranspiration (Ünlükara, 2014; Cömert et al., 2023), design of agricultural structures (Öztekin et al., 2014; Allardyce et al., 2017), terrestrial ecosystem studies (Ito, 2017), hydrological cycle (Huang et al., 2021) and agricultural production (Domínguez-Álvarez, 2021).

Although solar radiation data are measured at meteorological stations, they are unavailable at most stations, and data from previous years cannot be accessed. In regions where standard measurements cannot be made or where missing data are available, solar radiation data is calculated using the Angstrom formula from the outer surface radiation of the atmosphere and the measured actual sunshine hours. It has been proposed to use temperature differences to derive sunshine hours from the Hargreaves-Samani equation in locations where actual sunshine hours are unavailable (Allen et al., 1998). In recent years, many researchers have modeled solar radiation with different machine-learning methods (Hassan et al., 2017; Dong et al., 2020; Husain & Khan, 2022; Cömert et al., 2023; Arseven & Çınar, 2025).

Mann-Kendall, Linear regression, Spearman Rho, Holt's approach, and Innovative Trend Analysis methods are widely used in the literature to determine the changes in meteorological and hydrological time series (Singh & Kumar, 2016; Öztopal & Şen, 2017; Yürekli et al., 2017; Wang et al., 2019; Cömert et al., 2019; Yürekli, 2022; Laz et al., 2023; Agbo et al., 2023; Şan, 2025). Liu et al. (2010) analyzed the solar radiation trends in China between 1957 and 2008 using the Mann-Kendall approach. Aksoy (2011) obtained the solar radiation series covering 1984-2005 for 20 stations in Turkey from the NASA satellite database and determined the annual change trends with the Mann-Kendall method. In the evaluation, it was determined that there was an increasing trend that started in 1990. Zhou et al. (2018) determined seasonal and annual solar radiation series trends in China between 1962 and 2015 using the Innovative Sen method. They compared the results obtained with the Mann-Kendall and linear regression tests. The trends determined by the Mann-Kendall and linear regression tests were determined at a rate of 99% with the Innovative Sen approach. In approximately 39% of the total time series, the trends determined by the Innovative Sen approach could not be determined by the other two methods. These results show that the Innovative Sen approach is more effective for detecting hidden trends than traditional methods. Gümüş and Şimşek (2020) analyzed the solar radiation change between 1982-2010 in Şanlıurfa with two traditional methods, Mann-Kendall, Spearman Rho and the Innovative Şen Method. While the traditional methods determined an

increasing trend in March and October, it was determined that there was an increasing trend in annual and monthly series with the Innovative Şen approach.

This study was conducted in Tokat, Amasya, and Samsun, which constitute 50% of the Yeşilırmak basin in terms of area. It was aimed to reveal the solar radiation variation, which is one of the critical parameters of plant water requirement in these provinces located in the Central Black Sea Region, where important vegetables, fruits, and field crops are grown with irrigated agriculture. In addition, the Mann-Kendall and Yenilikçi Şen approaches were evaluated together and compared.

2. MATERIALS AND METHODS

In this study, actual sunshine durations measured between 1991 and 2024 at meteorological stations in Tokat, Amasya, and Samsun in the Central Black Sea region (Figure 1) were used as material. Solar radiation data were calculated using the Angstrom equation from the relationship between relative sunshine durations and extraterrestrial radiation in the specified provinces (Allen et al. 1998). The Angstrom equation is given in Equation 1.

$$R_s = \left(a_s + b_s * \frac{n}{N}\right) R_a \quad (1)$$

In the equation, R_s is solar or shortwave radiation (MJ m^{-2} day^{-1}), n is the actual duration of sunshine (hour),N maximum possible duration of sunshine or daylight hours (hour), n/N relative sunshine duration, a_s and b_s are regression constant (a_s=0,25 ve b_s=0,50).

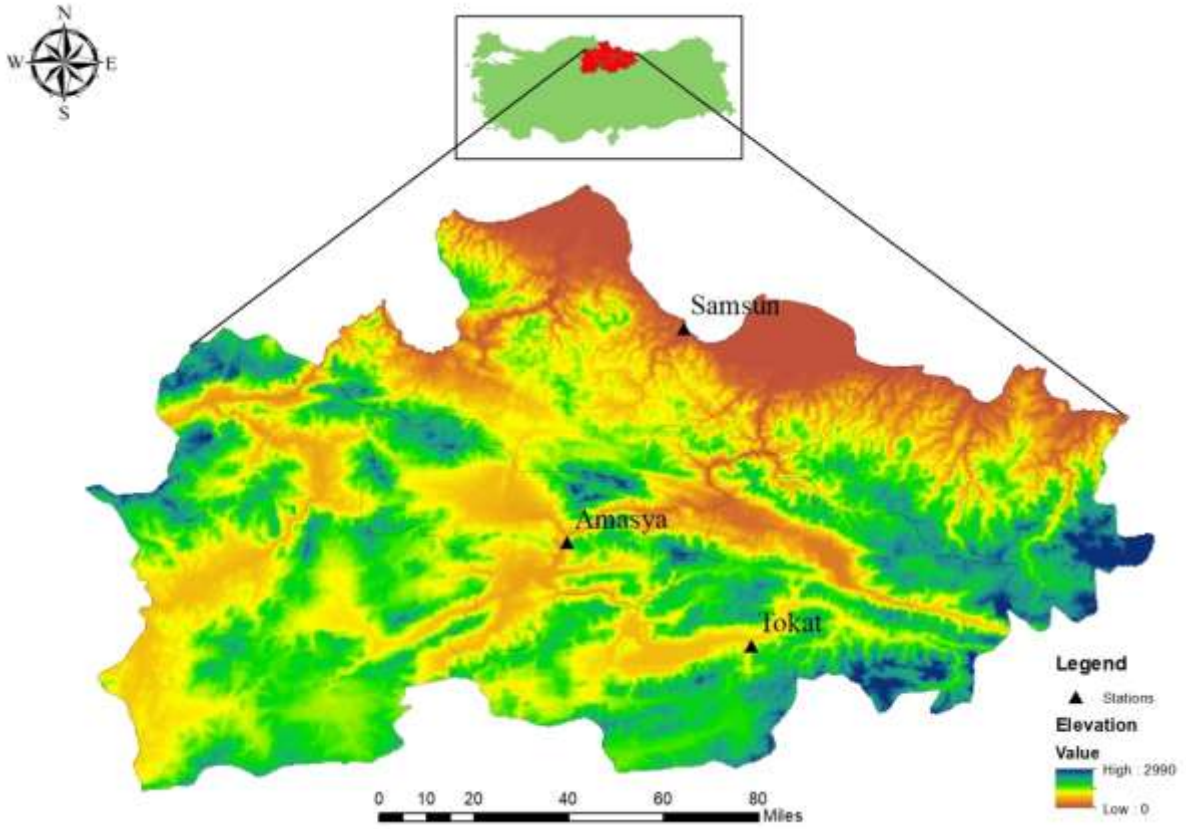

Figure 1. Geographic position of the meteorological stations

2.1. Innovative Trend Analysis (ITA)

The ITA method was first proposed by Şen (2012). Unlike other trend analysis methods, the most significant advantage of ITA is that it does not require any assumptions (serial correlation, non-normality, sample size, etc.). This approach's graphical structure and statistical analysis methodology were introduced to the literature by Şen (2012) and Şen (2017). To visually detect the presence of a trend, the time series is first divided into two equal sub-series, and the sub-series are sorted separately into increasing series. Then, the first and second sub-series of the time series are placed on the X-axis and Y-axis, respectively. Collecting the data on the 1:1 line (45° line) indicates that there is no trend in the time series; if the line is located in the upper triangle area, there is an increasing trend in the time series, and if the line is collected in the lower triangle area, there is a decreasing trend in the time series (Şen, 2012; Şen, 2014). In this way, the trends of low, medium, and high values of any hydrometeorological or hydro-climatic time series can be determined by this method.

The null hypothesis of this approach that there is no statistically significant trend in the data set is accepted when the slope (Scal) value calculated with Equation 3 falls within the confidence interval (CI) obtained from Equation 4. Otherwise, the alternative hypothesis is accepted.

$$S_{cal} = \frac{2(\bar{y}_2 - \bar{y}_1}{n} \quad (2)$$

$$\mathrm{CI}_{(1-a)} = 0 \pm \mathrm{S}_{\mathrm{crit}}\sigma_{\mathrm{S}} \quad (3)$$

In the equations,, $\bar{y}_2$ and $\bar{y}_1$, are the averages of the first and second subseries sequences generated from a complete data set containing "n" observations. The parameter "σ_S" in Equation 3 is calculated as follows.

$$\sigma_S = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{1 - \rho_{\bar{y}_1\bar{y}_2}} \quad (4)$$

Here, the terms " $\rho_{\bar{y}_1\bar{y}_2}$ " and "σ" are the cross-correlation coefficient and standard deviation of the complete data, respectively. The script value is taken from the Standard Normal Distribution Table for a 5% confidence level.

2.2. Mann-Kendal Test

It is a non-parametric test that examines whether there is a trend in time series (Mann, 1945; Kendall, 1962). For a series with dimensions n, when the annual values x_j and x_i are given in years j and i, respectively, and j > i, the Mann-Kendall statistic is obtained as follows:

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sgn(x_j - x_i); \quad with\ sgn(x_j - x_i) = \begin{cases} 1\ if\ (x_j - x_i) > 0 \\ 0\ if\ (x_j - x_i) = 0 \\ -1\ if\ (x_j - x_i) < 0 \end{cases} \quad (5)$$

If x_i are independent and randomly ordered, the S statistic for n > 10 follows a normal distribution with zero mean and variance and is given by:

$$Var(S) = {[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i i(i-1)(2i+5)]}/{18} \quad (6)$$

Here, m is the number of connected groups in the dataset, and t_i is the number of data points in the i. connected group.

Finally, the standard test statistic Z_{MK} is calculated with Equation 7.

$$Z_{MK} = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & for\ S > 0 \\ 0 & for\ S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & for\ S < 0 \end{cases} \quad (7)$$

For a given significance level α, using a two-tailed test, the null hypothesis is rejected if $|Z_{MK}|$ is greater than $Z_{1-\alpha/2}$.

3. FINDINGS AND DISCUSSION

Solar radiation values were calculated using the Angstrom equation using the daily sunshine durations measured between 1991 and 2024 for the Tokat, Amasya, and Samsun stations in the Central Black Sea Region. The temporal graph of the annual solar radiation data of the stations is given in Figure 2.

Figure 2. Temporal graph of annual solar radiation data of stations

Monthly and annual trends of calculated solar radiation values were evaluated and compared with ITA and Mann-Kendall tests. ITA graphs of Tokat, Amasya, and Samsun stations are given in Figure 3, Figure 4, and Figure 5, respectively.

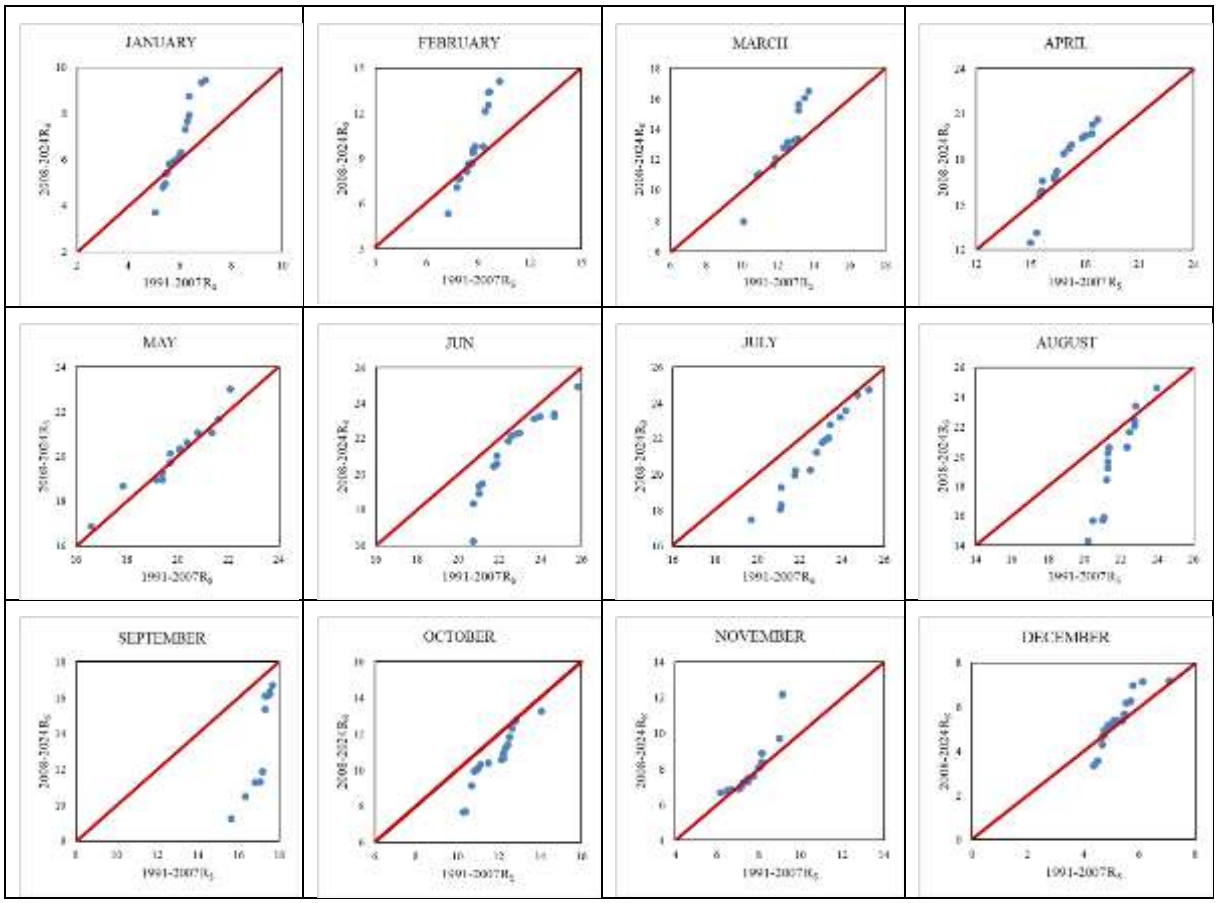

Figure 3. Monthly ITA graph of Tokat station

The data in Tokat station are found on the higher portion of the 1:1 line in January and February, as seen in Figure 3. This situation reveals that there is an increasing trend in these months. In June, July, August, September, and October, the data is located below the 1:1 line. In the graphs, it is seen that there is a decreasing trend in these months. Finally, it is seen that the solar radiation data for March, April, May, November, and December are on the 1:1 line, and there is no trend in these months. When Figure 4 is examined, it is seen that the data at the Amasya station are located on the upper part of the 1:1 line in January, February, April, August, October, November, and December. This situation reveals an increasing trend in the months in question. The data is located at the bottom of the 1:1 line in June. In the graphs, it is seen that there is a decreasing trend in these months. Finally, it is seen that the solar radiation data for March, May, July, and September are on the 1:1 line, and there is no trend in these months. When Figure 5 is examined, it is seen that Samsun is only located above the 1:1 line in April. This situation reveals that there is an increasing trend in April. It is seen that the solar radiation data for other months are located above the 1:1 line, and there is no trend in these months.

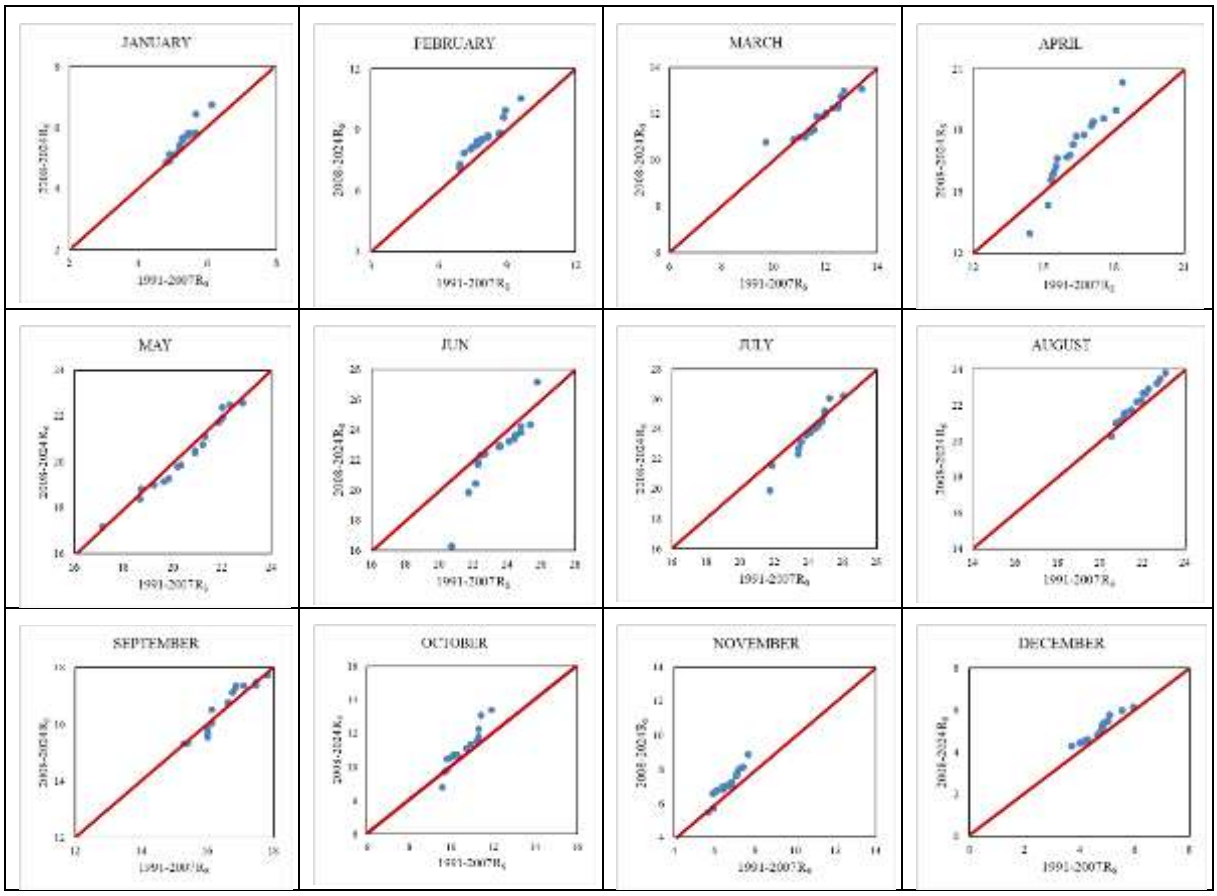

Figure 4. Monthly ITA chart of Amasya station

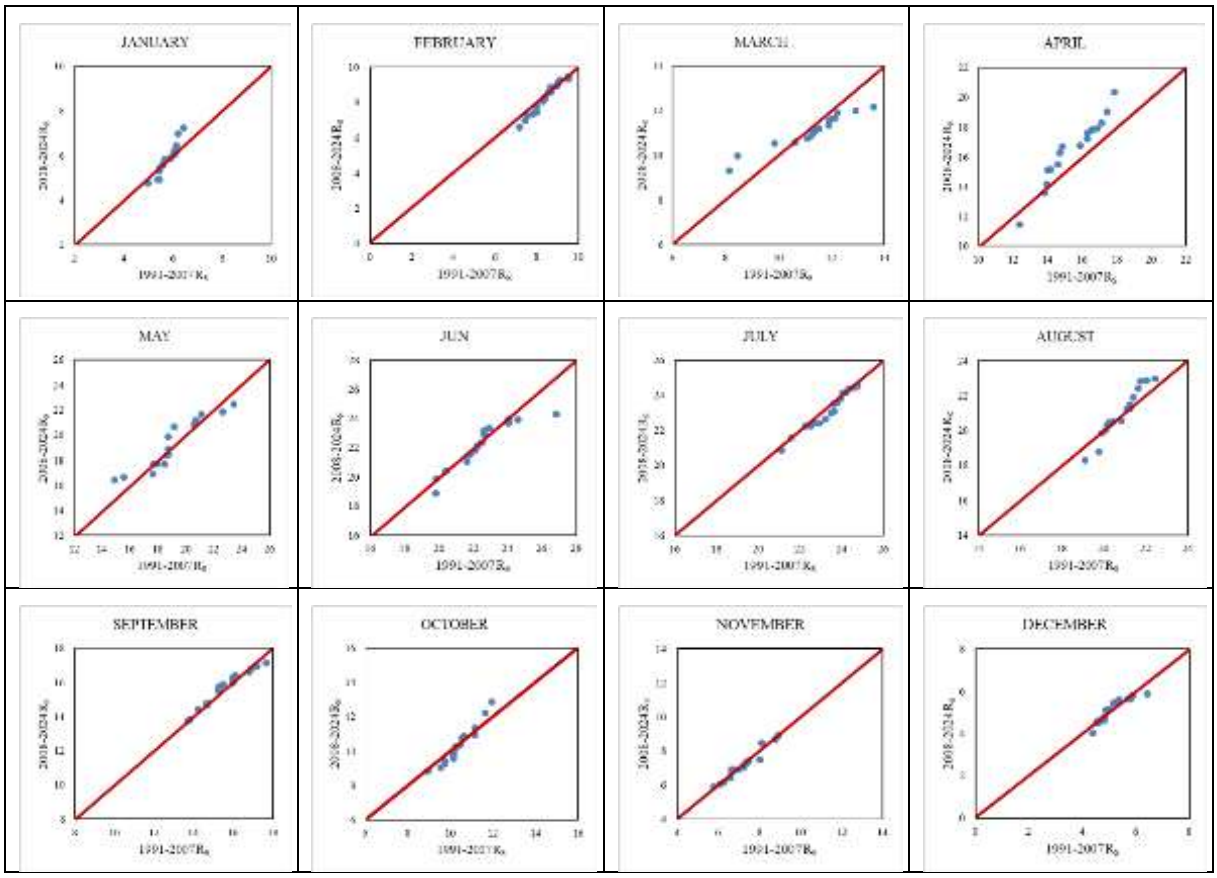

Figure 5. Monthly ITA chart of Samsun station

ITA graphs of annual solar radiation data are given in Figure 6. When the graphs are examined, it is seen that there is an increasing trend at Tokat station, a decreasing trend at Amasya station, and no trend at Samsun station.

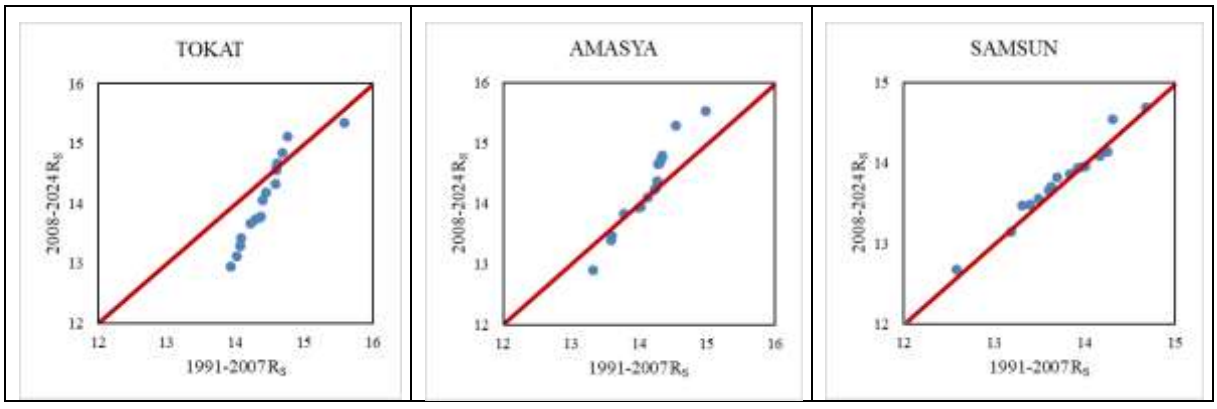

Figure 6. ITA graphs of annual solar radiation data

The data extracted from the ITA graphs has been statistically summarized in Table 1. Upon examination, Table 1 reveals a consistency between the trend results derived from the graphs and the statistically calculated ITA results.

Table 1. Innovative Trend analysis test results of solar radiation data

Months	TOKAT		AMASYA		SAMSUN	
	Slope	Confidence interval	Slope	Confidence interval	Slope	Confidence interval
January	0.035	± 0.033	0.015	± 0.012	0.003	± 0.018
February	0.059	± 0.055	0.035	± 0.022	-0.010	± 0.017
March	0.037	± 0.045	0.001	± 0.019	-0.011	± 0.034
April	0.040	± 0.044	0.041	± 0.032	0.060	± 0.038
May	0.029	± 0.058	-0.013	± 0.048	0.010	± 0.061
June	-0.079	± 0.045	-0.051	± 0.032	-0.018	± 0.042
July	-0.086	± 0.059	-0.021	± 0.029	-0.013	± 0.025
August	-0.117	± 0.083	0.022	± 0.015	0.008	± 0.017
September	-0.133	± 0.075	0.001	± 0.018	0.005	± 0.034
October	-0.069	± 0.036	0.028	± 0.027	-0.004	± 0.028
November	0.019	± 0.031	0.029	± 0.016	-0.002	± 0.022
December	0.009	± 0.025	0.021	± 0.014	-0.002	± 0.015
Annual	-0.021	± 0.012	0.009	± 0.008	0.002	± 0.012
	Decreasing trend					
	Increasing trend					
	No trend exists					

The Mann-Kendal test results of solar radiation data are given in Table 2. The Mann-Kendall test results for the Tokat station indicated no trend in January, February, March, April, May, June, and November. Conversely, a decreasing trend was observed in July, August, September, and October, while December showed an increasing trend. It was determined that there was a rising trend in January, February, April, August, November, and December at Amasya station, and there was no trend in March, May, June, July, September, and October. Finally, the Samsun station data analysis revealed no trend across all months. Furthermore, the annual solar radiation data evaluated via the Mann-Kendall test showed no trend for the Tokat and Samsun stations but indicated an increasing trend at the Amasya station.

Tablo 2. Solar radyasyon verilerinin Mann-Kendal test sonuçları

Months	TOKAT	AMASYA	SAMSUN
	Z Value	Z Value	Z Value
January	1.11	2.77	0.00
February	1.95	2.61	0.15
March	1.69	0.49	-0.93
April	1.84	2.34	1.91
May	0.90	0.24	0.42
June	-0.67	0.22	0.50
July	-2.12	0.36	1.17
August	-2.49	2.33	0.58
September	-2.63	0.98	0.91
October	-3.07	1.71	-0.39
November	0.36	2.54	0.39
December	2.15	3.06	0.56
Annual	-0.50	2.46	1.45
	Decreasing trend		
	Increasing trend		
	No trend exists		

4. CONCLUSION

Trend analysis is one of the most critical issues in climate change studies. In this context, ITA and Mann-Kendall tests investigated solar radiation change trends of Tokat, Amasya, and Samsun stations located in the Central Black Sea region between 1991-2024. The ITA method presents the results intuitively and efficiently as a graphical method. In addition, the statistical support of the visual results increases the power of the test. According to the ITA test results, it was concluded that there was an increasing trend in 11 data series at three stations, a decreasing trend in 7 data sets, and no trend in 21 data sets. The Mann-Kendall test identified an increasing trend in 8 data sets, a decreasing trend in 4 data series, and no significant trend in 27 data sets. It was concluded that the ITA test was more successful than the Mann-Kendall test in determining the trends in long-term solar radiation data of the Tokat, Amasya, and Samsun stations in the Central Black Sea region. Evaluation of the results indicated that the ITA test was more effective than the Mann-Kendall test in identifying both increasing and decreasing trends. It is predicted that there will be no increase in water loss through evapotranspiration, especially during the plant growth periods covering May and September (except August at Amasya station), since there is no increasing trend in solar radiation. In these areas where

irrigated agriculture is carried out, examining the relationship between energy exchange and precipitation and developing appropriate water management strategies are vital in alleviating the pressure on water resources.

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BALERS IN THE TRANSFORMATION OF AGRICULTURE: A HISTORICAL REVIEW FROM PAST TO PRESENT

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ABSTRACT

Since the early stages of human civilisation, the need to enhance agricultural efficiency, reduce manual labour, and facilitate the storage and transport of harvested crops has led to the development of various mechanised solutions. Among these innovations, balers have emerged as a critical component in modern agricultural mechanisation. Balers significantly facilitate the handling, transportation, and long-term storage of forage crops, straw, and certain industrial agricultural products—particularly in livestock-oriented production systems where efficient feed management is essential. The earliest examples of balers appeared in the United States in the late 19th century and were originally designed as simple mechanical systems. Over time, these machines have undergone substantial technological evolution. Modern balers are now equipped with advanced hydraulic systems, automatic knotting mechanisms, moisture sensors, and global positioning system (GPS) technologies, making them far more efficient and operator-friendly than their predecessors. Balers are generally categorised into two main types: rectangular (prismatic) and round (cylindrical) balers. Prismatic balers typically consist of a pickup mechanism that collects the windrowed crop, a set of tines or feeder arms that direct the material into a compression chamber, a piston system that shapes the bale, and a knotting unit that secures it. Round balers, in contrast, compress the crop into a cylindrical form within a rotating chamber and then wrap and eject it. Depending on the operational scale and intended application, these machines come in various sizes and technical configurations. This review aims to provide a comprehensive examination of the historical development of balers, their integration into agricultural production processes, and the technological advancements that have shaped their modern forms. Furthermore, the paper evaluates innovative approaches within the context of sustainable agriculture, considering environmental impacts and energy efficiency. The transformation observed over time reflects not only the mechanisation of balers

but also significant shifts in farmers' operational practices, expectations, and overall approach to agricultural productivity.

Keywords: Baler, Agricultural Machinery, Agricultural Mechanization, Sustainable Agriculture.

TARIMIN DÖNÜŞÜMÜNDE BALYA MAKİNELERİ: GEÇMİŞTEN GÜNÜMÜZE BİR İNCELEME

ÖZET

Tarım sektöründe verimliliğin artırılması, iş gücünün azaltılması ve hasat sonrası ürünlerin depolanabilir ve taşınabilir hale getirilmesi gerekliliği, insanlık tarihinin erken dönemlerinden itibaren çözüm arayışlarını beraberinde getirmiştir. Bu gereksinimler doğrultusunda geliştirilen pek çok teknolojiden biri de balya makineleri olmuştur. Özellikle hayvancılığın yaygınlaştığı ve yem ihtiyacının arttığı dönemlerde, yem bitkilerinin ve samanın hem taşınmasını hem de uzun süreli depolanmasını kolaylaştıran bu makineler, tarım makineleri arasında önemli bir yer edinmiştir. Balya makineleri, ilk olarak 19. yüzyılın sonlarında Amerika Birleşik Devletleri'nde kullanılmaya başlanmış ve bu süreçten itibaren sürekli olarak evrilmiştir. Başlangıçta basit mekanik prensiplere dayalı olarak çalışan bu makineler, zamanla hidrolik sistemler, otomatik bağlama mekanizmaları, nem sensörleri ve küresel konumlandırma sistemleri (GPS) gibi ileri teknolojilerle donatılmış modern makineler haline gelmiştir. Balya makineleri, genel olarak prizmatik (kare) ve rulo (yuvarlak) balya makineleri olmak üzere iki ana gruba ayrılmaktadır. Prizmatik balya makineleri, genellikle namlu şeklinde tarlada bırakılan yem materyalini toplayan bir ünite, bu materyali balya kanalına ileten parmaklı düzenek, sıkıştırma ve şekil verme işlemini gerçekleştiren piston mekanizması ve son olarak bağlama ünitesinden oluşur. Rulo balya makinelerinde ise yem materyali balya odasında döndürülerek sıkıştırılır; ardından bağlanarak silindirik formda çıkarılır. Bu makineler, işletme ölçeğine ve kullanım amacına bağlı olarak farklı ebatlarda ve özelliklerde üretilebilmektedir. Bu çalışma, balya makinelerinin tarihsel gelişimini inceleyerek, söz konusu makinelerin tarımsal üretim süreçlerine entegrasyonunu, teknolojik ilerlemelerini ve günümüzde ulaştıkları yapısal ve fonksiyonel seviyeyi kapsamlı bir biçimde ortaya koymayı amaçlamaktadır. Ayrıca, sürdürülebilir tarım politikaları çerçevesinde balya makinelerinde geliştirilen yenilikçi yaklaşımlar, çevresel etkiler ve enerji verimliliği açısından da ele alınmıştır. Geçmişten günümüze yaşanan bu dönüşüm yalnızca makinelerin yapısal özelliklerini değil, aynı zamanda çiftçilerin iş yapma biçimlerini, ihtiyaçlarını ve tarımsal üretime bakış açılarını da köklü şekilde değiştirmiştir.

Anahtar Kelimeler: Balya Makinesi, Tarım Makineleri, Tarımsal Mekanizasyon, Sürdürülebilir Tarım.

1. INTRODUCTION

Agriculture is one of human history's oldest and most deeply rooted economic activities (Erdoğan et al., 2021). Its significance in meeting basic human needs such as nutrition, clothing, and shelter has never diminished throughout history; however, it has increased further with population growth and the rise in living standards. Initially relying entirely on human labour, agricultural practices gradually evolved to incorporate animal power and machinery. This evolution has brought about profound changes in the quantity of production and the speed, efficiency, and cost of agricultural processes (Erdoğan et al., 2023).

One of the most critical turning points in the transformation of the agricultural sector has been the introduction of agricultural mechanisation. Mechanisation has enabled agricultural production to be carried out in a shorter time, with less labour and greater efficiency. Fundamental agricultural operations such as soil tillage, sowing, fertilisation, irrigation, and harvesting have gained a systematic structure through the use of machines, thereby significantly reducing dependence on human labour (Ercan et al., 2019).

As a natural consequence of these developments, new needs and challenges have emerged at every agricultural production stage. In particular, the difficulties encountered while transporting and storing post-harvest products have laid the groundwork for the emergence of baling technology as a sub-branch of agricultural mechanisation (do Canto et al., 2011). Agricultural products such as straw, green forage, and silage are inherently bulky, irregular, and difficult to handle. Therefore, compacting these materials has become essential for efficient storage and transportation (Grisso et al., 2020). At this point, balers have gained a significant place in the evolution of agricultural production. By compressing materials into compact masses under a specific pressure, balers facilitate transport and optimise storage space utilisation. Initially based on simple mechanical principles, these machines have gradually evolved—parallel to technological advancements—into modern systems equipped with automatic tying mechanisms, sensor-assisted monitoring technologies, and GPS-supported guidance systems (Shito et al., 2006; Niu et al., 2015).

This study explores the historical development and technological evolution of balers, evaluates their significance within agricultural production processes, and discusses the innovative approaches observed in these machines that align with sustainable agriculture's goals. Furthermore, the study aims to reveal how this transformation, experienced from the past to the present, has altered the machinery and farmers' production paradigms and perspectives on agricultural practices.

2.THE HISTORICAL ORIGINS OF THE NEED FOR BALING

2.1. Challenges of Crop Transportation in Agriculture and Early Solutions

Due to their inherent characteristics—bulky, irregular shape, and highly perishable—agricultural products have always made transportation and storage among the most critical stages of the production process. Products such as straw, green forage, and silage cannot be consumed immediately after harvest and therefore must be stored under appropriate conditions for a specific period. However, traditional methods—such as piling the products in the open or

covering them with tarpaulins—often led to significant product losses and required substantial labour input (Sabancı and Aydın, 2013).

Manual transportation of crops, especially across large fields, resulted in significant time and labour inefficiencies, posing a substantial barrier to agricultural productivity. Moreover, under traditional transport methods, products were directly exposed to environmental conditions such as rain, humidity, and sunlight, leading to quality degradation and economic losses (Sever and Duman, 2023). In response to the need for baling, one of the earliest attempts by agricultural communities involved primitive methods of hand-compressed and tied bundles (Figure 1). Typically performed manually, these procedures entailed placing the products into simple wooden molds for compression and securing them with plant fibres or natural ropes to make them suitable for transport (Figure 2). However, these methods had several disadvantages, including high labour requirements and non-uniform material compression. Consequently, during increased production volumes, these traditional practices proved inefficient. For all these reasons, the search for mechanical solutions to make post-harvest processes more efficient and systematic became inevitable.

Figure 1. Manually collected bundles (Anonymous, 2025a)

Figure 2. Fixed wooden molds (Anonymous, 2025b)

With the influence of the Industrial Revolution, the role of machines in production processes rapidly increased during the 18th and 19th centuries, and the need to mechanize labour-intensive operations in the agricultural sector became more pronounced. In the processing and transporting of post-harvest products, particularly on large-scale farms, the demand for faster and more efficient methods reached a critical level (Wild and Auernhammer, 1999). During this period, research focused on mechanical solutions that could enhance storage and transport efficiency by compressing products into smaller volumes. As a direct result of these needs, the first mechanical balers were designed in the late 19th century and introduced to the agricultural industry (Womac et al., 2012).

2.2. The History of the First Baler Machines

The historical development of baler machines dates back to the late 19th century, particularly during the agricultural revolution period in the United States. By the late 1870s, the scale of agricultural production in the U.S. had rapidly increased, but a growing shortage of labour accompanied this growth. Transporting and storing harvested products, especially on extensive agricultural lands, became a significant challenge (Ülger, 1978). The first balers developed during this period were based on a simple principle. Products were manually fed into the press chamber of the machine, compressed through a mechanical system, and then tied by hand. These balers were powered by horses, which walked on inclined leather or wooden treadmills. When a straw bale reached the correct size, twine or wire was wrapped around it and tied (Busse, 1984; Wedd, 1985). These machines were stationary systems, typically installed at a fixed location on a farm, where products were transported to the machine. In other words, the process was not fully automatic, but it was far more efficient than manual compression (Figure 3).

Figure 3. Image of the stationary baler (Taken by Caner Kövmen)

Following the success of the first mechanical balers, a significant leap occurred in the 1930s. With the widespread adoption of tractors, mobile balers that could be towed by tractors were developed. These machines further reduced the need for labour by offering the possibility of directly collecting and baling crops in the field. Simultaneously, developing tying mechanisms on the machines fully mechanised the baling process. In the 1940s, New Holland developed the "ghost knotter" (Figure 4), a knotting system that automatically cut, tied, and secured the baling twine, thereby maximising mechanical efficiency.

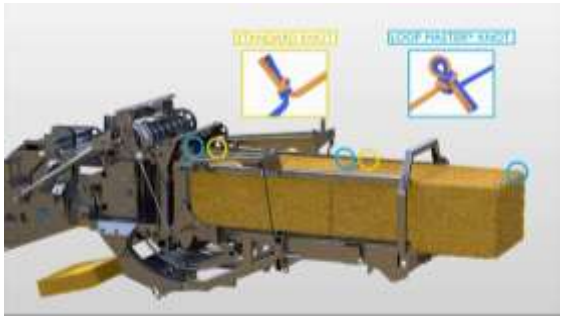

Figure 4. Knotter tying mechanism (Anonymous, 2025c)

In addition, integrating internal combustion engines into agricultural machinery in the early 20th century marked a significant breakthrough in baler technology. The first motorized balers were designed as self-propelled models that could operate independently of tractors. This development enabled the machines to perform pressing and make baling production faster and more continuous. Particularly in the 1930s, motorized balers developed by companies such as Allis-Chalmers and New Holland ushered in a new era in agricultural mechanization.

2.3. The Mechanical Evolution of Baler Machines

Following the development of the first baler machines, technology advanced rapidly, and balers' design and operating principles underwent significant changes over time. The main components of balers (Figure 5)—the collection unit, feeding mechanism, press chamber, tying unit, and bale exit chute—have become more complex and high-capacity in modern machines (Kahraman et al., 2023).

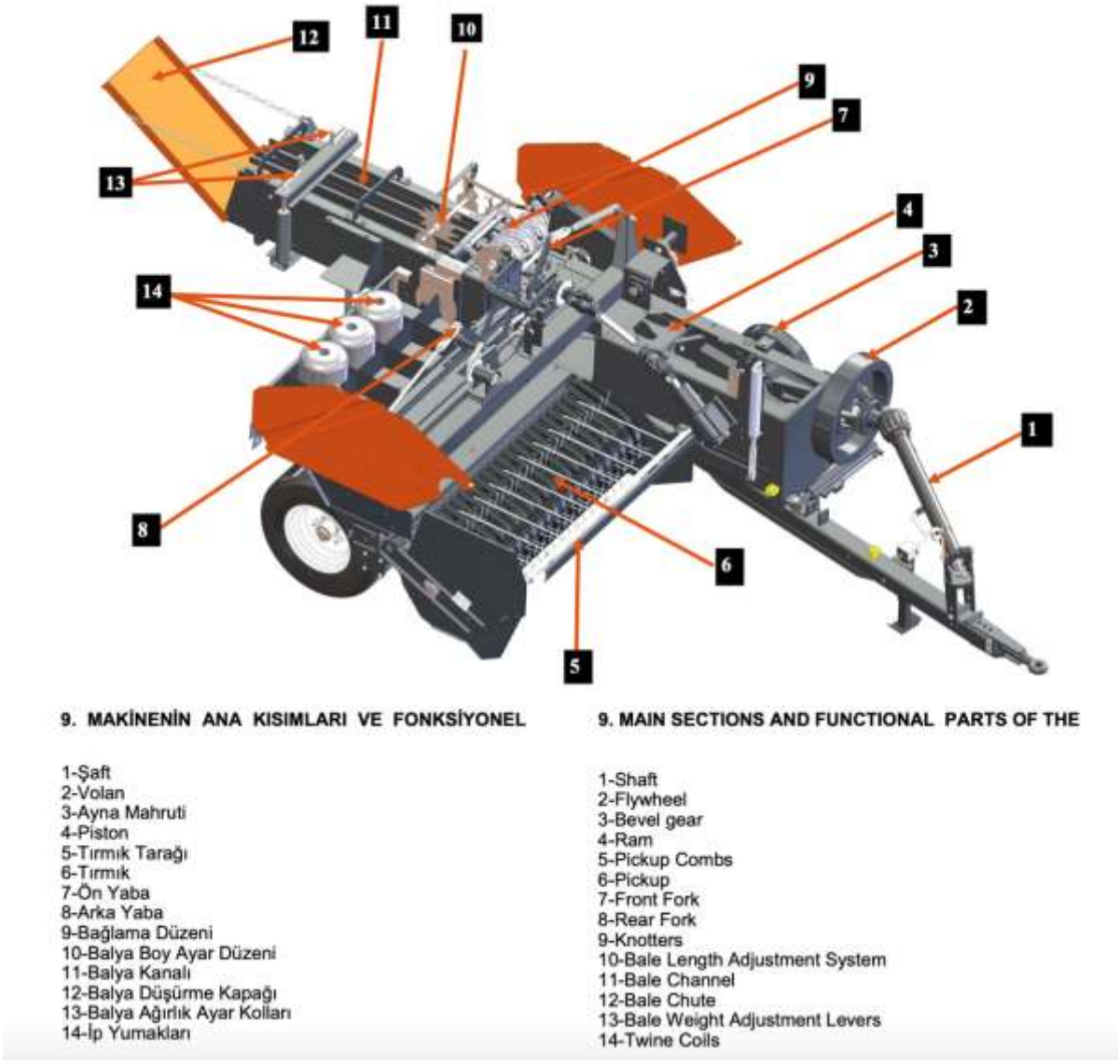

Figure 5. General components of a square baler machine (Paksan ve Gallignani, 2025)

2.3.1. Pickup unit

This unit is designed to collect products from the ground and feed them into the machine. Initially, collectors operated with simple rotary gear systems, but today, they are equipped with adjustable height, width, hydraulic controls, and vibration-reducing systems (Flick et al., 2019).

2.3.2. Feeding mechanism

The collected product is directed to the press chamber (piston chamber) through the feeding mechanism (inside the straw chamber). At this stage, the homogeneous distribution of the product directly affects the density and structural integrity of the bale. Optionally, a chopping

system known as a "hay knife" is located before the piston, which cuts the product before it reaches the piston, resulting in finer chopped material. This allows for a more uniform distribution and provides the option to directly feed the material to animals on farms without a feed mixer (Guo et al., 2022).

2.3.3. Pressing unit

The product is compressed at high density in the press chamber using mechanical or hydraulic force. With hydraulic systems, the pressing force has become more precisely adjustable, and customization according to different product types has become possible (Afzalinia and Roberge, 2008).

2.3.4. Tying unit (Knotter)

The tying unit (knotter) is one of the most critical components in modern baler machines. The knotter mechanism automatically cuts the twine, ties the knot, and secures the bale. The uninterrupted operation of this system directly affects baling efficiency, which is why it has been continuously developed. Additionally, it is equipped with a fan to prevent dust and debris from the hay from affecting the mechanism. Despite this, it remains the most prone to malfunction in the field (Guerrieri et al., 2019).

2.3.5. Bale exit chute

In the final stage, the formed bale is ejected from the exit chute in a controlled manner. This process has also been automated in modern machines, ensuring that the bales are stacked in an orderly line. The most common method, bale collection from the field surface, is still performed manually, although specialized systems for this purpose have been developed (Sun et al., 2010).

2.4. Bale Types and Their Applications

The development of baler machines has not been limited to improving mechanical systems; the types of bales produced have also been diversified to meet different agricultural needs. Various bale types have been developed, considering the intended use of agricultural products, transportation and storage conditions, and farm scales. This diversity has increased flexibility and efficiency in agricultural mechanization.

2.4.1. Rectangular (prismatic) baler machines

These machines produce rectangular bales and are particularly preferred in large-scale agricultural enterprises. The bales' uniform geometric shape makes transportation and stacking extremely easy. It provides significant advantages, especially regarding efficient vehicle space utilization for long-distance hauling (Liu et al., 2022).

Rectangular bales are indispensable when hay and forage crops need to be tightly and systematically stacked in storage areas. Fixed baling machines or large mobile balers can produce these bales. Small square balers (Figure 6) are common in small and medium-sized agricultural enterprises. These machines compress forage crops such as hay, grass, and alfalfa

into standard-sized bales (typically 36x46x90 cm), which are easy to handle. The bales usually weigh between 20 and 30 kg, although this can vary depending on the moisture content of the bale.

Figure 6. Image of a small rectangular (prismatic) baler (Paksan, 2025a)

Large rectangular baler machines (Figure 7) are preferred in large-scale agricultural fields where high efficiency is required. These machines possess significantly higher pressing power and can produce heavy bales with dimensions reaching up to 80×90×240 cm. Typically, their weight ranges from 500 to 600 kg. Large rectangular bales offer high efficiency in terms of both transportation and storage. They are widely used in biomass production, energy farming, and as raw material for industrial purposes, as well as by large-scale livestock farms. However, due to their need for high engine power and advanced technical equipment, these machines generally incur higher maintenance and operational costs than smaller balers. (Paksan, 2025b).

Figure 7. Image of a large rectangular baler machine (Paksan, 2025b)

2.4.2. Round (cylindrical) baler machines

Round balers (Figure 8) were introduced into agricultural mechanisation in the 1970s and quickly gained widespread use. These machines form cylindrical bales by rolling plant material in a spiral manner. The resulting bales typically have a diameter ranging from 1.2 to 1.8 metres and can weigh between 500 and 1,200 kilograms (Ünal, 2003). Round bales are particularly advantageous in pastures and large-scale fields due to their ease of handling. Moreover, they are considered more resistant to weather conditions. Because they are tightly wrapped, the optimal moisture content for fermentation can be maintained, making them an ideal solution for silage production (Wang et al., 2024a).

Figure 8. Image of round baler (New Holland, 2025)

2.5. Modern Balers and Digital Agriculture Integration

The integration of technology into the agricultural sector has caused a serious transformation of traditional mechanical systems, such as balers. Today's modern balers not only perform physical compression and tying operations, but also collect data from the field with advanced electronic systems, optimize the performance of the machines themselves, and provide real-time information to the operator.

2.5.1. Electronic control systems and sensors

Modern balers are equipped with various sensors to measure critical data such as product moisture, bale density and the working status of the tying mechanism. For example, the moisture content in the bale is measured instantly and reported to the operator via the in-cab display, thus preventing excessively moist products from being baled and causing quality loss (Yin et al., 2023). These sensor-based monitoring systems reduce product loss and help maintain feed quality.

2.5.2. GPS-aided guidance systems

Some modern models are equipped with GPS-based field navigation systems. Thanks to these systems, balers follow a more optimized route in the field, reducing fuel consumption and saving time. In addition, GPS data can be used to map crop productivity in the field and provide detailed analysis reports to farmers (Wang et al., 2021).

2.5.3. Autonomous balers and the vision for the future

The use of automation technologies in modern balers plays a groundbreaking role in terms of both productivity and product quality. Advanced sensor systems can continuously monitor the machine’s performance and automatically adjust the pressing density, tying tension and machine speed when necessary (Wang et al., 2024b). For example, load sensors and moisture sensors optimize the machine’s operating parameters according to product conditions, ensuring optimum bale quality. In addition, some advanced models minimize operator intervention with automatic tying yarn or wire changing systems and offer non-stop operation. These systems save time and reduce labor costs, especially in intensive baling operations in large areas (Jiao et al., 2025). In line with the increasing importance of automation in agriculture, autonomous baling machine development studies have gained momentum. Equipped with GPS, LIDAR and camera systems, these machines can navigate the field without human intervention and perform the baling process independently (Tang et al., 2024). Autonomous machines offer great advantages in terms of optimizing working hours, reducing human-related errors and reducing labor costs. In addition, these systems, which can work integrated with precision agriculture applications, increase productivity by minimizing product loss. These systems can determine their own routes by analyzing field conditions (based on data entry) and make automatic speed and pressure adjustments according to product quantity. Autonomous machines offer important

solutions that can increase agricultural productivity, especially in regions with labor shortages (Martelli et al., 2025).

2.5.4. Modern balers for sustainable agriculture

Ensuring sustainability in the agricultural sector is directly related to increasing the energy efficiency of machines and reducing fuel consumption. Thanks to the optimized drive systems, variable speed transmissions and lower resistance mechanical components used in modern balers, energy consumption is minimized. In addition, thanks to the integration in tractors with high engine efficiency and the optimization of the work process with GPS-supported routes, unnecessary fuel consumption is prevented (Karunaratne et al., 2020; Pranga et al., 2021). Thus, both operating costs are reduced and environmental impacts are minimized. The development of modern balers has not only increased production efficiency, but also contributed to reducing the environmental impacts of agricultural activities. Thanks to lower fuel consumption, optimized product handling processes and reduced product losses, balers play an important role in sustainable agricultural practices. In this context, baling technology has become not only an element of agricultural mechanization, but also an indispensable component of sustainable production systems (Vanamburg et al., 2006; Dusseux et al., 2022).

3. CONCLUSION AND GENERAL EVALUATION

Balers are considered one of the cornerstones in agricultural production's modernization and mechanization process. Baling technology, which replaces labor-based, time-consuming, inefficient transportation and storage methods, has accelerated production processes and provided critical advantages such as preserving product quality, reducing storage costs, and increasing agricultural productivity. The evolution from simple mechanical systems to high-tech, sensor-supported, GPS-controlled, and even autonomous balers throughout history demonstrates how technology has led to a profound transformation in the agricultural sector. Initially equipped with fixed and manual tying systems, today machines have evolved into smart systems that can automatically adjust according to field conditions and optimize bale quality by measuring product moisture. This technological development has also made significant contributions to sustainable agricultural practices. Elements such as low fuel consumption, reduced product losses, optimized logistics chains, and minimizing environmental impacts have further strengthened the place of balers in the modern agricultural vision.

Looking to the future, it is expected that balers will become more digital and fully autonomous systems supported by machine learning will become widespread in agriculture. These developments will both reduce labor costs and bring the data-based management approach to the forefront in agricultural production. Thanks to the new tractors developed, the speed level has reached very sensitive levels depending on the bale density.

In conclusion, the historical development of balers is not only a technological success story, but also a concrete indicator of humanity's efforts to achieve more sustainable, efficient and effective agricultural production. This study reveals the evolution of balers from the past to the

present, while also shedding light on the increasing strategic role of these machines in the agriculture of the future.

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REAL-TIME PLANT PEST MONITORING IN AGRIVOLTAIC FARMS USING DEEP LEARNING-BASED PEST IMAGE GENERATION MODELS FOR SUSTAINABLE PEST MANAGEMENT

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ABSTRACT

Microclimates are often created from the shading provided by solar panels, causing changes in humidity, temperature, and light levels, thereby altering pests' behavior and their patterns of distribution, as certain pests flourish under different environmental conditions. Moreover, there are many complexities and diversities in agricultural environments, with different conditions and climates for different crop production, and a large amount of robust data is required for effective training of models developed for real-time object detection and monitoring. We aim to (1) control the generation of pests' images and see to it that augmented samples comply with

real-world attributes, (2) enhance the generalization capabilities of pests' detection models to monitor pests' behavioral changes in shaded or unshaded areas in agrivoltaic farms. To achieve this, we propose a Diffusion Model-based Semantic Integration Guidance (DMSIG) and design a Multi-Level Alignment Distillation (MLAD) framework. While DMSIG integrates multi-source semantic features to control the generation of pests' images and see to it that augmented samples comply with real-world attributes, the MLAD framework leverages DMSIG and enhances the generalization capabilities of pests' detection models for real-time monitoring of pests' behavioral changes, where microclimate modifications may impact pest behavior in shaded or unshaded areas in agrivoltaic farms. Experimental results show that our proposed model generates quality images, predicts pests' behavioral changes accurately and produces samples with low FID scores and obtains exceptional AP improvement. This was evaluated by comparing it with various methods (StyleGAN2, AugGAN, DDPM, and LDM) for generative data augmentation and downstream detection tasks (teacher-student YOLOv8 network models) on the IP102 dataset, using the Fréchet inception distance (FID) and Precision evaluation metric.

Keywords: Agrivoltaic**,** Crop yields, Deep learning**,** Pest image generation, Plant pest

1. INTRODUCTION

Timely pest management is essential for healthy growth of plants and increased crop yields, particularly in agrivoltaic farms [1,2]. The advent of artificial intelligence (AI) and its various fields, such as machine learning (ML), deep learning (DL), and computer vision (CV) have facilitated fast and accurate detection, localization and identification of agricultural pests in real-time using various models of these technologies [3,4], thereby furnishing farmers with prompt information about pests and effective measures to control and manage crop production for overall economic gain [5,6]. Microclimates are often created from the shading provided by solar panels, causing changes in humidity, temperature, and light levels, thereby altering pests' behavior and their patterns of distribution, as certain pests flourish under different environmental conditions [7,8].

Moreover, there are many complexities and diversities in agricultural environments, with different conditions and climates for different crop production, and a large amount of robust data is required for effective training of models developed for real-time object detection and monitoring [9-11]. These complexities and heterogenous backgrounds of agricultural environments require that any detection model has capabilities for generalization to enable accurate detection of pests irrespective of the background complexity. Furthermore, it is a herculean task finding images of pest-infected crops, and the current data augmentation methods, though easy to apply to most image processing tasks, find it difficult to produce samples with substantially different features [12].

To cater for the farmers, significant methods that can address the abovementioned challenges were proposed in [13-16]. However, these methods were unable to generate pest images that contained more features and details, making availability of variety of data difficult. Moreover, pests monitoring in real-time is a challenge to the current methods, where microclimate modifications may impact pest behavior in shaded or unshaded areas in agrivoltaic farms. Therefore, we aim to (1) control the generation of pests' images and see to it that augmented samples comply with real-world attributes, (2) enhance the generalization capabilities of pests' detection models to monitor pests' behavioral changes in shaded or unshaded areas in agrivoltaic farms. Our proposed method in this paper is a step towards achieving real-time plant pest monitoring in agrivoltaic farms using deep learning-based pest image generation models for sustainable pest management.

The rest of the paper is structured as follows: Section 2 presents the related work, encompassing existing contributions to pest management, agrivoltaics farms, their methods, and strengths and weaknesses, where applicable. Section 3 presents the methods and materials we used in accomplishing the objectives of the paper. Section 4 presents the results, including implementation and discussions. Section 5 concludes the paper.

2. RELATED WORK

Chen et al. [3] combined AI, sensor technologies and Internet of Things (IoT) for image recognition and pest identification. They also combined DL and AIoT technology for smart agriculture applications. They obtained Tessaratoma papillosa localization using DL YOLOv3

image recognition model and predicted occurrence of pests by analyzing environmental information from weather locations using Long Short-Term Memory (LSTM). They obtained 90% pest identification accuracy from their experiments. However, due to some difficulties encountered in the research institute where the research was conducted, there was a challenge with training samples.

Vervloesem et al. [8] undertook a study on the influences of solar farms on microclimate and vegetation dynamics. They took at different solar farm locations, the surface temperature measurement, air temperature, photosynthetic active radiation, and humidity, for microclimate quantification. The vegetation's multidimensional functional diversity (FD) analysis revealed the presence of less light at a higher humidity and lower temperature under the panels. This revelation means that under-the-panel species preferred a lower pH and a higher nitrogen level.

Maguluri et al. [11] introduced an advanced fusion of Convolution Neural Networks (CNNs) and Transformer models designed for monitoring agricultural activity through remote sensing data. This advanced approach, unlike traditional models, effortlessly combines CNN's extracted spatial features with the all-inclusive contextual insights presented by Transformers. They evaluated the model by comparing it with nine existing models such as Random Forests, Gradient Boosting Machines, standard SVMs, Decision Trees, CNNs, Logistic Regression, RNNs, LSTMs, and GANs. Their model achieved an unparalleled 98.88% accuracy.

Dinesh and Pearce [16] developed a joined simulation model for photovoltaic and agricultural productions, to measure the technical capability of scaling agrivoltaic systems. The results revealed the benefits in using agrivoltaic systems over the traditional agricultural systems. Furthermore, the results demonstrate that the value of solar generated electrical energy in addition to low-light tolerant crop production produced over thirty percent rise in economic value. Employing low-light tolerant crops, as obtained in agrivoltaic farms, reduces crop yield losses, maintaining stability in crop price.

Other works that contributed to agrivoltaic farming and sustainable pest management in terms of using AI and image processing technologies are: Trommsdorff et al. [17], Mahto et al. [18], Wydra et al. [19], and Willockx et al. [20], who evaluated and compared the performance of two bifacial agrivoltaic systems, vertical bifacial and dynamic single-axis tracker, on arable land. They developed an empirical crop model that was based on radiation use efficiency (RUE) and utilized a radiation tool for simulation of crop produce and quality. The findings revealed dynamic solar tracker as a better tracker than the fixed vertical bifacial setup. However, the empirical crop growth model was unable to account for climatic variation in the dry season, limiting its effectiveness during the design phase.

3. MATERIALS AND METHODS

We propose a Diffusion Model-based Semantic Integration Guidance (DMSIG) and design a Multi-Level Alignment Distillation (MLAD) framework. DMSIG integrates multi-source semantic features to control the generation of pests' images and see to it that augmented samples comply with real-world attributes. The MLAD framework enhances the generalization capabilities of pests' detection models to monitor pests' behavioral changes in shaded or

unshaded areas in agrivoltaic farms. The training process is optimized by this framework for downstream detection tasks. This is achieved by the alignment of the intermediate feature representations and outputs (softened logits) of the teacher-student model, in addition to relational graphs construction for feature channels.

In the architecture of the MLAD framework, the teacher-student's intermediate feature representations were output over Convolutional to fused (C2f) blocks, and spatial and channel attention modules were employed for their alignment to reduce tensor dimension differences. Cosine similarity was used for calculating the inter-channel relationships, and L2 loss was used for measuring the differences between adjacent matrices. The distillation loss for output level is got by computing the KL loss with softened outputs from the detection head. The existing Latent Diffusion Model (LDM) [21] performs excellently in data augmentation and text-to-image tasks. LDM comprises forward diffusion and reverse denoising processes, where the forward process is responsible for transforming the sample x_0 into latent space variable z_0 by a Variational Autoencoders (VAEs) [22], as $z_0 = \varepsilon(y_0)$. The z_0 is transformed to z_t by bit-by-bit addition of Gaussian noise to the z_0 using a Markov chain. Equation (1) represents the expression.

$$q(z_t|z_{t-1}) := N(z_t; \sqrt{1-\beta_{tz_t-1,}}\ \beta_t I \qquad (1)$$

The reverse process involves inputting z_t into a U-Net for prediction and elimination of the noise gradually. The $\hat{z}_0$ is then transformed by VAE decoder into the generated image $\dot{y}_0$, as $\dot{y}_0 = D(\hat{z}_t)$. The reverse process is:

$$P_\theta(z_{t-1}|z_t) := N(z_{t-1}; \mu_\theta(z_{t,}t), \sum_\theta(z_{t,}t) \qquad (2)$$

$$\mu_\theta(z_{t,}t) = \frac{1}{\sqrt{\alpha_t}}(z_{t,} - \frac{\alpha_t}{\sqrt{1-\alpha_t}}\epsilon_\theta\ (z_{t,}t)) \qquad (3)$$

The network responsible for noise prediction (ϵ_θ (.)) is employed for generating (μ_θ (.)), for improved performance [23]. The expected loss between true noise and predicted noise is minimized by training with the condition input. By extending DDPM (Denoising Diffusion Probabilistic Models) [23], LDMs employ VAEs in performing the processes of diffusion and denoising in a latent space, thereby increasing the resolution of the images and reducing the cost of computation. In addition, the denoising process is altered by the conditional inputs presented by LDMs; also, a cross-attention mechanism was leveraged by LDMs, making the conversion of text-to-image possible using text prompts converted through CLIP (Contrastive Language-Image Pretraining) [24].

However, the semantic information of the augmented images generated by LDMs is not consistent with the original images. We proposed DMSIG as a solution to the limitation of LDMs, with sole aims of generating improved augmented images. The architecture of DMSIG is shown in Fig. 1. The pre-trained diffusion models were fine-tuned, at a reduced training cost, for the generation of desired images. Moreover, DMSIG exercise control and guidance during the original diffusion model's generation process. The semantic feature maps of an input image are extracted by preprocessors, which comprise various feature extractors to generate the semantic feature maps. The maps generated are combined and converted into shallow latent vectors. The DMSIG component consists of CNNs (for transforming each vector), trainable copies (for guiding the model), and a Multi-Layer Perceptron (MLP), which is a type of feedforward artificial neural network, as the last component.

CNNs transform individual vectors into actionable vectors (input to trainable copy layers) for guiding decisions or actions. The diffusion network's formation and initialization parameters are obtained by the trainable copy layers for the reduction of overfitting possibilities in using the pre-trained diffusion network for training. This is achieved by freezing the diffusion network' parameters, making only the SIG components' parameters trainable. A MLP layer guides the diffusion process while allowing the passage of trainable copy layer's output through it. Moreover, the Low-Rank Adaptation (LoRA) technique was applied for significant reduction of trainable parameters, thereby increasing training speed, reducing memory consumption and model weights.

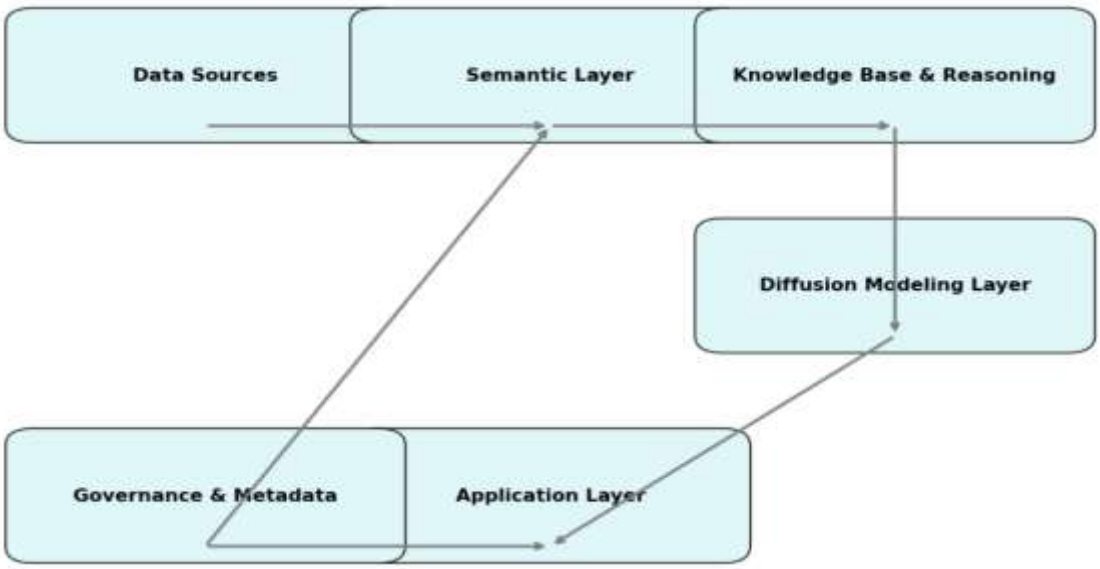

Fig. 1. Architecture of DMSIG and its application to plant pest monitoring in agrivoltaic farms.

For the validation of our proposed model effectiveness, we conducted extensive experiments on the accurately designed IP102 dataset [25] with a total of 75,222 images, categorized into

102 different classes of insect pests for smooth detection research of large-scale insect pests. The dataset, taken from both shaded and unshaded zones, includes pests that usually affect agrivoltaics-based crops and thrive in these zones. The MLAD framework (Fig. 2) was devised for the alignment of knowledge representations at different levels, enabling effective knowledge distillation, which is the technique employed in transferring knowledge from a larger and powerful model (called teacher) to a smaller one and less powerful model (called student) while maintaining validity.

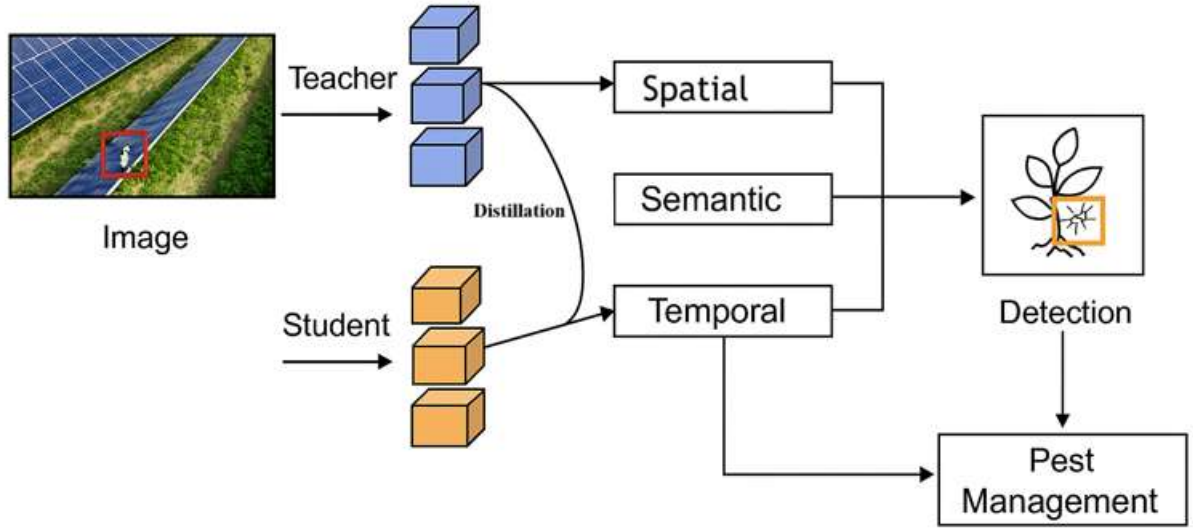

Fig. 2. Multi-level alignment distillation framework for real-time plant pest monitoring in agrivoltaic systems toward sustainable pest management.

Initially, channel attention and spatial attention were sequentially applied by CBAM to the intermediate layer outputs of both the teacher model and student model, facilitating utmost concentration of the model on regions of the feature maps with dense information. Average pooling and max pooling operations including MLP, were used for channel attention calculation, and the generated attention map was applied to the input feature map. As for spatial attention, its calculation is by combining both the average-pooled feature and max pooled feature on the axis of the channel before performing convolution operation, and the generated attention map was applied to the processed feature map. Interpolation and convolution operations enable the alignment of the teacher feature map and student feature map to the same tensor dimension. Following the alignment, a feature distillation loss is calculated to derive the difference between the teacher's and student's aligned feature maps.

Global information within the feature maps can be better captured by the student network using the relationships' distillation between the feature channels. These relationships do not only comprise a combination of local features but also comprise higher-level semantic information. The feature maps' inter-channel cosine similarity was calculated, which is useful for evaluating the relational alignment between the feature maps' channels from the teacher model and student model. Moreover, the relational distillation loss was defined based on the inter-channel cosine

similarity for evaluation of the difference between the contiguity matrices of the teacher model and student model. We employed the Frechet Inception Distance (FID) score and Inception Score (IS) for quality evaluation of the generated images. The distance between feature distributions of real and generated images is measured by FID, and the diversity and quality of generated images are measured by IS. We utilized Average Precision (AP) for performance assessment of both teacher and student models.

4. RESULTS

We employed the following hardware to perform the experiments; 13th Gen Intel(R) Core (TM) i7-1355U (12 CPUs) @ 1.7GHz with NVIDIA GeForce RTX 3090 GPUs of 24,260 MB of memory. For the software, we employed Python 3.10.14 and PyTorch 2.0.1 running on the Windows 11 Operating System. YOLOv8 network was selected for detection and contrast experiments were conducted on both the original and augmented datasets using Stable Diffusion. Adam optimizer was employed for the model training with 100 epochs, 0.0001 learning rate, and 16 batch size. The augmented datasets and the cleaned original datasets were combined under the same scale as the uncleaned original datasets.

The performance comparison of data augmentation techniques such as StyleGAN2 [26], AugGAN [27], DDPM [23], LDM [21], and our proposed method, on three randomly selected classes from the IP102 dataset using the FID and IS metrics is presented in Table 1. An average FID score of 9.1 and average IS score of 2.3 were obtained by DMSIG and IS, respectively, demonstrating the significant performance of our proposed method over others in generating images of high-quality. These results were employed in evaluating the DMSIG capability in improving the performance of object detection (Table 2). Table 3 presents the performance comparison of MLAD framework with other existing methods on the IP102 dataset.

Table 1: The performance comparison of data augmentation techniques such as StyleGAN2, AugGAN, DDPM, LDM and our proposed method, on three randomly selected classes from the IP102 dataset using the FID and IS metrics.

IP	StyleGAN2	AugGAN	DDPM	LDM	Proposed method
085	17.9/1.4	34.7/1.7	41.4/1.4	16.9/1.9	8.4/2.1
092	17.8/1.7	34.5/1.9	42.2/1.2	16.7/1.6	9.1/2.3
099	17.4/2.2	34.4/1.5	41.7/1.3	16.7/1.6	9.7/2.5
Average	17.7/1.8	34.5/1.7	41.8/1.3	16.8/1.7	9.1/2.3

Table 2: Comparison of different generative models and our proposed DMSIG method on downstream detection tasks (YOLOv8n student network).

Teacher	StyleGAN2	DDPM	LDM	Proposed method
YOLOv8l	44.7/43.9/45.8	43.8/42.3/45.2	45.8/44.7/45.9	45.9/45.1/46.7
YOLOv8m	43.9/42.9/45.1	42.9/41.7/44.1	44.5./43.9/45.8	45.1/44.8/46.1
YOLOv8s	42.4/41.1/44.1	42.1/40.1/43.2	43.1/41.6/43.9	44.6/44.1/45.7

Table 3: Performance comparison of MLAD framework with other existing methods on the IP102 dataset. The left values represent results before data augmentation, and the right values represent results after data augmentation.

Method	AP		
Teacher	YOLOv8l 42.6/46.7	YOLOv8m 41.7/45.9	YOLOv8s 40.3/44.6
Student	YOLOv8n 40.1/44.4	YOLOv8n 40.1/44.4	YOLOv8n 40.1/44.4
RKD [28]	40.6/44.9	40.5/44.8	40.2/44.1
FGD [29]	41.4/45.9	40.9/45.1	40.7/44.4
MLKD [30]	41.9/45.8	41.4/45.6	40.9/45.3
Proposed method	43.1/46.3	42.7/45.9	41.5/45.6

In Table 2, each value represents the performance (AP) for Teacher/Student/Distillation. The same original dataset was employed in training all the methods. When the YOLOv8l model was used as the teacher model, DMSIG, the proposed model achieved 45.9/45.1/46.7 AP scores for Teacher/Student/Distillation respectively, indicating the reliability in the images generated by DMSIG in capturing more features and details, thereby leading to an increase in data diversity. In practical applications, the generated pest images can be extended to diverse scenarios and object transformations, aiding the detection model in learning broad and intense feature representations during training. The student model performs better with a large parameter scale of the teacher model. Moreover, the MLAD framework leverages DMSIG for real-time pest monitoring, where microclimate modifications may impact pest behavior in shaded or unshaded areas in agrivoltaic farms.

5. CONCLUSIONS

In this paper, we proposed real-time plant pest monitoring in agrivoltaic farms using deep learning-based pest image generation models for sustainable pest management using DMSIG and a MLAD framework. For the validation of our proposed model effectiveness, extensive experiments were conducted on the accurately designed IP102 dataset with a total of 75,222 images, categorized into 102 different classes of insect pests for smooth detection research of large-scale insect pests. We employed the techniques of both enhanced data augmentation and model optimization for the improvement of the practicality and variety of generated images, for overall robust performance and accuracy in agrivoltaic applications. The results of the experiments significantly validate the accuracy and effectiveness of our approach and proposed model for detecting agricultural pests in complex agrivoltaic environments, providing a sustainable solution for timely pest management, healthy growth of plants and bountiful crop yields.

We understand that agrivoltaic systems influence pest populations in a variety of ways, as certain pests flourish under different environmental conditions. For example, pests like aphids, beetles, and caterpillars habitually have individual environmental preferences. In agrivoltaic systems, these pests might feel more hospitable in the shaded areas, especially if the shaded areas are cooler and more humid in conditions. Likewise, the prevalence of pests like certain types of mites might be less in the shaded regions. We have as our future work, a lot of research to carry out in this regard including the potential of AI in leveraging all the strategies for pest control in these settings for sustainable pest management.

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EMERGENCY OF WHEAT PRODUCTION AMONG SMALL-SCALE FARMERS AND ITS EFFECT ON POVERTY REDUCTION IN JIGAWA STATE, NIGERIA

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ABSTRACT

Nigeria's local wheat production remains grossly insufficient to meet domestic demand, despite wheat-based foods accounting for about 45% of daily meals consumed in Nigerian households. Wheat is the second-largest contributor to the country's food import bill, with over $2 billion spent annually on the importation of more than five million metric tonnes. This study analyzed wheat production among small-scale farmers and its effect on poverty reduction in Jigawa State, Nigeria. Primary data were collected from 170 respondents during the 2023 farming season using a structured interview schedule. The Cobb-Douglas stochastic frontier cost function revealed that the coefficients for seed cost (0.673), fertilizer cost (-0.749), and agrochemical cost (-0.914) were statistically significant at various levels, indicating that these inputs significantly influence production costs. In the inefficiency model, age (0.179) and farming experience (-0.215) were significant and increased inefficiency, while gender (-0.775) significantly reduced inefficiency. The Foster-Greer-Thorbecke (FGT) poverty indices showed that 58.36% of wheat farmers were below the poverty line, although the poverty gap (21.1%) and severity (7%) were relatively low. The study concludes that wheat production holds potential for improving cost efficiency and alleviating poverty. It recommends enhancing access to credit for wheat farmers through favorable government interventions and commercial bank financing to boost productivity and income.

Keywords: Wheat, Poverty reduction, efficiency, cost of seed, Nigeria

INTRODUCTION

Wheat (Triticum aestivum) is among the most important staple crops globally, serving as a major source of calories and nutrition for billions of people. The global production of wheat is led by China, followed by India, Russia, and the United States. In the marketing year 2024/2025, the global production volume of wheat amounted to approximately 793 million metric tonnes (MMT), reflecting an increase compared to the previous year. In contrast, Africa contributes about 27 MMT, with Sub-Saharan Africa (SSA) accounting for a mere 7.5 MMT. These figures highlight the continent's limited capacity to meet its own wheat demands (Statista, 2025).

Wheat is a cool-season crop that performs best in temperate environments, a factor that has historically made its cultivation challenging in Nigeria due to the country's predominantly hot climate (Haruna et al., 2017). Consequently, wheat farming in Nigeria has remained underdeveloped, despite the crop's significant importance. Wheat-based products constitute a substantial portion approximately 45% of daily meals in Nigerian households, underscoring the country's heavy reliance on the commodity. This dependency has led to an alarming rise in wheat imports, making it the second-largest contributor to Nigeria's food import bill. Over $2 billion is spent annually on importing more than five million metric tonnes of wheat (Central Bank of Nigeria [CBN], 2021).

Nigeria's annual local wheat production remains insufficient to meet growing demand. In 2020, only about 200,000 metric tonnes were produced locally, while national demand was estimated between 4.5 and 5.0 MMT. This glaring production deficit has significant implications—not only for food security but also for the nation's foreign reserves, particularly since the oil price shock between 2014 and 2016. The crisis compelled policymakers to reconsider Nigeria's agricultural potential, especially in terms of increasing wheat production to reduce import dependency (Umar & Muhammad, 2021; Statista, 2025).

Despite the challenges, Nigeria possesses considerable agro-ecological potential to expand wheat production under both irrigated and rainfed conditions. In particular, northern states such as Jigawa have witnessed increasing participation in irrigated wheat farming, with over 1.5 million farmers engaged in the practice during the harmattan period from October to February. Additionally, rainfed wheat is cultivated on the highlands of the Mambilla Plateau in Taraba State, the Jos Plateau in Plateau State, and the Obudu Plateau in Cross River State. Wheat's role as a raw material for the flour industry and its nutritional value further justifies the need to scale up production efforts (Benjamin et al., 2024; Mohammed et al., 2023).

However, despite various government-led initiatives such as the National Agricultural Land Development Authority (NALDA), aimed at revitalizing agriculture in northern Nigeria, wheat production remains stagnant. Many smallholder farmers are abandoning wheat in favor of other more profitable or less demanding crops, such as rice. This shift raises critical concerns, given that small-scale farmers constitute the bulk of Nigeria's wheat producers and are often among the most impoverished segments of the population (Mohammed et al., 2023).

The continued challenges of inadequate funding for research, lack of mechanized farming practices, poor extension services, and limited access to quality inputs have further weakened

local wheat production. These constraints have contributed to persistently low productivity levels and limited income generation among wheat farmers. Therefore, addressing the efficiency of wheat production is a critical step toward enhancing agricultural productivity and alleviating poverty among small-scale farmers. This study seeks to investigate the socio-economic characteristics of wheat farmers in Jigawa State, assess the cost efficiency of smallholder farmers, and examine the extent to which increased wheat cultivation contributes to poverty reduction in the region.

METHODOLOGY

1. Description of the Study Area

The study was conducted in Hadejia Local Government Area (LGA) of Jigawa State, located in north-western Nigeria. Geographically, it lies between latitudes 12°23′N and 12°28′N and longitudes 10°00′E and 10°05′E. The area falls under the Sudan Savannah agroecological zone, characterized by a tropical wet and dry climate. The rainy season typically occurs between May and September, while the dry season spans from October to April. The mean annual temperature is about 25°C, with monthly temperatures ranging from 21°C in the coolest months to 31°C during the hottest months (Hadejia, 2012). The area is situated within the inland drainage basin of Lake Chad, and the Hadejia River flows approximately 828 km through the region.

Farming is the predominant economic activity, with crops such as rice, sorghum, millet, wheat, maize, cotton, cassava, cowpea, soybean, and groundnut widely cultivated. Vegetable crops including tomato, pepper, onion, and carrot are also produced. Livestock rearing is significant, involving cattle, sheep, goats, and poultry.

2 Sampling Techniques and Sample Size

A multistage sampling technique was adopted for the selection of respondents. In the first stage, Hadejia LGA was purposively selected due to the predominance of wheat production. In the second stage, three villages—Aguyaka, Masama, and Gudincin—were purposively selected based on the intensity of wheat production activities. Finally, in the third stage, random sampling was used to select farmers from the sample frame in each village.

Sixty-five percent (65%) of the total sampling frame (170 farmers) was selected, resulting in a final sample size of 110 wheat farmers.

Table 1: Distribution of Sample Size in the Study Area

LGA	Village	Sample Frame	Sample Size (65%)
Hadejia	Aguyaka	65	42
	Masama	49	32
	Gudincin	56	36
Total		**170**	**110**

Source: Field Survey, 2023

3. Method of Data Collection

Primary data were collected using a structured questionnaire. Information was obtained on farmers' socio-economic characteristics such as age, marital status, education level, household size, farming experience, farm size, extension contact, and membership of associations.

4. Analytical Techniques

Descriptive Statistics

Descriptive statistics such as frequencies, means, and percentages were used to describe the socio-economic characteristics of the respondents and the constraints faced in wheat production.

Stochastic Frontier Cost Function

This function was used to assess allocative efficiency and is defined as:

$C = f(P_i, Y_i; \gamma) \cdot \exp(V_i + U_i)$

The Cobb-Douglas form is specified as:

$$lnC = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + (V_i + U_i)$$

Where: C = total production cost (₦), X_1 = cost of seed (₦), X_2 = cost of fertilizer (₦), X_3 = cost of labour (₦), X_4 = cost of agrochemicals (₦)

The inefficiency model is:

$$U_i = \delta_0 + \delta_1 ln Z_1 + \delta_2 ln Z_2 + \delta_3 ln Z_3 + \delta_4 ln Z_4 + \delta_5 ln Z_5 + \delta_6 ln Z_6 + \delta_7 ln Z_7$$

Where: Z_1 = age (years), Z_2 = years of formal education, Z_3 = farm size (hectares), Z_4 = years of wheat farming, Z_5 = number of extension visits, Z_6 = household size and Z_7 = amount of credit obtained (₦)

The a priori expectation is that coefficients of the efficiency inputs ($\beta_1 to \beta_4$) should be positive, while the coefficients of the inefficiency variables ($\delta_1 to\ \delta_7$) should be negative.

Foster-Greer-Thorbecke (FGT) Poverty Index

The FGT poverty index was employed to determine the poverty status of wheat farmers. It uses a relative poverty line based on the two-thirds mean expenditure of sampled households.

The general formula for the FGT index is:

$$P_{\alpha} = \frac{1}{N}\sum_{i=1}^{H}\left(\frac{z - Y_i}{z}\right)$$

Where: $P_{\propto}$= FGT poverty index, α = poverty aversion parameter (0 = incidence, 1 = depth, 2 = severity), z = poverty line, Y_i = income/expenditure of the *i*th household, H = number of poor households and N = total number of households

The poverty line was set at two-thirds of the mean expenditure. Based on this, the classification is: Non-poor: Expenditure > ⅔ mean, Poor: Expenditure between ⅓ and ⅔ mean

RESULTS AND DISCUSSIONS

Socio-Economic Characteristics of Wheat Farmers

Table 1 presents the socio-economic characteristics of wheat farmers in the study area. Results show that most farmers (29.1%) were aged 26–35 years, indicating an active and productive workforce. Males constituted the majority (96.4%), which may reflect cultural norms influencing gender roles in farming. A large proportion (59.1%) were married, suggesting a stable social structure that can enhance decision-making in farming. About 61% had some form of formal education, with 38.2% having Quranic education. The household size was generally large, with 30% having 11–15 members, implying the availability of family labour. Regarding farming experience, 42.8% had 1–5 years' experience. Only 48.2% belonged to cooperatives, 33.6% had access to credit, and 93.6% had contact with extension agents. Most respondents (73.6%) cultivated only 1 hectare, showing the small-scale nature of production.

Table 2: Socio-Economic Characteristics of Wheat Farmers

Variable	Category	Percentage (%)
Age	26–35	29.1
	Above 36	70.9
Sex	Male	96.4
	Female	3.6
Marital Status	Married	59.1
	Single	40.9
Education	Formal Education	61.8
	Quranic Education	38.2
Household Size	6–15 members	61.0
	Others	39.0
Farming Experience	1–10 years	77.3
	>10 years	22.7
Cooperative Membership	Yes	48.2
	No	51.8
Access to Credit	Yes	33.6
	No	66.4
Extension Contact	Yes	93.6
	No	6.4
Farm Size (ha)	1	73.6
	>1	26.4

Cost efficiency of wheat production among small-scale farmers

The results presented in Table 3 provide insight into the factors influencing cost inefficiency among wheat farmers. The model summary of the Cobb-Douglas Stochastic Frontier Cost Function provides important insights into the efficiency of wheat farmers in Hadejia LGA. The gamma value (0.174) implies that approximately 17.4% of the variation in production cost among farmers is due to inefficiency effects, with the rest attributed to statistical noise. While this value is relatively low, it still justifies the use of the stochastic frontier approach. This result aligns with Adeleke et al. (2023), who analyzed costs and returns of wheat production along the Hadejia Valley irrigation scheme, and Obianefo (2021), who examined efficiency metrics in farming systems in northern Nigeria. The mean efficiency score of 0.163 reflects low cost efficiency, suggesting substantial scope for cost minimization among wheat producers,

consistent with Adeleke et al. (2023), and the findings of Ja'afar-Furo et al. (2020), who emphasized efficiency gaps in cereal marketing

Table 3: Maximum Likelihood Estimates for Cobb-Douglas Stochastic Frontier Cost Function

Variable	Coefficient	Std. Error	T-ratio
Frontier Function			
Constant	0.122	0.166	0.737
Seed cost	0.673*	0.349	1.928
Fertilizer cost	-0.749	0.739	-1.013
Chemical cost	-0.914**	0.430	-2.125
Inefficiency Effects			
Constant	0.251*	0.132	1.899
Age	0.179	0.334	-0.535
Household Size	0.335	0.239	0.138
Farming Experience	-0.215*	0.128	-1.679
Gender	-0.775*	0.423	-1.832
Marital Status	-0.148	0.214	-0.691
Cooperative Group	-0.104	0.504	-0.205
Model Summary			
Sigma	0.496	0.731	0.678
Gamma	0.174	0.217	0.801
Log Likelihood	244.451		
LR Statistic	184.744		
Mean Efficiency	0.163		

Among the frontier function variables, seed cost had a positive and statistically significant coefficient (0.673, $p < 0.10$), indicating that an increase in seed expenditure raises the total cost of production. This is expected, as seeds represent a major input in cereal production. Similar findings were reported by Adeleke et al. (2023), who studied determinants of wheat production costs, and Ja'afar-Furo et al. (2020), who highlighted seed costs as a predictor of production expenses in cereal farming. Chemical cost was also significant, but negatively signed (-0.914, $p < 0.05$), implying that increased spending on agrochemicals leads to a reduction in total cost—possibly due to their impact on reducing yield losses from pests and diseases. This cost-saving

effect has been supported by Ja'afar-Furo et al. (2020), emphasizing the role of agrochemicals in efficiency improvements.

From the inefficiency model, farming experience was found to be negatively significant (-0.215, $p < 0.10$), suggesting that experienced farmers operate at lower levels of cost inefficiency. This aligns with the findings of Adeleke et al. (2023), who discussed farming experience in wheat cultivation, and Obianefo (2021), who highlighted its role in improved resource allocation. Furthermore, gender was significant and negative (-0.775, $p < 0.10$), implying that male farmers tend to be more efficient than their female counterparts, possibly due to differential access to inputs, information, and labor. This observation mirrors the study of Ja'afar-Furo et al. (2020), which discussed gender-based disparities in cereal marketing systems.

Decomposition of Poverty Status of Wheat Farmers

Table 4 presents the decomposition of poverty status among wheat farmers in Hadejia Local Government Area of Jigawa State. The poverty line was estimated at ₦31,733.40, meaning that any household earning below this threshold is considered poor. Based on this benchmark, the poverty headcount ratio stood at 0.58, indicating that 58% of the wheat farming households live below the poverty line. This high headcount suggests a significant prevalence of poverty among the sampled farmers.

Table 4: Decomposition of Poverty Status of Wheat Farmers

Poverty Measure	Value
Poverty Line (₦)	N31,733.40
Poverty Headcount Ratio	0.58
Poverty Gap	0.21
Poverty Severity	0.07
Percentage of Poor (%)	58.3
Percentage of Non-Poor (%)	42.7

The poverty gap index was 0.21, implying that, on average, poor households would require 21% of the poverty line to escape poverty. This reflects the depth of poverty in the area and highlights the level of income shortfall below the poverty threshold. Moreover, the poverty severity index was 0.07, which measures the inequality among the poor. Though lower than the headcount and gap indices, this figure suggests that income distribution among the poor is relatively unequal.

Furthermore, the data show that 58.3% of the respondents were classified as poor, while 42.7% were non-poor. These findings emphasize the pressing need for policy interventions aimed at

increasing farm income, improving access to productive inputs, and facilitating access to social safety nets in order to reduce poverty levels among wheat farmers in the area. These results align with findings by Umar and Haruna (2019), who also reported high poverty rates among rural farming households in Nigeria, particularly in regions with limited access to market infrastructure and agricultural support services.

Constraints Associated with Wheat Production

The Table 5 presents key constraints affecting wheat production. The most frequently reported challenge is pest and disease infestation, cited by 45.45% of respondents. This aligns with findings by Benjamin et al. (2024), who emphasized the devastating impact of pest pressure on cereal crop yields in Sub-Saharan Africa. High cost of seed was identified by 21.82% of respondents as a major constraint, suggesting that access to improved varieties is limited due to unaffordable input prices. This mirrors observations by Umar and Muhammad (2021), who found that input cost was a key barrier to wheat technology adoption in Nigeria. Additionally, 14.55% of farmers highlighted lack of access to credit as a limiting factor, a recurring issue in rural agriculture, as credit availability directly affects the ability of farmers to invest in productivity-enhancing inputs.

The absence of mechanized farming practices (11.82%) and poor extension services (6.36%) further exacerbate these challenges, limiting farm efficiency and farmers' exposure to improved practices. These findings underscore the urgent need for targeted interventions such as affordable input schemes, better extension coverage, and inclusive rural financing mechanisms, in line with recommendations by Benjamin et al. (2024) and Umar and Muhammad (2021) on strategies to boost local wheat production in Nigeria.

Table 5: Constraints Associated with Wheat Production

Constraints	Frequency	Percentage (%)	Rank
Pest and Diseases	50	45.45	1st
High Cost of Seed	24	21.82	2nd
Lack of Access to Credit	16	14.55	3rd
lack of mechanized farming practices	13	11.82	4th
poor extension services	7	6.36	5th

Conclusion

This study investigated the cost inefficiency, poverty status, and production constraints of wheat farmers in Hadejia Local Government Area of Jigawa State, Nigeria. The stochastic frontier cost function revealed that seed and chemical costs significantly influenced the cost efficiency of wheat production, while the inefficiency model showed that gender and farming experience had significant effects on cost inefficiency. The low mean efficiency score of 0.163

indicates substantial room for improvement in minimizing production costs. Furthermore, poverty analysis showed that 58% of the respondents live below the poverty line, with moderate poverty gap and severity indices, pointing to both income shortfall and inequality among the poor. The major constraints affecting wheat production were pest and disease outbreaks, high cost of seed, and limited access to credit. These findings highlight the need for policy interventions targeting access to affordable inputs, improved agricultural extension, credit facilities, and mechanization support to enhance productivity, reduce cost inefficiency, and improve the livelihood of wheat farmers in the study area.

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EVALUATION OF KIRŞEHİR PROVINCE MUCUR DISTRICT 2024 AGRICULTURE AND LIVESTOCK SUPPORTS

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ABSTRACT

The aim of this study is to evaluate the support payments made by the Ministry of Agriculture and Forestry to farmers engaged in plant and animal production in the basin of Mucur District of Kırşehir Province in 2024 in terms of agricultural economy. In this context, official data in the basin of Mucur District were examined and necessary suggestions were made. There is a total of 803,627 da of agricultural land in the district, including 779,567 da of dry land and 24,060 da of irrigated land. There are 3,227 da of vegetable gardens, 6,199 da of fruit gardens, 752 da of vineyards, 482,271 field areas and 29,900 fallow lands. The number of farmers registered in the Farmer Registration System is 3,445. The number of cattle in the district is 29,042, the number of small cattle is 52,597, the number of poultry animals is 357,348 and the number of beehives with bees is around 1,562. The Ministry of Agriculture and Forestry provides various support payments for crop production and animal husbandry in order to ensure the continuity of sustainable production for farmers. The supports provided by the Ministry of Agriculture and Forestry are as follows; Fuel Oil and Fertilizer Support (185 TL per decare), Grain-Premium and Licensed Warehousing Support (kg/ 75 krş – 1.75 krş), Certified Seed Support (15-260 TL per decare), Small Family Businesses Engaged in Plant Production Support (200 TL per decare), Organic Agriculture-Good Agriculture Support (50-400 TL per decare), Fodder Crop Support (180 TL per decare), Fallow Support (50 TL per decare), Free Farm Support, Pregnant Heifer Support, Calf Support (2000-6500 TL per head/piece), Lamb-Kid Support (200-580 TL per head/piece), Raw Milk Support (liter/14.90 krş), Red Meat Support (500 TL per head/piece), TL), Beehive Support (number of hives/80-190 TL) are given many supports. Turkey's agricultural sector is one of the cornerstones of our country's economic and social structure. The labor of our farmers and the sustainability of our agricultural production directly affect not only our food supply security but also our economic growth and rural

development. In this context, agricultural supports and farmer premium payments are vital to maintain and strengthen the vitality of the economy.

Keywords: Mucur, agricultural economy, agriculture and forestry, support.

KIRŞEHİR İLİ MUCUR İLÇESİ 2024 YILI TARIM VE HAYVANCILIK DESTEKLEMELERİNİN DEĞERLENDİRİLMESİ

ÖZET

Bu çalışmanın amacı, Kırşehir İli Mucur İlçesi havzasında yer alan bitkisel ve hayvansal üretim yapan çiftçilere 2024 yılındaki Tarım ve Orman Bakanlığınca yapılan destekleme ödemelerinin tarım ekonomisi açısından değerlendirilmesidir. Bu kapsamda Mucur ilçesi havzasındaki resmi veriler incelenmiş ve gerekli öneriler getirilmiştir. İlçede susuz arazi alanı 779.567 da, sulu arazi alanı 24.060 da olmak üzere toplam 803.627 da tarım alanı vardır. 3.227 da sebzelik, 6.199 da meyvalık, 752 da bağ, 482.271 tarla alanı ve 29.900 nadas alanı vardır. Çiftçi Kayıt Sistemine kayıtlı çiftçi sayısı 3.445'dir. İlçedeki büyükbaş hayvan sayısı ise 29.042, küçükbaş hayvan sayısı 52.597, kanatlı hayvan sayısı 357.348 ve arılı kovan sayısı 1.562 civarındadır.Tarım ve Orman Bakanlığı tarafından çiftçilerin sürdürülebilir üretimin devamlılığını sağlamak için bitkisel üretim ve hayvancılığa ilişkin çeşitli destek ödemeleri yapmaktadır. Tarım ve Orman Bakanlığı tarafından yapılan desteklemeler; Mazot ve Gübre Desteklemesi (dekar/ 185 TL), Hububat-Prim ve Lisanslı Depoculuk Desteklemeleri (kg/ 75 krş – 1,75 krş), Sertifikalı Tohum Desteklemesi (dekar/ 15- 260 TL), Bitkisel Üretim Yapan Küçük Aile İşletmeleri Desteklemeleri (dekar/ 200 TL) , Organik Tarım- İyi Tarım Desteklemeleri (dekar/ 50-400 TL), Yem Bitkisi Desteklemeleri (dekar/ 180 TL) , Nadas Desteklemesi (dekar/ 50 TL) Ari İşletme Desteklemeleri, Gebe Düve Desteklemeleri, Buzağı Desteklemeleri (baş/adet/2000-6500 TL), Kuzu-Oğlak Desteklemeleri (baş/adet/ 200-580 TL), Çiğ Süt Desteklemesi (litre/14.90 krş), Kırmızı Et Desteklemesi (baş/ 500 TL), Arılı Kovan Desteklemeleri (kovan sayısı/ 80-190 TL) gibi birçok destekler verilmektedir. Türkiye'nin tarımsal sektörü, ülkemizin ekonomik ve sosyal yapısının temel taşlarından biridir. Çiftçilerimizin emekleri ve tarımsal üretimimizin sürdürülebilirliği, sadece gıda arz güvenliğimizi değil, aynı zamanda ekonomik büyümemizi ve kırsal kalkınmamızı da doğrudan etkilemektedir. Bu bağlamda, tarım destekleri ve çiftçi prim ödemeleri, ekonominin canlılığını korumak ve güçlendirmek için hayati önem taşımaktadır.

Anahtar Kelimeler: Mucur, tarım ekonomisi, tarım ve orman, destekleme.

GİRİŞ

Mucur ilçesi Ankara-Kayseri karayolu kenarına kurulmuştur. Ankara'ya 210 km. Kayseri'ye 110 km, Kırşehir'e 23 km uzaklıktadır. Yüzölçümü 1068 km2, yüksekliği ise 935 metredir. Mucur ilçesi bir yayla özelliği gösterir. Dağlar ilçenin kuzeyindedir. Armutlu Dağı (1557m.), Köpekli Dağı (1554 m.), Kırlangıç Dağı (1472 m.), Uyluk Dağı (1356 m.), Kızıldağı (1351 m.) dir. İlçenin güneyinden geçen Kızılırmak nehri ilçenin sınırı halindedir. Başlıca çayı Acıöz çayıdır. İlçenin kuzeyinde 15 km2lik alana sahip Seyfe gölü bulunmaktadır. Bakanlar Kurulunun 90/825 sayılı kararıyla Seyfe gölü ve çevresi Tabiatı Koruma Alanı olarak ilan edilmiştir. Seyfe gölü kuş cennetinde 167 çeşit kuş barınmakta iken ve özellikle Flamingo kuşları dikkati çekmekte iken küresel ısınmanın da etkisiyle suyun azalmasıyla kuşlara rastlanmamaktadır. Mucur İlçesinde tipik karasal iklim gözlenmektedir. Yazlar sıcak ve kurak, kışlar soğuk ve kar yağışlıdır. Yıllık yağış miktarı azdır. Yıllık ve günlük sıcaklık farkları yüksektir. Bitki örtüsü bozkırdır (http://www.kirsehir.gov.tr/).

MATERYAL YÖNTEM

Bu çalışmanın materyalini literatürdeki veriler ve ilgili kurumlardan alınan istatistiki veriler oluşturmaktadır. Araştırmanın yöntemi ise literatür taraması ve sahadaki derinlemesine mülakat verileri oluşturmaktadır. Bu kapsamda TUİK, Kırşehir Tarım ve Orman Bülteni, Mucur İlçe verilerine elektronik olarak erişim sağlanmış ayrıca Mucur İlçe Tarım ve Orman Müdürü ile derinlemesine mülakat yapılmıştır. Araştırma verileri literatür ışığında yorumlanarak bilime katkı sağlaması amaçlanmıştır.

BULGULAR

2024 üretim yılı için Bakanlığın yayınlamış olduğu destekleme tebliği kapsamında Mucur İlçesinde 3445 çiftçi Mazot Gübre desteklemesine başvuruda bulunmuştur.

Aşağıdaki tabloda Mucur İlçesi sınırları içerisinde bulunan 44 köy ve 7 mahallede bulunan çiftçilerin Çiftçi Kayıt Sistemine başvuru yapan çiftçi sayıları mevcuttur.

Mucur Merkez, Kızıldağyeniyapan, Kurugöl, Bayramuşağı, Kuşaklı, Avcı, Geyicek ve Yazıkınık Köyleri köylerinin çiftçi sayısı köylerin nüfusunun fazla olması nedeniyle yüksektir.

Şekil 1.Yamula Barajı Görseli (Kuveloğlu, 2024)

Şekil 2. Yamula Barajı (Kuveloğlu 2024)

Seyfe Gölü ve çevresi doğal hayatı korumaya yönelik çalışmalar sonucunda, farklı koruma statüleri ile koruma altına alınmıştır. Göl ve çevresi ”I. Derece Doğal Sit Alanı”, “Tabiatı Koruma Alanı” ve Ramsar Alanı statülerine sahiptir (Yurteri, 2020).

Bu nedenle Çevre Amaçlı Tarim Arazilerini Koruma Programı (ÇATAK) kapsamında İlçenin Yazıkınık, Gümüşkümbet, Seyfe, Dalakçı, Budak, Kızıldağyeniyapan köylerinde 2006-2020 tarihleri arasında uygulanmıştır.

Bu çalışmanın amacı, Kırşehir İli Mucur İlçesi havzasında yer alan bitkisel ve hayvansal üretim yapan çiftçilere 2024 yılındaki Tarım ve Orman Bakanlığınca yapılan destekleme ödemelerinin tarım ekonomisi açısından değerlendirilmesidir. Bu kapsamda Mucur ilçesi havzasındaki resmi veriler incelenmiş ve gerekli öneriler getirilmiştir. İlçede susuz arazi alanı 779.567 da, sulu arazi alanı 24.060 da olmak üzere toplam 803.627 da tarım alanı vardır. 3.227 da sebzelik, 6.199 da meyvalık, 752 da bağ, 482.271 tarla alanı ve 29.900 nadas alanı vardır. Çiftçi Kayıt Sistemine kayıtlı çiftçi sayısı 3.445'dir. İlçedeki büyükbaş hayvan sayısı ise 29.042, küçükbaş hayvan sayısı 52.597, kanatlı hayvan sayısı 357.348 ve arılı kovan sayısı 1.562 civarındadır (http://www.mucur.gov.tr/). Tarım ve Orman Bakanlığı tarafından çiftçilerin sürdürülebilir üretimin devamlılığını sağlamak için bitkisel üretim ve hayvancılığa ilişkin çeşitli destek ödemeleri yapmaktadır.

Tarım ve Orman Bakanlığı tarafından yapılan desteklemeler; Mazot ve Gübre Desteklemesi (dekar/ 185 TL), Hububat-Prim ve Lisanslı Depoculuk Desteklemeleri (kg/ 75 krş – 1,75 krş), Sertifikalı Tohum Desteklemesi (dekar/ 15- 260 TL), Bitkisel Üretim Yapan Küçük Aile İşletmeleri Desteklemeleri (dekar/ 200 TL) , Organik Tarım- İyi Tarım Desteklemeleri (dekar/ 50-400 TL), Yem Bitkisi Desteklemeleri (dekar/ 180 TL) , Nadas Desteklemesi (dekar/ 50 TL) Ari İşletme Desteklemeleri, Gebe Düve Desteklemeleri, Buzağı Desteklemeleri (baş/adet/2000-6500 TL), Kuzu-Oğlak Desteklemeleri (baş/adet/ 200-580 TL), Çiğ Süt Desteklemesi (litre/14.90 krş), Kırmızı Et Desteklemesi (baş/ 500 TL), Arılı Kovan Desteklemeleri (kovan sayısı/ 80-190 TL) gibi birçok destekler verilmektedir (https://www.tarimorman.gov.tr/).

SONUÇ VE ÖNERİLER

Kırşehir İli Mucur İlçesi, tarımsal üretim açısından önemli bir potansiyele sahip olup, çeşitli tarımsal faaliyetler ve hayvancılık faaliyetleriyle bölge ekonomisine katkı sağlamaktadır. 2024 yılında Tarım ve Orman Bakanlığı tarafından yapılan destekleme ödemeleri, çiftçilerin sürdürülebilir üretim faaliyetlerinin devamını sağlamak amacıyla önemli bir destek aracı olmuştur. İlçedeki tarım alanının büyük bir kısmı tarla arazisinden oluşmakta olup, aynı zamanda sebze, meyve, bağ ve nadas alanları da mevcuttur. Hayvancılık açısından bakıldığında ise büyükbaş, küçükbaş ve kanatlı hayvan sayıları oldukça yüksek seviyelere ulaşmaktadır.

Mucur ilçesindeki çiftçiler, Tarım ve Orman Bakanlığı'nın sağladığı çeşitli desteklemelerle ekonomik anlamda önemli katkılar almışlardır.

Mazot, gübre, tohum, hububat-prim ve küçük aile desteklemeleri gibi doğrudan üretim maliyetlerini azaltmaya yönelik ödemeler, üreticilerin daha verimli çalışmasına olanak tanımaktadır. Bunun yanı sıra, hayvancılık alanında yapılan desteklemeler de üreticilerin üretim kapasitelerini artırmalarına yardımcı olmuştur. Özellikle gebe düve, buzağı, kuzu ve oğlak desteklemeleri ile hayvancılığın sürdürülebilirliği sağlanmaya çalışılmaktadır. Buna rağmen, ilçede sulama alanlarının sınırlı olması, üretim verimliliğini olumsuz yönde etkileyebilmektedir. Bu bağlamda, sulama sistemlerinin geliştirilmesi, üretim alanlarının daha verimli kullanılması açısından önemli bir ihtiyaç olarak öne çıkmaktadır.

Öneriler: Sulama Altyapısının Geliştirilmesi: Mucur ilçesindeki susuz arazi oranının yüksek olması, üretim verimliliğini doğrudan etkileyen önemli bir faktördür. Bu nedenle, ilçeye yönelik sulama altyapısının güçlendirilmesi, Kızılırmak'tan yada çevre illerden getirilecek alternatif su kaynakları ile bu bölge verimli hale gelecektir. Özellikle damla sulama sistemleri gibi verimli sulama yöntemlerinin yaygınlaştırılması önerilmektedir. Bu yöntemler çiftçilerin su kullanımını daha verimli hale getirmelerine olanak tanıyacaktır.

Modern Tarım Tekniklerinin Yaygınlaştırılması: Tarımda verimliliğin artırılması ve sürdürülebilirliğin sağlanması için çiftçilere yönelik modern tarım tekniklerinin eğitimini sağlamak önemlidir. Bu kapsamda, organik tarım, iyi tarım uygulamaları ve agroekolojik yöntemlerin teşvik edilmesi, hem çevresel hem de ekonomik faydalar sağlayacaktır. Üniversiteler ve Tarım ve Orman Müdürlüklerinin destekleri ile çiftçi eğitimlerinin (köy toplantılarının) arttırılması önem arz etmektedir. Hayvancılıkla İlgili Desteklerin Artırılması: Mucur ilçesinde büyükbaş, küçükbaş ve kanatlı hayvancılık faaliyetleri büyük bir yer tutmaktadır. Bu alandaki desteklerin devam ettirilmesi ve artırılması, hayvancılıkla uğraşan çiftçilerin üretim kapasitelerini daha da geliştirecektir. Özellikle süt üretimi ve kırmızı et üretimi alanlarında, daha yüksek desteklemeler ve uygun finansman imkanları sağlanabilir.

Tarım ve Hayvancılık Üreticilerine Finansal Destekler: Tarımsal üretimin finansal yönü, üreticilerin karar alma süreçlerinde önemli bir etkendir. Çiftçilere verilen kredi miktarlarının arttırılması ve üreticilere uygulanan düşük faizlerin tamamen kaldırılması ülkemiz tarım ve hayvancılığın sürdürülebilirliği açısından önem taşımaktadır.

Eğitim ve Danışmanlık Hizmetlerinin Artırılması: Çiftçilerin tarımda verimliliği artırmalarına yardımcı olacak eğitim ve danışmanlık hizmetleri daha fazla yaygınlaştırılmalıdır. Bu hizmetler, çiftçilerin tarım desteklerini doğru şekilde kullanmalarına ve yeni üretim teknikleri hakkında bilgi edinmelerine olanak tanıyacaktır.

Bitkisel üretimde bölgeye dayanıklı ürün çeşitlerin deneme ekimlerinin yapılarak bölgeye adapte edilmesi, kuraklığa dayanıklı aspir gibi bitkilerin ekilişleri arttırılmalıdır. Daha önceki yıllarda bölgelerde uygulanan ÇATAK (Çevre Amaçlı Tarım Arazilerini Koruma) gibi projeler arttırılarak (kanola gibi ürünlerin) devamlılığı sağlanmalıdır.

Sonuç olarak, Mucur ilçesinde tarım ve hayvancılık sektöründeki mevcut potansiyel, verilen desteklerle daha da güçlendirilebilir. Tarımsal üretimin sürdürülebilirliğini sağlamak ve çiftçilerin ekonomik refahını artırmak adına yukarıda belirtilen önerilerin hayata geçirilmesi, bölge ekonomisine uzun vadeli katkı sağlayacaktır.

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IMPACTS OF DROUGHT STRESS ON BREAD MAKING QUALITY OF WHEAT: A REVIEW

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ABSTRACT

Climate change refers to long-term variations in meteorological events and average temperatures. Drought is one of the most dramatic consequences of climate change and is defined by irregular precipitation patterns and soil moisture imbalance. This condition is an environmental stress factor that directly or indirectly affects plant production, limiting agricultural output at a time when global food demand is steadily increasing.

The reasons of yield reductions of bread wheat due to unfavorable environmental conditions can lead to severe nutritional and economic challenges. High levels of drought stress significantly reduce the grain-filling duration results with early senescence of plants. A shorter grain-filling period does not allow better utilization of stem reserves for grain filling under stress conditions.

Drought is not only the most important risk factor affecting the yield potential of wheat, it also leads to a reduction in the chemical and physical quality parameters of wheat. Mild to moderate drought stress increases the protein content of wheat grains, resulting in improved quality, but causes changes in gliadin/glutenin and HMW glutenin subunits. In general, drought increases the gliadin/glutenin ratio and decreases the HMW glutenin subunits. This situation is often observed during drought, which is generally undesirable and results in a weaker dough and therefore lower gluten quality for bread making. Drought remains a significant threat in all circumstances and efforts to prevent its effects and improve adaptation strategies need to be intensified. Therefore, this study aims to identify and review the effects of drought on gluten quality in wheat.

Keywords: Bread wheat, drought, quality, gluten, glutenin, HMW glutenin

KURAKLIK STRESİNİN EKMEKLİK KALİTE ÜZERİNDEKİ ETKİLERİ: Derleme

ÖZET

İklim değişikliği, meteorolojik olaylardaki ve ortalama sıcaklıklardaki uzun vadeli değişimleri ifade eder. Kuraklık, iklim değişikliğinin en dramatik sonuçlarından biri olmakla birlikte düzensiz yağış rejimi ve toprak nemi yetersizliği ile olumsuz etkileri açığa çıkmaktadır. Bu durum, bitkisel üretimi doğrudan veya dolaylı olarak etkileyen ve küresel gıda talebinin giderek arttığı bir dönemde tarımsal üretimi sınırlayan çevresel bir stres faktör olmaktadır.

Olumsuz çevre koşulları nedeniyle ekmeklik buğdayda verim düşüşlerinin nedenleri bazı beslenme ve ekonomik zorluklara yol açabilmektedir. Yüksek düzeyde oluşan kuraklık stresi, bitkilerin erken yaşlanmasıyla sonuçlanan tane dolum süresini önemli ölçüde azaltır. Daha kısa bir tane dolum süresi, stres koşulları altında tane dolumu için sap rezervlerinin etkili bir şekilde kullanılmasını önlemektedir.

Kuraklık, buğdayın verim potansiyelini etkileyen en önemli risk faktörü olmasının yanı sıra, buğdayın kimyasal ve fiziksel kalite parametrelerinde de azalmaya yol açmaktadır. Hafif ve orta dereceli kuraklık stresi buğday tanelerinin protein içeriğini artırarak kalitenin iyileşmesini sağlar, ancak gliadin/glutenin ve HMW glutenin alt birimlerinde değişikliklere neden olur. Genel olarak, kuraklık, gliadin/glutenin oranını artırır ve HMW glutenin alt birimlerini azaltır. Bu durum genellikle kuraklık sırasında gözlenir ve genellikle istenmeyen bir durumdur ve daha zayıf bir hamur ve dolayısıyla ekmek yapımı için daha düşük gluten kalitesi ile sonuçlanır. Kuraklık her koşulda önemli bir tehdit olmaya devam etmektedir ve etkilerini önlemeye ve adaptasyon stratejilerini geliştirmeye yönelik çabaların yoğunlaştırılması gerekmektedir. Bu nedenle, bu çalışma kuraklığın buğdayda gluten kalitesi üzerindeki etkilerini belirlemeyi ve gözden geçirmeyi amaçlamaktadır.

Anahtar Kelimeler: Ekmeklik buğday, kuraklık, kalie, gluten, glutenin, yüksek molekül ağırlıklı glutenin

1. GİRİŞ

Küresel iklim değişikliği, tarımsal üretimi doğrudan etkileyen en önemli çevresel sorunlardan biri hâline gelmiştir. Bu bağlamda kuraklık, özellikle yarı kurak ve kurak bölgelerde tahıl üretimi için ciddi bir tehdit oluşturmaktadır (Farooq vd., 2014). Kuraklık, toprakta su yetersizliği nedeniyle bitkinin fizyolojik aktivitelerinde bozulmalara yol açarak hem verimi hem de kaliteyi sınırlamaktadır. Buğday (*Triticum aestivum L.*), dünya genelinde temel besin kaynaklarından biri olup, özellikle ekmek üretiminde en çok tercih edilen türlerden biridir. Ancak, su stresine oldukça duyarlıdır ve kuraklık koşulları altında kalite parametrelerinde önemli değişiklikler meydana gelmektedir (Triboï vd., 2003; Gooding vd., 2003).

Kuraklık, buğdayda protein sentezini artırarak bazı durumlarda tane protein oranını yükseltebilirken (Rharrabti vd., 2001), şiddetli su stresi glutenin yapısını bozmakta, düşük çözünebilirlik ve zayıf hamur özellikleri ile sonuçlanmaktadır (Altenbach, 2012). Bunun yanında kuraklık, tane dolgusu süresini kısaltarak nişasta birikimini sınırlandırır ve bin tane ağırlığını düşürür (Barnabás vd., 2008). Sonuç olarak, ekmeklik buğdayın un verimi, işleme kalitesi ve son ürün fonksiyonelliği olumsuz etkilenmektedir.

Dolayısıyla bu çalışmada, kuraklık stresinin ekmeklik buğdayın fiziksel, kimyasal ve teknolojik kalite özellikleri üzerindeki etkileri ele alınmakta; sürdürülebilir tarımsal üretim açısından bu etkilerin bilimsel olarak anlaşılmasının önemi vurgulanmaktadır.

2. İKLİM DEĞİŞİKLİĞİ ETKİSİ

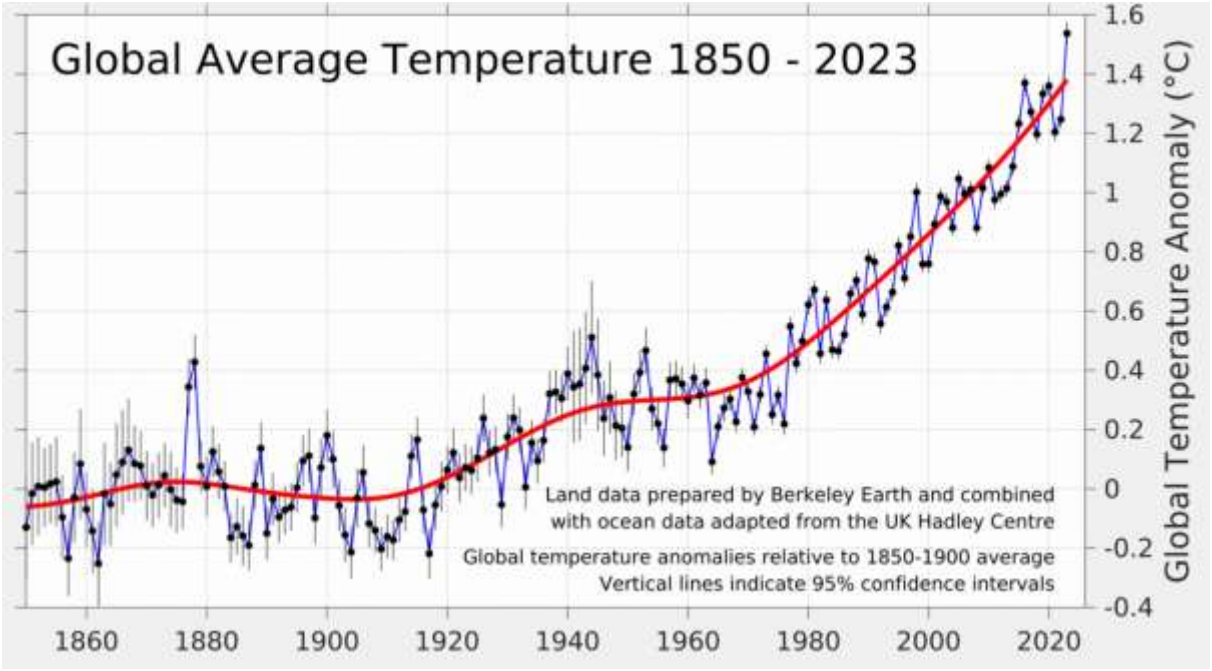
İklim değişikliği, atmosferin bileşiminde ve yer yüzeyindeki enerji dengesinde meydana gelen değişimlerin, uzun dönemli sıcaklık ve yağış rejimlerini etkilemesiyle oluşur. Bu süreç, yüz yıllar boyunca meydana gelir; ancak günümüzde insan kaynaklı etkilerle çok daha hızlı ve şiddetli bir şekilde yaşanmaktadır. İklim değişikliğinin temel nedenleri arasında sera gazı emisyonları (karbondioksit (CO_2), metan (CH_4), azot oksit (N_2O) gibi gazların atmosferde birikmesi (sera etkisi), fosil yakıt tüketimi (Sanayi, ulaşım ve enerji üretimi), ormansızlaşma (karbon yutaklarının azalması), Tarım ve Hayvancılık (metan ve azot oksit salımı), sanayi atıkları ve aşırı tüketimden kaynaklanmaktadır. Tüm ekolojik dengeyi olumsuz yönde etkileyen etkilerinin yanında özellikle tarımsal üretimde düzensiz yağış rejimi, kuraklık, yüksek sıcaklık stresi, ani düşük sıcaklıklar, dolu yağışı, erozyon artışı ve sel gibi doğal afetlerin artması sonucu önemli verim kayıplarına neden olmaktadır.

3. İKLİM DEĞİŞİKLİĞİ VE SONUÇLARI

Son yıllarda etkileri daha da artan iklim değişikliği yanlızca yüksek sıcaklık ve kuraklık şeklinde etkisini göstermemektedir. İklim değişikliğinin geniş çaplı etkileri kısaca aşağıdaki gibi sıralanabilmektedir;

- Küresel ortalama sıcaklıkların artması
- Kutup buzullarının erimesi
- Deniz seviyesinin yükselmesi

- Kuraklık, aşırı yağış, fırtına, orman yangınlarında artış
- Mevsim kaymaları
- Ekosistemlerde bozulma ve biyoçeşitlilik kaybı.



Şekil 1. 1850-2023 yılları arasındaki küresel sıcaklık artış anormallikleri (Anonymous 2025, Artık vd., 2024).

4. BUĞDAY VE ÜRÜN KALİTESİ

Buğday, insan beslenmesinin en temel gıdasıdır ve dünyada 6 kıtanın farklı iklim koşullarına uyum sağlamış bir bitkidir. Gelişmekte olan ülkelerdeki büyük nüfus çoğunluğunun günlük kalori ihtiyacının %21'i ve protein ihtiyacının %20'sini buğday karşılamaktadır. Ekmeklik buğday (*Triticum aestivum* L.), özellikle un kalitesi ve hamur işleme özellikleri bakımından değerlendirilen bir üründür. Kalite hem fiziksel tane özellikleri hem de un ve gluten fonksiyonelliği temelinde belirlenir.

Fiziksel kalite, buğday tanesinin dış özellikleri ile ilgilidir ve endüstriyel işleme uygunluğu açısından önemlidir. Bu özellikler arasında bin tane ağırlığı, hektolitre ağırlığı, tane sertliği, tane şekli ve renk gibi parametreler yer alır. Yüksek hektolitre ağırlığı (≥76 kg/hl), sağlam ve yoğun taneleri işaret ederken, yüksek tane sertliği ise daha iyi öğütme performansı ile ilişkilidir (Perten, 1964). Sert buğdaylar, un elde etmede daha verimli ve yüksek protein içerikli olmaları nedeniyle tercih edilir (Dexter & Marchylo, 2000; Bayhan vd., 2021).

Kimyasal kalite, buğdayın besin içeriğini belirleyen protein, nişasta, kül, yağ ve enzim aktiviteleri gibi parametreleri kapsar. Ekmeklik buğdayda en kritik kimyasal parametre, tane protein oranıdır. Protein oranı genellikle %10–15 arasında değişir ve bu oran, gluten kalitesini

doğrudan etkiler. Bunun yanı sıra, nişasta miktarı da un verimini ve ürün dokusunu belirleyen önemli bir etkendir. Alfa-amilaz enzimi aktivitesi, düşme sayısı testiyle ölçülür ve bu değer, unun pişirme kalitesi açısından belirleyicidir (Finney, 1992).

Buğdayın ekmek üretimine uygunluğunu belirleyen en kritik parametrelerden biri teknolojik kalitedir. Bu kapsamda değerlendirilen özellikler arasında gluten kalitesi, su absorpsiyon kapasitesi, farinograf ve alveograf parametreleri, mikser süresi ve hamur stabilitesi gibi ölçütler yer alır. Gluten, buğday proteinlerinin işleme esnasında suyla birleşerek oluşturduğu kompleks bir ağ yapısıdır. Bu yapı, gaz tutma kapasitesi sağlayarak ekmeğin hacmini, yapısını ve dokusunu belirler (Shewry & Halford, 2002; Dizlek, 2012). Özellikle yüksek moleküler ağırlıklı glutenin alt birimleri (HMW-GS), güçlü ve esnek bir gluten matrisi oluşumunda kilit rol oynar (Payne vd., 1987).

Tablo 1. Ekmeklik buğdayda fiziksel kalite özellikleri (Stojanovic and Milovanovic, 2015).

Fiziksel Parametre	**Birim / Değer**	**Açıklama**
Bin Tane Ağırlığı	g (35–45 g)	Tane dolgunluğu ve nişasta birikimi hakkında bilgi verir.
Hektolitre Ağırlığı	kg/hL (76–82)	Tane hacmine göre kütle; doluluk ve sağlamlık göstergesidir.
Tane Sertliği	Puan (50–80)	Sert buğdaylar yüksek kalite ve irmik verimi sağlar.
Tane Büyüklüğü	mm (2.5–3.5)	Boyut, un verimi ve işleme kalitesi ile ilişkilidir.
Tane Renk Özelliği	L*, a*, b*	Pazarlama ve sınıflandırmada kullanılır, kalite algısını etkiler.
Tane Yoğunluğu	g/cm³ (1.3–1.5)	Tanenin yapısal sağlamlığı ve yoğunluğunu gösterir.

Tablo 2. Ekmeklik buğdayda tane ve ekmeklik kalite özellikleri ve fonksiyonel önemleri (Shewry and Halford, 2002).

Parametre	**Birim/Yöntem**	**Fonksiyonel Önemi**
Protein oranı (%)	Kjeldahl/Dumas/NIRS	Yüksek protein, güçlü gluten ve iyi yoğurma özellikleri sağlar
Gluten İndeksi (%)	Puan (0-100)	Gluten dayanıklılık derecesini ölçer; >%80 yüksek kaliteli gluten anlamına gelmektedir.
Yaş Gluten (%)	Manuel / Glutomatik	Gluten miktarını verir, hamur oluşumu ve esneklik için gereklidir.
SDS sedimentasyon	ml	Gluten kalitesini ve protein gücünü yansıtır.
Alveograf W değeri	10^{-4} J	Unun enerji gücünü ölçer; yüksek W daha güçlü hamur anlamına gelmektedir.
P/LOranı (Alveograf)	Oran	Hamurun elastikiyet/uzayabilirlik dengesini gösterir
Farinograf su absorbsiyonu	%	Hamurun su tutma kapasitesini ve kararlılığını gösterir
Düşme sayısı	sn	Alfa-amilaz aktivitesini belirler; düşük değer erken çimlenmeye işaret eder.

5. EKMEKLİK BUĞDAYDA KURAKLIK ETKİSİNİN FİZYOLOJİK ÖZELLİKLER ÜZERİNDEKİ DEĞİŞİMİ

Kuraklık, özellikle buğdayın dane doldurma döneminde oluştuğunda, fotosentez ürünlerinin taşınmasını, hücre bölünmesini ve solunum süreçlerini sınırlandırır. Bu durum, tanelerde karbonhidrat ve nişasta birikiminin azalmasına, ancak bazı metabolitlerin (özellikle proteinlerin) artmasına neden olur. Sonuç olarak, taneler küçük, buruşuk ve düşük nişasta içerikli olurken, protein oranı görece artar. Ancak bu artış niteliksel değildir; protein yapısı zayıf olabilir (Tsenov vd., 2015; Tatar vd., 2020).

Tablo 3. Ekmeklik buğdayda kuraklığa karşı fizyolojik cevaplar (Plaut vd., 2004; Araus vd. 2005; Kılıç ve Yağbasanlar, 2010)

Fizyolojik Özellik	**Kuraklık Altındaki Etki**	**Açıklama**
Fotosentez Hızı	Azalır	Karbon fiksasyonu sınırlanır, enerji üretimi düşer.
Tane Doldurma Süresi	Kısalır	Taneye madde akışı daha kısa sürede sona erer.
Tane Ağırlığı	Düşer	Küçük, buruşuk taneler oluşur.
Nişasta Birikimi	Düşer	Azalan fotosentez nedeniyle depo karbonhidrat sentezi düşer.
Protein Yüzdesi	Artabilir (göreceli)	Nişasta sentezi azalırken protein oranı göreceli olarak artar.
Transpirasyon Hızı	Azalır	Stomaların kapanmasıyla su kaybı azalır.
Kök Uzaması	Yavaşlar	Toprak nemi azaldıkça kök büyümesi baskılanır.
Fertil çiçek Verimliliği	Azalır	Çiçek organ gelişimi kuraklıkla sınırlandığı için dane verimi düşer.

6. KURAKLIK-KALİTE İLİŞKİSİ

Hafif ve orta dereceli kuraklık stresi buğday tanelerinin protein içeriğini artırarak kalitenin iyileşmesini sağlar, ancak gliadin/glutenin ve HMW (yüksek molekül ağırlıklı) glutenin alt birimlerinde değişikliklere neden olur. Genel olarak, kuraklık, gliadin/glutenin oranını artırır ve HMW glutenin alt birimlerini azaltır. Bu durum genellikle kuraklık sırasında gözlenir ve genellikle istenmeyen bir durumdur ve daha zayıf bir hamur ve dolayısıyla ekmek yapımı için daha düşük gluten kalitesi ile sonuçlanır.

Gluten kompleksinin meydana gelmesini sağlayan başlıca bileşenler glutenin ve gliadin proteinleridir. Toplam miktarlarının ve birbirine oranlarının yanı sıra iki proteinin de özellikleri ayrı ayrı etkilidir. Kuraklık stresi, buğdayda özellikle gluten proteinlerinin fraksiyonel bileşimini ve teknolojik kalitesini önemli ölçüde etkiler. Gerçekleştirilen çeşitli çalışmalarda, kuraklığın gluten protein fraksiyonları olan gliadin, yüksek molekül ağırlıklı glutenin (HMW-GS) ve düşük molekül ağırlıklı glutenin (LMW-GS) üzerindeki etkileri net olarak ortaya konmuştur (Li vd. 2013; Olckers vd. 2022; Sattar vd., 2022).

Tablo 4. Kuraklık şartlarında protein fraksiyonları ve değişimleri

Fraksiyon	Kuraklık Etkisi
Ex-Gliadin	Artar → fazla viskozluk, az elastikiyet
Ex-Glutenin (HMW+LMW)	Azalır → zayıf gluten yapısı
Unextractable HMW/LMW	Azalır → zayıf polimerleşme
G:G Oranı (gliadin/glutenin)	Artar → hamur kalitesi düşer

7. SONUÇ

Küresel iklim değişikliği senaryolarının gelecekteki etkileri göz önüne alındığında mevsimsel değişimler ve sıcaklık değişimlerinin olacağı öngörülmektedir. Buğdayın tane kalitesinin belirlenmesinde en önemli fenolojik dönemler olan çiçeklenme sonrası dönemlerde meydana gelebilecek kuraklık şartları kaliteli buğday kavramına etki edecektir.

Bahar yağışlarının düzensizliği ve generatif dönemde meydana gelen kuraklık şartları sonucu kurak şartlarda her ne kadar bazı kalite özelliklerinde istenilen değişimlere yol açsa da gluten proteinlerinin zayıflaması nedeniyle değirmencilik ve kaliteli ürün açısından önemli bir sorun oluşturması beklenmektedir.

Verim özelliklerin yanında kuraklık ile birlikte tane protein sentezi aşamalarında ekmeklik özelliklerine olumlu etki yapacak proteinlerin sentezlenmesinin moleküler düzeyde anlaşılması stres koşullarında bile kalitesi ve verimi stabil bir çeşit geliştirmeye katkıda bulunacaktır.

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CURRENT SITUATION, PROBLEMS AND DEVELOPMENT POTENTIAL OF MAIZE CULTIVATION IN THE AEGEAN REGION

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ABSTRACT

In the context of the global challenges posed by climate change and the contraction of agricultural areas, it has become imperative to optimize the yield per unit area. In this context, it is of great importance to protect the yield and production potential of maize plants, which have versatile uses in human, animal nutrition and industrial use.

In this paper, the current situation, application errors, causes of yield loss and directions for improvement were discussed in the context of field observations and studies on maize cultivation in the Aegean Region since 2019. A comprehensive evaluation of numerous agronomic practices, ranging from soil preparation to the harvest period, was conducted through field observations. The objective of this study is to provide scientifically based guidance to enhance the productivity of maize in the Aegean Region. In accordance with the field observations, critical practices in maize cultivation were identified, including early sowing and emergence period, appropriate maturity group and variety selection, sowing frequency, soil pH status, herbicide use, irrigation method, fertilization, *fusarium*, aphids, stem borer and harvest moisture.

It is imperative that producers in the Aegean Region adopt scientific, technological and agrotechnical practices that enhance productivity and continuity in maize cultivation, as opposed to adhering to conventional, fixed methodologies. Specifically, practices such as soil analysis-based fertilization, the implementation of drip irrigation systems, and the selection of early and disease-resistant varieties should be adopted on a wide scale. The implementation of these practices will ensure the sustainability of maize agriculture in the region, thereby contributing to the attainment of optimal yield stability and the attainment of high production levels. A comprehensive review of critical practices reveals that the changing precipitation

regime due to climate change poses the primary challenge to future maize agriculture in the region, given its impact on water availability. Consequently, enhancing water use efficiency and formulating effective irrigation methods are of paramount importance.

Keywords: Maize, Aegean region, yield, irrigation, FAO maturity groups, variety

EGE BÖLGESİ'NDE MISIR YETİŞTİRİCİLİĞİNİN MEVCUT DURUMU, SORUNLARI VE GELİŞTİRİLME POTANSİYELİ

ÖZET

Dünya genelinde iklim değişikliği etkisi ve azalan tarım alanları nedeniyle birim alandan maksimum verim alınması zorunlu hale gelmiştir. Bu bağlamda, insan ve hayvan beslenmesi ile endüstriyel anlamda çok yönlü kullanım alanına sahip mısır bitkisinin veriminin ve üretim potansiyelinin korunması büyük önem arz etmektedir.

Bu bildiride, Ege Bölgesi'nde mısır yetiştiriciliği üzerine yapılan 2019 yılından itibaren saha gözlemleri ve çalışmaları ışığında mevcut durum, uygulama hataları, verim kaybı nedenleri ve gelişime açık yönler tartışılmıştır. Toprak hazırlığından hasat dönemine kadar yapılan birçok agronomik uygulama ayrıntılı olarak arazi gözlemleri ile değerlendirilmiştir. Amaç, Ege Bölgesi tarımının sürekliliğini ve verimliliğini artıracak bilimsel temelli yön göstermektir. Yapılan saha gözlemleri doğrultusunda mısır yetiştiriciliğinde kritik uygulamalar; erken ekim ve çıkış dönemi, uygun olum grubu ve çeşit seçimi, ekim sıklığı, toprak pH durumu, herbisit kullanımı, sulama yöntemi, gübreleme, *fusarium*, kırmızı örümcek, sap kurdu ve hasat nemi olmak üzere gözlemlenmiştir.

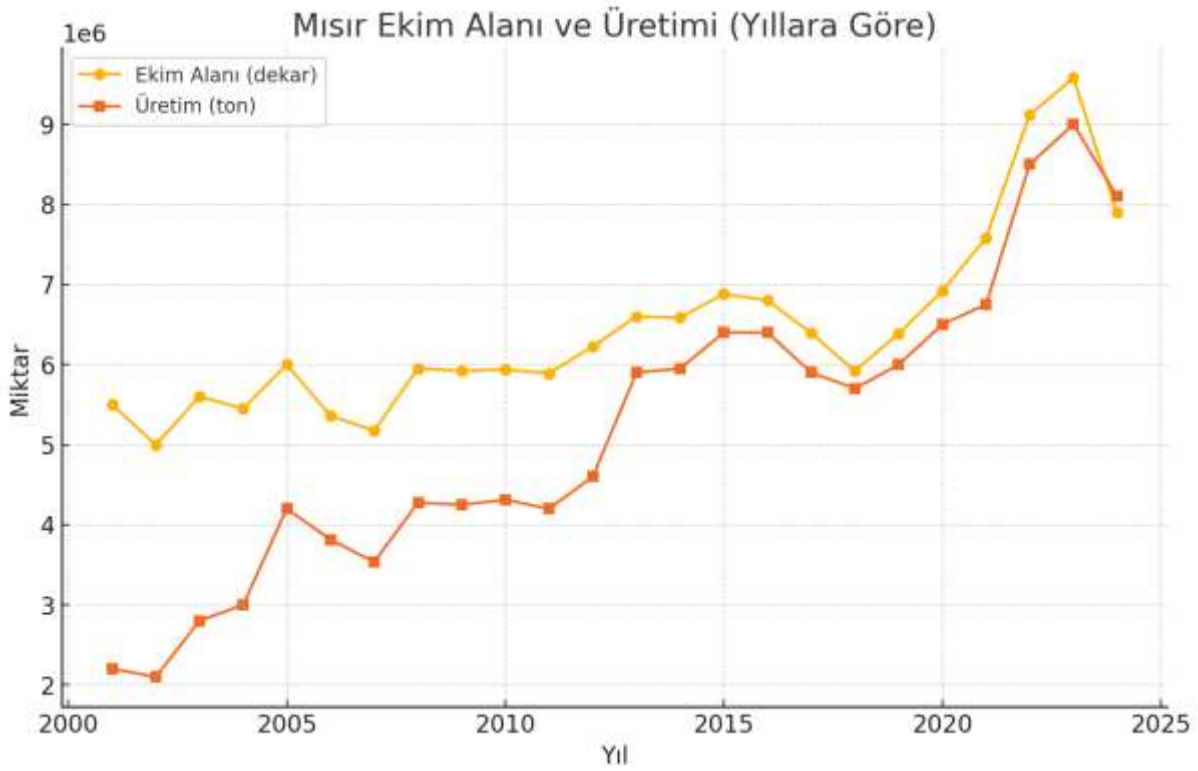
Ege Bölgesi'nde mısır yetiştiriciliğinde süreklilik ve verimliliğin artması, üreticilerin geleneksel ve sabit uygulamalardan ziyade verim artışını sağlayacak bilimsel, teknolojik ve agroteknik uygulamalara yönelmeleriyle mümkün olacaktır. Özellikle toprak analizine dayalı gübreleme, damlama sulama sistemleri, erkenci ve hastalıklara dayanıklı çeşit seçimi gibi uygulamalar yaygınlaştırılmalıdır. Bölgede mısır tarımının güvence altına alınması, optimum verim stabilitesi sağlanması ve yüksek üretim düzeyine ulaşılabilmesi bilinçli tarım uygulamaları neticesinde uygun olabilecektir. Bölgede değerlendirilen tüm kritik uygulamalar içerisinde özellikle iklim değişikliği nedeniyle değişen yağış rejiminin su varlığını etkilemesi ile gelecekte bölgede mısır tarımını kısıtlayacak en temel sorun olduğu gözlemlenmektedir. Bu nedenle su kullanım etkinliğinin arttırılması ve etkin sulama yöntemlerinin geliştirilmesi büyük önem arz etmektedir.

Anahtar kelimeler: Mısır, Ege bölgesi, verim, sulama, FAO olgunlaşma grupları, çeşit

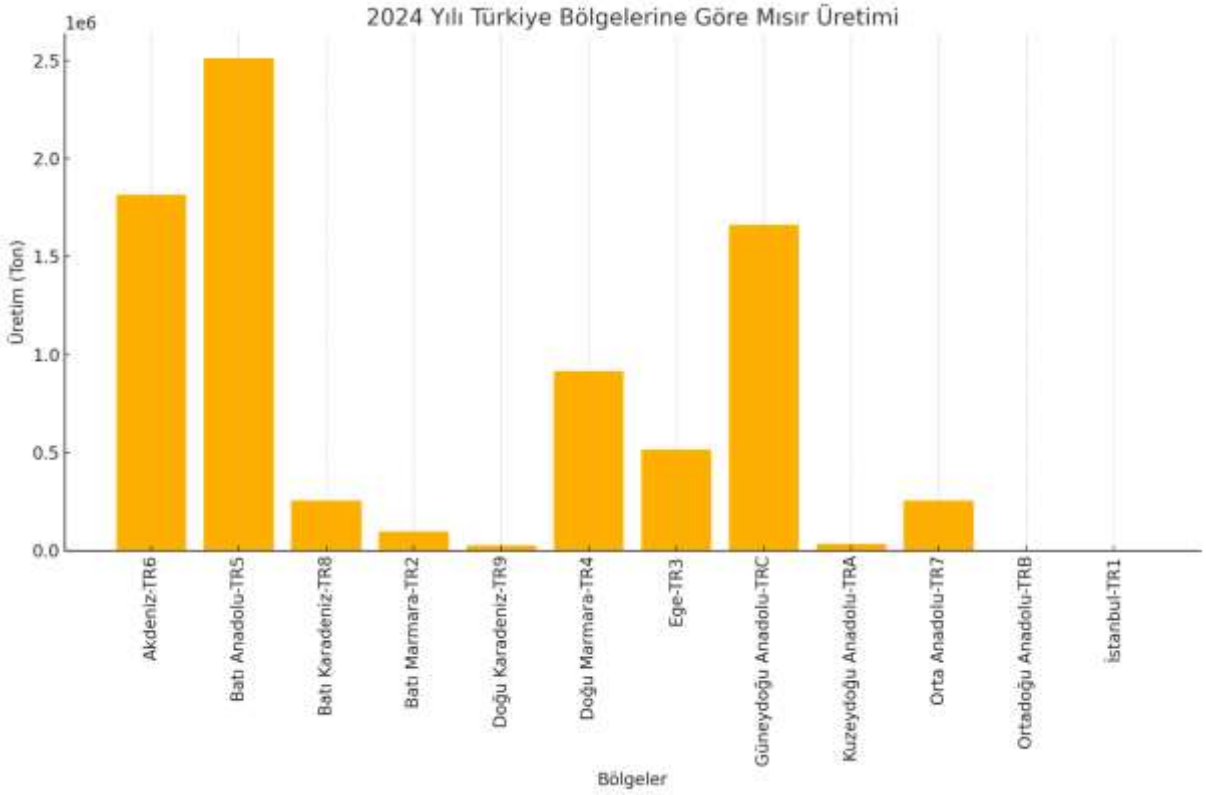
1. EGE BÖLGESİ MISIR ÜRETİM POTANSİYELİ

Dünya'da sınırlı tarım alanlarının bulunması, bu alanların artan dünya nüfusu ve yerleşke sıkıntısı sebebiyle genişletilememesi, birim alanda yüksek tane verimi ve biyolojik ürün elde edilebilecek bitkilerin yetiştirilmesini ve bu bitkilerin yeni teknolojiye ve gelişmelere uyabilecek özellikte olmasını zorunlu kılmaktadır. Kökeni ve gen merkezi Amerika kıtası olan mısır bitkisi; Dünya'da en fazla tarımı yapılan tahıl bitkileri olan buğday ve çeltikten sonra en fazla ekim alanına sahip bitkidir. Bu bitki bitkisel kaynaklı proteinlerin yeterli ve ekonomik üretimi için büyük önem taşımaktadır.

Mısır binlerce yıldır tarımı yapılan bir bitkidir. Anavatanı olan Amerika'da yapılan arkeolojik çalışmalar sonucunda bitkinin geçmişinin 8000-10 000 yıl öncesine dayandığı gözlemlenmiştir (Kün, 1985, Douswell vd. ,1996, Kırtok, 1998). Ülkemize ise adını aldığı ülkeden; Mısır ve Suriye üzerinden girdiği tahmin edilmektedir (Kün, 1985; Kırtok, 1998). Ülkemizde özellikle 2000'li yıllardan sonra mısır ekim alanı ve üretimi önemli düzeyde artmıştır (Şekil 1.).

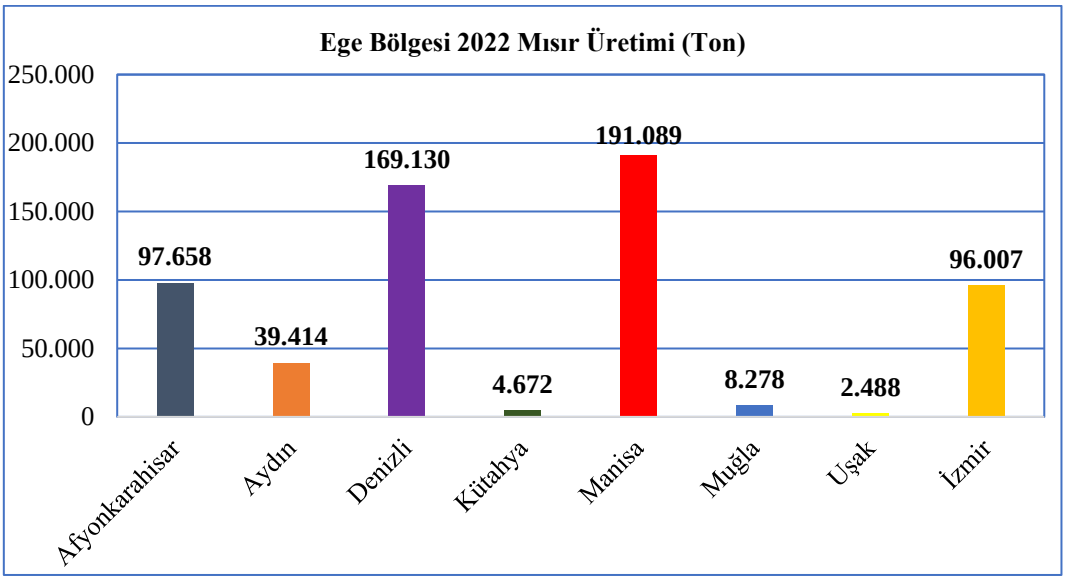


Şekil 1. 2000-2025 yılları arasında ülkemizde mısır ekim alanı (mil. da) ve üretim miktarı (mil. ton), TÜİK, 2025.

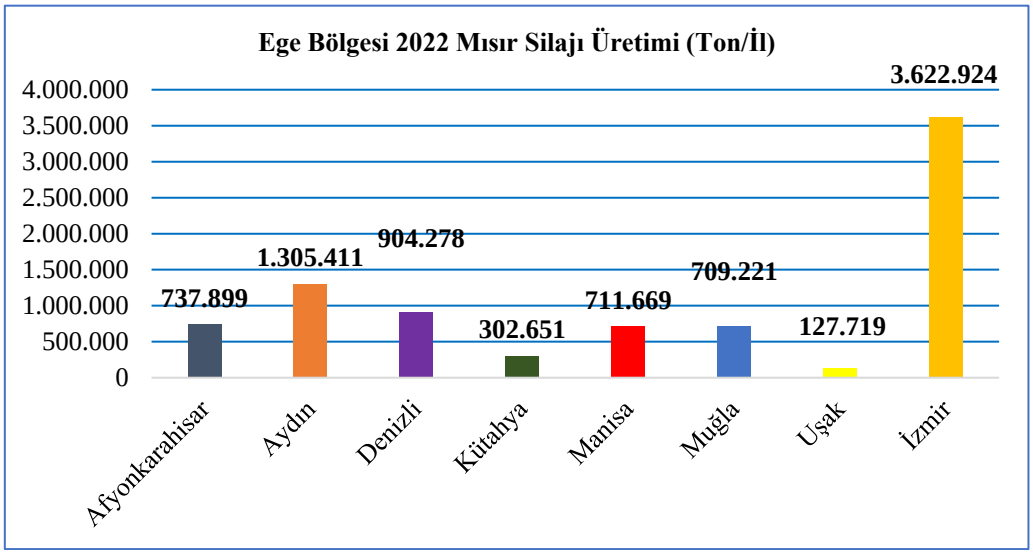


Şekil 2. Ülkemizde 2024 yılında bölgelere göre mısır üretim miktarı (ton), TÜİK, 2025.

Ülkemizde 2024 yılı en fazla mısır üretim miktarına sahip bölgemiz TÜİK Düzey 1 bölgelerinden Batı Anadolu-TR5 (Ankara, Konya, Karaman) ilk sırada yer alırken Güneydoğu Anadolu-TRC ise 2. sırada yer almaktadır. Ege Bölgesi mısır üretim miktarı bakımından ise ülkemizde 5. sırada yer almaktadır (TÜİK, 2025). Ege bölgesi, 3.2 milyon ha tarım alanı ve bu tarım alanlarının %60 düzeyindeki bölümü sulu tarımı yapılabilir olması ile çok büyük bir üretim potansiyeline sahiptir (UHL,2011). Ege bölgesinde dekardan en fazla verim alınan iller Manisa, Aydın ve İzmir'dir. Son dönemlerde pamuk tarımının azalması; mısıra ve diğer bitkilere verilen teşvikler yardımıyla ülke genelinde ve Ege Bölgesinde mısır üretim alanları artmaya başlamıştır.



Şekil 3. Ege Bölgesi 2022 yılı il düzeyinde tane mısır üretim değerleri



Şekil 4. Ege Bölgesi 2022 yılı il düzeyinde silajlık mısır üretim değerleri

Ege Bölgesinde il düzeyinde mısır üretim değerleri incelendiğinde özellikle tanelik ve tohum üretimi açısından Manisa ve Denizli illeri ön plana çıkarken süt sığırı işletmeciliğinin oldukça yaygın olduğu İzmir ilinde ise silajlık mısır üretimi en yüksek düzeyde olduğu tespit edilmiştir (TÜİK, 2022).

2. EGE BÖLGESİ MISIR ÜRETİM SORUNLARI VE TESPİTLER

Bu bildiride, Ege Bölgesi'nde mısır yetiştiriciliği üzerine yapılan 2019 yılından itibaren saha gözlemleri ve çalışmaları ışığında mevcut durum, uygulama hataları, verim kaybı nedenleri ve gelişime açık yönler tartışılmıştır. Toprak hazırlığından hasat dönemine kadar yapılan birçok agronomik uygulama ayrıntılı olarak arazi gözlemleri ile değerlendirilmiştir. Amaç, Ege Bölgesi tarımının sürekliliğini ve verimliliğini artıracak bilimsel temelli yön göstermektir.

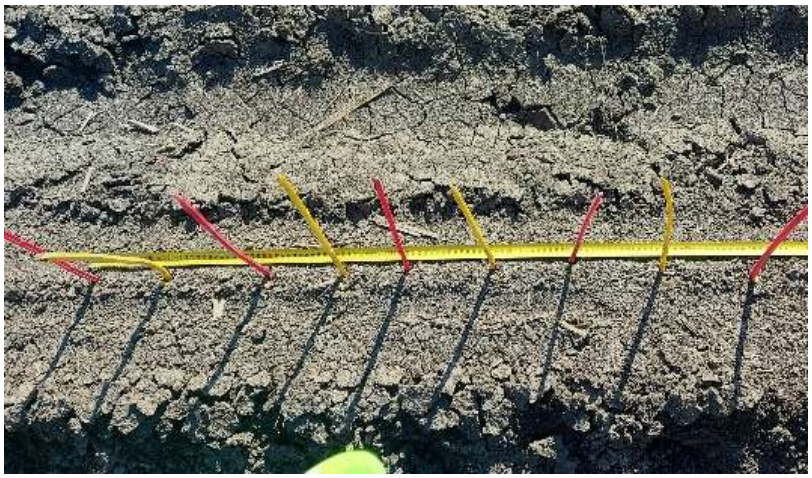
Bu nedenle genel anlamda tespit ve sorunlar aşağıdaki şekilde belirtilmiştir;

A. Toprak Hazırlığı
B. Ekim (Bitki Sıklığı)
C. Ekim Zamanı
D. Gübreleme
E. Generatif Dönem Stres Koşulları
F. Sulama Yöntemi
G. *Fusarium* Hastalık Etmeni
H. İklim değişikliği ve su

Toprak Hazırlığı; Üreticilerimizde mısır bitkisinin, pamuk gibi bitkilerle kıyaslandığında toprak hazırlığı daha önemsiz ve zorlu koşullarda dahi çok rahat çıkış sağlayabilen bir bitki türü olduğu algısı mevcuttur. Ne yazık ki bu algı, toprak hazırlığına yeterince özen gösterilmemesine sebep olmaktadır. Özellikle Bahar yağışlarının düzensizliği nedeniyle toprak hazırlığının geciktirilmesi ekimde nem kayıplarına neden olmaktadır.

Ekim (Bitki Sıklığı); Toprağın homojen ve doğru bir şekilde hazırlanmaması ekim sırasında tohumların aynı derinliğe düşmemesine sebep olabilmekte, bu durum ise homojen olmayan çıkışların yaşanmasına sebep olabilmektedir. Ekim sonrasında yapılacak olan toprak işçiliği, gübreleme, sulama, ilaçlama gibi agronomik faaliyetlerde ise homojen bitki çıkışı son derece önemlidir.

Ege Bölgesi'nde ekseriyetle sıra arası 70 cm sıra üzeri ise 14.5 – 18 cm aralığında ekim sıklıkları tercih edilmektedir. Sıra arası ekim mesafesi genel anlamda çok değişmese de sıra üzeri ekim mesafesi değişkenlik göstermektedir. Bitki sayısının belirlenmesinde ekilecek çeşidin sıklığa olan toleransı iyi bilinmeli ve hasada kadar yaşanılacak bitki kayıpları da göz önünde bulundurulmalıdır. Sık ekimlerde dik yaprak yapısına sahip çeşitlerin tercih edilmesi önerilebilir.



Şekil 5. Arazide ekim sıklığı kontrolü (orijinal Oktay Yavuz)

Ekim Zamanı; Ekim zamanı da diğer uygulamalar gibi verimi doğrudan ya da dolaylı olarak etkileyebilmektedir. Genel itibariyle erken ekimin getirileri olsa da, bölge ve mikro klimalara göre erken ekim tercihleri dikkatlice yapılmadır. Özellikle don tehlikesinin bulunduğu yerlerde erken ekim ile don zararına maruz kalmak sezon sonunda yüksek verim kayıplarına sebep olabilir. Çıkış öncesi yaşanan donlar verime pek etki etmese de çıkış sonrası gerçekleşen donların verim kaybına sebep olması çok yüksek ihtimaldir. Bu durumda üreticiler yeniden ekim yapma tercihine gidebilir. Ege Bölgesi genel olarak ılıman bir iklime sahip olan bir bölge olduğu için mısır yetiştiriciliğinde don zararı pek görülmese de sahile uzak bölgelerde bu tehlike önemsenmelidir. Toprak hazırlığı ve ekim yöntemlerinin sonrasında Ege Bölgesi'nde bitki sayısını ve dolayısıyla verimi etkileyen faktörlerden biri de çıkış sürecinde yaşanan kaymak problemleridir. Özellikle Aydın gibi genel anlamda kumsal toprak tipine sahip bölgelerde çıkış öncesinde gerçekleşen yağışlar kaymak tabakası oluşturmakta ve özellikle çimlenme ve tohum gücü düşük tohumlarda bitkilerde "sarı kıvrım" meydana gelmesine neden olmaktadır. Bu nedenle erken dönemde kaymak tabakası sorununa karşı kaymak kırma aleti kullanılmalıdır.

Şekil 6. Toprak kaymak tabakası sorunu ve çıkış problemi (sol), kaymak kırma aleti (sağ) (orijinal Oktay Yavuz)

Ekim zamanının optimize edilmesi ve özellikle bölge için uygun FAO olum gruplarının tercih edilmesi ile bitkilerin ihtiyaç duydukları vejetasyon süreleri iyi bir şekilde karşılanabilmektedir. Ancak uygun olmayan olum grubu, yanlış çeşit seçimi ve ekim zamanı gecikmesi nedeniyle bölgede önemli verim kayıpları tespit edilmiştir.

Tablo 1. Mısır bitkisinde FAO olum grupları ve olgunlaşma gün sayıları (Croitoru vd., 2020).

Olgunlaşma tipi	FAO Sınıfı	Olgunlaşma gün sayısı (gün)
Aşırı erkenci	100-199	76-85
Erkenci	200-299	86-112
Orta-erkenci	300-399	113-129
Geç olum	400-600	130-145
Çok geç olum	>600	>150

Gübreleme; Ege Bölgesi'nde genel anlamda pH değerleri alkali düzeyde olduğu tespit edilmiştir. Mısır yetiştiriciliğinde toprak pH'ının 6.5–7 (nötr) aralığında olması istenmektedir (Zengin ve Özbahçe, 2013). Bu nedenle toprak analizlerinin düzenli olarak yaptırılması her yetiştiricilik sezonu sonrasında yetiştirilen bitki türü ve uygulanan gübre türü ve miktarları sonucunda oluşan yeni değerlerin saptanmasını sağlamaktadır. Toprak analiz sonucunda önerilen düzeyde yapılan gübreleme ile bölgede önemli verim artışlarının olduğu tespit edilmiştir.

Şekil 7. Ege Bölgesinde bazı mısır arazilerinden alınan toprak analiz sonuçları (orijinal Oktay Yavuz)

Yüksek pH düzeyindeki arazilerde analizler sonucunda toz kükürt uygulaması önemli pH'ın düşmesinde önemli katkı sağlamaktadır.

Şekil 8. Arazide toz kükürt uygulaması (orijinal Oktay Yavuz)

Generatif Dönem Stres Koşulları; Ege Bölgesi'nin yaz aylarında sahip olduğu ortalama sıcaklık değerleri oldukça yüksektir. Bu yüksek sıcaklıklar mısır bitkisinin tozlanma döneminde döllenme problemlerine yol açabilmekte, bu sebeple verim kayıplarına sebep olabilmektedir

(Naveed vd., 2014). Tozlanma ve döllenmenin sıcaklıkların daha düşük olduğu erken döneme denk getirilmesi verim kaybını azaltabilir. Erken ekimin getirilerinden bir diğeri ise genel itibariyle bitkideki kök gelişiminin daha iyi olması ve sonraki dönemlerde kök yapısının bitki beslenmesi ve su ihtiyacının karşılanmasında daha etkin olması söylenebilir.

Sulama Yöntemi; Mısır yetiştiriciliğinde verim kayıplarına sebep olabilen ya da verimi arttırabilen oldukça önemli bir diğer faktör ise sulama yöntemidir. Ege Bölgesi'nde mısır yetiştiriciliğinde damlama, karık ve tava sulama gibi çok çeşitli sulama yöntemleri uygulanmaktadır. Manisa ve Salihli Bölgelerinde damlama sulama yöntemi giderek yaygınlaşmakta olsa da karık sulama yöntemi de birçok alanda uygulanmaktadır. Aydın'da ise tava sulama yöntemi en yaygın kullanılan yöntemdir. Tava sulama yönteminde tarlanın büyüklüğü, su miktarı ve debisi, tesviye gibi kriterler göz önünde bulundurularak belirli bir alan ya da tarlanın tamamı toprak set ile çevrilir ve bu bölge havuz şeklinde su ile doldurulur.

Aydın'da özellikle 2021 yılında yaşanılan kuraklığın getirdiği kayıplar, iklim değişikliğinin etkileri ile yaşanması muhtemel kuraklıklar göz önünde bulundurulduğunda suyun kıymeti çok daha iyi bilinmelidir. Bu nedenle su kısıtlılığı sorununa karşı etkin sulama yöntemi olan damlama sulama ve toprak altı sulama yöntemleri bölgede önerilebilecek sulama yöntemi olarak karşımıza çıkmaktadır.

Şekil 9. Ege Bölgesinde en yaygın kullanılan karık sulama (sol) yöntemi ve önerilen damlama sulama yöntemi (sağ) (orijinal Oktay Yavuz)

Fusarium Hastalık Etmeni; Ege Bölgesi'nde mısır yetiştiriciliğinde görülen başlıca hastalık ve zararlılar içinde *Fusarium*, kırmızı örümcek, yaprak bitleri, koçan kurdu ve sap kurdu, mısır rastığıdır. *Fusarium* mantari bir hastalıktır ve ruhsatlı bir fungusiti mevcut değildir. En iyi mücadele yöntemi olarak toleranslı çeşitlerin tercih edilmesi söylenebilir. Kışı toprakta geçiren bir patojendir. Özellikle üst üste tanelik mısır yetiştiriciliği yapılan tarlalarda etkisini gösterir. Toprağın hastalıktan arınması için uzun yıllar mısır yetiştiriciliği yapılmaması gerekir.

Toleranslı çeşitlerin tercih edilmesinin yanında münavebe uygulamak da bu hastalıkla mücadelede etkili olabilir. Farklı çevre şartlarına uyum sağlayabilen bu hastalık etmeninin genetik çeşitliliğinin tanımlanması hem toleranslı çeşit geliştirmede hem de adaptasyon yeteneğinin anlaşılmasında önemli rol oynamaktadır (Swamy vd. 2020). Bu nedenle üreticiler mısır çeşitlerini seçerken bölgedeki hastalık etmeni yayılışını dikkate alarak toleranslı çeşit seçiminde bulunmak durumunda kalkmaktadırlar.

İklim değişikliği ve su; tüm bu faktörlerin içinde bölgede mısır üretimini sınırlayacak olan faktör "su" durumudur. Özellikle yazlık dönemde sıcaklık artışı ile birlikte toprakta önemli düzeyde nem kaybı yaşanmaktadır. Bu nedenle etkin sulama sistemleri kullanılarak bölgede "su" yönetiminin oldukça etkili bir şekilde yapılması gerekmektedir.

3. SONUÇ

Ege Bölgesi'nde mısır yetiştiriciliğinde süreklilik ve verimliliğin artması, üreticilerin geleneksel ve sabit uygulamalardan ziyade verim artışını sağlayacak bilimsel, teknolojik ve agroteknik uygulamalara yönelmeleriyle mümkün olacaktır. Özellikle toprak analizine dayalı gübreleme, damlama sulama sistemleri, erkenci ve hastalıklara dayanıklı çeşit seçimi gibi uygulamalar yaygınlaştırılmalıdır.

Bölgede değerlendirilen tüm kritik uygulamalar içerisinde özellikle iklim değişikliği nedeniyle değişen yağış rejiminin su varlığını etkilemesi ile gelecekte bölgede mısır tarımını kısıtlayacak en temel sorun olduğu gözlemlenmektedir.

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DETERMINING THE MANAGEABILITY OF IRRIGATION SYSTEMS WITH LORA COMMUNICATION TECHNOLOGIES IN GREENHOUSES

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ABSTRACT

Greenhouses are agricultural structures where agricultural production can be carried out using high technology in today's conditions, regardless of climatic environmental conditions. While the technology used in greenhouses is used in many agricultural production areas such as air conditioning, irrigation, fertilization, systems that facilitate management in the greenhouse have come to the forefront. While remote-controlled modern pressurized systems are used in irrigation systems designed in greenhouses, the importance given to applications that facilitate management in the greenhouse in terms of irrigation period, irrigation duration, evapotranspiration values and especially controllers, which provide savings in energy consumption, has increased. In this context, LoRa communication technologies, which are used in many areas, stand out as a technology that should be taken into consideration in terms of irrigation method in greenhouses with their wide coverage area and low energy consumption. In this context, the general features, energy expenditures, coverage areas, sustainability and general application areas of communication technologies such as LoRa-based loT, LPWAN, LoRaWAN have been determined separately in the study, and the possibilities of using these technologies in irrigation management in one or more greenhouses within the greenhouse have been investigated. In addition, the ability to record climatic environmental conditions in greenhouses without human intervention in the use of LoRa technologies in irrigation systems and the feasibility of irrigation planning and control based on this information has been tried to be revealed within the scope of the literature. At the same time, by using LoRa-based communication systems in greenhouses, remote monitoring, control and intervention in necessary cases will be provided in an energy-efficient and economical manner in irrigation management. In addition, as a result of determining soil moisture and climatic conditions in greenhouses, future soil moisture estimation and irrigation time and duration according to these estimations were determined. With the research, it was seen within the scope of the literature that LoRa-based communication systems, which are still a new technology in greenhouses, can be used in irrigation management and that sustainable agricultural production can be achieved by saving energy, manpower and time.

Keywords: Greenhouse, LoRa, LPWAN, loT, LoRaWAN, Greenhouse Irrigation Management.

SERALARDA LORA İLETİŞİM TEKNOLOJİLERİ İLE SULAMA SİSTEMLERİNİN YÖNETİLEBİLİRLİĞİNİN BELİRLENMESİ

ÖZET

Seralar, günümüz koşullarında yüksek teknoloji kullanılarak iklimsel çevre koşullarına bağlı olmaksızın tarımsal üretim yapılabilen tarımsal yapılardır. Seralarda kullanılan teknoloji iklimlendirme, sulama, gübreleme gibi birçok tarımsal üretim alanında kullanılmakla birlikte, sera içerisindeki yönetimi daha fazla kolaylaştıran sistemler ön plana çıkmıştır. Seralarda tasarlanan sulama sistemlerinde uzaktan kontrollü modern basınçlı sistemler kullanılmakla birlikte, enerji tüketiminde tasarruf sağlayan sulama periyodu, sulama süresi, evapotransprasyon değerleri ve özellikle kontrolör açısından sera içerisindeki yönetimi kolaylaştıran uygulamalara verilen önem artmıştır. Bu bağlamda birçok alanda kullanımı bulunan LoRa iletişim teknolojileri kapsama alanının geniş olması ve düşük enerji tüketimi ile seralarda sulama yöntemi açısından dikkate alınması gereken bir teknoloji olarak ön plana çıkmaktadır. Bu bağlamda, çalışmada LoRa tabanlı loT, LPWAN, LoRaWAN gibi iletişim teknolojilerinin genel özellikleri, enerji harcamaları, kapsama alanları, sürdürülebilirlikleri ve genel olarak uygulamalar alanları ayrı ayrı belirlenmiş olup, bu teknolojilerin sera içerisinde bir veya birden fazla serada sulama yönetiminde kullanılabilme olanakları araştırılmıştır. Ayrıca, Lora teknolojilerinin sulama sistemlerinde kullanılmasında sera içerisindeki iklimsel çevre koşullarının insan müdahalesi olmadan kayıt altına alınabilirliği ve bu bilgilerden hareketle sulama planlaması ve kontrolünün yapılabilirliği literatür kapsamında ortaya konulmaya çalışılmıştır. Aynı zamanda seralarda LoRa tabanlı iletişim sistemlerinin kullanılması ile sulama yönetimin uzaktan izlenebilirliği, kontrolü ve gerekli durumlarda müdahalesi de enerji tasarruflu ve ekonomik olarak sağlanmış olacaktır. Bununla birlikte, sera içi toprak nemi ve iklimsel koşulların belirlenmesi sonucunda gelecek dönem toprak nemi tahmini ve bu tahminlere göre sulama zamanı ve süresinin LoRa temelli olarak yapılabilirliği belirlenmiştir. Araştırma ile seralarda henüz yeni bir teknoloji olan LoRa tabanlı iletişim sistemlerinin sulama yönetiminde kullanılabilirliği, bu kullanımın enerji, insan gücü ve zaman tasarrufu sağlayarak sürdürülebilir tarımsal üretimin gerçekleştirilebileceği literatür kapsamında görülmüştür.

Anahtar Kelimeler: Sera, LoRa, LPWAN, loT, LoRaWAN, Sera Sulama Yönetimi.

1. INTRODUCTION

Rapid population growth, globalization and migrations are rapidly increasing, limiting soil and water resources. In addition, the effects of climate change on these resources create negative results. In order to meet the food needs of the increasing population today, studies have accelerated to obtain more yield from unit area in agricultural production [1].

Agricultural structures that can technologically accommodate the conditions that can create the desired climatic environmental conditions for all seasons in terms of plant production are called greenhouses. Greenhouses, which are among the leading agricultural activities globally, are developing in line with the development of technology. As modern systems, they are becoming more responsive to the needs in plant production. Greenhouse systems differ from other agricultural production branches in terms of being carried out under a closed structure, requiring more labor, and the initial investment cost [2].

The increase in yield in agricultural production can be achieved in greenhouses independently of environmental conditions compared to field agriculture. However, it is possible to produce fresh vegetables and fruits continuously in line with demand throughout the entire season with greenhouse farming [3]. However, greenhouses have the potential to contribute to solving the negativities of water, environmental pollution and the ecological system [4].

Compared to agricultural production areas, greenhouses are agricultural structures with high operating costs and where technical knowledge and skills are always at the forefront. In addition, they provide more yield from the unit area. Compared to field agriculture, the possibility of harvesting in the desired season ensures that the products create a high price in the market, increases business profits and allows the reduction of hidden unemployment in agriculture [5].

Greenhouse systems in the modern sense can be defined as agricultural structures where modern cultivation practices are used in terms of structure, cover materials and air conditioning, and where climatic environmental conditions are controlled by automation systems. Soilless cultivation practices are common in modern greenhouses. In these greenhouses, the use of chemical pesticides is low, quality products are grown and high yields are obtained. Modern agricultural production in greenhouses can be achieved by ventilating, cooling, heating, shading the greenhouse and irrigating it as the plant needs [6]. The increase in modern greenhouse areas compared to current conditions has been influenced by the change in consumer demands, environmentally sensitive production, food safety and certification [7].

The most important climatic environmental conditions that must be provided in order to obtain income with maximum yield in greenhouses is the provision of water proportional to the evapotranspiration value of the plant [8]. Irrigation practices are the agricultural practices that affect the increase in yield the most in terms of plant production. In addition to the limited water resources, the increase in industrial and urban water requirements causes the decrease or decrease in quality of water used in irrigation [9]. This situation necessitates obtaining the highest benefit from the decreasing irrigation water, that is, obtaining more products with minimum water consumption per unit area [10].

When evaluated in terms of irrigation, approximately 70% of the existing freshwater resources are used for agricultural purposes. When agricultural production is evaluated in general, the total water application efficiency is very low. In terms of our country, the water application efficiency is around 35%. It is estimated that the total population of the world will reach 9.15 billion in 2050. TÜİK has predicted that our country's population will be 100 million in 2030. While the amount of water per person is approximately 1,519 m3/year in today's conditions, it has been reported that the amount of usable water per person in 2030 could be approximately 1,120 m3/year. Especially the Central Anatolian region of our country is among the regions that will be most affected by water shortage [11].

In terms of the development of modern agricultural production methods, technological developments, primarily communication and internet applications, have gained great importance. The Internet of Things can be defined as the communication of objects with each other. This concept (Internet of Things, IoT) came to the fore in 2000. During this period, it has increased the degree of integration of end products, systems and services, and has gained great fame in technology markets and technological applications with this feature. In today's conditions, it is seen as an advanced generation technology. In addition, IoT and machine-to-machine communication (M2M) concepts have radically changed the interaction between people, devices and machines, paving the way for the creation of interconnected infrastructures everywhere. These promising innovations in terms of the coming periods create very attractive opportunities for both the industry and customers [12].

IoT technologies are developing rapidly, and this has also accelerated the formation of new demands regarding systems. It is seen that ease of use, dependence on a fixed power source and the desire for wireless communication in large areas are at the top of the list among technological constraints. Objects connected to wireless sensor networks (WSN) want to move in as wide an area as possible and in the desired way and talk to each other [13]. The prerequisite for objects to move freely is that they do not need any fixed power source. Many valuable studies have been carried out on the development of energy efficiency and communication methods by obtaining powerful batteries in terms of energy storage. However, despite the acquisition of long-lasting and capacious energy sources, since the components such as high-speed processors and fast storage units developed require more energy, it has not been possible for the batteries to last much longer. In this context, IoT applications need technologies with low-power operating capability that can communicate wirelessly in large areas where the internet is not an infrastructure. These technologies, Low-Power Wide-Area Network (LPWAN) technologies, come to the forefront [14].

In this study, the general features, energy consumption, coverage areas, sustainability and general application areas of communication technologies such as LoRa-based loT, LPWAN, LoRaWAN have been determined separately and the possibilities of using these technologies in irrigation management in one or more greenhouses have been investigated. In addition, the fact that climatic environmental conditions in the greenhouse can be recorded without human intervention in the use of LoRa technologies in irrigation systems and the feasibility of irrigation planning and control based on this information has been tried to be revealed within the scope of the literature. At the same time, with the use of LoRa-based communication systems in greenhouses, remote monitoring, control and intervention in necessary cases will be provided

in an energy-saving and economical way. In addition, as a result of determining the soil moisture and climatic conditions in the greenhouse, the future soil moisture estimate and the feasibility of irrigation time and duration based on these estimates have been determined. With the research, the usability of LoRa-based communication systems, which are still a new technology in greenhouses, in irrigation management, has been seen within the scope of the literature that sustainable agricultural production can be achieved by saving energy, manpower and time with this use.

2. GREENHOUSE PRESENCE IN TÜRKİYE

When Türkiye's greenhouse presence is examined, an increase is seen from the past to the present. According to the greenhouse presence in Türkiye given in Figure 1, a regular increase is seen in the last 20 years according to all the covering materials used in greenhouses. This increase has been greater in plastic covering materials [15].

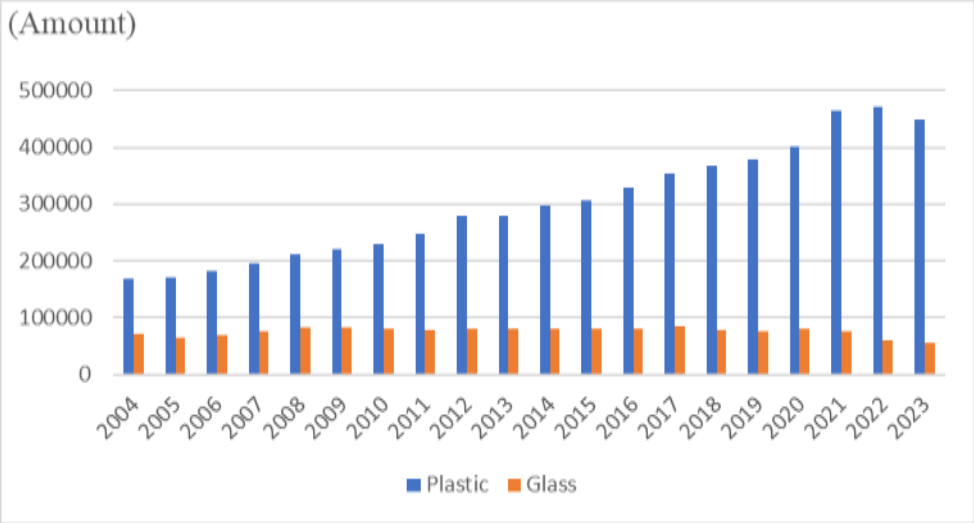

Figure 1. Greenhouse presence in Turkey

Currently, greenhouses with plastic sheeting are more common. According to approximate values, greenhouses with plastic sheeting were twice as many as glass greenhouses in 2004, but today this rate has increased tenfold. In addition, there has been a decrease in the number of glass greenhouses in recent years. This situation can be associated with the cost advantage of greenhouses made of plastic sheeting materials. According to greenhouse farming data in our country, it is generally concentrated in the Mediterranean, Aegean, and Yalova regions in terms of suitability of climatic environmental conditions, and it is also developing in Kütahya and Aydın provinces with the use of renewable geothermal resources for heating [15].

3. IRRIGATION SYSTEMS IN GREENHOUSES

After calculating the evapotranspiration values according to the climate conditions and plant type in the greenhouses, appropriate irrigation programs are made. Fogging method is also applied to provide humidification together with irrigation. Fogging method is one of the systems established to provide the humidity required by the plant in greenhouses and to reduce the internal temperature of the greenhouse (Figure 2.). In the fogging system, heat is absorbed from the ambient air by evaporation of the water sprayed with high pressure and the absorbed heat is carried out of the greenhouse by air. The system is positioned at the top point of the greenhouse [16].

Irrigation is defined as the artificial transmission of the part of the water required for plant development that cannot be met by natural precipitation. The way this irrigation water is given to the soil according to the effective root depths of the plants is called the irrigation method. Sprinkler and micro irrigation methods can be used in greenhouse conditions. Micro irrigation methods include drip, bubbler and micro spray methods [16].

Figure 2. Irrigation method

In sprinkler irrigation systems, irrigation water is transported under pressure to mechanical sprayers in closed pipes and applied to the soil in a manner similar to natural rainfall [17]. With drip irrigation, water is used with maximum efficiency in areas where water availability is most limited. Since events such as evaporation, surface runoff and deep leakage can be prevented in this irrigation system, efficiency is relatively higher. Irrigation water is given to the plant root zone with the help of small diameter pipes [18]

The method applied by using sprinkler heads with a more micro structure compared to the heads used in sprinkler irrigation is called micro spray irrigation system. Irrigation opportunity is provided in narrow areas by using micro structured spray sprinkler heads [19]. Bubbler irrigation systems are generally used in ground cover plants and shrub groups. It consists of a lateral pipe that transmits water with a relatively lower pressure compared to sprinkler irrigation and transparent polyethylene water distribution pipes with a diameter of 10-12 mm [16].

4. INTERNET OF THINGS – COMMUNICATION TECHNOLOGIES

The concept of the Internet of Things (IoT) is explained as the communication of objects with each other. It emerged approximately 25 years ago and has increased the degree of integration of end products, systems and services. In this context, it has been at the forefront of technological applications. It is seen as an advanced technology among the existing technologies in today's conditions. The concepts of IoT and machine-to-machine communication (M2M) have radically changed the interaction between people, devices and machines and paved the way for the creation of interconnected infrastructures everywhere. It creates quite attractive opportunities for the industry and customers in the coming periods [12].

With the very rapid development of IoT technologies, the negative aspects of the systems in practice have also begun to emerge and new demands. When technological and physical constraints are evaluated, it can be said that dependence on a fixed power source and the desire for wireless communication in wide areas come first. Objects connected to wireless sensor networks (Wireless Sensor Network, WSN) want to talk. The prerequisite for objects to move freely is that they do not need any fixed power source [13].

4.1.LORA COMMUNICATION TECHNOLOGIES

LPWAN technologies, which form the basis of LoRa communication technologies, create innovations such as calculating the most appropriate transmission power and providing it with minimum power loss, along with the development of communication technologies to create a more efficient network performance according to the current conditions, and are examined in three different categories. In terms of the first category, cellular technology-based LPWAN systems have NB IoT, LTE-M and GSM IoT varieties. The width of the coverage area, speed, reliability and height of data transmission are at the forefront [20].

In the second category, French companies Sigfox [21] and Telensa [22] have switched to ultra-narrow band application in order to resolve the conflict created by LoT technologies. Sigfox has come to the fore in terms of simplicity, efficiency, integration and two-way communication. Sigfox has a coverage area of 3-10 kilometers in the city and 30-50 kilometers in rural areas [23].

LoRa, which is in the third category, was patented by Semtech in 2014. A global network platform can be easily established. According to the regulations in the countries, it can operate at 868 MHz in Europe, 915 MHz in the United States and 433 MHz in some regions without a license. [24] LoRaWAN technology has come to the fore with its low energy consumption, wide coverage, simplicity, enabling private network installation, security and easy network management. According to the current conditions, LoRa systems have a coverage area of 45 km in rural areas and 5 km in urban areas. [25, 26].

The general working principle of LoRa systems is given in Figure 3 and is generally implemented as LoRaWAN. Sensors with LoRa technology transmit data to the gateway located at a suitable distance. Then, the data is sent to the servers via Wi-Fi, cellular, radio frequency or Ethernet connection [27]. The most important factor that makes LoRa technology

generally prominent and dominant in many application areas is its ability to operate for 10 years with a single energy source. [28].

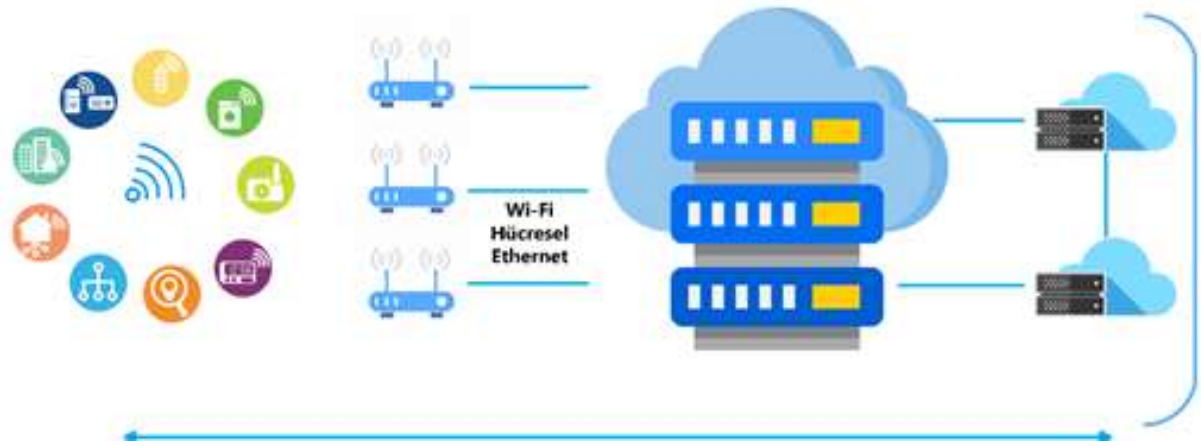

Figure 3. LoRaWan System

4. MANAGEMENT OF IRRIGATION WITH LORA SYSTEMS IN GREENHOUSES

The wide use of modern communication technologies such as the Internet of Things and LoRa in agricultural structures has resulted in the reorganization of agricultural activities [29]. With these technologies, it is possible to reach and monitor agricultural areas from any place and at any time. With LoRa systems, management is provided by giving the necessary commands in agricultural structures and lands through wireless networks and mobile applications. In addition, the use of these technologies and the increase in yield are also seen in the face of the negative effects of climate change. Especially in agricultural structures and lands in rural areas, the use of long-distance technologies based on radio frequency can be an important factor that provides an increase in yield [30].

Greenhouses come to the forefront as agricultural structures equipped with modern sensors and communication technologies and controlled from mobile and web environments with the integration of the LoRa system. In this context, there are many studies on smart greenhouse management, where irrigation can also be managed. Thus, in addition to irrigation management in greenhouses, many variables such as air conditioning, temperature, light intensity and humidity value can be kept under control. [31-34].

With the use of LoRa systems, it is possible to monitor the humidity and temperature values by starting and ending irrigation without going to the area where the greenhouse is located, how many days the irrigation will be done, with the support of sensors. There are many studies on the use of LoRa systems in irrigation management. However, it is possible to use all sprinkler, drip and mist systems with LoRa systems. In this context, it is possible for new generation communication technologies such as LoRa to meet many needs in terms of irrigation management, and access to greenhouses can be provided from any place at any time. It is possible to follow the latest status in greenhouses and to provide irrigation management in

greenhouses by giving the necessary commands through sensors, actuators, wireless networks and mobile applications. An important need in this area is met with radio frequency-based LoRa technologies, especially as an alternative or complement to internet and cellular communication in greenhouses located in rural areas [35-39].

5. CONCLUSİON

Within the scope of the research, the potential of LoRa systems, which are still a very new system in terms of agricultural use, to provide irrigation methods in greenhouses has been evaluated within the scope of literature. According to the results of the study, it is seen that irrigation methods can be performed by using the LoRa system in greenhouses. This situation will create many positive effects. Irrigation duration and planning in greenhouses can be provided with sensor systems integrated with LoRa. In this context, management of sensor systems according to climatic environmental conditions in the greenhouse can also be provided.

Another management element in terms of irrigation projects is solenoid valves. With the irrigation commands sent to the electrovalves from LoRa systems, irrigation water will be delivered to the greenhouse and will be closed appropriately when irrigation is finished. In addition, in cases where a pressure source needs to be created in greenhouse irrigation projects, the management of the pump-hydraulic unit can also be provided by LoRa systems.

The relative humidity level inside the greenhouse can be monitored with humidity sensor systems integrated with LoRa. If the humidity level is outside the desired level, fogging can be operated by activating LoRa systems. Success can be achieved with the full integration of sensor, LoRa and fogging systems. The most important positive effects of LoRa systems in terms of greenhouse farming and agricultural production is the ability to work without internet or wifi. It is possible for LoRa systems to work even when there are problems with the internet in some regions. The fact that LoRa systems work with radio frequencies will be a positive preference for greenhouse farming and agricultural production in general. According to current conditions, the possibility of providing irrigation management with LoRa in greenhouses covering an area of approximately 45 km in rural areas will provide great savings in cost, labor and time.

It can be said that LoRa systems provide irrigation management at a relatively low cost with the use of greenhouses. Currently, controllers used in irrigation management are more costly devices. It can be said that LoRa systems that can be applied instead of controllers can create a cost advantage in today's conditions. In addition, their ability to work in a wide area will also save labor. The fact that more than one and a large number of different greenhouses can be controlled with LoRa systems is among the targets of R&D studies in this regard. In addition, the high communication speed of LoRa systems will ensure that irrigation commands are transmitted without delay. This is important in terms of irrigation duration and start-end times. A delay in the irrigation command may cause an increase in the previously determined irrigation duration in the greenhouse. In such a case, excessive irrigation will be done. With the high communication speed in LoRa systems, it will be possible to prevent excessive consumption of

irrigation water and unnecessary irrigation that exceeds the evapotranspiration value of the plant.

As a result, it is seen that it is possible to manage irrigation systems with LoRa systems in greenhouses. In this respect, it is recommended that LoRa systems, which are a very new field of study in our country, be used in greenhouses as well as in all agricultural structures and irrigation applications. Thus, it can be said that sustainable agricultural production can be achieved with cost, time and labor savings.

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RISK PERCEPTION IN LIVESTOCK PRODUCTION

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ABSTRACT

The aim of this study is to identify the main economic risk factors encountered in the livestock sector and to analyze their impact on producer behavior through a literature-based evaluation. The livestock sector inherently involves higher risks compared to other agricultural sectors due to its direct engagement with living organisms.

Factors such as age, education level, farm size, and previous experience play a determining role in producers' risk perceptions. Risk management strategies in the livestock sector can be categorized under three main headings: preventive strategies (such as vaccination, hygiene, and care), financial strategies (including insurance and the establishment of cash or credit reserves), and diversification strategies (such as product diversification). In Türkiye, although risk management strategies are not yet fully effective or sufficient, preventive health practices appear to be more commonly employed. In contrast, financial risk management tools—particularly livestock insurance—are significantly underutilized. This reflects both a lack of awareness among producers and the fact that the current insurance system is not sufficiently inclusive or accessible. However, in Türkiye, alongside animal diseases, feed prices and market uncertainty also constitute major risk categories. Despite this, risk management strategies remain limited and are often based on personal experience rather than institutional frameworks.

To ensure the effective implementation of risk management tools, it is essential to strengthen education and extension services targeting producers, develop flexible insurance models tailored to regional characteristics and accessible to small-scale farms, and improve financial support mechanisms through premium subsidies. Particularly in response to price volatility, small-scale producers should be encouraged to enhance their bargaining power through direct marketing, contract farming, and cooperatives, while the state should contribute by implementing input subsidies, price stabilization mechanisms, and market information systems. Moreover, improving communication between producers and veterinarians, who are seen as reliable sources of information in risk perception, is crucial. Such efforts would significantly contribute to increasing the adoption of preventive and protective practices against animal diseases and to reducing overall risk in livestock production.

Keywords: Livestock, Risk, Disease, Price Fluctuations, Livestock Insurance

HAYVANSAL ÜRETİMDE RİSK ALGISI

ÖZET

Bu çalışmanın amacı, hayvancılık sektöründe karşılaşılan başlıca ekonomik risk unsurlarını belirlemek ve bu risklerin üretici davranışı üzerindeki etkilerini literatür temelli bir değerlendirmeyle analiz etmektir. Hayvancılık sektörü, doğrudan canlı organizmalarla ilgilenmesi nedeniyle diğer sektörlerden daha fazla risk içermektedir.

Üreticilerin risk algılarında yaş, eğitim düzeyi, işletme büyüklüğü ve geçmiş deneyim gibi faktörlerin belirleyici olmaktadır. Hayvancılık sektöründe risk yönetim stratejileri ise üç temel başlık altında sınıflandırılabilir: Önleyici stratejiler (aşı uygulamaları, hijyen ve bakım), Finansal stratejiler (sigorta, nakit ve kredi rezervi oluşturma), Çeşitlendirme stratejileri (Ürün çeşitlendirme). Türkiye'de risk yönetimi stratejilerinde ise etkin ve yeterli olmasa da önleyici sağlık uygulamalarının ön planda yer aldığı, buna karşılık, finansal risk yönetimi araçlarının özellikle hayvancılık sigortalarının kullanım düzeyinin oldukça düşük olduğu söylenebilir. Bu durum, hem üretici davranışlarını yönlendirecek bilinçlendirme eksikliğine hem de mevcut sigorta sisteminin yeterince kapsayıcı ve erişilebilir olmamasına işaret etmektedir. Oysa Türkiye'de hayvan hastalıklarının yanı sıra, yem fiyatları ve piyasa belirsizliği gibi alanlar yüksek risk grubu içinde yer almaktadır. Ancak bu risklere karşı yönetim stratejilerinin sınırlı ve çoğunlukla kişisel deneyim temelli olduğu söylenebilir.

Risk yönetim araçlarının başarılı bir şekilde uygulanabilmesi için, üreticiye yönelik eğitim ve yayım hizmetlerinin güçlendirilmesi, bölgesel özelliklere ve küçük ölçekli işletmelere de ulaşabilen esnek sigorta modellerinin geliştirilmesi, prim destekleri ile finansal destek mekanizmalarının geliştirilmesi büyük önem taşımaktadır. Özellikle fiyat dalgalanmalarına karşı, küçük ölçekli işletmelerin doğrudan pazarlama, sözleşmeli üretim ve kooperatifleşme yoluyla pazarlık güçlerini artırmaları; devletin ise fiyat istikrarını destekleyici girdi desteği ve fiyat uygulamaları ile piyasa bilgilendirme sistemleriyle bu sürece katkı sunması gerekmektedir. Ayrıca risk algısında güvenilir bilgi kaynağı olarak ön plana çıkan veteriner hekimler ile üreticiler arasındaki iletişimin etkinleştirilmesi, hastalıklara karşı koruyucu ve önleyici uygulamaların artmasına ve riskin azaltılmasında önemlidir.

Anahtar Kelimeler: Hayvancılık, Risk, Hastalık, Fiyat dalgalanmaları, Hayvancılık sigortası

GİRİŞ

Hayvancılık, gıda arz güvenliğinin sağlanması, kırsal kalkınmanın desteklenmesi ve üretici-sanayi-ülke ekonomisi için stratejik bir öneme sahiptir. Ancak hayvancılık sektörü, doğası gereği çok çeşitli risk unsurlarına maruz kalabilmektedir. Özellikle üretim sürecinin canlı varlıklarla yürütülmesi, hayvansal ürünlerin biyolojik döngülere bağlı olması ve piyasa yapısındaki kırılganlıklar, sektörü hem ekonomik hem de yapısal olarak risklere açık hâle getirmektedir (Gökgöz ve Kayahan, 2021; Özsayın, 2005). Bu riskler hem üretim süreçlerini hem de ekonomik istikrarı etkileyebilmektedir (Njavro ve ark. 2007).

Risk, belirli bir olayın gerçekleşme olasılığı ile bu olayın etkisinin birleşimi olarak tanımlanabilir (Meraner ve Finger 2017). Hayvancılık faaliyetlerinde riskler; üretim riski (hastalık, verim düşüklüğü, ölüm oranları), fiyat ve pazar riski (girdi ve ürün fiyatlarındaki dalgalanmalar), finansal risk (gelir istikrarsızlığı, kredi erişimi), politik ve kurumsal riskler (destekleme politikalarının belirsizliği) ve çevresel riskler (doğal afetler, iklim değişikliği) olarak 5 başlık altında incelenebilir (Meuwissen et al., 2001; Meraner & Finger, 2017). Özellikle kur riski, enflasyon ve faiz oranı gibi makroekonomik değişkenler, doğrudan ya da dolaylı olarak ülke ekonomisinde yaşanan gelişmeler gibi ekonomik risk unsurları hayvancılık işletmelerinin mali sürdürülebilirliğini etkileyebilmektedir (Göktürk ve Yalçınkaya, 2017; Bayramoğlu, 2020). Bu bağlamda, hayvancılık sektöründeki ekonomik kırılganlıkların ve belirsizliklerin yönetilebilmesi, etkin bir risk yönetimi yaklaşımını gerekli kılmaktadır. Zira hayvancılık sektöründe, risk yönetimi stratejileri işletmelerin sürdürülebilirliğini sağlamak için kritik bir öneme sahiptir.

Risk algısı ve bu algıya dayalı davranış biçimleri, üreticilerin hem kısa hem de uzun vadeli kararlarını doğrudan etkilemektedir (Hayran & Gül, 2015). Literatürde, üreticilerin risklere verdikleri tepkilerin genellikle bireysel özellikler (yaş, eğitim, deneyim), işletme ölçeği ve bilgi kaynaklarına erişimle şekillendiği görülmektedir (Njavro et al., 2007; Valeeva et al., 2011). Bu nedenle, hayvancılık sektöründe ekonomik risklerin çok boyutlu olarak ele alınması ve risk yönetim stratejilerinin bölgesel ve işletme bazlı farklılıkları dikkate alacak şekilde tasarlanması gereklidir.

Bu çalışmanın amacı, hayvancılık sektöründe karşılaşılan başlıca ekonomik risk unsurlarını belirlemek ve bu risklerin üretici davranışı üzerindeki etkilerini literatür temelli bir değerlendirmeyle analiz etmektir. Aynı zamanda, risk algısı ile ekonomik sürdürülebilirlik arasındaki ilişki incelenerek, sektörde uygulanabilecek etkili risk yönetimi stratejilerine yönelik politika önerileri sunulacaktır.

Hayvancılıkta Risk Algısı

Hayvancılık sektörü, doğal, ekonomik ve politik koşullarındaki değişkenliklere yüksek derecede duyarlılık gösteren bir üretim alanıdır. Canlı varlıklarla yürütülen üretim sürecinde hastalık, ölüm, verim kaybı gibi üretim risklerine; piyasa yapısındaki dalgalanmalar ise fiyat ve gelir istikrarsızlığına açık hâle getirmektedir (Hardaker et al., 2004; Gökgöz & Kayahan, 2021). Bu kapsamda, üreticilerin karşı karşıya kaldığı belirsizlikler yalnızca ekonomik çıktıları değil, aynı zamanda karar alma davranışlarını da doğrudan etkilemektedir.

Meuwissen et al. (2001) ve Njavro et al. (2007) de Avrupa'daki hayvancılık işletmelerinin fiyat dalgalanmaları ve üretim risklerine karşı kırılgan olduğunu ve bu risklerin sektörel istikrarı tehdit ettiğini bildirmişlerdir. Özsayın (2005) ve Altay (2019) çalışmalarında tarımsal ve hayvansal üretimin doğal, ekonomik ve politik risklere karşı yüksek duyarlılık taşıdığını ve bu nedenle risk yönetim araçlarına ihtiyaç duyulduğunu belirtmişlerdir. Ayrıca Afyonkarahisar'da yapılan bir çalışmaya göre, üreticilerin en çok karşılaştıkları riskler arasında hayvan hastalıkları, yem fiyatları ve devlet politikaları öne çıkmaktadır (Gökgöz ve kayahan, 2021).

Hayvancılık sektöründe risk faktörleri beş başlıkta toplanabilir; Hayvan sağlığı riski (hastalık, ölüm), 2) Fiyat ve Pazar belirsizliği, 3) Finansal, ekonomik sorunlar, 4) Politik belirsizlik, 5) Doğal afet ve iklim riski (Hayran ve Gül, 2015; Yalçınkaya, 2017).

Hayvancılık işletmelerinde en yaygın risk unsurlarından biri, hayvanlarda ortaya çıkabilecek epidemik ve endemik hastalıklardır. Bu hastalıklar, hayvanların büyüme, üreme ve verim performansını olumsuz etkileyerek üretim kapasitesinde ciddi kayıplara yol açmakta ve dolayısıyla işletmenin kârlılığını doğrudan tehdit etmektedir (Hayran & Gül, 2015; Valeeva et al., 2011). Özellikle yüksek hayvan yoğunluğuna sahip entansif üretim sistemlerinde, bulaşıcı hastalıkların yayılma hızı ve etkisi daha büyük olmakta, bu da hem ekonomik hem de biyolojik açıdan riskin şiddetini artırmaktadır. Bu nedenle, hastalık risklerinin etkin biçimde yönetilebilmesi için koruyucu veteriner hizmetlerinin yaygınlaştırılması, düzenli sağlık kontrollerinin yapılması, karantina uygulamalarının benimsenmesi ve biyogüvenlik önlemlerinin işletme ölçeğinde sistematik biçimde uygulanması büyük önem taşımaktadır (Njavro et al., 2007; Garforth et al., 2013). Ayrıca, üreticilerin hastalık riskine ilişkin farkındalık düzeyleri ile bu riski algılama biçimleri, hastalıklarla mücadele stratejilerini doğrudan şekillendirmektedir.

Fiyat ve pazar riski, hayvancılık sektöründe girdi ürünleri ve çıktı ürünlerinin; arz-talepten ya da hükümet tarafından uygulanan politikalar sonucu, fiyatlarda meydana gelen dalgalanmalar olarak tanımlanabilir (Akçaöz ve Kızılay, 2006). Buna göre fiyat riskinin hükümetin uyguladığı tarım ve hayvancılık politikalarıyla doğrudan ve dolaylı olarak ilişkili olduğu ve sektörü olumlu ya da olumsuz etkilediği söylenebilir. Örneğin, yem fiyatlarının yüksek seyretmesine rağmen kaba yem üretimine yönelik desteklerin yetersiz kalması veya girdi sübvansiyonlarının sadece bitkisel üretime yönlendirilmesi, hayvancılık işletmelerini yem maliyetlerini daha artıracak ve gelir kaybına neden olacaktır. Bunun yanı sıra hayvancılık sektörü yem maliyetinin artması olan et, süt, deri vb. çıktı ürünlerinin satış rakamlarının değişmesine ve üretimin azalmasına neden olacaktır. Bu bağlamda, üreticilerin gelecek planlamalarını yaparken hükümetin destekleme politikalarını dikkatle takip etmeleri ve kararlarını bu doğrultuda şekillendirmeleri, fiyat riskine karşı koruyucu bir önlem niteliği taşıması bakımından önemlidir.

Üreticilerin en yoğun olarak algıladığı risk türlerinden biri de girdi maliyetlerinin artmasıdır. Bu durum, yem, aşı-ilaç gibi temel girdilerin dışa bağımlılığının yüksek olması ile açıklanabilir. Özellikle yem fiyatları, enerji, işçilik ve veterinerlik hizmetleri gibi girdilerdeki artış, hayvancılık sektörünün ekonomik sürdürülebilirliğini tehdit eden temel unsurlar arasında yer almaktadır. Meraner ve Finger (2017)'de Almanya'daki üreticilerin risk algılarını analiz ederken, ekonomik çevredeki değişkenliğin özellikle de girdi maliyetlerindeki artış ve piyasa dalgalanmalarının risk algısını etkileyen temel belirleyicilerden olduğunu bildirmiştir. Gökgöz

ve Kayahan (2021), yaptıkları çalışmada üreticilerin, girdi maliyetlerinin yükselmesini ciddi bir risk olarak algıladığını ve bu durumun faiz oranlarındaki artışla daha da derinleştiğini bildirmişlerdir.

Yalçınkaya (2017) yaptığı çalışmada, işletmelerde yem fiyatı riski ile hayvan sayısı arasında negatif bir korelasyon bulmuş ve hayvan sayısı arttıkça yem fiyatı riskinin daha belirgin hâle geldiği bildirilmiştir. Nitekim, yüksek girdi maliyetleri, hayvancılık işletmelerinin kârlılığını azaltıp, işletme sermayesinin yetersizliğine neden olduğu için risk algısını daha da güçlendirmektedir.

Önemli risklerden biri olan pazar riski, hayvansal ürünlerin (et, süt, yumurta vb.) pazarlanması sürecinde meydana gelen belirsizliklerden kaynaklanmakta ve sektördeki gelir istikrarını doğrudan tehdit etmektedir. Pazar riski; fiyat dalgalanmaları, talep daralması, pazara erişimde yaşanan güçlükler, sözleşmeli üretimde karşılaşılan sorunlar ve dış ticaret kısıtlamaları gibi çok yönlü unsurları kapsamaktadır. Özellikle destek politikalarının yetersizliği, girdi fiyatlarının sürekli artışı ve piyasa yapısındaki oligopol yapı, üreticilerin pazarlama gücünü zayıflatarak pazar riskini artırmaktadır. Üreticiler, çoğu zaman ürünlerini maliyetin altında fiyatlarla elden çıkarmak zorunda kalmakta ya da piyasada talep yetersizliği nedeniyle ürünlerini satamama riskiyle karşı karşıya kalmaktadır. Bu durum üretici gelirlerinde azalmaya yol açtığı gibi üretimi artırma kararını da olumsuz etkilemektedir. Bu bağlamda, hayvancılık işletmelerinde pazar riskinin tanımlanması, nedenlerinin ortaya konulması ve bu riske karşı geliştirilebilecek yönetim stratejilerinin belirlenmesi, sürdürülebilir bir hayvansal üretim için büyük önem taşımaktadır.

Son dönemlerde sıkça rastlanan doğal afetler ve iklim kaynaklı çevresel riskler, hayvan sağlığı, yem üretimi, su kaynakları, barınak altyapısı ve genel işletme sürdürülebilirliği üzerinde ciddi tehditler oluşturmaktadır (Göktürk ve Yalçınkaya, 2017; Njavro et al., 2007). Hayvancılıkta karşılaşılan iklimsel riskler, yalnızca hayvanların doğrudan maruz kaldığı sıcaklık stresi, hastalık yayılımı veya ölüm gibi etkilerle sınırlı kalmayıp; aynı zamanda yem bitkilerinin yetişme dönemlerini, su teminini ve genel üretim maliyetlerini de etkilemektedir (Njavro et al., 2007; Altay, 2019). Özellikle kuraklık ve aşırı yağışlar gibi ekstrem hava olayları, hem otlatma alanlarının verimliliğini düşürmekte hem de kaba ve kesif yem teminini sekteye uğratmaktadır. Bu durum, hayvansal üretimin maliyetlerini artırmakta ve gelir dalgalanmalarına neden olmaktadır (Yalçınkaya, 2017; Özsayın, 2005).

Hayvancılıkta Risk Algısının Üretici Davranışlarına Etkisi

Risk algısı, bireyin karşılaştığı olay ya da durumun taşıdığı tehlikeyi nasıl değerlendirdiğini ifade eden öznel bir kavram olup, tarımsal üretimde alınan kararların temel belirleyicileri arasında yer alır (Slovic et al., 1982; Meraner & Finger, 2017). Hayvancılık işletmelerinde risk algısı, sadece nesnel risk düzeyleriyle değil; üreticinin geçmiş deneyimleri, eğitim düzeyi, işletme büyüklüğü, bilgi kaynaklarına erişimi, sosyoekonomik yapısı ve bölgesel şartlara bağlı olarak şekillenmektedir (Meuwissen et al., 2001; Hayran & Gül, 2015). Üreticilerin risk algısına verdiği tepkiler hayvancılıkta koruyucu, uyum sağlayıcı ya da tepkisel biçimde değişkenlik göstermektedir.

Nitekim her üretici, benzer risk ortamında bulunmasına rağmen hastalık riskine karşı farklı düzeyde duyarlılık gösterebilir. Bu fark, genellikle bireyin geçmiş deneyimleri, eğitimi, bilgiye erişim düzeyi ve hastalıkların ekonomik etkilerine ilişkin bilinç düzeyiyle ilgilidir (Meuwissen et al., 2001; Meraner & Finger, 2017). Örneğin genelde küçük ölçekli işletmeler, hayvanlarında sık görülen subklinik mastitis vakalarının üretim kaybına neden olduğunun farkında olmadıklarından, risk algısı daha düşük düzeyde kalır. Ancak bu farkındalık eksikliği, uzun vadede ciddi ekonomik kayıplara yol açabilmektedir.

Valeeva ve ark. (2011)'nın yapmış olduğu çalışmada, üreticilerin bir risk yönetimi stratejisini benimsemesinde geçmiş deneyimlerin önemli olduğu vurgulanmıştır. Özellikle üreticilerin geçmişte yaşadıkları doğal afetler, hayvan hastalıkları veya yem krizleri sonrası bazı koruyucu önlemleri arttırdıkları ancak düzenli önlem alma konusunda sürdürülebilir davranış örüntüsü geliştiremedikleri bildirilmiştir. Buna karşın hayvan hastalıklarıyla ilgili güncel bilgilere ulaşabilen ve veteriner danışmanlık hizmeti alan üreticilerin, riskleri daha doğru değerlendirebildikleri ve koruyucu yöntemlerine daha çok başvurdukları bildirilmektedir (Garforth et al., 2013).

Meuwissen ve ark. (2001) çalışmasında daha büyük ölçekli ticari işletmelerin risk yönetim araçlarına daha yatkın olduğu, küçük ölçekli işletmelerin ise riskleri doğal sürecin bir parçası olarak görüp daha pasif stratejiler benimsediklerini ifade etmiştir. Benzer şekilde Gökgöz ve Kayahan (2021), Afyonkarahisar'daki hayvancılık işletmelerinde sosyoekonomik yapı ile risk algısı arasında anlamlı bir ilişki bulmuş; düşük eğitim düzeyi ve sınırlı ekonomik kaynaklara sahip üreticilerin, riskleri fark etseler bile önlem alma davranışı göstermede isteksiz olduklarını bildirmiştir.

Risk yönetim stratejilerine ilişkin davranışlarda işletme büyüklüğü ve bilgiye erişim önemli belirleyicilerdendir. Yapılan araştırmalar, büyük ölçekli hayvancılık işletmelerinin, risk algısı ve risk yönetimi stratejileri açısından küçük ölçekli işletmelere kıyasla daha sistematik ve planlı bir yaklaşım sergilediklerini göstermektedir. Bu durum, özellikle finansal kaynaklara erişim, teknik bilgi düzeyi ve profesyonel danışmanlık hizmetlerinden yararlanma imkânlarının büyük işletmelerde daha yüksek olmasından kaynaklanmaktadır (Meuwissen et al., 2001; Meraner & Finger, 2017; Valeeva et al., 2011). Ayrıca, finansal güvenceye erişim düzeyi yüksek olan çiftçilerin riskleri yönetme konusunda daha etkili stratejiler geliştirdiği belirlenmiştir (Valeeva ve ark. 2011). Buna karşılık küçük ölçekli üreticiler, risklere karşı daha kırılgan bir yapıya sahip olduğu söylenebilir.

Meuwissen ve ark. (2001) tarafından yapılan çalışmada, büyük ölçekli işletmelerde sigorta kullanımı, kayıt tutma ve danışmanlık hizmetlerinden faydalanma düzeyleri daha yüksek olup, bu işletmeler daha sistematik risk yönetim davranışları sergiledikleri bildirilmiştir. Özsayın (2005)'ın Türkiye özelinde ortaya koyduğu çalışmada ise küçük ölçekli üreticilerde, sigorta primlerinin yüksekliği, bilgiye sınırlı erişim ve risk algısının soyutluğu, koruyucu davranışları sınırlı kaldığı bildirilmiştir.

Küçük ve büyük işletmelerin risk yönetim farklılıkları Tablo 1'de verilmiştir (Meuwissen et al., 2001; Meraner ve Finger, 2017; Valeeva et al., 2011; Hayran ve Gül, 2015).

Tablo 1. Küçük ve Büyük Ölçekli Hayvancılık İşletmelerinin Risk Yönetimi Karşılaştırması

Kriterler	Küçük Ölçekli İşletme	Büyük Ölçekli İşletme
Risk algısı	Düşük-orta (tepkisel)	Orta-yüksek (proaktif)
Önleyici strateji kullanımı (aşılama, biyogüvenlik)	Sınırlı	Yaygın ve sistematik
Sanayi ile etkileşim	Düşük	Yüksek
Teknik bilgiye erişim	Düzensiz	Düzenli/ Veteriner hekim gözetiminde
Hayvancılık Sigorta kullanımı	Düşük	Yüksek
Planlama ve kayıt tutma	Zayıf	Gelişmiş
Finansal Dayanıklılık	Yüksek	Düşük

Tablo incelendiğinde birçok başlıkta büyük ölçekli işletmeler, küçük ölçekli işletmelere oranla risk yönetimde daha etkin olduğu ancak finansal dayanıklılık konusunda küçük ölçekli işletmelerin daha avantajlı oldukları görülmektedir. Nitekim Türkiye koşullarında küçük ölçekli işletmeler, üretimlerini genellikle düşük maliyetli aile işgücünü kullanması, arazi ve yem kaynaklarını büyük ölçüde kendi imkânlarıyla temin etmesi ve faaliyetlerini daha esnek bir yapıda sürdürmelerine neden olmaktadır. Bu esnekliğin, piyasa dalgalanmalarına, girdi fiyatlarındaki artışa ve süt fiyatlarındaki volatiliteye karşı adaptasyon kabiliyetlerini artırdığı ve işletmelerin yaşam süresini uzattığı söylenebilir. Buna karşın, büyük ölçekli süt işletmelerin çok daha yüksek sabit yatırım gereksinimleri (modern tesisler, ileri teknolojili sağım sistemleri, geniş ölçekli yem tedariki vb.) ve yüksek işletme sermayesi ihtiyacı nedeniyle daha kırılgan bir yapıya sahiptirler. Nitekim yatırım ve sabit giderlerin çok ağır olması (kredi geri ödemeleri, enerji, işçilik, amortisman giderleri), Pazar bağımlılıklarının fazla olması (özellikle sanayi tipi alıcılara ya da ihracata bağımlı üretim modelleri), yem katkı maddeleri gibi dışa bağımlılıkların yüksek olması ve devlet desteklerinden yeterince yararlanamama, işgücü yönetiminde yaşanan sorunlar ve profesyonel yönetim eksiklikleri gibi nedenlerle finansal kırılganlık daha fazla olması hızlı iflas ya da faaliyet sonlandırma riski ile karşı karşıya kalmalarına neden olabilmektedir.

Hayvancılık İşletmelerinde Risk Yönetim Stratejileri

Risk algısı, yalnızca tehlikenin varlığına dair farkındalığı değil, aynı zamanda bu tehlikeyi bertaraf etmek için geliştirilen stratejileri de şekillendirmektedir. Üreticiler, riskleri azaltmak amacıyla çeşitli yönetim stratejilerine başvurabilmektedir. Risk yönetim stratejileri ise üç temel başlık altında sınıflandırılabilir: 1) Önleyici stratejiler (aşı uygulamaları, hijyen ve bakım), 2) Finansal stratejiler (sigorta, kredi rezervi oluşturma, erken satış, sözleşmeli üretim), 3) Çeşitlendirme stratejileri (farklı türde hayvancılık, Ürün çeşitlendirme). Ancak bu stratejilerin

seçimi, üreticinin riske yönelik tutumu, kaynak yapısı ve bilgi düzeyi ile doğrudan ilişkilidir (Altay, 2019; Njavro et al., 2007).

Önleyici stratejiler, özellikle hayvan sağlığı risklerinin yönetiminde kritik öneme sahiptir. Aşı uygulamaları, düzenli veteriner kontrolleri, karantina uygulamaları ve hijyen önlemleri gibi uygulamalar, enfeksiyöz hastalıkların yayılımını önlemeye yönelik etkili müdahale yollarıdır. Bu tür stratejiler, Valeeva ve ark. (2011) tarafından yapılan çalışmada da en etkin ve üretici tarafından ilk tercih edilen risk azaltım yolları arasında gösterilmiştir. Ancak bu stratejilerin başarısı, üreticinin bilgi düzeyine, veteriner hizmetlerine erişimine ve işletmenin teknik kapasitesine bağlı olarak değişmektedir. Özellikle küçük ölçekli işletmelerde bu stratejilerin yeterince uygulanmadığı, bilgi eksikliği ve ekonomik kısıtların önemli bir engel oluşturduğu söylenebilir (Garforth et al., 2013; Gökgöz ve Kayahan, 2021).

Finansal stratejiler, risklerin ekonomik etkilerini sınırlamak amacıyla geliştirilmiş olup, özellikle iklimsel ve piyasa temelli belirsizlikler karşısında işletmenin gelir istikrarını koruma işlevi görmektedir. Sigorta sistemleri (hayvan hayat sigortası, doğal afet teminatları), acil durumlar için nakit rezervi oluşturma ve kredi mekanizmaları, maliyeti sabitleme veya düşürme bu başlık altında değerlendirilebilir. Küçük ve orta ölçekli işletmeler için finansal planlama ve gelir-gider kontrolü, nakit akışını izleme ve borç yönetimi açısından önemli bir araç olup, işletmenin uzun vadeli sürdürülebilirliğini güçlendirir.

Hayvancılık işletmeleri için önemli bir risk olan, fiyat dalgalanmalarına karşı özellikle küçük ölçekli işletmeler sermaye birikiminin düşük olması, pazarlık güçleri sınırlı olması ve çoğu zaman üretimin sadece geçimlik düzeyde olması nedeniyle büyük ölçekli işletmelere göre daha kırılgandır. Küçük işletmeler, fiyatlar üzerinde doğrudan kontrol sahibi olamasalar da girdi maliyetlerini azaltarak fiyat dalgalanmasının gelir üzerindeki etkisini sınırlayabilir. Yem girdisi, hayvancılıkta maliyetin %60-70'ini oluşturduğundan, kendi yemini üretmek veya kooperatif yoluyla toplu yem alımı yapmak etkili bir stratejidir (Yalçınkaya, 2017). Ayrıca, düşük verimli hayvanların elden çıkarılması ve sürü yönetiminin rasyonelleştirilmesi, verim başına maliyeti düşürür. Küçük işletmelerin tek başına pazarlık gücü sınırlıdır. Bu nedenle üretici birlikleri ve kooperatifler aracılığıyla hem girdi tedariki hem de ürün satışı alanında kolektif hareket etmek, pazarlık gücünü artırır ve fiyat oynaklığından daha az etkilenmeyi sağlar (Özsayın, 2005). Kooperatifler aynı zamanda stok yönetimi, soğuk zincir ve pazara erişim konularında da destek sağlayabilir. Fiyat dalgalanmasına karşı geliştirilen araçlardan biri de sözleşmeli üretimdir. Bu yöntemle üretici, ürününü önceden belirlenen fiyattan satmayı taahhüt ederek, piyasa dalgalanmasına karşı korunur. Türkiye'de bu yöntem süt, kırmızı et ve bazı yem bitkilerinde yaygınlaşmakla birlikte, küçük üreticilerin bu pazarlara entegrasyonu hâlâ sınırlıdır.

Njavro ve ark. (2007) sigortanın, sistematik risklere karşı etkili bir araç olduğunu belirtmiştir. Ancak uygulamada üreticiler nezdinde sigorta primlerinin yüksekliği, tazminat sürecine olan güvensizlik ve bilgi eksikliği gibi faktörlere bağlı olarak işletmelerde sigortalılık oranları düşük kalmaktadır (Özsayın, 2005). Sigorta gibi formel finansal risk yönetim araçlarının düşük kullanım düzeyleri, Türkiye'deki mevcut tarım sigortası sisteminin hayvancılık sektöründe yeterince yaygınlaşmadığı göstermektedir. Bu bağlamda, finansal stratejilerin etkinliğini

artırmak için devlet desteklerinin güçlendirilmesi, üretici bilgilendirme faaliyetlerinin yaygınlaştırılması gerekmektedir.

Çeşitlendirme stratejileri ise hem üretim hem de gelir kaynaklarının çeşitlendirilmesini içermekte ve işletmenin risklere karşı esnekliğini artırmaktadır. Özellikle piyasa ve fiyat dalgalanmasının etkisini azaltmanın bir diğer yolu, sadece hayvansal üretime bağlı kalmamak, bitkisel üretim, yan işler ya da kırsal turizm gibi alternatif gelir kaynakları oluşturmaktır (Meraner & Finger, 2017). Özellikle mevsimsel ürünler veya aile iş gücüyle yapılabilecek işler, düşük yatırım gerektirir ve riskin farklı sektörlere yayılmasını sağlar. Bu sayede sektörel ve çevresel risklere karşı işletmeler daha dirençli hale gelebilirler (Meraner ve Finger 2017). Ancak çeşitlendirme stratejilerinin uygulanabilirliği, bölgesel kaynaklara, altyapıya ve üreticinin yönetim kapasitesine bağlıdır. Örneğin, yüksek rakımlı ve iklimsel olarak dezavantajlı bölgelerde çeşitlendirme olanakları sınırlı kalabilirken, entansif üretim yapan işletmelerde bu stratejiler daha etkin biçimde uygulanabilmektedir (Yalçınkaya, 2017).

Bu üçlü sınıflama çerçevesi, hayvancılık sektöründe risklerin yalnızca tek boyutlu araçlarla değil, çok katmanlı ve entegre stratejilerle yönetilmesi gerektiğini göstermektedir. Ancak, üreticilerin çoğunun riskleri yönetmek için kendi bilgi ve deneyimlerine dayalı karar alma eğiliminde olduğu, resmi bilgi kaynaklarının (veteriner, danışman, kurumlar) yeterince etkin kullanılmadığı söylenebilir (Garforth ve ark., 2013). Bununla birlikte, eğitim düzeyi yüksek, genç ve büyük ölçekli işletme sahiplerinin daha planlı ve çoklu stratejilere başvurma eğiliminde oldukları söylenebilir (Valeeva et al. 2011; Meraner & Finger, 2017). Özellikle Avrupa'da geliştirilen özelleştirilmiş risk yönetim modellerinin Türkiye koşullarına uygun olarak revize edilmesi ve yaygınlaştırılması, risklerin daha etkin yönetilmesine katkı sağlayabilir.

Sonuç ve Öneriler

Türkiye'de hayvancılık işletmeleri, özellikle hayvan sağlığı, yem fiyatları ve piyasa belirsizliği gibi alanlarda yüksek risk algısına sahip olup, bu risklere karşı başvurdukları yönetim stratejileri genellikle sınırlı ve kişisel deneyim temelli olduğu söylenebilir.

Sonuç olarak, hayvancılık sektöründe risk yönetimi sadece teknik bir süreç değil, aynı zamanda üreticinin risk algısı, davranış biçimi ve çevresel koşulların etkileşiminden oluşan çok boyutlu bir yapıdır. Bu nedenle etkili bir risk yönetimi yaklaşımı, üreticinin bireysel özelliklerini, sosyoekonomik yapısını ve faaliyet gösterdiği bölgenin iklimsel, coğrafi ve altyapısal koşullarını dikkate alan bütüncül bir strateji gerektirmektedir. Risk yönetim araçlarının başarılı bir şekilde uygulanabilmesi için, üreticiye yönelik eğitim ve yayım hizmetlerinin güçlendirilmesi, bölgesel özelliklere göre uyarlanmış sigorta ve finansal destek mekanizmalarının geliştirilmesi büyük önem taşımaktadır. Özellikle fiyat dalgalanmalarına karşı, küçük ölçekli işletmelerin doğrudan pazarlama, sözleşmeli üretim ve kooperatifleşme yoluyla pazarlık güçlerini artırmaları; devletin ise fiyat istikrarını destekleyici fiyat uygulamaları, müdahale alımları ve girdi destekleri ile piyasayı düzenlemesi gerekmektedir.

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EFFECT OF MYCORRHIZAL INOCULATION OF ASPIR (CARTHAMUS TINCTORIUS L.) SEEDS ON GERMINATION UNDER DIFFERENT IRRIGATION WATER SALINITY CONDITIONS

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ABSTRACT

Varieties adapted to abiotic stress have a stronger structure in the growth and development processes, leading to higher quality and higher yield potential. Reducing stress conditions encountered in the plant production process to an optimal level is crucial, especially during germination. In plants, gaining tolerance to stress can be achieved by various biological methods.

This study was conducted to determine some physiological and morphological responses during the germination period in Dinçer Aspir (Carthamus tinctorius L.) cultivar to which mycorrhiza doses (0, 0.03 g, 0.07 g, 0.10 g) were applied under different conditions of irrigation water salinity (0, 1, 4 and 8 dS/m). In the study, the germination rate, germination speed, fresh weight and dry weight decreased with increasing salinity, while the average germination time and root length increased. When mycorrhiza was applied, it was found that the fresh and dry weights generally increased, but the germination rate decreased. The highest fresh weight and average root length were found with the 0.07 g mycorrhiza application at 4 dS/m irrigation. However, the highest germination rate was observed with the 0.03 g mycorrhiza application at the same salinity. The highest germination and biomass increase was generally observed with medium salinity and mycorrhiza application.

As a result, it was concluded that mycorrhizal applications have an effect on enhancing the resistance mechanisms of aspirin under salt stress conditions, but this effect varies according to dose and salinity. In this respect, mycorrhiza can be evaluated as a potential biological support for sustainable production in safflower cultivation.

Keywords: Irrigation Water Salinity, Mycorrhiza, Abiotic Stress, Germination, Safflower

FARKLI SULAMA SUYU TUZLULUĞU KOŞULLARINDA ASPİR (CARTHAMUS TİNCTORİUSL.) TOHUMLARINA MİKORİZA AŞILAMASININ ÇİMLENME ÜZERİNE ETKİSİ

ÖZET

Abiyotik strese adapte olan çeşitler büyüme ve gelişme süreçlerinde daha güçlü bir yapıya sahip olduğu için daha kaliteli ve daha yüksek verim gücüne sahip olurlar. Bitkisel üretim sürecinde karşılaşılan stres koşullarının optimum düzeye indirgenebilmesi özellikle çimlenme döneminde önemli rol oynamaktadır. Bitkilerde, strese karşı tolerans kazanımı çeşitli biyolojik yöntemler ile sağlanabilmektedir.

Bu çalışma, farklı sulama suyu tuzluluğu (0, 1, 4 ve 8 dS/m) koşullarında mikoriza dozları uygulanan (0, 0.03 g, 0.07 g, 0.10 g) dinçer aspir (Carthamus tinctorius L.) çeşidinde, çimlenme dönemine ait bazı fizyolojik ve morfolojik tepkileri belirlemek amacıyla yürütülmüştür. Çalışmada, artan tuzluluk seviyelerinde çimlenme oranı, çimlenme hızı, yaş ve kuru ağırlıklarda azalış meydana gelirken ortalama çimlenme süresi ve kök uzunluğunda artış görülmüştür. Mikoriza uygulamalarında ise genel olarak yaş ve kuru ağırlıklarda artış görülürken çimlenme hızını düşürdüğü tespit edilmiştir. En yüksek yaş ağırlık ve ortalama kök uzunluğu 4 dS/m ile sulanan 0.07 g mikoriza uygulamasında belirlenmiştir. Bununla birlikte en yüksek çimlenme oranı aynı tuzluluk seviyesindeki 0.03 g mikoriza uygulamasında görülmüştür. En yüksek çimlenme ile biyokütle artışı genel olarak orta düzey tuzluluk ve mikoriza uygulamalarında tespit edilmiştir.

Sonuç olarak, tuz stresi koşullarında mikoriza uygulamalarının aspirin direnç mekanizmalarını güçlendirecek etkisinin olduğu, ancak bu etkinin doz ve tuzluluk düzeyine göre değişkenlik gösterdiği sonucuna ulaşılmıştır. Bu yönüyle mikoriza aspir tarımında sürdürülebilir üretim için potansiyel bir biyolojik destek olarak değerlendirilebilir.

Anahtar Kelimeler: Sulama Suyu Tuzluluğu, Mikoriza, Abiyotik Stres, Çimlenme, Aspir

1. GİRİŞ

Artan insan nüfusu ve iklim değişikliğinin yol açtığı sorunlardan ötürü tarım sektörünü daha fazla üretim yapmaya zorlamaktadır. Ancak bu üretimin temelini oluşturan su kaynaklarının hem sınırlı olması hem de iklimsel değişiklikler nedeniyle giderek azalması, süreci daha da zorlaştırmaktadır. Buna ek olarak, suyun bilinçsizce kullanılması ve kirlenerek kullanılamaz hale gelmesi tarımda tuzlu sulama koşullarının yaygınlaşmasına neden olmakta ve bu durum bitkisel üretim açısından ciddi bir sorun haline gelmektedir. Topraklarda ve sulama sularında biriken tuzlar bitkilerin çimlenme, çıkış ve besin alımını zorlaştırmakla birlikte büyüme ve verimde olumsuz etki oluşturmaktadır. Dolayısıyla tarımsal üretim için bitkilerin tuzlu koşullara dayanıklı veya bu koşullarda yetiştirilmesi daha avantajlı olarak görülen stratejik olarak seçilecek tür veya cinslerin seçimi giderek daha önemli olmaktadır. Bu stratejik bitkilerden biri olan aspir *(Carthamus tinctorius L.)* dünya genelinde yaklaşık 816 bin hektarlık ekiliş alanı ve 653 bin tonluk toplam üretimiyle önemli bir yağ bitkisi olarak ön plana çıkmaktadır (Beyyavaş ve ark., 2023; FAO, 2022). Küresel aspir üretiminin ise yaklaşık %95'i Kazakistan, Rusya, ABD, Meksika, Türkiye ve Hindistan gibi ülkeler tarafından ihtiyaç karşılanmaktadır. Türkiye'de üretim alanı olarak ise 14,59 bin hektarlık alanda ekilen aspir bitkisi yıllık olarak 16,20 bin ton üretim miktarı ve buna ek olarak 1.110 kg ha^{-1} Verim potansiyeli ve ekonomik değeriyle tarımsal açıdan öne çıkan önemli bir ürün olarak değerlendirilmektedir (Beyyavaş ve ark., 2023; TÜİK, 2022).

Aspir bitkisinin tohumları, %13–46 oranında değişken olarak yağ içeriğine sahip olup (Beyyavaş ve ark., 2023; Beyyavas ve Haliloglu, 2021; Dogan, 2021), bu yağın yaklaşık %90'ı oleik ve linoleik asit gibi doymamış yağ asitlerinden oluşmaktadır (Belgin ve ark., 2007; Beyyavaş ve ark., 2023; Johnson ve ark., 1993). Ayrıca yüksek tokoferol (E vitamini) içeriği nedeni ile antioksidan özelliklerinin bulunması sayesinde aspir yağının besin takviyesi olarak kullanılmasının yanı sıra kozmetik sanayi gibi alanlarda da oldukça tercih edilmektedir (Bergman ve Kandel, 2019; Beyyavaş ve ark., 2023; Matthäus ve ark., 2015).

Ancak bu değerli olarak görülen ve yüksek besin potansiyeline sahip olduğu bilinen bitkinin tarımsal üretimi özellikle yarı kurak ve kurak bölgelerde karşılaştıkları abiyotik stres faktörlerinden de önemli ölçüde etkilenmektedirler. Kuraklık ve tuzluluk gibi abiyotik stres faktörlerinin tarımsal üretimde de verime ve kalitede sınırlayıcı temel unsurlardan biri olmasına ek olarak (Bot ve ark., 2000; Somerville ve Briscoe, 2001; Ulukapı ve ak., 2020) ılıman iklim kuşağında bulunan Türkiye gibi yarı kurak ve kurak bölgelerde yetişilmekte olan aspir bitkisinin ciddi üretim kayıplarına neden olduğu bilinmektedir (Hamzehzarghani ve ark., 2011; Koç, 2020). Orta Anadolu Bölgesi de Türkiye'de aspir ekiminin en yoğun olarak tarımının yapıldığı alanlardan biri olup burada meydana gelen erken ilkbahar kuraklığı aspir veriminde belirgin bir düşüşe yol açmaktadır. Tarım arazilerinin yaklaşık %45'inin kuraklık tehdidi altında olduğu bildirilmekte ve nüfus artışına, iklim değişikliğine bağlı olarak mevcut su kaynaklarının yetersiz kalacağı tahmin edilmektedir (Somerville ve Briscoe, 2001; Bot ve ark., 2000)

Abiyotik stres faktörlerinden birisi olan kuraklık ile ilgili stres çalışmaları aspir bitkisi için büyük ölçüde eksik ve yersizdir kalmaktadır (Koç, 2020; Singh, 2006). Ancak özellikle tarla bitkilerinde, bu tür abiyotik stres faktörlerinin verim üzerindeki olumsuz etkilerini azaltmak

amacıyla yapılan bazı çalışmalarda kuraklık ve tuzluluk stresine dayanıklı genotiplerin geliştirilmesi ve biyolojik uygulamaların etkinliği üzerine yoğunlaşmaktadır.

Tarımda bitkisel üretimde abiyotik streslerden biri olan tuzluluk faktörünün stresinin azaltılması ve olası verim, büyüme gibi kayıpların en aza indirilmesi için tuz stresine karşı toleranslı genotiplerin ıslahı gibi bazı biyoteknoloji ve fonksiyonel genomik çalışmaların arbusküler mikoriza funguslarının ve bitki gelişimini teşvik edici bakterilerin (Plant Growth Promoting Bacteria–PGPB) kullanılması, bunlara ek olarak hormon uygulamaları ve tohuma priming teknikleri gibi birçok yönetim stratejisi bulunmaktadır (Farooq ve ark., 2017; Gupta ve Rautaray 2025; Iqbal ve ark., 2020; Tarhan ve ark., 2024).

Mercimek (*Lens culinaris M*.) bitkisinin çimlenme ile ilgili yapılmış bir çalışmada 100 mM seviyesinde dahi çimlenme ve fide gelişiminin tüm özelliklerinde kayda değer bir azalış görülmesine karşın, 200 mM NaCl konsantrasyonlarında önemli çimlenme ve gelişme kayıpları ortaya çıktığı bildirilmiştir (Tarhan ve ark., 2024). Bordi (2010) ve Tarhan ve ark. (2024) ise kolzada *(Brassica napus)* NaCl uygulamasına bağlı olarak çimlenme yüzdesinin ve hızının sırasıyla %38 ve %33'e kadar azaldığını raporlamıştır. Benzer şekilde, Khodarahmpour ve ark. (2012) ve Tarhan ve ark. (2024), mısır *(Zea mays)*'da 240 mM NaCl uygulamasının çimlenme oranında %32, kök uzunluğunun da ise %80, sürgün uzunluğunu %78 ve tohum gücünü %95 oranında azalttığını yaptığı çalışma sonucu bildirmiştir.

Görüldüğü üzere tuzluluk stresi ve bitki büyümesi gibi veriminde etkilendiği olumsuzlukların etkilerinden kurtulmak adına pek çok strateji düşünülüp geliştirilmiştir. Bu stratejilerin birçoğu, bitki-mikroorganizma faydalarından yararlanarak sürdürülebilir ve çevre dostu üretimi hedeflemektedir. Özellikle arbusküler mikoriza funguslarının bitki köklerinde simbiyotik bir ilişki oluşturarak su ve besin alımını iyileştirdiği bilinmektedir. Aynı zamanda strese bağlı oluşan iyon dengesizliklerinin etkilerini belirli düzeyde azaltarak bitkileri desteklemektedir (Onoğur, 1999). Bu kapsamda bakıldığında mikoriza uygulamalarının tuz stresi altındaki bitkiler üzerindeki etkileri giderek daha fazla araştırılmakta ve umut verici sonuçlar alınmaktadır.

Mikoriza mantarlarının kolonileşmesinin 1000 milyon yıl öncesine kadar dayandığı düşünülmekte olup bu zamandan itibaren mikoriza fungusları ile bitkilerin aralarında karşılıklı olarak etkileşim kurulmaya başladığı düşünülmekte ve hatta bitkilerin ekosisteme dağılıp yayılması durumuna yol açtıkları tahmin edilmektedir (Smith ve Read, 2008; Yıldız, 2009).

Kurak ve tuzlu tarım alanlarında bitki verimliliğini artırmak ve çevresel stres faktörlerinin etkilerini azaltmak amacıyla biyolojik yöntemlere duyulan ilgi giderek artmaktadır. Mikoriza mantarları, bitki kökleriyle simbiyotik ilişki kurarak su ve besin maddesi alımını artıran önemli biyolojik ajanlardan biridir (Smith ve Read, 2008; Yıldız, 2009). Yapılan araştırmalarda mikoriza uygulamalarının özellikle kuraklık ve tuzluluk gibi stres koşullarında bitki büyümesi ve gelişimi üzerinde olumlu etkiler sağladığını göstermektedir (Çelik ve ark., 2019; Sönmez ve ark., 2013). Mikoriza aşılaması yaprak yaş ağırlığı, yaprak kuru ağırlığı gövde uzunluğu gibi morfolojik özelliklerde de anlamlı artışları desteklemektedir (Özbucak ve ark., 2020).

Yapılan benzer bir artan sulama suyu tuzluluğu koşullar altında soğan bitkisinin mikoriza mantarı ile aşılanmasının yaprak alanı ile yeşil ve kuru aksam ağırlıklarında olumlu artış

sağladığı bildirilmiştir (Borde ve ark., 2010; Küçük ve ark., 2024). Bakla *(Vicia faba)* üzerinde yapılan başka bir benzer çalışmada ise mikoriza aşılamasının tuz stresine karşı toleransı artırarak bitki kuru aksam ağırlığını ve bitki boyunu artırdığı, mikoriza uygulaması yapılmayan diğer bitkilere göre daha yüksek boyda olduğu rapor edilmiştir (Kumar ve ark., 2022; Küçük ve ark., 2024).

Farklı tuz dozları uygulanan arpa bitkisinin *(Hordeum vulgare)* mikoriza (mikorizalı ve mikorizasız) uygulamasının etkilerinin araştırıldığı bir diğer çalışmada, tuz stresine maruz kalan bitkilerde bazı enzim faaliyetlerinin iyileştirildiği belirtilmiştir.100 mM NaCl + mikoriza uygulamasının 200 mM NaCl + mikoriza uygulamasına göre tuzun olumsuz etkisini daha fazla azalttığı mikorizanın tuz stresine karşı fayda sağladığı vurgulanmaktadır (Küçük ve ark., 2024).

Özellikle tuz stresinin aspir bitkisi üzerindeki olumsuz etkileri dikkate alındığında, bu bitkinin stres toleransını artıracak biyolojik yöntemlerin araştırılması büyük önem taşımaktadır. NaCl gibi tuzlar, bitkilerin su alımını azaltarak hücre zarında iyon dengesini bozmakta ve gelişimi engellemektedir (Ahmed ve ark., 2017; Bybordi ve Tabatabaei, 2009; Kereçin ve ark., 2024; Wu ve ark., 2015). Mikoriza mantarı, bitkilerin kök sistemlerini etkili bir şekilde enfekte ettiğinde, bitkiye normal koşullara kıyasla daha fazla besin ve su taşımakta olup tuz stresine karşı bitkiye yardımcı olmaktadır (Ortaş, 1997).

2. Materyal ve Yöntem

3.1. Deneme Alanı ve Koşulları

Bu çalışma, 2025 yılında Ahi Evran Üniversitesi Ziraat Fakültesi Biyosistem Mühendisliği Bölümü Laboratuvarında (39,143445° K; 34,12144° D; rakım 1069 m) yürütülmüştür. Çimlenme denemesi, 25ºC sabit sıcaklığa ayarlanmış inkübatörde karanlık ortamda gerçekleştirilmiştir. Tesadüf parseller faktöriyel deneme deseni düzenine göre 3 tekerrürlü olarak gerçekleştirilmiş olup, sıcaklık ve nem koşulları sabit tutulmuştur.

2.2. Kullanılan Materyaller ve Metot

Denemede kullanılacak petri kapları önce %5'lik (endüstriyel) sodyum hipoklorit ile yıkanıp saf su ile durulama işleminden geçirilmiştir. Daha sonra kullanılacak Petri kapları ve diğer malzemelerde herhangi bir fungisit oluşumunu önlemek amacıyla, petri kaplarına sterilizasyon işlemi tekrar uygulanarak 70°C'de 150 dk boyunca etüvde bekletilmiştir. Çimlenme denemesinde tuzluluk stresi faktörünü oluşturmak amacıyla, kontrol grubunda distile su (0dS/m) tuz ilave edilmeksizin saf su kullanılmıştır. Diğer gruplarda ise dört farklı tuz konsantrasyonu belirlenerek 1 dS/m, 4 dS/m ve 8dS/m seviyelerinde hazırlanmıştır. Bu çözeltiler, Sodyum Klorür (NaCl), Magnezyum Sülfat ($MgSO_4$) ve Kalsiyum Klorür ($CaCl_2$) kullanılarak hazırlanmış ve EC metre ile doğrulanmıştır. Denemede *Dinçer* aspir (*Carthamus tinctorius L.*) çeşidine ait, homojen tohumlardan seçilerek materyal olarak kullanılmıştır. Tohum sterilizasyonu için %1,5'lik sodyum hipoklorit çözeltisi kullanılarak tohumlar 5 dakika süreyle %1,5'lik sodyum hipoklorit çözeltisinde bekletilmiş, hemen ardından 5 dakika süreyle saf su içerisinde tutulmuştur. Mikrobiyal gübre olarak Endo Roots Soluble (ERS) mikoriza kullanılmıştır. Uygulamalarına göre ise 0.03(g), 0,07(g) ve 0,10 (g) miktarları kullanılarak

aşılama uygulanması yapılmıştır. Mikoriza aşılaması çimlenme denemesinde kullanılacak tohumlara doğrudan uygulanarak gerçekleştirilmiştir. Aşılama işlemi için, sterilize edilen tohumlar hafifçe nemlendirilmiş, ardından belirlenen miktarda mikoriza tozu yüzeye eşit şekilde dağıtılmış ve homojen bir şekilde kaplanması sağlanmıştır. Çimlenme ortamı olarak steril Petri kapları ve filtre kağıtları kullanılmıştır. Petri kaplarının tabanına tek kat steril filtre kâğıdı yerleştirilmiş ve tohumlar belirlenen düzene göre yerleştirilmiştir. Her bir Petri kabına 20 adet tohum eklenmiştir. Tohumların kurumasını önlemek ve uygun çimlenme ortamını sağlamak amacıyla, ilgili tuz konsantrasyonlarına sahip çözeltiler 3 mL olacak şekilde her Petri kabına eşit miktarda damlatılmıştır (Kurtuluş ve Boydak, 2022) 2. gün de ise 2 mL solüsyon ile sulandıktan sonra bir daha sulamaya ihtiyaç görülmemiştir. Çözelti uygulaması kontrollü bir şekilde damlalık kullanılarak gerçekleştirilmiştir. Petrilerin kapları buharlaşmayı önlemek adına kapatılmıştır. Çimlendirme denemeleri 5 gün sürdürülmüştür.

2.3. Ölçüm ve Analizler

Bitki boyu (mm) ile kök ve gövde (mm) uzunluklarının belirlenmesinde her bir örnek milimetrik kâğıt üzerine yerleştirilerek kök tacı ile kök ucu arasındaki mesafe ölçülmüştür (Çavumirza ve Demir, 2023). Her bir grup için fidelerin kök uçundan boğaza kadar ölçülen uzunlukları toplayıp, bu toplamı o gruptaki fide sayısına bölerek (mm cinsinden) ortalama kök uzunluğu elde edilir. Fidelerin yaş ağırlıkları, ±0,001 g hassasiyetindeki dijital analitik terazide ölçülmüştür. Ölçümü takiben örnekler, 35 °C'deki etüvde 48 saat boyunca kurutularak sabit ağırlığa ulaşmaları sağlanmıştır. Kuru ağırlıklar da aynı terazinin ±0,001 g doğruluğuyla kaydedilmiştir. Kuru madde içeriği, örneklerin yaş ağırlığı ile kuru ağırlığı arasındaki fark temel alınarak hesaplanmış ve su kaybı miktarı hesaplanmıştır (Kaman, 2017).

Çimlenme oranı (%): Tohumların çimlenme başarısını değerlendirmek amacıyla her bir Petri kabına 20 adet steril edilmiş tohum yerleştirilmiştir. Petri kapları sabit sıcaklık koşullarında tutulmuş tohumlar her gün aynı saatte gözlemlenmiştir. Kökçük uzunluğu 2 mm'ye ulaşan tohumlar çimlenmiş kabul edilerek ortamdan uzaklaştırılmıştır (Goertz ve Coons, 1989; Elkoca, 1997; Kayış, 2014) Çimlenme oranı, aşağıdaki eşitlik 1 kullanılarak hesaplanmıştır.

Çimlenme oranı (%) = (Çimlenen toplam tohum sayısı / 20) x 100 (Eşitlik 1)

Çimlenme hızı: Tohumların belirli bir süre zarfında ne kadar hızlı çimlendiğini gösteren önemli bir fizyolojik parametredir. Bu parametre, özellikle stres koşullarında çimlenmenin zamanlamasındaki farklılıkları ve gecikmeleri sayısal olarak değerlendirmeye olanak sağlar. Çimlenme hızı, her bir günde çimlenen tohum sayısının, o gün sayısına oranlarının toplamı alınarak hesaplanmaktadır (Güldüren, 2012; Abazarian 2011) (Burada n1, n2… çimlenen tohum sayısını, t1, t2…. İse çimlenmenin gerçekleştiği gün sayısını ifade etmektedir.

Çimlenme hızı=n1/t1+n2/t2+……+nn/tn (Eşitlik 2)

Ortalama Çimlenme Süresi (OÇS): Çimlenmenin sadece gerçekleşip gerçekleşmediğini değil, aynı zamanda ne kadar sürede tamamlandığını gösteren ortalama çimlenme süresi (OÇS), tohumların zamana bağlı çimlenme performansını analiz etmede kullanılmıştır. Her gün çimlenen tohum sayısı (f) ile o günün sırası (x) çarpılarak elde edilen toplam, çimlenen tüm tohum sayısına bölünerek ortalama çimlenme süresi hesaplanmıştır (Kaya ve ark., 2005).

$$OÇZ\ (gün)=\Sigma(fx)/\Sigma f \qquad \text{(Eşitlik 3)}$$

3. GELİŞME

4.1.Sulama Suyu Tuzluluk Uygulamaları

Petri kabı kullanılarak yapılan çimlenme denemelerinde elde edilen yaş ve kuru ağırlık verilerinin artan sulama suyu tuzluluğunun aspir bitkisinin gelişiminde ve çimlenmesi üzerinde olumsuz etkiler yarattığını açıkça ortaya koymuştur. En yüksek yaş ve kuru ağırlık değerleri saf su (S1) uygulamasında elde edilmiştir. Tuz konsantrasyonunun artmasıyla birlikte biyokütle üretiminde kademeli bir azalma gözlenmiştir. Özellikle S4 (8dS/m) uygulamasında yaş ve kuru ağırlıklardaki belirgin düşüş gözlemlenmiştir. Yüksek tuzluluk koşulları altında S4 (8dS/m) bitkinin su alımında ve kuru madde birikiminde azalış olmuştur. Elde edilen bulgular doğrultusunda aspir bitkisinin çimlenme sürecinde tuz stresine karşı duyarlı olduğunu ve artan tuz seviyelerinin genç fide gelişimini anlamlı biçimde gerilettiğini doğrulamaktadır (Çavumirza ve Demir, 2023). Kaya ve ark. (2003) çalışmasında, Dinçer aspir çeşidinde artan tuz dozlarıyla birlikte gövde kuru ağırlığında azalma gözlemlemiştir. Bu durumda çalışmamızın sonucunu desteklemektedir. Tuz stresinin Dinçer çeşidinin gövde gelişimini olumsuz etkilediğini ve biyokütle birikiminin tuz düzeyinde artış meydana geldikçe bitki gelişimini azalttığını ortaya koymuştur.

Ortalama kök uzunluğu verilerine bakıldığında tuzluluk düzeylerinin aspir bitkisinin kök gelişimi üzerinde bazı azrtışlar oluşturduğu gözlenmiştir. Özellikle S3 (4 dS/m) uygulamasında kök uzunluğunun en yüksek değere ulaşmış olması bitkinin orta düzey tuz stresine karşı bir yanıt olarak düşünülebilir ve köklerini uzatarak suya ulaşma çabasını artırdığını düşündürmektedir. Ancak S4 (8dS/m) seviyesinde kök uzunluğunda meydana gelen azalma da yüksek tuz konsantrasyonlarının kök gelişimini sınırladığı görülmektedir. Buna karşın, saf su uygulamasında (S1) en kısa kök uzunluğunun ölçülmesi, bitkinin stres altında daha çok kök gelişimi benimsediğini ortaya koymaktadır. Benzer bir şekilde Çavumirza ve Demir, (2023) aspir bitkisinde artan tuz miktarının kök uzunluğunda azalmalar olduğunu yaptıkları çalışma sonucu rapor etmişlerdir.

Farklı tuzluluk seviyelerinde yapılan çimlenme denemeleri sonucunda, artan tuz konsantrasyonunun aspir tohumlarının çimlenme oranlarını olumsuz etkilediği belirlenmiştir. En yüksek çimlenme oranı saf su (S1) uygulamasında elde edilmiştir. Tuzluluk düzeyinin artmasıyla birlikte çimlenme oranlarında kademeli bir düşüş eğilimi gözlenmiştir. Özellikle S4 (8dS/m) uygulamasında çimlenme oranındaki azalışlar yüksek tuz konsantrasyonlarının tohumun su alımını ve çimlenme sürecini engellediğini göstermektedir. Bu durumda aspir bitkisinin çimlenme aşamasında tuz stresine duyarlı olduğunu ve erken dönemde bile

tuzluluğun olumsuz etkilerine maruz kaldığını ortaya koymaktadır. Öte yandan, abiyotik stres olan tuz stresinin tohum çimlenmesi üzerindeki etkisinin özünde osmotik basınç artışı ve iyon toksisitesi ortaya çıkmakta; Sodyum (Na^+) ve Klor (Cl^-) gibi iyonlar tohumun su alımının önüne geçerek çimlenmeyi doğrudan baskılamaktadır (Essa, 2002; Güldüren ve Elkoca, 2012; Sadeghian ve Yavari, 2004).

Tuzlu su uygulamalarının aspir tohumlarının ortalama çimlenme süresi üzerindeki etkisi değerlendirildiğinde, tuzluluk seviyesindeki artışın çimlenme süresini uzattığı görülmüştür. En kısa çimlenme süresi saf su (S1) uygulamasında kaydedilirken, tuz konsantrasyonunun artmasıyla birlikte çimlenme gecikmiş ve S4 (8 dS/m) uygulamasında en uzun süreye ulaşmıştır. Elde edilen bulgular, tuz stresinin yalnızca çimlenme oranını değil, aynı zamanda çimlenme hızını da olumsuz etkilediğini göstermektedir. Farklı aspir çeşitlerinin tuza toleransı üzerine yaptıkları çalışmada, Arslan ve ark. (2012), artan tuzluluğun çimlenme oranı, çimlenme süresi ve erken fide gelişimi üzerinde olumsuz etkiler yarattığını, ayrıca çeşitlerin tuzluluğa karşı farklı tepkiler gösterdiğini belirtmişlerdir. Bu durum, elde edilen bulgularla uyum göstermektedir.

Farklı tuzluluk seviyelerinde yapılan denemelerde, çimlenme hızının tuz konsantrasyonu arttıkça azaldığı belirlenmiştir. En yüksek çimlenme hızı saf su (S1) uygulamasında gözlenmiş olup, artan tuz düzeyleri ile çimlenme süreci yavaşlamış ve en düşük değer S4 (8dS/m) uygulamasında kaydedilmiştir. Bu durum, yüksek tuzluluk koşullarının aspir tohumlarının metabolik aktivasyonunu geciktirerek çimlenme hızını önemli ölçüde düşürdüğünü ortaya koymaktadır. Aydın, (2015) Çalışmamıza uygun olarak tuz stresinin çimlenme hızını tuzluluğun her düzeylerinde arttığını rapor etmiştir.

3.2. Mikoriza Uygulamaları

Aspir bitkisine uygulanan mikoriza dozlarının yaş ve kuru ağırlık üzerine etkilerine bakıldığında mikorizasız grupta (M1) en düşük değerlerin elde edildiği, mikoriza uygulamalarıyla birlikte yaş ve kuru ağırlıklarının anlamlı şekilde arttığı belirlenmiştir. Özellikle orta doz mikoriza uygulaması (M3) en yüksek kuru ağırlık değerini verirken, yaş ağırlıkta da benzer bir artış gözlenmiştir. Bu bulgularla beraber arbusküler mikoriza mantarlarının aspir fidelerinin erken dönem gelişimini desteklediğini ve su-besin alımını iyileştirerek biyokütle birikimini artırdığını göstermektedir. Elde ettiğimiz verilerden yararlanarak uygun dozda mikoriza uygulamasının aspir üretiminde erken gelişim avantajı sağlayabileceğini ortaya koymaktadır. Mikoriza aşılamasının yaprak yaş ağırlığı, yaprak kuru ağırlığı, gövde uzunluğu gibi morfolojik özelliklerde de anlamlı artışlara neden olmuştur (Özbucak ve ark., 2020). Gözlemlendiği üzere, mikoriza uygulaması özellikle tuz stresinin baskıladığı gelişim parametrelerini iyileştirme potansiyeli taşımaktadır. Benzer şekilde, Sönmez ve ark. (2013), mikorizalı uygulamaların mikorizasızlara göre mısır bitkisinde yaş ve kuru ağırlık ile P ve Zn alımında da anlamlı artış sağladığını bildirmiştir.

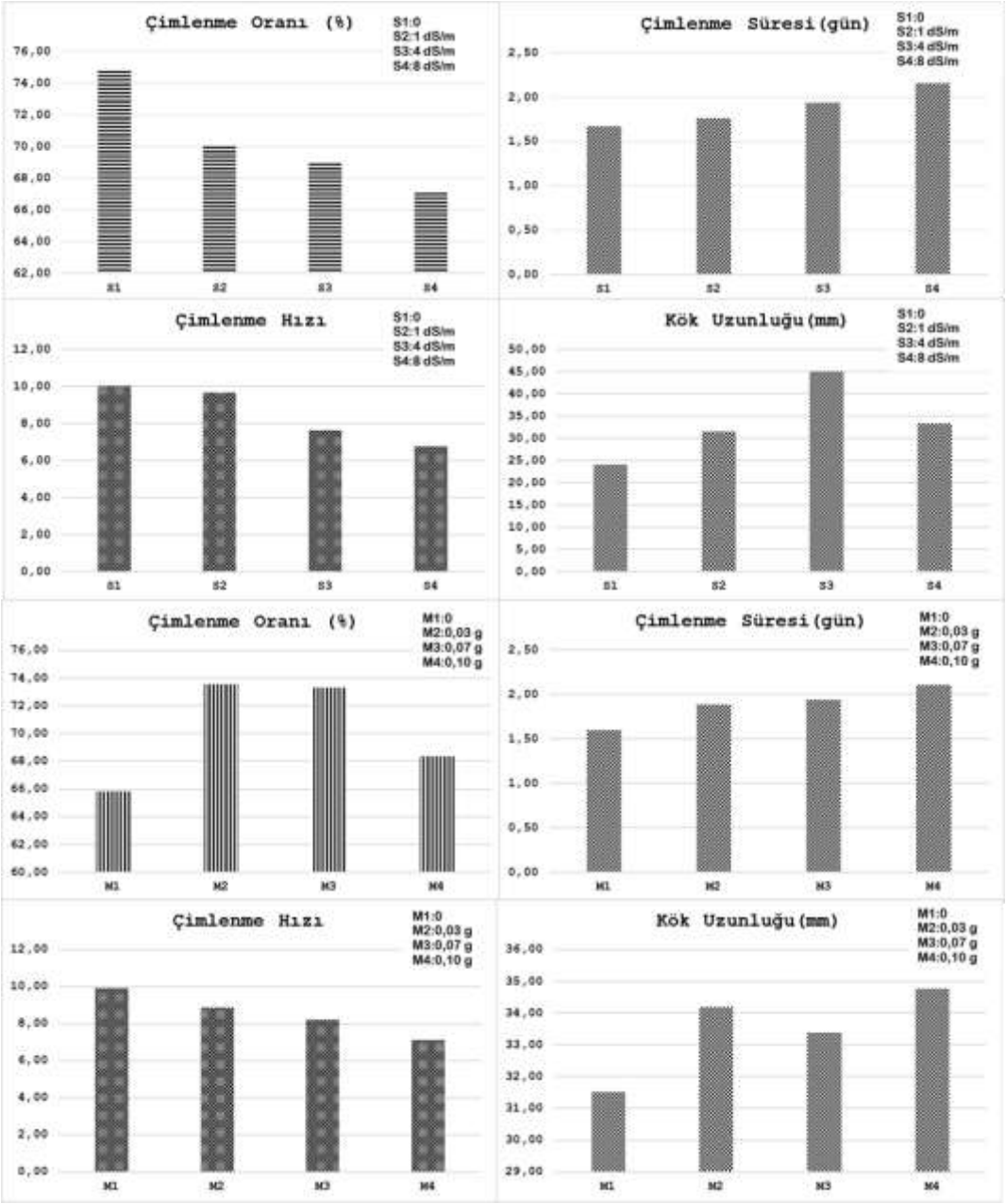
Mikoriza uygulamalarının aspir bitkisinin kök gelişimi üzerindeki etkileri değerlendirildiğinde, mikorizasız gruba kıyasla tüm mikoriza dozlarında kök uzunluğunun arttığı gözlenmiştir. En kısa kök uzunluğu mikorizasız (M1) grupta ölçülürken, en uzun kök değerine yüksek doz

mikoriza uygulamasıyla (M4) ulaşılmıştır. Bu durum, arbusküler mikoriza mantarlarının kök sistemini teşvik edici etkisini ve bitkinin topraktan su ile besin alımını artırarak kök büyümesini desteklediğini göstermektedir. Mikoriza aşılaması aspir bitkisinin kök morfolojisinde iyileşme sağlayarak stres koşullarına karşı adaptasyon kabiliyetini artırabilir. Mikorizanın köklerde simbiyotik olarak yaşamaları sonucunda bitkide besin maddelerinin alımına olumlu etkisinin olması ve bunun sonucunda bitki verimi ve verim değerlerinin artmış olduğu köklerde mikoriza aktivitesi sonucunda daha iyi gelişiminin teşvik edebileceği sonucuna varıldı (Kardüz ve Öztekin, 2015). Mikoriza aşılaması ile aspir bitkisinin gövde uzunluğu, yaş ağırlığı, kuru ağırlığı gibi morfolojik özelliklerde de anlamlı artışlara neden olmuştur (Özbucak ve ark., 2020) Mikorizal aşılama bitkilerde tuz stresine karşı toleransını arttırmada yardımcı olmaktadır (Sharma ve Adholeya, 2004; Çimrin ve ark., 2020).

Mikoriza uygulamalarının aspir tohumlarının çimlenme oranı üzerindeki etkilerine bakılıp değerlendirildiğinde, mikorizasız (M1) uygulamada en düşük çimlenme oranı kaydedilmiştir. Mikoriza aşılaması ile bu oran anlamlı şekilde artmıştır. En yüksek çimlenme oranı orta doz mikoriza (M2) grubunda gözlemlenmiştir. Yüksek dozda (M4) çimlenme oranı bir miktar azalma eğilimi olduğu görülmektedir. Bu durum neticesinde mikoriza fungusunun toz formda olmasından kaynaklanıyor olabilir. Çalışmamızda mikoriza uygulaması, düşük ve orta düzey tuz (S2-S3) koşullarında ve düşük, orta (M2-M3) düzey mikoriza aşılamasının etkisi olarak çimlenmede ve fide gelişimini anlamlı düzeyde desteklemeler görülmektedir. Bu sonuçlar, Altunlu (2019) tarafından bildirilen bulgularla örtüşmektedir.

Farklı dozlarda uygulanan mikoriza mantarlarının aspir tohumlarının ortalama çimlenme süresi üzerindeki etkileri mikoriza uygulamasının çimlenme süresini uzattığı belirlenmiştir. En kısa çimlenme süresi kontrol (M1) grubunda olmuştur. Mikoriza uygulamasında ise çimlenme süresi en uzun değerine ulaşmıştır. Mikoriza uygulamalarının çimlenmeyi geciktirici etkisi olmuştur. Bu durum mikoriza sporlarının toz formda olmasından ve mantarın kök ile ortam neminden yararlanma kaynaklanabilir ve bu durum ortamın ozmotik baskı oluşmasına zemin hazırlamış olabilir. Nitekim önceki çalışmalarda da artan tuzluluk seviyelerinde fasulye ve benzeri türlerde tohum çimlenmesinin ozmotik baskı nedeniyle azaldığı ve çimlenme süresinin uzadığı bildirilmiştir (Esechie, 1994; Goertz ve Coons, 1989; Güvenç ve Kantar, 1996; Özdemir ve Engin, 1994; Kırtok ve., 1994; Kaya ve ark., 2005; Güldüren ve Elkoca, 2012).

Farklı mikoriza dozlarının aspir tohumlarının çimlenme hızı üzerindeki etkilerine bakıldığında çimlenme hızının mikorizasız grupta (M1) en yüksek olmuştur. Mikoriza dozları arttıkça bu hızda kademeli bir azalma gözlendiği belirlenmiştir. Bu durumun mikoriza uygulamalarının çimlenme sürecine başlangıçta gecikmeli bir etki yaratabileceğini, simbiyotik ilişkinin kurulmasının zaman aldığını göstermektedir. Her ne kadar çimlenme oranı ve gelişim parametreleri genel olarak mikoriza lehine olsada, çimlenme hızındaki bu düşüşün uygulama dozunun dikkatli olarak belirlenmesi gerektiğini ve erken dönemde fizyolojik dengenin mikoriza etkisiyle yeniden şekillendiğini ortaya koymaktadır. Mikoriza belirli tuz kuşlularında strese karşı tolerans göstermede etkisi olurken daha yüksek dozlarda etkisini kaybediyor ve çok yüksek tuz koşullarında etkisiz kalabiliyor (Çimrin ve ark., 2020).

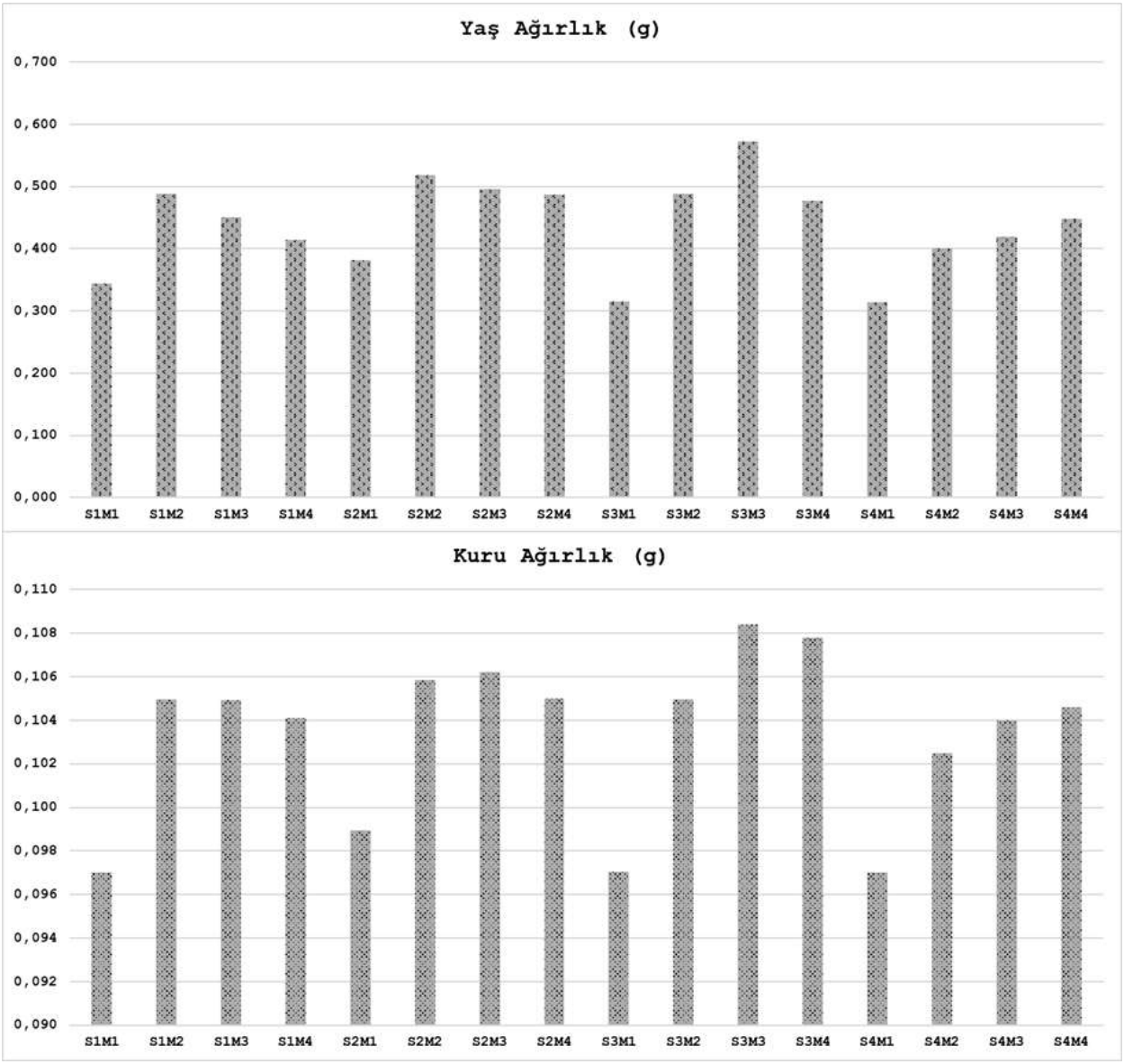


Şekil 1: Tuzluluk ve Mikoriza Uygulamalarının Etkisi

3.3. Tuzluluk ve Mikoriza Etkileşiminin Yaş ve Kuru Ağırlığa Etkisi

Yaptığımız çalışmada farklı tuzlu sulama suyu koşullarında mikoriza dozlarının aspir bitkisi fidelerinin yaş ağırlığı ile kök uzunluğu üzerindeki etkileri incelendi. Düşük tuzluluk koşulunda mikoriza dozu arttıkça bitkinin biyokütlesinde belirgin bir artış gözlenmiştir. S1M4 kombinasyonunda kontrol grubuna kıyasla anlamlı bir kazanım sağlanmış ve kök uzaması da desteklenmiştir. Orta tuzluluk seviyelerinde S2 ve S3'te orta doz (M3) mikoriza uygulamaları

her iki parametrede de en dengeli artışı sağlamıştır. Özellikle S3M3 kombinasyonunda kök gelişimi en etkili biçimde teşvik edilmiştir. Konulara tek tek bakılması durumunda kontrol (S1) grubu için distile su kullanılarak farklı dozlarda mikoriza aşılması aspir bitkisinde yaş ağırlığında doz artışına artış göstermektedir. (S2) grubunda ise S2 kontrolüne kıyasla anlamlı yaş ağırlık artışları gözlemlenmiştir. (S3) grubunda ise yine benzer sonuçlar görülmektedir. Mikoriza aşılamasının yaş ağırlığı orta düzey tuz koşulu altında da etkili olmaktadır. (S4) grubu ise yüksek tuzdan ötürü diğer çalışma gruplarına kıyasla daha az etkili olmuştur. Bu durumda bize açık bir şekilde yüksek tuzlulukta mikoriza aktivitesinde azalma meydana getirmektedir. Saf su koşullarında (S1) mikoriza dozu arttıkça kök sistemine gelişme görülmüştür. (S2) grubunda kök gelişimi mikoriza dozunun artışı ile artış göstermiş belirli bir seviyeden sonra ise doz miktarı fazla gelerek bir miktar azalma eğilimi göstermiştir. (S3) grubunda ise (S2) grubuna benzer bir tablo görülmektedir buna ek olarak yaptığımız çalışmada en iyi sonucu bu grupta elde edilmiştir. S3M3 grubu en uzun kök uzunluğu meydana gelmiştir. Bu durum da bize mikorizanın en iyi gelişim ve aktifliğini belirli tuz stresi altında verdiğini göstermektedir. (S4) grubunda tuz stresi mikoriza kolonizasyonuna fazla geldiği grafikte görülmektedir. Buna rağmen kontrol grubuna kıyasla daha iyi bir sonuç elde edilmiştir. Tuz stresi arttıkça mikoriza aktivitesi yavaşlamaktadır (Çimrin ve ark., 2020).



Şekil 2: Tuzluluk ve Mikoriza Etkileşiminin Yaş ve Kuru Ağırlığa Etkisi

4. SONUÇ VE ÖNERİLER

Yapmış olduğumuz çalışmada aspir (*Carthamus tinctorius L.)* tohumlarının çimlenme ve erken gelişim döneminde hem tuzluluk stresine hem de arbusküler mikoriza uygulamalarına verdiği tepkiler incelenmiştir. Artan sulama suyu tuzluluğunda yaş ve kuru ağırlık, kök uzunluğu, çimlenme oranı, ortalama çimlenme süresi ve çimlenme hızı gibi temel gelişim parametrelerinde belirgin azalmalar aspir bitkisinde süreçlerini olumsuz yönde etkilemiştir. Özellikle yüksek tuzluluk düzeyinde (8dS/m) daha anlamlı değişimler meydana getirmiştir. Çimlenmelerde ise gecikmeler meydana gelmiştir. Buna karşın, mikoriza uygulamaları özellikle düşük ve orta dozlarda çimlenme oranınında artış eğilimi göstermiştir. Gelişim

parametrelerinde ise anlamlı sayılabilecek iyileşmeler sağladığı gözlemlenmiştir. Ancak yüksek doz mikoriza uygulamasının bazı durumlarda çimlenme hızı ve süresi üzerinde olumsuz etkiler oluşturduğu gözlemlenmiştir.

Çalışmamızdaki verilere dayanarak 4 dS/m tuzluluk düzeyine sahip S3 uygulamasında orta düzeyde mikoriza aşılamasının (M3) ile en başarılı çimlenme ve erken gelişim sonuçları elde edilmiştir. Sonuç olarak, ise arbusküler mikoriza uygulamasının, tuz stresinin olumsuz etkilerini hafifletmede ve etkili bir biyolojik araç olarak görülüp uygulanabileceği ancak dozunun dikkatle belirlenerek verilmesi gerektiğini ortaya koymaktadır. Tuzlu koşullarda aspir üretiminin sürdürülebilirliği açısından mikoriza fungusunun doğal ve çevre dostu bir strateji olarak düşünüp değerlendirilebilir. Gelecekte yapılacak çalışmalarda ise farklı mikoriza türlerinin karşılaştırmalı etkileri ve uzun dönemli tarla koşullarındaki verim sonuçları da değerlendirilmelidir.

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EFFECT OF MICROPLASTIC POLLUTION ON PHYSICO-CHEMICAL AND MICROBIOLOGICAL PROPERTIES OF SOIL

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ABSTRACT

Microplastics, which are particles smaller than 5 mm formed through the degradation of larger plastic materials, can enter environmental systems and subsequently reach the soil, where they influence various properties including physical, chemical, and microbiological characteristics. One of the primary pathways through which microplastics are introduced into soil is the degradation of plastics used in agricultural practices. This study aimed to investigate the potential effects of microplastic residues derived from commonly used polypropylene (PP) ground covers and low-density polyethylene (PE) seedling bags on soil properties.

In the experiment, 5-liter pots were treated with microplastics of two types (PP and PE) at three different concentrations (1%, 2%, and 3%). Each treatment was replicated three times, and three control groups were included, resulting in a total of 21 pots arranged in a completely randomized design. Hot pepper (Capsicum annuum) was used as the test plant. Once the plants reached harvest maturity, both plant and soil analyses were conducted. The plant material was analyzed for total nitrogen (N) and available phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn). Additionally, soil samples taken from a depth of 0–30 cm were analyzed for bulk density, maximum water holding capacity, moisture content, pH, electrical conductivity, cation exchange capacity, organic matter, total N, and available nutrients. To assess the microbiological characteristics of the soil, dehydrogenase and alkaline phosphatase enzyme activities as well as total bacterial count were measured.

The results indicated that increasing microplastic concentrations led to reductions in soil bulk density for both PP and PE treatments. An increasing trend in maximum water holding capacity was observed in soils treated with PP, while the opposite trend was found for soils treated with PE. Alkaline phosphatase enzyme activity decreased in soils containing PE. Available phosphorus and iron levels increased in soils treated with both types of microplastics, while copper levels declined.

Keywords: Polypropylene (PP), Low-Density Polyethylene (PE), *Capsicum annuum*

MİKROPLASTİK KİRLİLİĞİNİN TOPRAĞIN FİZİKO-KİMYASAL VE MİKROBİYOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİSİ

ÖZET

Plastik atıkların zaman içerisinde daha küçük parçalara ayrılmasıyla ortaya çıkan ve 5 mm'den küçük boyutlara sahip olan mikroplastikler, çevresel ortamlara yayılarak toprağa da ulaşmakta ve toprak sistemlerinin fiziksel, kimyasal ve mikrobiyolojik özelliklerini etkileyebilmektedir. Tarımda kullanılan plastiklerin bozunması, mikroplastiklerin topraklara geçişinde en belirgin nedenlerden biridir. Bu çalışma, tarımsal üretimde sıklıkla tercih edilen polipropilen (PP) taban örtüleri ile düşük yoğunluklu polietilen (PE) fidan torbalarının parçalanmasıyla ortaya çıkan mikroplastik kalıntılarının, toprak özellikleri üzerindeki potansiyel etkilerini incelemeyi amaçlamaktadır.

Araştırmada, 5 litrelik saksılara farklı tür ve dozlarda (PP ve PE olmak üzere %1, %2, %3 oranlarında) mikroplastikler eklenmiş, her uygulama üç tekerrürle birlikte değerlendirilmiş ve üç kontrol grubu da dahil edilerek toplamda 21 saksı kullanılmıştır. Denemeler tesadüf parselleri deneme desenine göre kurulmuş ve test bitkisi olarak sivri biber yetiştirilmiştir. Bitkiler hasat olgunluğuna ulaştığında toprak ve bitki analizleri gerçekleştirilmiştir. Bitki materyalinde toplam azot (N) ile birlikte alınabilir fosfor (P), potasyum (K), kalsiyum (Ca), magnezyum (Mg), demir (Fe), bakır (Cu), çinko (Zn) ve mangan (Mn) düzeyleri belirlenmiştir. Ayrıca 0–30 cm derinlikten alınan toprak örneklerinde hacim ağırlığı, maksimum su tutma kapasitesi, nem içeriği, pH, elektriksel iletkenlik, katyon değişim kapasitesi, organik madde, toplam N ve alınabilir besin elementleri analiz edilmiştir. Toprağın mikrobiyolojik özelliklerini değerlendirmek amacıyla ise dehidrogenaz ve alkalin fosfataz enzim aktiviteleri ile toplam bakteri sayısı ölçülmüştür.

Elde edilen bulgular, mikroplastik dozu arttıkça PP ve PE içeren topraklarda hacim ağırlığında azalmalar olduğunu göstermiştir. PP uygulamalarında maksimum su tutma kapasitesinde artış eğilimi gözlenirken, PE uygulamalarında bu değer azalma eğilimindedir. PE içeren topraklarda alkalin fosfataz enzim aktivitesinde düşüş saptanmıştır. Her iki mikroplastik türüyle işlem gören topraklarda alınabilir P ve Fe miktarlarında artış gözlemlenirken, Cu düzeylerinde azalma meydana gelmiştir.

Anahtar Kelimeler: Polipropilen, Düşük Yoğunluklu Polietilen, Mikroplastik, Toprak Özellikleri, Sivri Biber

1. GİRİŞ

1950'li yıllardan bu yana üretimi süren plastikler; ekonomik olmaları, dayanıklı yapıları, esneklikleri ve suya karşı yüksek dirençleri sayesinde günlük yaşamda yaygın bir şekilde kullanılmaktadır (Li-Huang vd., 2022). Plastik malzemeler yalnızca konfor, sağlık ve güvenlik gibi alanlarda avantaj sunmakla kalmayıp, küresel ölçekte çevresel etkiler yaratacak kadar yaygınlaşmıştır (Ya-Jiang vd., 2021). Kullanım süreci tamamlandıktan sonra bu plastikler, çeşitli yollarla çevreye karışarak potansiyel bir kirlilik unsuru hâline gelebilmektedir (Bruge-Dhamelincourt vd., 2020). Doğaya bırakılan büyük plastik parçalar; ultraviyole ışınları, fiziksel aşınma, hidroliz, erozyon ya da biyolojik süreçlerin etkisiyle zamanla 5 mm'nin altındaki boyutlara parçalanarak "mikroplastik" adı verilen küçük katı partikülleri oluşturmaktadır (Ya-Jiang vd., 2021). Mikroplastikler; lif, granül ya da kırıntı şeklinde karışık yapılarda olabilen, çeşitli plastik türlerini içeren ve çevresel anlamda yeni nesil kirleticiler arasında değerlendirilen maddelerdir (Guo-Huang vd., 2020).

Günümüzde yapılan araştırmalar, mikroplastiklerin yalnızca sucul ekosistemlerde değil; kutup bölgeleri, açık ve derin denizler, kıyı alanları gibi birçok farklı çevresel ortamda da yaygın şekilde bulunduğunu göstermektedir. Bununla birlikte, bu kirleticiler toprak ortamlarında da tespit edilmektedir (Ya-Jiang vd., 2021). (Horton-Walton vd., 2017) çalışmasına göre, mikroplastiklerin karasal ekosistemlerdeki birikimi, deniz ortamlarındakinden 4 ile 23 kat daha fazladır. Bu durum, toprakların da mikroplastik kirliliği açısından ciddi risk altında olduğunu ortaya koymaktadır. Toprakta mikroplastik birikimine neden olan kaynaklar arasında tarım faaliyetleri önemli bir yer tutmaktadır. Özellikle plastik malç filmleri, organik gübreler, kompost materyalleri ve plastik içeren sulama suları mikroplastiklerin tarım topraklarına geçişini kolaylaştırmaktadır (Tian-Jinjin vd., 2022); (Liu-Shao vd., 2021). Bu kaynaklar arasında en baskın olanı plastik malçlama uygulamalarıdır. Soğuk ve kurak iklim koşullarında ürün verimini artırmak ve uygun toprak sıcaklığını korumak amacıyla yaygın olarak kullanılan bu malzemeler, zamanla parçalanarak mikroplastiklere dönüşebilmektedir (Liu-Shao vd., 2021). Benzer şekilde, toprak verimliliğini artırmak için kullanılan kompostlar da mikroplastik kaynakları arasında yer almaktadır. Kompostlama sırasında oluşan yüksek sıcaklıklar ve mikrobiyal aktiviteler, büyük plastiklerin daha küçük parçalara ayrılmasını hızlandırarak toprakta mikroplastik birikimini artırmaktadır (Braun-Mail vd., 2020). Ayrıca, kanalizasyon kaynaklı atık suların sulamada kullanılması da toprağa ek mikroplastik yükü getirebilmektedir (Zhang-Xie vd., 2020). Bu yollarla toprağa giren mikroplastikler, zamanla toprak yapısında çeşitli değişikliklere yol açmaktadır. Fiziksel, kimyasal ve mikrobiyolojik toprak özelliklerinde meydana gelen bu değişimler, doğrudan ya da dolaylı olarak o toprakta yetişen bitkilerin büyüme ve gelişme süreçlerini de etkileyebilmektedir.

2. MATERYAL VE YÖNTEM

2.1. MATERYAL

Düşük yoğunluklu polietilen ve polipropilen plastikleri İzmir'de yer alan Gıda Çarşısı semtindeki tarım plastikleri satan bir dükkândan temin edilmiştir. Düşük yoğunluklu polietilen örneği için 22x35 cm'lik körüklü siyah fidan torbası satın alınmıştır. Polipropilen örneği için

eni 1,5 m olan siyah sera taban örtüsü alınmıştır. Alınan materyallerin saksı denemesinde kullanılacak miktarları toplamda yaklaşık 2'şer kg'dır. 27 Şubat 2024 tarihinde plastik materyaller Ege Üniversitesi Ziraat Fakültesi Dekanlığından temin edilen şerit kâğıt kesme makinesi ile küçük parçalar haline getirilmiştir.

Saksı denemesi şeklinde yürütülen denemede kullanılacak toprak örneği Ege Üniversitesi Ziraat Fakültesi arazisinden 38°27'08"N 27°13'31"E konumundan 1 Şubat 2024 tarihinde alınmıştır. Alınan toprak örneği kış mevsiminin etkisiyle nemli olduğu için yaklaşık 1 ay gibi süre zarfında plastik bir örtünün üzerine serilerek Toprak Bilimi ve Bitki Besleme Bölümü serasında bekletilip kurutulmaya bırakılmıştır. Kuruma işleminin ardından topraklar 8 mm'lik eleklerden geçirilip saksı denemesi kurmaya hazır hâle getirilmiştir. Deneme toprağının bazı fiziksel ve kimyasal özellikleri Çizelge 2.1'de verilmiştir.

Çizelge 2.1: Deneme toprağına ait bazı fiziksel ve kimyasal analizler.

pH	7,37	**Alınabilir (mg kg^{-1})**	**Fosfor (Olsen)**	11,60
EC (dS m^{-1})	1,41		**Potasyum**	405,00
$CaCO_3$ (%)	20,27		**Kalsiyum**	7850,00
Kum (%)	34,24		**Magnezyum**	455,10
Kil (%)	38,00		**Sodyum**	40,00
Mil (%)	27,76		**Mangan**	4,90
Bünye	Killi Tın		**Demir**	7,12
Organik Madde (%)	0,24		**Bakır**	1,80
Toplam N (%)	0,190		**Çinko**	4,10

Yukarıdaki çizelgeye göre deneme toprağı; pH durumuna bakıldığında nötr seviyeyi biraz geçmiş olmakla birlikte düşük alkali düzeyde ve orta derecede tuzluluk seviyesinde, kireçli, organik madde açısından oldukça fakir, N ve P bakımından orta, K bakımından iyi, Ca bakımından çok yüksek, Mg bakımından yüksek, Na bakımından düşük, Fe bakımından ideal, Mn açısından hafif düşük, Cu bakımından yeterli düzeyde ancak yüksek sınıra yakın ve Zn bakımından ise yeterli ve ideal düzeydedir.

2.2. YÖNTEM

Bu çalışma; Ege Üniversitesi Ziraat Fakültesi Toprak Bilimi ve Bitki Besleme Bölümü serasında, 3,5 ay süre zarfında saksı denemesinde sivri biber yetiştirilmesi ile yürütülmüştür. 5 kg kapasiteli bitki saksılarına, 4 kg deneme toprağı ve %1 [doz 1 (D1)], %2 [doz 2 (D2)] ve %3 [doz 3 (D3)] şeklinde 3 farklı doz ile plastik materyal homojen bir şekilde karıştırılarak koyulmuştur. Deneme dozları aşağıdaki çizelgede olduğu gibidir.

Çizelge 2.2: Saksı denemesi için plastik materyal uygulama dozları.

Uygulama Dozları:	%1 (D1)	%2 (D2)	%3 (D3)
1) Polipropilen (PP)	40 g PP	80 g PP	120 g PP
2) Düşük Yoğunluklu Polietilen (LDPE)	40 g PE	80 g PE	120 g PE
3) Tanık (Kontrol)			

Saksı denemesine 3 Mayıs 2024 tarihinde başlanmıştır (Şekil 2.2.1). Geniş bir kap içerisine 4000 g toprak tartılıp, polietilen ve polipropilen içerikli plastiklerden yukarıdaki çizelgede belirtilmiş olan dozlarda (%1, %2 ve %3) homojen bir şekilde karışım sağlanarak 5 kg kapasiteli saksılara koyulmuştur. Tanık (kontrol) gruplarına ise sadece 4000 g toprak tartılıp koyulmuştur. Saksılara koyulan toprak işleminin ardından, Ege Tarımsal Araştırma Enstitüsü Müdürlüğünün bu çalışma için hibe ettiği tatlı sivri biber fideleri tanık ve plastik içerikli saksılara ekilmiştir. 3 Mayıs 2024 tarihinde 600 mL su verilerek başlatılan saksı denemesi, iki günde bir 200 mL musluk suyu ve sulanmayan günlerde de Hoagland Çözeltisi verilmek koşulu ile 11 Haziran 2024 tarihine kadar sulamaya devam edilmiştir. Hava sıcaklıklarının artmasına bağlı olarak her gün 200 mL olacak şekilde 19 Ağustos'a kadar sulama işlemi sürdürülmüştür. 21 Ağustos 2024 tarihinde ise bitkiler hasat edilmiştir.

Bitkilerin hasat edileceği tarihte, bitkiler henüz saksılardan çıkarılmadan önce toprak hacim ağırlığı analizi gerçekleştirilmiştir. Silindir aparat ile alınan toprak örnekleri hava kurusu haline getirilerek kurutulmaya çalışılmıştır (Tüzüner, 1990).

2.2.1. Bitki Analiz Yöntemleri

Bitkiler saksılardan dikkatlice çıkartılıp köklerindeki topraklardan arındırılmak üzere yıkanmıştır. Bitkilerde yaş biyokütle ağırlığı tartılıp not edilmiştir. Ardından kökler ve gövdeler ayrı ayrı kese kağıtlarına koyularak 65ºC'de yaklaşık 48-72 saat süreyle kurutulduktan sonra değirmende öğütülüp toplam N miktarı modifiye makrokjeldahl yöntemine göre (Bremner, 1965); P, Na, K, Ca, Mg, Fe, Cu, Mn ve Zn miktarları ise modifiye (Zarcinas, Cartwright vd., 1987) yöntemine göre mikrodalga yakma cihazında yakılmasından sonra, örneklerin konsantre HCl ile muamelesi sonucunda elde edilen süzükte ICP-OES Cihazı ile okuması yapılarak belirlenmiştir.

2.2.2. Toprağın Bazı Fiziksel ve Kimyasal Analiz Yöntemleri

Toprak reaksiyonu (pH) analizi (Jackson, 1967), elektriksel geçirgenlik (Rayment ve Higginson, 1992), maksimum su tutma kapasitesi (Schlichting ve Blume, 1966), katyon değişim kapasitesi tayini (Jackson, 1967), organik madde miktarı (Black, 1965), toplam azot (N) analizi (Bremner, 1965), alınabilir fosfor (P) tayini (Olsen, Cole vd., 1954), alınabilir kalsiyum (Ca), magnezyum (Mg), sodyum (Na) ve potasyum (K) (Pratt, 1965) yöntemi ile belirlenirken, alınabilir demir (Fe), bakır (Cu), çinko (Zn) ve mangan (Mn) (Lindsay ve Norvell, 1978) yöntemi ile tespit edilmiştir.

2.2.3. Toprağın Bazı Mikrobiyolojik Analiz Yöntemleri

Nemli toprak örneklerinde toprak solunumu (CO_2) (Isermeyer, 1952), alkalin fosfotaz enzim aktivitesi analizi (Eivazi ve Tabatabai, 1977); (Tabatabai ve Bremner, 1969) yöntemi ile belirlenirken dehidrogenaz enzim aktivitesi analizi (Thalmann, 1968) yöntemi ile saptanmıştır. Toplam bakteri sayımı analizi ise dökme plak yöntemi ile petri kaplarında gerçekleştirilmiştir.

2.2.4. İstatistiksel Analizler

Çalışma sonucunda elde edilen bulguların, üç tekerrürün ortalaması olacak şekilde istatistik analizi yapılmıştır. Tüm veriler SPSS 30.0 (SPSS Inc., Chicago, IL, USA) programı kullanılarak One-Way ANOVA analizi ile gerçekleştirilip, ortalamalar arasındaki farklılıklar ise Duncan Çoklu Karşılaştırma Testi ile belirlenmiştir (P<0.05).

3. BULGULAR VE TARTIŞMA

3.1. Mikroplastik İçeriğinin Toprağın Bazı Fiziksel Özellikleri Üzerine Etkisi

Çalışmada polipropilen (PP) ve polietilen (PE) mikroplastik uygulamalarının toprağın hacim ağırlığı, maksimum su tutma kapasitesi ve nem içeriği üzerinde istatistiki anlamda ($p<0.05$) bir etkisi olduğu tespit edilmiştir (Çizelge 3.1). En düşük hacim ağırlığı değerleri PP-D2 ve PP-D3 uygulamalarında (0.95 gr/cm^3 ve 0.93 gr/cm^3), en yüksek hacim ağırlığı değerleri ise PE-D1 ve Kontrol uygulamalarında (1.19 gr/cm^3 ve 1.17 gr/cm^3) ortaya çıkmıştır. Mikroplastiklerin uygulama dozlarındaki artışa bağlı olarak toprağın hacim ağırlığı değerlerinde azalmalar kaydedilmiştir. Araştırma topraklarının hacim ağırlığı değerleri 0.93 g/cm^3 ile 1.19 g/cm^3 arasında değişiklik göstermiştir.

Çizelge 3.1: Farklı mikroplastik uygulamalarının toprağın bazı fiziksel özellikleri üzerine etkisi

Uygulamalar	Organik Madde (%)	pH	EC (dS/m)	Katyon Değişim Kapasitesi (me/100 g toprak)
Kontrol	0.65 *c*	7.58 *a**	1.716	33.94
PP-D1	1.26 *b*	7.54 *b**	1.744	33.23
PP-D2	2.18 *a*	7.54 *bc*	1.753	32.88
PP-D3	2.06 *a*	7.54 *ab*	1.691	33.94
PE-D1	0.58 *c*	7.56 *ab*	1.77	35
PE-D2	0.42 *c*	7.53 *c**	1.819	34.29
PE-D3	0.42 *c*	7.57 *ab*	1.723	33.94

(Aynı harfle gösterilen ortalamalar Duncan testine göre (α =0.05) birbirinden istatistiksel olarak farklı değildir.)

Çalışmamızda, toprakta mikroplastik uygulamalarının hacim ağırlığı üzerinde yarattığı değişiklikler, önceki araştırmalarla benzer sonuçlar göstermektedir. (Qi, Beriot vd., 2020) tarafından yapılan bir çalışmada, nişasta katkılı biyoplastikler ve düşük yoğunluklu polietilen (LDPE) gibi farklı plastik türlerinin toprak hacim ağırlığı üzerindeki etkileri incelenmiştir. Çalışmada, plastik içeriği arttıkça (%1, %2) toprak hacim ağırlığında belirgin bir azalma gözlemlenmiştir. Ayrıca, plastik türlerinin etkisi incelendiğinde, LDPE içeren toprakların nişasta katkılı biyoplastiklerden, makroplastik içeren toprakların ise mikroplastiklerden daha düşük hacim ağırlığına sahip olduğu bulunmuştur.

Mikroplastikler, toprak agregasyonunu ve stabilitesini etkileyerek daha gevşek bir yapı oluşmasına sebep olmuşlardır. Bu yapısal değişim, toprak gözeneklerinin artmasına neden olmuş ve bu durum hacim ağırlığının düşmesiyle sonuçlanmıştır. Ayrıca, mikroplastiklerin genellikle düşük yoğunlukta olması ve toprak içerisindeki yoğunluk dağılımını değiştirmesi, hacim ağırlığında gözlemlenen bu azalmanın bir başka temel nedenidir.

Kontrol grubu ile PP ve PE grupları karşılaştırılarak yapılan incelemede, Kontrol grubunun PP ve PE gruplarından daha düşük maksimum su tutma kapasitesine sahip olduğu bulunmuştur (Çizelge 3.1). Ancak PP grupları artan doza bağlı olarak maksimum su tutma kapasitesinde artış gösterirken, PE grupları artan dozun etkisiyle azalış göstermişlerdir. PP grubu içerisinde en düşük maksimum su tutma kapasitesi PP-D1 grubundadır (%68,27). En yüksek ise PP-D3 grubunda (%71,33) bulunmuştur. PE grubunda en düşük değer PE-D3 grubunda (%67,90) iken en yüksek değer PE-D1 grubunda (%71,47) tespit edilmiştir. Artan mikroplastik konsantrasyonuna bağlı olarak azalan hacim ağırlık, daha gevşek bir toprak yapısı oluşturmaktadır. Bu sebeple PE mikroplastik uygulamaları, maksimum su tutma kapasitesi üzerinde de azaltıcı bir etki göstermiştir. Ayrıca PE mikroplastiğinin kesim işlemi sonrasında, PP mikroplastiğinden nispeten daha büyük parçalardan oluşması, mevcut toprak agregatlarını daha fazla bir araya getirerek topraktaki mikropor saysını azaltıp, yüzey alanını düşürdüğü için maksimum su tutma kapasitesi üzerinde de azaltıcı bir etkiye sebep olmuştur. PP mikroplastik uygulamaları ise toprak parçacıkları arasında fiziksel bir boşluk oluşturarak daha gevşek bir yapı sağlayabilir. Bu gevşek yapı, suyun depolanmasını kolaylaştırabilir. Bu sebeple PP mikroplastik uygulamalarında toprak maksimum su tutma kapasitesinde artış gözlenmiştir. (Lozano, Lehnert vd., 2021) yaptıkları bir çalışmada, mikroplastiklerin şekline bağlı olarak toprak su tutma kapasitesinde değişiklikler gözlemlenmiştir. Çalışmada, özellikle lif formundaki mikroplastiklerin, toprağın su tutma kapasitesini artırdığı ve bu etkinin, mikroplastiklerin şekli ve boyutuna göre değişebileceği vurgulanmıştır. Lif şeklindeki mikroplastikler, toprağın gözenek yapısını gevşeterek, suyun toprakta daha uzun süre tutulmasını sağlayabilir. Benzer şekilde, PP mikroplastiklerinin lifsi formda, toprak üzerindeki etkisi, toprağın su tutma kapasitesinin artmasına neden olmuş olabilir. Bu durum, mikroplastiklerin fiziksel özellikleri içerisinde yer alan şekil yapılarının, toprağın su tutma kapasitesi üzerinde önemli bir etkiye sahip olduğunu göstermektedir. Dolayısıyla, bu çalışmada gözlemlenen su tutma kapasitesindeki artış, PP mikroplastiklerin lifsi yapısının toprağın su yönetimi üzerinde sağladığı faydalı etkilerle açıklanabilir.

Kontrol grubunun nem içeriğinin, PP ve PE mikroplastik uygulamaları ile yapılan karşılaştırılmasında, Kontrol grubunun her iki mikroplastik uygulamalarına göre daha yüksek olduğu bulunmuştur (%23,76). PE mikroplastiklerinin uygulandığı topraklarda, doz artışına

paralel olarak nem içeriğinde belirgin bir azalma gözlemlenmiştir. Buna karşılık, PP mikroplastiklerinin kullanıldığı gruplarda doz artışına rağmen nem içeriğinde belirgin ve düzenli bir değişim eğilimi saptanamamıştır. Ancak her iki mikroplastik uygulamaları da Kontrol grubu ile kıyaslandığında daha düşük nem içeriği değeri göstermiştir. Özellikle PE mikroplastik uygulamalarının toprağın nem içeriğini azaltma mekanizması, toprağın maksimum su tutma kapasitesini düşürmesi ile yakından ilgilidir. Bu mikroplastikler, toprak agregatlarının parçalanmasına ve gözenekli yapının bozulmasına neden olarak toprakta sıkışmayı artırmakta toprakta suyun tutulmasını sağlayamayarak ayrıca suyun toprağa sızmasını engelleyip yüzeyde biriktirmesiyle birlikte suyun daha çabuk buharlaşmasını tetiklemiş olabilirler. Bu nedenle toprak nem içeriği artan PE mikroplastik uygulamalarında azalma eğilimindedir.

3.2. Mikroplastik İçeriğinin Toprağın Bazı Kimyasal Özellikleri Üzerine Etkisi

Bu çalışmada, polipropilen (PP) ve polietilen (PE) mikroplastik uygulamalarının, toprağın organik madde içeriği ile pH değeri üzerinde istatistiksel olarak anlamlı bir etkiye sahip olduğu belirlenmiştir ($p<0.05$). Buna karşın, elektriksel iletkenlik (EC) ve katyon değişim kapasitesi (KDK) parametrelerinde anlamlı bir farklılık tespit edilmemiştir (Çizelge 3.2).

Çizelge 3.2: Farklı mikroplastik uygulamalarının toprağın bazı kimyasal özellikleri üzerine etkisi

Uygulamalar	Organik Madde (%)	pH	EC (dS/m)	Katyon Değişim Kapasitesi (me/100 g toprak)
Kontrol	0.65 *c*	7.58 *a**	1.716	33.94
PP-D1	1.26 *b*	7.54 *b**	1.744	33.23
PP-D2	2.18 *a*	7.54 *bc*	1.753	32.88
PP-D3	2.06 *a*	7.54 *ab*	1.691	33.94
PE-D1	0.58 *c*	7.56 *ab*	1.77	35
PE-D2	0.42 *c*	7.53 *c**	1.819	34.29
PE-D3	0.42 *c*	7.57 *ab*	1.723	33.94

(Aynı harfle gösterilen ortalamalar Duncan testine göre (α =0.05) birbirinden istatistiksel olarak farklı değildir.)

PP mikroplastiklerinin artan dozları, toprak organik maddesi üzerinde belirgin bir artış eğilimi yaratmıştır. Özellikle PP-D2 uygulamasında (%2.18) en yüksek değer gözlenmiş, bu da PP'nin mikrobiyal aktiviteyi uyararak organik madde birikimini teşvik edebileceğini düşündürmektedir. Bu artışın temelinde, PP mikroplastiklerinin yüzey özelliklerinin mikrobiyal kolonizasyonu teşvik etmesi yatmaktadır. (Chen, Wang vd., 2022) tarafından sera tarımı yapılan topraklarda yürütülen bir çalışmada, PP de dâhil olmak üzere çeşitli mikroplastik

türlerinin yüzeylerinde mikrobiyal biyofilm oluşumunun gerçekleştiği gösterilmiştir. PP'nin hidrofobik ve pürüzlü yüzey yapısı, mikroorganizmalar için uygun mikro-nişler sağlayarak biyofilm gelişimini teşvik etmektedir. Bu biyofilmler içerisinde üretilen ekstraselüler polimerik maddeler (EPS), özellikle polisakkarit ve protein gibi karbon bakımından zengin bileşenler içermektedir. Toprakta bu tür biyolojik kökenli karbon bileşiklerinin birikmesi, organik madde düzeyinin yükselmesine yardımcı olabilmektedir. Ayrıca çalışmada, biyofilm topluluklarının çoğunlukla aerobik kemootrof bakterilerden oluştuğu ve bu bakterilerin karbon döngüsünde aktif rol oynadığı vurgulanmıştır. Bu bulgular, PP mikroplastiklerinin mikrobiyal kaynaklı karbon akışlarını artırarak toprak organik madde birikimini dolaylı olarak desteklediğini göstermektedir. Öte yandan PE uygulamalarında, özellikle PE-D2 ve PE-D3 gruplarında (%0.42), organik madde düzeyleri anlamlı şekilde azalmıştır. Bu durum, LDPE'nin toprakta mikrobiyal aktiviteyi baskılaması ve enzimatik süreçlerle ilişkili olması ile açıklanabilir. PE mikroplastikler, toprak mikrobiyal topluluklarının yapısını ve işlevini değiştirerek toprak organik maddesinin ayrışma oranlarını etkileyebilir. Bu etki, toprak organik karbonunun azalmasına yol açabilir. PE mikroplastiklerin toprağın bazı mikrobiyolojik analizleri üzerindeki etkileri de incelendiğinde, Çizelge 3.3'te yer alan enzim analiz sonuçları, mikrobiyal aktiviteyi baskılamasıyla gelişen toprak organik madde içeriğinin azaldığını gösterir niteliktedir. (Liu, Wen vd., 2023) tarafından yapılan bir çalışmada, PE mikroplastiklerinin toprak agregat yapısını bozarak toprak porozitesini azalttığı ve bu durumun su ve hava hareketini kısıtlayarak mikrobiyal habitatları olumsuz etkilediği belirtilmiştir. Bu fiziksel değişiklikler, mikrobiyal çeşitliliğin azalmasına ve dolayısıyla toprak organik madde birikiminin sınırlanmasına yol açmaktadır.

Bu çalışmada, PP ve PE mikroplastik uygulamalarının toprak pH'ı üzerinde istatistiksel olarak anlamlı fakat biyolojik olarak sınırlı etkiler gösterdiği tespit edilmiştir. PP uygulamalarında pH değerleri dozdan bağımsız olarak 7.54 düzeyinde sabit kalırken, PE uygulamalarında pH değeri PE-D2 dozunda en düşük (7.53), PE-D3 dozunda ise kontrol seviyesine yakın (7.57) ölçülmüştür. PP mikroplastiklerinin pH üzerinde sabit ve sınırlı bir etki göstermesi, bu polimerin hidrofobik ve kimyasal olarak daha inert yapısına bağlanabilir. Ayrıca (Chen, Wang vd., 2022) PP yüzeylerinin mikrobiyal kolonizasyonu destekleyerek biyofilm oluşumunu teşvik ettiğini ancak bu biyofilm süreçlerinin toprak pH'ını anlamlı ölçüde değiştirecek düzeyde asidik ürün oluşturmadığını belirtmiştir. Bununla birlikte PE mikroplastik uygulamalarının artan dozuna bağlı olarak, toprak pH değeri üzerinde kararlı ve net bir değişim gözlenmemiştir.

EC ve katyon değişim kapasitesi değerleri ise istatistiksel açıdan anlamlı bulunmamıştır. EC değerleri artan mikroplastik konsantrasyonuna bağlı olarak istikrarlı bir şekilde artma veya azalma göstermemiştir. PE ve PP mikroplastiklerinin toprak katyon değişim kapasitesi (KDK) üzerindeki etkileri değerlendirildiğinde ise, her iki mikroplastik türünün de KDK değerlerinde belirgin bir artış ya da azalma oluşturmadığı, ancak dozlara bağlı küçük dalgalanmalara neden olduğu görülmüştür. Özellikle PE uygulamalarında düşük dozda KDK'nın arttığı (PE-D1: 35), ancak artan dozlarla birlikte bu etkinin azaldığı ve kontrol seviyesine yaklaştığı (PE-D2: 33.36, PE-D3: 34.38) belirlenmiştir. Bu durum, PE mikroplastiklerinin toprak fiziksel yapısına olan etkisiyle açıklanabilir. (Wang, Li vd., 2023) tarafından yapılan bir çalışmada, PE mikroplastiklerinin düşük dozlarda (0.5%) toprak gözenekliliğini artırdığı ve bu sayede toprak içindeki yüzey alanının genişlediği gözlemlenmiştir. Bu artan yüzey alanı, katyonların daha

fazla tutunmasına imkân sağlayarak toprak yapısında iyileşme ve geçici bir katyon değişim kapasitesi (KDK) artışı meydana getirebilmektedir.

3.3. Mikroplastik İçeriğinin Toprağın Bazı Mikrobiyolojik Özellikleri Üzerine Etkisi

Çalışmada polipropilen (PP) ve polietilen (PE) mikroplastik uygulamalarının toprak solunumu (CO_2), dehidrogenaz enzim aktivitesi, alkalin fosfataz enzim aktivitesi analiz sonuçları istatistiksel anlamda ($p<0.05$) anlamlı bulunmuştur. Ancak bakteri sayımı analizi istatistiksel olarak anlamlı bulunmasa dahi Kontrol grubu ile kıyaslandığında daha düşük değerlerde olduğu saptanmıştır (Çizelge 3.3).

Çizelge 3.3: Farklı mikroplastik uygulamalarının toprağın bazı mikrobiyolojik özellikleri üzerine etkisi

Uygulamalar	Toprak Solunumu (CO_2) (%)	Dehidrogenaz Enzim Aktivitesi (µg TPF/g kuru toprak)	Alkalin Fosfataz Enzim Aktivitesi (µg pNP/ gr KM/h)	Bakteri Sayımı (%)
Kontrol	23.63 *bc*	48.69 *a*	430.87 *ab*	$136.92*10^6$
PP-D1	23.34 *bc*	41.4 *b**	424.43 *ab*	$13.41*10^6$
PP-D2	22.34 *c*	46.13 *ab**	417.07 *ab*	$6.26*10^6$
PP-D3	22.43 *c*	42.57 *ab*	433.36 *a**	$12.75*10^6$
PE-D1	25.18 *a*	43.41 *ab*	419.88 *ab*	$11.07*10^6$
PE-D2	23.49 *bc*	44.52 *ab*	414.99 *ab**	$15.73*10^6$
PE-D3	24.57 *ab*	43.8 *ab*	397.56 *b*	$25.74*10^6$

(Aynı harfle gösterilen ortalamalar Duncan testine göre (α =0.05) birbirinden istatistiksel olarak farklı değildir.)

Toprak solunumu, mikroorganizmaların organik maddeleri parçalarken ortama saldığı karbondioksit (CO_2) miktarının belirlenmesini sağlayan bir göstergedir. Dolayısıyla, mikrobiyal aktivitenin en genel göstergelerindendir. Toprak solunumu analizi, PP uygulamalarında Kontrol grubuna göre nispeten azalış göstermiştir. Bu durum PP mikroplastiklerinin; mikrobiyal hücre zarında por yapısını tıkayarak aerasyonu bozduğu ve PP mikroplastiğinin yapısında bulunan toksik katkı maddeleri nedeniyle mikroorganizmaların

çoğalmasını engellediği düşünülebilir. (de Souza, Lau vd., 2018) toprakta, oksijenin mikropor boşluklara girememesi ve anaerobik koşullara kayması sebebiyle PP mikroplastik uygulamalarındaki toprak solunumu üzerindeki düşüşün nedenini belirtmişlerdir. (Lozano, Lehnert vd., 2021) yaptıkları bir çalışmada da, PP mikroplastik parçacıklarının toprak mikrobiyal aktivitesini %20 oranında azalttığını rapor etmişlerdir. PE uygulamalarında ise düşük dozda Kontrol grubundan da fazla seviyede, anlamlı bir yükseliş bulunmuştur. Artan konsantrasyona bağlı olarak toprak solunumu değerlerinde dalgalanma söz konusu olmuştur. Bu durum PE mikroplastiklerinin düşük dozlarda, gözenekli yapısı sayesinde toprakta havalanmayı artırmasıyla açıklanabilir. (Lozano, Lehnert vd., 2021) aynı çalışmada PE mikroplastiklerinin özellikle film şeklinde uygulandığında, toprakta hava boşluğu ve poroziteyi artırıp düşük dozlarda suyun daha iyi dağılımı ve gaz değişimini destekleyen fiziksel bir bir yapı oluşturduğunu, bu durumun mikrobiyal etkinliği destekleyerek toprak solunumunu artırabileceğini ortaya koymuşlardır.

Dehidrogenazlar, mikroorganizmaların organik maddeyi oksitlemesinde görev alan temel enzimlerdir ve toprak canlılığına dair en hassas göstergelerden biridir. Dehidrogenaz enzim aktivitesi analizinde PP-D1'de %15'e yakın düşüş bulunmuştur (PP-D1, 41,4). Bu durum PP'nin mikrobiyal metabolizma enzimlerini doğrudan baskıladığını gösterebilir. PP mikroplastiklerinin parçacık boyutu, toprak mikrobiyal aktivitesi üzerinde önemli bir etkiye sahiptir. Küçük boyutlu PP parçacıkları, toprak mikrobiyal topluluklarını daha fazla etkileyerek enzim aktivitelerinde daha belirgin azalmaya neden olabilir. Bu durum, küçük parçacıkların toprak mikroorganizmalarıyla daha fazla etkileşime girmesi ve potansiyel olarak toksik etkiler göstermesiyle açıklanabilir (Zhao, Lozano vd., 2021). PP-D2'de ise kısmi bir artış gelişmiştir. Bu durum, mikroorganizmaların biyofilm oluşturmuş olabilmeleri ve bu şekilde ortama uyum sağlamaya başladığını gösterebilir. PE mikroplastik uygulamaları ise, toprak dehidrogenaz enzim aktivitesi üzerinde Kontrol grubuna göre stabil olmayan bir düşüş gösterdiği görülmüştür. Mikroplastiklerin toprak ekosistemlerine dahil olması, mikrobiyal hücre zarlarında fiziksel hasara ve hücre içi redoks dengesinde bozulmalara neden olarak oksidatif stres oluşturabilmektedir. Bu durum, hücresel solunum süreçlerinde görev alan dehidrogenaz enzimlerinin NADH/NAD^+ redoks döngüsünü olumsuz yönde etkileyerek enzim aktivitesinde azalmaya yol açmaktadır (de Souza, Lau vd., 2019). Bu durum, çalışmada kullanılan PP ve PE mikroplastik uygulamalarının dehidrogenaz enzim aktivitesi üzerinde gözlemlenen azalmanın olası etkilerini açıklamaktadır.

Alkalin fosfataz aktivitesine ilişkin olarak, yapılan çalışmada PP uygulamalarında özellikle PP-D3 uygulamasında artan alkalin fosfataz enzim aktivitesi, toprakta PP'den kaynaklanan fosfor kullanımının azalmasına bağlı olarak mikroorganizmalar tarafından artmış olabilir. Fosfor eksikliğini hisseden mikroorganizmalar bu enzimi daha fazla salgılamış olabilirler. PE uygulamaları ile karşılaştırıldığında, Kontrol grubunda daha yüksek düzeyde alkalin fosfataz enzim aktivitesi tespit edilmiş; mikroplastik maruziyetinin ise bu enzim aktivitesinde azalmaya yol açtığı belirlenmiştir. Bu durum, mikroplastiklerin alkalin fosfataz enzimi üzerinde inhibitör bir etkisi olduğunu göstermektedir. (Shah, Ali vd., 2023) yaptıkları bir çalışmada da kontrol grubuna göre PE uygulamasında daha düşük alkalin fosfataz enzim aktivitesi değeri bulmuşlardır. PE mikroplastiklerin toprakta mikrobiyal topluluk yapısını değiştirmesi ve nem

içeriği gibi çevresel faktörlerin bu enzimi baskın şekilde etkilemesi, alkalin fosfataz enzim aktivitesindeki azalmanın olası nedenleri arasında yer almaktadır.

Yapılan bu çalışmada PP ve PE mikroplastiklerinin bakteri sayısı üzerindeki etkilerine bakıldığında, her iki mikroplastik uygulamasının Kontrol grubundan daha az bakteri sayısına sahip olduğunu göstermektedir. Bu durum, PP ve PE mikroplastiklerinin toprak mikroorganizmaları üzerinde baskılayıcı bir etkisi olduğunu düşündürmektedir.

3.4. Mikroplastik İçeriğinin Toprağın Bazı Makro ve Mikro Besin Elementleri Üzerine Etkisi

Çalışma kapsamında toprağa uygulanan PP ve PE mikroplastik uygulamalarının, toprak besin elementleri üzerinde de çeşitli etkiler gösterdiği bulunmuştur. Aşağıda yer alan Çizelge 3.4'te toprak makro ve mikro besin elementlerinin mikroplastik varlığında değişen değerleri yer almaktadır. Çizelge 3.4'te potasyum (K) ve azot (N) düzeyleri, PP ve PE uygulamalarında kontrol grubuna göre anlamlı bir değişiklik göstermemiş ve istatistiksel açıdan da anlamlı bir sonuç vermemiştir. Bu durum, mikroplastiklerin toprakta K ve N hareketliliği üzerinde belirgin bir etkisi olmadığını gösterebilir. Toprak sodyum (Na) değerinin PP mikroplastik uygulaması sonucunda Kontrol grubuna göre düşük bir miktar arttığı görülürken, PE mikroplastik uygulaması sonucunda artan doza bağlı olarak azaldığı bulunmuştur. Bu durum PP mikroplastiğinin toprakta Na çözünürlüğünü artırmış olabileceğinin düşündürmektedir. Toprak kalsiyum (Ca) değerleri PP ve PE mikroplastik uygulamaları sonucunda istatistiksel olarak anlamlı çıksa dahi, belirgin bir yükseliş ya da düşüş göstermemiştir. Ancak toprak magnezyum (Mg) değeri PP ve PE mikroplastik uygulamalarında istatistiksel açıdan anlamlı sonuç bulunmuştur. Kontrol grubu ile kıyaslandığında ise en yüksek dozun PP-D3 (454,4 a*) grubunda olduğu ve artan mikroplastik dozuna bağlı olarak toprak Mg değerinin arttığı tespit edilmiştir. Bu durum bazı mikroplastiklerin toprakta Mg çözünürlüğünü artırabileceğini göstermektedir. PP mikroplastiklerinin toprak porozitesini artırması, toprakta su ve hava hareketliliğini iyileştirerek Mg^{2+} gibi katyonların daha serbest hareket etmesine ve bitki kökleri tarafından daha kolay alınmasına olanak tanıyabilir. Ayrıca, artan porozite toprak mikrobiyal aktivitesini de etkileyebilir, bu da besin elementlerinin mineralizasyonunu ve bitki tarafından kullanılabilirliğini artırabilir (de Souza, Lau vd., 2019). PE mikroplastik uygulamalarında ise artan doza bağlı olarak azalan Mg değerleri bulunmuştur. Bu durum PE mikroplastiklerinin toprakta Mg^{2+} gibi katyonların adsorpsiyonunu etkileyerek toprak çözeltisindeki serbest Mg miktarını azaltabileceğini göstermektedir. (Li, He vd., 2024) yaptıkları çalışmada PE mikroplastiklerinin toprakta katyon değişim kapasitesini (KDK) etkileyebileceğini ve bu durumun toprakta bulunan katyonların (Mg^{2+} vb.) toprak çözeltisindeki serbest miktarını azaltabileceğini belirtmişlerdir. PP ve PE mikroplastik uygulamalarının toprak fosforu (P) üzerindeki etkisi, artan mikroplastik dozuna bağlı olarak yükseliş gösterdiği bulunmuştur. Mikroplastiklerin yüzeyleri, mikroorganizmalar için bir taşıyıcı ve kolonizasyon yüzeyi oluşturabilir. Bu durum, fosfor döngüsüne katılan enzimatik faaliyetlerin artmasına sebep olarak toprakta organik fosforun çözünmesi hızlanabilir. PP ve PE mikroplastik uygulamalarının artan dozuna bağlı olarak topraktaki demir (Fe) değerlerinde artış gözlenirken, topraktaki bakır (Cu) değerlerinde düşüş tespit edilip, bu değerler istatistiksel açıdan önemli

bulunmamıştır. Cu değerindeki düşüşün nedeni, PP ve PE mikroplastiklerinin yüksek yüzey alanına sahip olmalarından kaynaklı olarak toprak çözeltisindeki Cu^{2+} iyonlarını adsorbe edebileceği ile ilgili olabilir. Bu durumda Cu iyonları mikroplastik yüzeyine bağlanarak toprak çözeltisinden uzaklaşmış olabilmektedir (Han, Wang vd., 2021).

Çizelge 3.4: Farklı mikroplastik uygulamalarının toprağın bazı makro ve mikro elementleri üzerine etkisi

Uygulamalar	Alınabilir (mg kg^{-1})									Toplam N (%)
	K	Na	Ca	Mg	P	Fe	Cu	Zn	Mn	
Kontrol	235	131.66 *b*	7666.66 *a*	442.86 *b**	5.06 *c*	4.13	1.67	5.33	1.08	0.13
PP-D1	238.33	136.66 *ab*	7683.33 *a*	445.26 *ab*	5.06 *c*	4.31	1.68	5.2	1.22	0.12
PP-D2	250	140 *a*	7516.66 *b*	445.26 *ab*	7.2 *bc*	5.11	1.66	6.19	1.29	0.12
PP-D3	248.33	140 *a*	7683.33 *a*	454.4 *a**	7.46 *b*	5.46	1.62	6.3	1.25	0.13
PE-D1	226.66	140 *a*	7533.33 *b*	453.36 *ab*	6.93 *bc*	4.79	1.95	5.39	1.09	0.12
PE-D2	236.66	138.33 *a*	7616.66 *a*	448.73 *ab*	7.6 *b*	5.36	1.72	5.5	1.13	0.12
PE-D3	231.66	131.66 *b*	7466.66 *b*	445.2 *ab*	11.2 *a*	5.71	1.64	5.12	1.31	0.12

(Aynı harfle gösterilen ortalamalar Duncan testine göre (α =0.05) birbirinden istatistiksel olarak farklı değildir.)

4. SONUÇ

Bu çalışmada kullanılan polipropilen (PP) ve polietilen (PE) mikroplastiklerin, toprak sağlığını çok yönlü olarak etkilediği belirlenmiştir. Mikroplastik uygulamaları; fiziksel özelliklerde yapısal bütünlüğün bozulmasına, kimyasal özelliklerde ise besin elementlerinin dengesinin bozulmasına yol açmaktadır. Ayrıca, mikrobiyolojik aktivitelerde azalmaya neden olarak toprak biyotasının işlevselliğini zayıflatmaktadır. Bu olumsuz etkiler, özellikle uzun süreli birikim durumunda, toprak verimliliğini azaltabilir ve bitki gelişimini sekteye uğratabilir. PP, bazı mikrobiyal parametrelerde daha az yıkıcı etki gösterirken, yapısal olarak toprağa karışması daha yavaş gerçekleştiğinden uzun vadeli etkileri olabilir. PE, daha esnek ve yaygın bir plastik türü olması nedeniyle fiziksel yapı ve mikrobiyolojik aktivite üzerinde daha belirgin baskılayıcı etkilere sahiptir. Bu sonuçlar, mikroplastiklerin sadece fiziksel ve kimyasal toprak özelliklerini değil, aynı zamanda toprak biyolojik sağlığını da doğrudan etkilediğini göstermektedir. Özellikle enzim aktiviteleri ve mikrobiyal canlılık üzerine olumsuz etkiler, toprağın ekosistem hizmetleri (besin döngüsü, organik madde ayrışması vb.) üzerinde risk oluşturabileceğini ortaya koymaktadır. Bu çalışma, mikroplastiklerin karasal ortamlardaki ekosistem işlevlerini zayıflattığını ve sürdürülebilir tarım için ciddi bir tehdit oluşturduğunu göstermektedir. Mikroplastiklerin toprak sağlığı üzerindeki etkileri yalnızca bir kirlilik sorunu değil, aynı zamanda bir toprak işlevselliği krizi olarak ele alınmalıdır. Gelecek çalışmaların, farklı toprak

tipleri ve uzun vadeli etkiler göz önüne alınarak yürütülmesi, mikroplastiklerin toprak sağlığı üzerindeki etkilerini daha derinlemesine anlamamıza katkı sağlayacaktır.

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OUTPUT SUPPLY AND INPUTS DEMAND ELASTICITIES OF SMALL-SCALE ONION PRODUCTION IN NIGERIA'S KANO STATE

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ABSTRACT

The present study analyzed the structure of onion production in Nigeria's Kano State using pseudo-profit function, symmetric normalized quadratic profit function (translog) and constant elasticity of substitution. Using a multi-stage sampling technique to select a representative sample size of 132 respondents, a well-structured questionnaire complemented with an interview schedule was used to elicit cross-sectional data. Besides, both descriptive and inferential statistics were used to achieve the specified objectives. Empirically, onion is a viable enterprise in the study area and input substitution at various combination levels has complimentary effect. Furthermore, change in quantity supply of onion is in conformity with the a priori expectation; change in output supply is in conformity with a priori expectation with respect to inputs' cost- only seeds, NPK fertilizer and petrol-engine oil exerted significant influence. Nevertheless, profit in onion production was influenced by output price, wage rate, NPK fertilizer and petrol-engine oil. However, ten challenges hovered around onion production viz., poor market information, problem of climate change, poor public-private investment, problem of land tenure system etc. Therefore, for output supply enhancement, onus lies on the policymakers to devise a realistic approach that will contain poor pricing efficiency of input prices in the study area.

Keywords: Structure, Supply, Demand, Smallholder, Onion, Nigeria

INTRODUCTION

Onions (*Allium cepa*) are a vital component of Nigeria's agricultural landscape, particularly in Kano State, where small-scale production plays a crucial role in both local consumption and regional economic activity. The production of onions in Kano State contributes significantly to the livelihoods of many rural households and serves as a source of income generation and food security. Despite its importance, the small-scale onion production sector in Kano State faces numerous challenges that impact its productivity and profitability. Key among these challenges are the dynamics of output supply and input demand elasticities, which determine how responsive production levels are to changes in input prices and how input demands fluctuate with changes in output prices (Beckman *et al*., 2022; Vink*et al*.,2022).

Understanding the elasticities of output supply and input demand is essential for designing effective agricultural policies (Camara and Savard, 2023), improving resource allocation (Sadiq *et al*., 2024a), and enhancing overall productivity in the onion farming sector. These elasticities provide insights into the efficiency of resource use, the sensitivity of production decisions to market conditions, and the potential impacts of policy interventions (Nainggolan*et al*., 2022; Wijetunga, 2016). While studies on agricultural production elasticities abound globally, there is a notable gap in empirical research specific to small-scale onion production in Kano State, Nigeria. Existing literature often overlooks the unique socio-economic and environmental factors that characterize onion farming in this region, making it imperative to conduct localized research that addresses these specificities.

This study aims to fill this gap by empirically investigating the output supply elasticity and input demand elasticity of small-scale onion production in Kano State. By employing rigorous econometric methods and leveraging primary data collected through surveys, the research seeks to quantify the responsiveness of onion output to variations in production inputs such as labor, land, seeds, and fertilizer. Additionally, it aims to analyze how input demands respond to changes in input prices and other economic factors within the local context. The findings of this study are expected to provide valuable insights for policymakers, agricultural extension services, and stakeholders involved in the onion production value chain in Kano State. By shedding light on the elasticities governing small-scale onion production, this research aims to inform evidence-based strategies that can promote sustainable agricultural development, enhance farmer livelihoods, and contribute to food security in the region. In summary, this study addresses a critical knowledge gap and aims to offer practical implications for enhancing the efficiency and resilience of small-scale onion production in Nigeria's Kano State. Succinctly, the broad objective was to analyse output supply and inputs demand elasticities of small-scale onion production in Nigeria's Kano State. The specific objectives were to: estimate the costs and return(s) to small-scale onion production; determine the inputs substitution in small-scale onion production; determine the output supply and inputs demand elasticities of small-scale onion production; and determine the challenges affecting small-scale onion production in the study area.

LITERATURE REVIEW

Empirical Review

Empirical evidence highlights the responsiveness of small-scale farmers to changes in input prices and market dynamics, offering insights into productivity and resource allocation. For example, Hayati *et al*.(2024) explored input production elasticity among smallholder maize farmers in East Java, demonstrating that farmers adjust input use to optimize output and efficiency. This study underscores the broader relevance of elasticity analysis in agricultural contexts, including onion farming in Nigeria's Kano State, to enhance policy and economic interventions. Deribe *et al*.(2022) evaluated technical efficiency in irrigated onion production in Ethiopia's Central Rift Valley. Input elasticities were found to be inelastic, highlighting a need for better technological interventions.

Mgale (2020) explored price elasticity in Tanzanian onion markets, emphasizing the relationship between producer and market price transmission. Findings suggested significant inefficiencies in value chain integration. Omotesho *et al*.(2020) studied economic viability in onion production in Benin, reporting farm size had the highest output elasticity, underlining its importance in achieving economies of scale. Alemu *et al*.(2018) examined technical efficiency in smallholder onion farming under Ethiopia's Koga Dam. Results indicated constant returns to scale and strong potential for resource reallocation. Bapari *et al*.(2016) analyzed the economic efficiency of onion production in Bangladesh, finding that seeds and fertilizers significantly impacted production output elasticity. This study underscores the role of input cost management in maximizing returns.

Shettima *et al*.(2016) assessed economic efficiency in Nigeria's vegetable production, identifying significant room for improving irrigation techniques and input allocations. Nigussie *et al*.(2015) focused on onion production under small-scale irrigation systems in Ethiopia. Results showed educational attainment among farmers improved resource utilization and overall productivity. Haile (2015) investigated input elasticities in onion farming in Ethiopia's Kobo District. Findings revealed positive elasticity for inputs like urea and labor, indicating the potential for improving efficiency through resource optimization.

Theoretical Framework

The theoretical framework for analyzing the output supply and input demand elasticities in small-scale onion production is grounded in microeconomic principles of production and consumer behavior. The **production theory** postulates that farmers, as rational economic agents, aim to maximize output or profit given constraints such as input costs, technology, and resource availability. The elasticity of supply reflects the responsiveness of farmers to price changes, emphasizing how economic incentives influence production decisions.

The **demand theory for inputs** complements this by analyzing how input prices and availability affect the quantity of inputs utilized, such as seeds, fertilizers, and labor. This relationship is further framed within the **Cobb-Douglas production function**, which illustrates the marginal productivity of each input and the interplay of inputs in achieving optimal output.

Additionally, the **theory of duality in economics** allows for the derivation of input demand functions from the profit-maximization behavior of producers. This approach integrates market dynamics, price mechanisms, and resource constraints, providing a comprehensive basis for examining elasticities. By situating the study within these theoretical constructs, the framework captures the complexities of small-scale onion farming and its responsiveness to economic variables in Kano State.

Conceptual Framework

The conceptual framework for analyzing the output supply and input demand elasticities in small-scale onion production in Kano State is structured around the interaction of key variables: economic, agronomic, and institutional factors. It emphasizes the dynamic relationship between onion farmers' decisions, market conditions, and external influences.

1. **Input Factors**: Inputs such as seeds, fertilizers, labor, water, and pesticides are central to production. Their availability and price influence input demand elasticity and affect output levels.
2. **Output Supply**: The quantity of onions produced depends on market price, production costs, and farmer responsiveness, captured through supply elasticity.
3. **Market Variables**: Market price fluctuations, demand conditions, and value chain dynamics impact both input demand and output supply decisions.
4. **External Influences**: Institutional support (e.g., subsidies, training, and market access), climatic conditions, and technology adoption act as moderating variables that shape production efficiency and elasticity responsiveness.
5. **Outcome Variables**: Key outcomes include changes in output levels, input utilization patterns, and overall profitability of onion farming.

This framework integrates economic theory with real-world considerations, guiding the study to evaluate how farmers' resource allocation decisions respond to external stimuli, thereby shaping the sustainability and growth of small-scale onion production in Kano State.

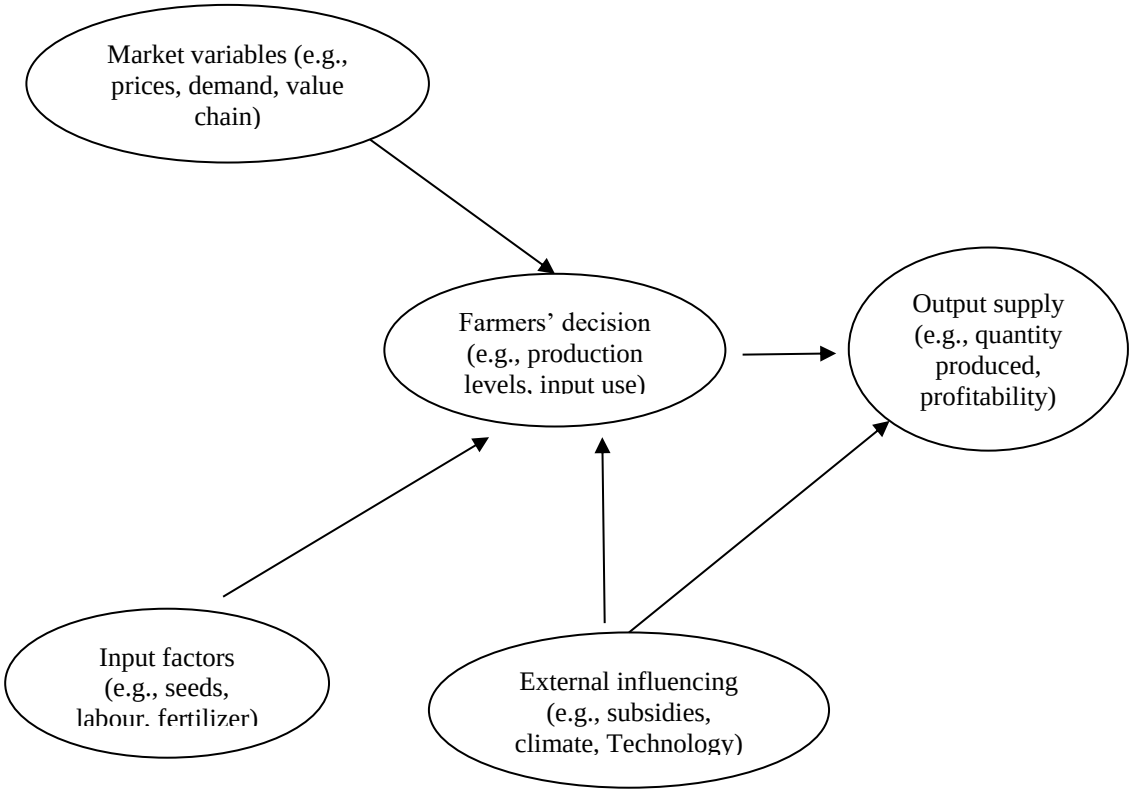

Figure 1: Conceptual framework for onion production analysis

RESEARCH METHODOLOGY

Kano State, located in northern Nigeria, is one of the country's most populous and economically significant states. It is known for its rich cultural heritage, historical significance, and vibrant agricultural sector. The State is bordered by Katsina State to the northwest, Jigawa State to the northeast, and Kaduna State to the southwest. Its geographic coordinates ranged from approximately 11.5°N to 13.5°N latitude and 7.5°E to 9.5°E longitude (Figure 1b). Further, the State exhibits diverse agro-ecological zones, including the Sudan savanna, Sahel savanna, and Guinea savanna. These zones are characterized by varying levels of rainfall, soil types, and vegetation cover, which influence agricultural production systems and cropping patterns within the state. Agriculture is the backbone of the economy in Kano State, employing a significant portion of the population and contributing substantially to the state's Gross Domestic Product (GDP). The state is known for its diverse agricultural activities, including crop cultivation, livestock rearing, and agro-processing industries. Onion production is a prominent agricultural activity in Kano State, with the state being one of the leading onion-producing regions in Nigeria. In other words, the State is renowned for its substantial onion production, with the cultivation of onions being a major economic activity for smallholder farmers in the region. The state's favorable agro-climatic conditions, including sandy soils, warm temperatures, and adequate rainfall during the rainy season, provide conducive environments for onion

cultivation. Smallholder farmers play a significant role in onion production, employing traditional farming practices alongside modern techniques.

The State is characterized by a diverse mix of ethnic groups, including the Hausa, Fulani, Kanuri, and others, each with its unique cultural heritage and farming traditions. Traditional institutions, social networks, and community-based organizations play crucial roles in shaping agricultural practices, resource management, and collective decision-making processes within rural communities. Despite its agricultural potential, Kano State faces various challenges, including land degradation, water scarcity, pest and disease outbreaks, limited access to inputs and credit facilities, and inadequate infrastructure. However, the state also presents opportunities for innovation, investment, and sustainable development initiatives aimed at enhancing agricultural productivity, resilience, and environmental sustainability.

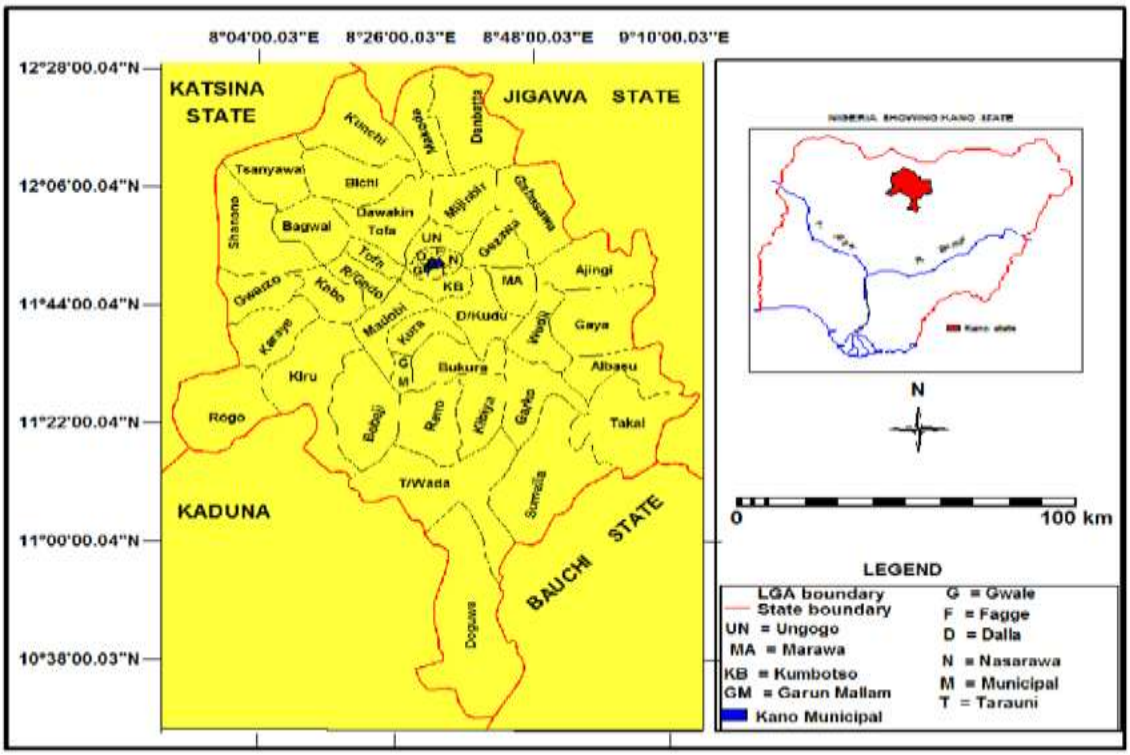

Figure 1b: Map of Kano State

Using a multi-stage sampling technique, a total of 132 onion farmers constituted the sample size. Firstly, given the prevalence of onion cultivation in the state, all the stratified ADP (Agricultural Development Project) zones namely Zones I (Rano), II (Dambatta) and III (Gaya) were adopted. Secondly, a proportionate sampling technique that adopted a scale of 30 percent was used to select the representative Local Government Areas (LGAs). Noteworthy, given the high density of onion production in Zones I and II, all the LGAs totaling twenty seven (27)constituted the sampling frame. Whereas, in Zone III, only eleven (11) out of the seventeen (17) LGAs comprised the sampling frame as the remaining six (6) LGAs are metropolis with little or no onion farming activities. Succinctly, from Zones I and II; and Zone III respectively four (4) and three (3) LGAs each were randomly selected, thus given a total selection of eleven

(11) LGAs. Fourthly, from each of the selected LGAs, three (3) villages were randomly selected. Lastly, due to the absence of finite sampling frame of onion farmers, using a freelance survey, four (4) farmers were randomly selected from each of the chosen villages, thus gave a total sample size of 132 farmers. Further, using an easy-cost route approach, a well-structured questionnaire coupled with an interview schedule was used to elicit cross-sectional data of onion production during the 2023 cropping (rainy) season. Objectives I, II, III and IV respectively were achieved using pseudo-profit function, constant elasticity of substitution (CES), symmetric normalized quadratic profit function (trans-log), and exploratory factor analysis complemented with Kendall's coefficient of concordance and k-means cluster model.

Table 1: Sampling procedure and sample size

Zones	LGAs	Villages	Sample size
Zone I	Bebeji	Kiriya	4
		Babuda	4
		Dirbawa	4
	Garun Malam	Dorawar Sallau	4
		Kadawa	4
		Garin Babba	4
	Kura	Karfi	4
		Imawa	4
		Kura	4
	Rano	Jan Garu	4
		Rurum	4
		Sabuwar Kaura	4
Zone II	Dambatta	Diggol	4
		Gwanda	4
		Zakirai	4
	Kunchi	Kasuwar Kuka	4
		Zanchi	4
		Sabon Ruwa	4
	Makoda	Dan Marke	4
		Dunawa	4
		Koguna	4
	Minjibir	Baita	4
		Dan Madanho	4
		Wasai	4
		Gidan Gayawa	4

Zone III	Dawakin Kudu	Sarai	4
		Yan Baran	4
	Warawa	Garin Dau	4
		Katarkawa	4
		Dan Hawa Giwa	4
	Wudil	Tsibiri	4
		Lajawa	4
		Wudil	4
3	11	33	132

Source: KNADP and Reconnaissance survey, 2023

Empirical Model

Farm budgeting technique: The farm budgeting technique gives a blurb of enterprise's profitability. Following Sadiq *et al.*(2024a & 2024b) the model is given below:

$NFI = TR - TC$ …… (1)

$GM = TR - TVC$ …….. (2)

$ROI = GM/TVC$ …….. (3)

$ROCI = NI/TC$ …….. (4)

$BEP(kg) = TFC/(P - V)$ …… (5)

$BEP(Naira) = TFC/(1 - V/P)$ …… (6)

Margin of safety (kg) = Total output – BEP(kg) …… (7)

Where, TR = Total revenue; TC= Total cost (TVC+TFC); TVC= Total variable cost; TFC= Total fixed cost; ROI = Return on Naira invested; ROCI = Return on capital invested; BEP = Break-even-point.

Constant Elasticity of Substitution (CES): Following Hanningsen and Hanningsen (2011), CES production with two inputs in its formal specification is as follows:

$$Y_i = \gamma\left[\delta X_1^{-\rho} + (1-\delta) X_2^{-\rho}\right]^{\frac{\upsilon}{\rho}} \quad \text{…… (8)}$$

Where,

Y_i = Output quantity;

X_{1-2} = Input quantities;

$\gamma \in [0,\infty] =$ Determines the productivity;

$\delta \in [0,1] =$ Determines optimal distribution of the inputs (optimal distribution parameter) $(0 < \delta < 1)$

$\rho \in (-1,0) \cup (0,\infty) =$ Determines the (constant) elasticity of substitution (substitution parameter), which is $\sigma = 1/1+\rho, (\rho \geq -1)$

$\upsilon \in [0,\infty] =$ Is equal to the elasticity of scale (return to scale parameter)

For elasticity of substitution (σ), the following relationships between (σ) and (ρ) hold:

$\sigma = \infty$, then $(\rho = -1)$: CES takes the linear form and the inputs are perfect substitute so that the farmers have no special preference for any of the inputs.

$\sigma = 1$, then $(\rho = 0)$: CES becomes Cobb-Douglas function and expressed a perfect balance between substitution and complementary effects. It implies unity elasticity of substitution between the two inputs.

$\sigma = 1$, then $(\rho > 0)$: CES becomes production function with significant complementarity's effect between inputs.

$\sigma > 1$, then $(\rho < 0)$: CES function shows inputs that are partial substitutes.

$\sigma = 0$, then $(\rho = \infty)$: CES takes the form of Leontief production function. This means that, the optimal inputs combination or substitution in the production process does not depend on input prices but fully determined by the parameters defining the production process.

The formal specification of CES for three inputs is as follows:

$$Y = \gamma \left(\sum_{i=1}^{n} \delta_i x_i^{-\rho} \right)^{\frac{-\nu}{\rho}} \quad \text{..... (9)}$$

With $\sum_{i=1}^{n} \delta_i = 1$

Where, n is the number of inputs and x_{1-n} are the quantities of n inputs.

$$Y = \gamma \left[\delta (\delta_1 x_1^{-\rho} + (1-\delta_1) x_2^{-\rho})^{\rho/\rho} + (1-\delta) x_3^{-\rho} \right]^{-\nu/\rho} \quad \text{..... (10)}$$

The formal specification for CES production for four inputs is as follows:

$$Y = \gamma \left[\delta (\delta_1 x_1^{-\rho 1} + (1-\delta_1) x_2^{-\rho 1})^{\rho/\rho 1} + (1-\delta)(\delta_2 x_3^{-\rho 2} + (1-\delta_2) x_4^{-\rho 2})^{\rho/\rho 2} \right]^{-\nu/\rho}$$

..... (11)

Symmetric normalized quadratic profit function (trans-log)

$$\pi(p,z)=\sum_{i=1}^{n}\alpha_i p_i+\frac{1}{2}w^{-1}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}p_i p_j+\sum_{i=1}^{n}\sum_{j=1}^{m}\delta_{ij}p_i z_j+\frac{1}{2}w\sum_{i=1}^{m}\sum_{j=1}^{m}\gamma_{ij}z_i z_j \quad \ldots\ldots\ldots\ldots$$

(12)

With π = profit, p_i = netput prices, z_i = quantities of fixed inputs, $w=\sum_{i=1}^{n}\theta_i p_i$ = price for normalization, θ_i = weights of prices for normalization, and $\alpha_i, \beta_{ij}, \delta_{ij}$ and γ_{ij} = coefficients to estimated.

The netput equations (output supply in input demand) can be obtained by Hotelling's Lemma $(q_i=\partial\pi/\partial pi)$:

$$x_i=\alpha_i+w^{-1}\sum_{j=1}^{n}\beta_{ij}p_j+\frac{1}{2}\theta_i w^{-2}\sum_{j=1}^{n}\sum_{k=1}^{n}\beta_{jk}p_j p_k+\sum_{i=1}^{m}\delta_{ij}z_j+\frac{1}{2}\theta_i\sum_{j=1}^{m}\sum_{k=1}^{m}\gamma_{jk}z_j z_k \quad \ldots\ldots$$

(13)

Noteworthy, Output (kg); inputs: labour (manday), Seed (kg), NPK fertilizer (kg), pesticides (litre), Herbicides (litre), Petrol (litre), Engine oil (litre), Depreciation on capital item (₦), and farm size (hectare).

RESULTS AND DISCUSSION

Costs and Return(s) to Onion Production

The breakdown of the costs and return structures of onion production in Table 1 showed the cost of cultivation cum total variable cost and fixed cost to be ₦456,567.60k, ₦417,873.60k and N38,694.05k respectively. Of the cost of cultivation, the proportions of the total variable cost cum fixed cost were 91.53 and 8.47% respectively. Besides, the costs incurred on labour followed by NPK fertilizer were the highest while incurred cost on engine oil was the lowest. Consequently, the high cost proportion of labour might be attributed to intensive agronomic practices involved in onion production from pre-planting to harvesting stage. Likewise, inability of the farmers to substitute labour for herbicides due to resource paucity is a contributory factor. Noteworthy, the cost of production, i.e., cost incurred per 1kg of onion was ₦6215.22k.

Furthermore, the observed short and long-run profit margins per hectare were ₦952,300.60k and ₦913,606.50k. Besides, nuancing the benefits that accrued to the enterprise, respectively, the benefit-cost ratio indexes in the short and long-run were 2.28(ROI) and 2.00(ROCI). Thus, for the former and latter respectively, for every Naira invested, the cost, i.e., ₦1 is returned and profits of ₦1.28k and ₦1.00 were gained. However, using the ROCI to adjudge the credit solvency, i.e., ability of the farmers to defray a borrowed capital devoid of default/delinquency, at the prevailing cost of credit (interest rate) of 14%, the farmers will be able to retire the principal plus the interest rate and still gain 86 kobo (cent). Nevertheless, the BEP at price and

output are ₦58201.90 and 3.14kg respectively. Besides, the output margin of safety is 70.32kg. Succinctly, it can be concluded that onion production in the study area is not only profitable but a viable venture.

Table 2: Costs and return structure of onion production

Items	Unit	Qty	Unit price	Total value	%
Labour	Manday	93.21	1665.50	155236.30	34
Seed	Kg	2.70	26670.45	72045.44	15.78
NPK fertilizer	Bag (50kg)	4.64	23496.21	109106.20	23.9
Pesticides	Litre	2.38	3529.17	8389.05	1.84
Herbicides	Litre	2.45	3196.97	7836.80	1.72
Petrol	Litre	159.35	185	29479.41	6.46
Engine oil	Litre	1.47	2400	3526.73	0.77
IWC	14% of TVC	32253.70		32253.70	7.06
DCI	Naira	7655.69		7655.69	1.68
Rent	hectare		8000	8000	1.75
Managerial Cost	10% of TVC		23038.36	23038.36	5.05
TVC				417873.60	91.52
TFC				38694.05	8.47
TC				456567.60	
Output	Bag (80kg)	73.46	18543.18	1362174	
Lease-out	hectare	1	8000	8000	
TR				1370174	
Gross Margin				952300.60	
Net Farm Income				913606.50	
ROI				2.28	
ROCI				2.00	
CP				6215.22	
BEP(Output)	Kg			3.14	
BEP (Price)	Naira			58201.90	
Margin of safety	Kg			70.32	

Source: Field survey, 2023

Note: IWC = Interest on working capital; DCI = Depreciation on capital items; CP = Cost of production (i.e., cost per unit of output); ₦ = Naira; k = kobo; BEP = Break-even-point

Inputs Substitution

Keeping land constant (Table 3), the CES production function for two inputs *viz.* lumped working capital and labour showed all the parameter estimates in the model to be within the plausible margin of 10% probability level, thus confirms the fit of the model for the specified crop using lumped capital and labour production inputs. Empirically, it was observed that these two inputs accounted for 74.10% of the variation in the output of onion as evident by the coefficient of multiple determination (R^2) value of 0.7410. Furthermore, the managerial efficiencyparameter (gamma) coefficient of 1.107 implied that managerial efficiency accounted for 1.107% in the productivity of onion production in the study area. However, the low value of managerial efficiency clearly points to poor decision making process by most of the farmers on the business going concern of onion production and the possible reason mightbe due to low educational level, thus affected technological contribution to the onion output. Besides, it showed that the use of primitive implements dominate in the production of onion, i.e., in raising elasticity of substitution, the yield of onion can be raised but its effect may not be potentially large due to the use of conventional farm tools-crude implements. Based on a general normalized CES function, as reported by Idisi *et al*.(2020), Klump and de La Grandville (2000) presented a formal proof on the foregoing conjecture.Furthermore, the return to scale parameter (nu) coefficient of 1.06733, in this case variable proportion to scale, given that land is held constant, showed that the farmers were experiencing an increasing return to scale in the yield of onion. This stage of production is irrational (stage I) as MPP >APP; consequently, the farmers can increase their yield level as there is still room for input mix expansion keeping in-view the input prices or costs so as to attaining the economic optimum level of production in stage II, i.e., rational production level. Moreover, to obtain an optimal distribution of lumped capital and labour for an efficient onion production in the study area, the inputs substitution between lumped capital and labour should be in the ratio of 0.64187 and 0.35813 respectively as evident by the distribution parameter (delta) coefficient that is 0.64187.Further, the constant elasticity of substitution coefficient being less than 1, i.e. 0.5477, implied that the duo of lumped capital and labour in the production of onion had a significant complementary effect. Besides, it indicates that in the study area, the farmers used lumped capital to complement labour in enhancing the productivity of onion. Succinctly, these farmers used more of labour than lumped capitalin the production of onion in the study area. Inspite of the cultivation of onion on small-scale, the complementarity effect of lumped capital over labour was marginal, thus an indication of moderate financial investment in the enterprise. The possible reason could be the costs implication of agronomic practices involved in onion production of the study area.

On the other hand, holding land constant, for the three inputs *viz*. labour, partial lumped working capital and energy/fossil fuel (Table 3), except substitution parameter 1 (rho 1), all the parameter estimates of the CES production function were within the acceptable margin of 10% degree of freedom, thus implying the fitness of the model for the crop using labour, partial lumped working capital and energy/fossil fuels as the production inputs. The coefficient of multiple determination (R^2) been 0.8219 means that these three inputs accounted for 82.19% variation in the yield of onion. The efficiency parameter (gamma) coefficient being 1.269 implied that managerial efficiency that owed to decision making contributed 1.269% to the yield of onion. Besides, this low contribution of management could be attributed to low

educational level of most of the farmers, thus affected the efficiency of the farmers in exploring technological potentials in the production of onion. In addition, the potential effect of management in raising the productivity of onion is minimal and this may not be unconnected with the use of rudimental farm implements in the cultivation of onion in the study area. Further, to achieve an efficient production of onion in the study area, optimal substitutions of labour for partial lumped working capital and energy/fossil fuels should be in the ratio of 0.72947 to 0.27053; and, 0.63887 to 0.36113 respectively, as evident by their respective distribution parameters (delta and delta 1). Moreso, the empirical evidence revealed that the farmers were operating at constant return to scale as indicated by the return to scale parameter (nu) coefficient of 1.00. Thus, the study advises the farmers to be cautious at this rational stage of production and should work meticulously on attaining the economic optimum point given that any input mix expansion will exerts the same marginal effect on the yield level of onion. Furthermore, it was observed that in the production of onion, the constant elasticities of substitution oflabour for lumped partial working capital (0.85418), likewise nested labour and lumped partial working capital for energy/fossil fuels (0.46342) were less than unity as evident by Hicks-McFadden (direct) and Allen-Uzawa/Morishima (partial) elasticities of substitution parameters respectively. These implied that labour and partial lumped working capital; likewise labour and lumped partial working capital combined versus energy/fossil fuels inputs in the production of onion have significant complementarity effect. Therefore, for the direct elasticity, the farmers used labour to complement lumped partial working capital for onion yield enhancement; whereas for the partial elasticity, the farmers combined labour-lumped partial working capital to complement energy/fossil fuel in enhancing the onion's productivity in the study area. Consequently, for the former, farmers used more of lumped partial working capital than labour while for the later the farmers used more of energy/fossil fuels than nested labour-lumped partial working capital. However, the results showed indispensable of the three inputs used in the production of onion in the study area. Nevertheless, for the direct elasticity it can be inferred that the resource poor status of the farmers could be the possible reason for the high deployment of human labour in the production of onion; while for the partial elasticity, the challenge of climate change- dry spell, could be the possible reason that forced the farmers to use appreciable quantity of fossil fuels/energy for irrigation purposes in order to achieve high productivity of onion in the study area.

For the four input combination (labour, seed, biocides an energy/fossil fuels) (Table 3), *ceteris paribus*, the CES function was found to be fit for the specified equation as evident by most of its estimated parameters that were different from zero at 10% degree of freedom. Noteworthy, 79.46% of variation in the output of onion is being explained by the joint influence of all the inputs included in the model as evident by the R^2 value that is 0.7946. The significant of the efficiency parameter entails that there was significant technological progress in the production of onion but due to the use of rudimental implements for cultivation coupled with poor education level that masked the management of the firm, the potential effect of the technical progress was small, i.e., 1.088% as evident by the efficiency parameter coefficient value of 1.088. Further, both the optimal distribution parameter estimates were significant, meaning the presence of proportional substitution between these inputs. For the distribution parameter (delta), the coefficient value of 0.67332 implied that to achieve an efficient onion production in the study, an optimum distribution of labour for seed should be in the proportion of 0.67332

and 0.32668 respectively. Besides, for the distribution parameter (delta 1), the coefficient value been 0.63904, means that an optimum substitution of labour for biocides in the ratio of 0.63904: 0.36096 is needed for the farmers to achieve an efficient onion production. Nevertheless, for labour and energy/fossil fuels, the ratio of 0.48577 to 0.51423 respectively, is the optimum substitution required by the farmers to have an efficient onion production. Moreso, the result showed that the farmers were operating at an increasing proportion to scale as indicated by the coefficient value of return to scale parameter (1.07149). Therefore, given that the operational scale level of production is irrational, keeping inview the input and output prices, by adopting appropriate input mix, the farmers are advised to increase their output level so as to achieve economic efficiency in onion production. Furthermore, as evident by the significant of CES coefficients that are within the acceptable margin of 10% error gap, the constant elasticity of substitution for onion production at various input combinations were less than unity, thus implied significant complementarity effect between inputs at various level of combination in the production of onion in the study area. The complementarity effects of input combinations *viz*. labour and seed; and, biocides and energy/fossil fuels as evident by their respective Hicks-McFadden (direct) elasticity of substitution mean that more of seed than labour is used in cultivation of onion for the former while for the later the farmers used more of energy/fossil fuels than biocides in the cultivation of onion. Nuancing empirically, it can be inferred that the farmers used improved seed varieties and fossil fuels for the purpose of irrigation to improve the yield of onion. Nevertheless, the complementarity effect between combined labour-seed and combined biocides-energy/fossil fuels as indicated by the Allen-Uzawa (partial) elasticity of substitution means that more of combined biocides and energy/fossil fuels than combined labour and seed is used by the farmers to cultivate onion production in the study area. Succinctly, the effect of climate change, attributable to erratic rainfall which inturn makes the crop highly susceptibility to pest and diseases; and, favourable marketfor the cropmakes the farmers to invest more in the purchase of biocides and energy/fossil fuels for higher output in the study area.

Table 3: Inputs substitution at various levels

Variables	Two-inputs	Three-inputs	Four-inputs
γ	1.1072 (6.677)***	1.2690(8.329)***	1.0881(7.553)***
δ	0.6418 (17.19)***	0.7294(22.03)***	0.6733(16.717)***
δ_1	-	0.6388(25.99)***	0.6390(17.03)***
δ_2	-	-	0.4857(17.42)***
ρ	0.8258(1.937)*	$0.1707(0.439)^{NS}$	$0.2502(0.615)^{NS}$
ρ_1		1.1578(3.746)***	0.6336(1.743)*
ρ_2			0.6705(1.873)*
ν	1.0673(17.51)***	1.0052(19.73)***	1.0714(19.23)***
σ_{1-2}	0.5477(4.282)***	0.8541(3.011)**	0.7998(3.073)**
σ_{3-4}			0.6121(4.493)***
$\sigma_{1,2-3}/\sigma_{1,2-3,4}$		0.4634(6.982)***	0.5986(4.667)***
R^2	0.7410	0.8219	0.7946

Source: Field survey, 2023

Note: Significant at 1% "***"; 5% "**"; 10% "*"; NS = Non-significant; lumped working capital (seeds; biocides- NPK fertilizer, herbicides and pesticides; and energy/fossil fuel- petrol and engine oil); partial lumped working capital (excluding energy/fossil fuels)

Elasticities of Output Supply and Inputs Demand

Presented in Table 4 are the parameter estimates of the symmetric normalized quadratic (translog) profit function for onion production in the study area. Besides, convexity was achieved in the non-linear least square estimation. Empirically, of the 74 parameter estimates, 28 estimated coefficients were asymptotically significant at the acceptable margin of 10% probability level. Nuancing, the coefficients of factor prices vis-à-vis labour, NPK fertilizer and petrol-engine oil had negative significant influence on profit, whereas, the coefficient of the output price had significant-positive influence on the profit, thus conform to the a priori expectations. However, the values of the estimated coefficients were greater than unity, implying that the output-input prices had elastic effect on the profit. Further, all the aforementioned coefficients were elastic in nature, thus, a slight increase in the prices of former and latter will lead to a more than proportionate decrease and increase respectively in the output of onion. However, the non-significant of seed coefficient might be attributed to use of third filial generation of improved seed varieties while that of pesticides and herbicides might be associated with a low usage due to a high substitution effect with labour. Noteworthy, the poor substitutions of pesticides and herbicides for labour have been justified in the discussion of costs and return. Furthermore, in descending order, the coefficient values of labour, petrol-engine oil and NPK fertilizer prices been the highest, implied the high dependency of profit on these prices.

Table 4: Estimated symmetric normalized quadratic profit function for onion production

Parameters	Coefficient	Stand error	t-statistics	Parameters	Coefficient	Stand error	t-statistics
α 1	50.174	14.109	3.556***	β 4 4	-52.411	16.895	3.102***
α 2	-31.897	9.5121	3.353***	β 4 5	-2.8727	11.881	0.241^{NS}
α 3	-5.8041	4.4898	1.292^{NS}	β 4 6	-14.51	15.537	0.933^{NS}
α 4	-14.582	5.8065	2.511**	β 4 7	0.9507	11.149	0.085^{NS}
α 5	-5.8271	4.2479	1.371^{NS}	β 5 1	-0.6244	2.9185	0.213^{NS}
α 6	-7.6296	4.9965	1.526^{NS}	β 5 2	7.0061	9.5844	0.731^{NS}
α 7	-22.423	7.8673	2.85***	β 5 3	-8.126	8.5469	0.951^{NS}
β 1 1	0.3099	1.2017	0.257^{NS}	β 5 4	-2.8727	11.881	0.241^{NS}
β 1 2	1.2519	3.002	0.417^{NS}	β 5 5	-20.965	14.394	1.456^{NS}
β 1 3	-2.4283	2.154	1.127^{NS}	β 5 6	-8.2628	13.384	0.617^{NS}
β 1 4	-2.0114	3.1942	0.629^{NS}	β 5 7	33.845	10.564	3.203***
β 1 5	-0.6244	2.9185	0.213^{NS}	β 6 1	2.8302	3.7601	0.752^{NS}
β 1 6	2.8302	3.7601	0.752^{NS}	β 6 2	-20.237	13.015	1.554^{NS}
β 1 7	0.672	3.1197	0.215^{NS}	β 6 3	-20.689	11.337	1.824*
β 2 1	1.2519	3.0018	0.417^{NS}	β 6 4	-14.51	15.537	0.933^{NS}
β 2 2	-4.5093	16.303	0.276^{NS}	β 6 5	-8.2628	13.384	0.617^{NS}
β 2 3	-16.964	6.3152	2.686***	β 6 6	3.9965	23.435	0.171^{NS}
β 2 4	11.206	10.488	1.068^{NS}	β 6 7	56.873	13.569	4.191***
β 2 5	7.0061	9.5844	0.731^{NS}	β 7 1	0.6721	3.1197	0.215^{NS}
β 2 6	-20.237	13.015	1.554^{NS}	β 7 2	22.246	10.364	2.146**
β 2 7	22.246	10.364	2.146**	β 7 3	13.651	7.3126	1.866*
β 3 1	-2.4283	2.154	1.127^{NS}	β 7 4	0.9507	11.1495	0.085^{NS}
β 3 2	-16.964	6.3152	2.686***	β 7 5	33.845	10.564	3.203***
β 3 3	-25.091	9.8011	2.56***	β 7 6	56.873	13.569	4.191***
β 3 4	59.648	9.4758	6.294***	β 7 7	-128.23	14.621	8.771***
β 3 5	-8.126	8.5469	0.951^{NS}	δ 1 1	5.0831	-2.9573	1.718*
β 3 6	-20.689	11.337	1.824^{NS}	δ 1 2	-0.0619	3.1724	0.019^{NS}
β 3 7	13.651	7.3126	1.866*	δ 2 1	7.4733	-1.9611	3.811***
β 4 1	-2.0114	3.1942	0.629^{NS}	δ 2 2	0.1531	2.0941	0.073^{NS}

β 4 2	11.206	10.488	1.068^{NS}	δ 3 1	10.354	-0.7131	14.519***
β 4 3	59.648	9.4758	6.294***	δ 3 2	0.451	0.6807	0.662^{NS}

Source: Field survey, 2023

Table 4: Continued ……..

Variable	Coefficients	Standard error	t-statistics
δ 4 1	7.9791	-1.0508	-7.592
δ 4 2	0.1936	1.0681	0.181
δ 5 1	8.403	-0.6276	-13.38
δ 5 2	0.1353	0.5725	0.236
δ 6 1	8.2907	-0.7209	-11.49
δ 6 2	-0.0264	0.6484	0.04
δ 7 1	3.3524	-1.6095	2.082
δ 7 2	0.4363	1.7094	0.255
ϒ 1 1	0.0255	1.1701	0.021
ϒ 1 2	0.0865	-0.955	0.091
ϒ 2 1	0.0865	-0.955	0.091
ϒ 2 1	0.0239	1.0326	0.091
R^2	0.9604		

Source: Field survey, 2023

Shown in Table 5a are the elasticities of the output supply cum inputs demand. The own-price elasticity of all the inputs demand were negative (ranged from -0.139 to -4.869), thus, impliedthat all the estimated inputs' demand slopes downward as required for convexity of the profit function. Except the prices of labour and herbicides that were inelastic, all the input prices were elastic, thus meaning that an increase in the input prices of the former will lead to a less than proportionate decrease in their demand while in the case of the latter, the resultant effect will be more than a proportionate increase in their demand. Succinctly, the input demand elasticity of the former implied they are necessary (necessities) goods while that of the latter implied they are luxury goods. Noteworthy, only own-price elasticities of seeds, NPK fertilizer and petrol-engine oil were found to be significant. Therefore, for a unit increase in the prices of seeds, NPK fertilizer and petrol-engine oil respectively by 1%, their respective demand will plummet by 3.061, 3.467 and 4.869%.

Furthermore, the output price of onion (a change in quantity supply) had a significant and positive effect on supply, thus indicated the upward slope of the onion output supply curve. This conforms to the a priori expectation as postulated by the theory of supply. Thus, for a

percent increase in the output price (0.0066), the output supply will increase by 0.0066%. Nevertheless, all the variable factor prices had negative effect on output supply (change in supply); however, only seeds, NPK fertilizer and petrol-engine oil prices were significant. Likewise, fixed inputs *viz*. land and depreciation on capital items were inversely related to the output supply.The negative elasticities with respect to the variable inputs implied that there will be a decline in input use in the eventuality of a price hike, thus plummet the supply of onion output. Given the price coefficients of seeds, NPK fertilizer, and petrol-engine oil been 0.0499, 0.041 and 0.0118 respectively, for a unit price increase (1%), the resultant decrease in their demand will lead to a decline in onion output by 0.0499, 0.041 and 0.0118%. Also, the negative elasticity of land with respects to the output means that diseconomies of size prevailed in production of onion in the study area (Table 5b). This is expected as the operational farm holdings of majority of the farmers are marginal. Likewise, the negative elasticity of depreciation on capital items implied that cost implication of wear and tear decreased output supply of onion. However, the significant of the fixed costs couldn't be ascertained as the R software estimation guide used had no provision for it. Nevertheless, the price and cross-price elasticities of supply were inelastic, thus means that a change in the prices of output-inputs would lead to a less than proportionate change in the supply of onion output. By implication, onion is a necessary commodity in the study area. Generally, it can be inferred that supply of onion is being influenced by its output price and prices of improved seeds, NPK fertilizer and petrol-engine oil. Therefore, the study advises policymakers to devise a realistic means of subsidizing these inputs as hyper-inflation occasioned by petrol subsidy removal has permeated the price efficiency of these inputs. Besides, particularly petrol-engine oil, the farmers are advised to adopt energy friendly tools that used alternative green energy source (e.g., solar driven water pump machines). Though,expensive, but by social capital pooling (co-operative organization) and support from policymakers (private and public), access to this machine and hosts of others are possible.

Table 5a: Output supply and variable inputs demand elasticities

Variable	P_Y	P_L	P_S	P_N	P_P	P_H	P_{PE}
	Elasticity coefficients						
Output (Y)	0.0066	0.0256	-0.0499	-0.041	-0.0121	0.0591	0.0117
Labour (L)	0.0397	-0.1393	-0.5261	0.3472	0.2164	-0.6211	0.6832
Seed (S)	-0.3041	-2.0697	-3.0608	7.276	-0.9858	-2.506	1.6506
NPK fertilizer (N)	-0.1355	0.7401	3.9421	-3.4667	-0.1885	-0.9514	0.0602
Pesticides (P)	-0.1088	1.2516	-1.4492	-0.5116	-3.7196	-1.4622	5.9998
Herbicides (H)	0.5128	0.5128	-3.5672	-2.4997	-1.416	-0.6893	9.7593
Petrol/Engine oil (PE)	0.0225	0.8466	0.5199	0.035	1.2856	2.1595	-4.8693
	t-statistics						
Output (Y)	2.2693	0.4223	-1.1449	-0.6355	0.207	0.7822	0.1877
Labour (L)	0.4223	-0.2763	-2.6901	1.0688	0.733	1.5508	2.1411
Seed (S)	-1.1449	-2.6901	-2.5631	6.3017	0.9508	1.8241	1.8621
NPK fertilizer (N)	-0.6355	1.0688	6.3017	-3.1065	0.2414	0.9325	0.0822
Pesticides (P)	-0.207	0.733	-0.9508	0.2414	1.4556	0.6161	3.2028
Herbicides (H)	0.7822	-1.5508	-1.8241	0.9325	0.6161	0.1714	4.1931
Petrol/Engine oil (PE)	0.1877	2.1411	1.8621	0.0822	3.2028	4.1931	8.7694

Source: Field survey, 2023

Note: P = Price (s)

Table 5b: Fixed inputs demand elasticities

Variable	Farm size	DCI
Output (Y)	-0.01803	-0.001003
Labour (L)	-0.03935	0.053711
Seed (S)	-0.21067	0.495163
NPK fertilizer (N)	-0.08851	0.124481
Pesticides (P)	-0.24991	0.224213
Herbicides (H)	-0.23855	-0.02787
Petrol/Engine oil (PE)	-0.02214	0.158356

Source: Field survey, 2023

Note: DCI = depreciation on capital item

Challenges Affecting Onion Production

A perusal of the challenges showed that any challenge with a threshold below 2.0 is a very severe constraint that affected onion production: few examples are high perishability, post-harvest losses, inadequate storage facilities etc (Table 6). Further, the challenges with a threshold value of equal to 2.0 and less than 3.0 are perceived as severe constraints (e.g., high cost of transportation, problem of land tenure system etc.); challenges with a threshold value of 3.0 are perceived as moderate constraints (e.g., poor access to market information, seed viability constraint etc.). Generally, the farmers have negative/unfavourable perception about the challenges affecting onion production as evident by the grand mean index value of 2.61 that is less than the likert scale mean threshold value of 3.5. Besides, 43.61 percent of the respondents had negative perceptions on the challenges that affected onion production as evident by the perception index value of 0.4361. Nevertheless, the Kendall's coefficient of concordance showed that the farmers didn't anonymous agreed with the ranking of these challenges as evident by the significant KCC index value of 0.201.

Furthermore, the factor analysis conducted on the barriers affecting small-scale onion farmers, utilizing the verimax rotation method (Table 6), revealed noteworthy insights. The computed Kaiser-Meyer-Olkin (KMO) index, standing at 0.769, along with a statistical significant Barlett's sphericity test (BST), signifies the suitability of the dataset for factor analysis. This is corroborated by a review of the KMO value, which surpasses the recommended threshold value of 0.50 set by Kaiser (1974); Sadiq (2023); Sadiq *et al*.(2024b). Such statistical indicators establish a robust foundation for deriving meaningful factors affecting onion production among small-scale farmers. The factor extraction process, guided by item loadings, yielded eight distinct components representing barriers to onion production. These components are elucidated as follows: Market information problem (F1), Climate change problem (F2), Low public-private investment problem (F3), Land tenure problem (F4), Infrastructure problem (F5), Capital problem (F6), Storage facilities problem (F7), postharvest losses problem (F8), Theft/poaching problem (F9) and Agronomic practices knowledge problem (F10).

The factors affecting onion production and market success are multifaceted, and a comprehensive understanding of these factors is crucial for effective planning and resource allocation. This study explores the explicit barriers associated with various factors, shedding light on critical challenges faced by farmers in optimizing their agricultural practices and navigating market dynamics. In the realm of "market information problem" (factor one), barriers manifest prominently in the form of poor access to market information (.728) and inadequate awareness of postharvest technology usage (.622). Notably, poor access to market information emerges as the most formidable challenge within this factor, underscoring its pivotal role as a major constraint in the context of market information. This revelation emphasizes the urgent need for interventions aimed at enhancing farmers' access to timely and accurate market data. Factor two delves into obstacles related to technical advice on input usage (.882) and Climate change constraints (.715). Here, climate change constraints take center stage with the highest loading, signifying their significance as the primary barriers of climate change challenges. Acknowledging and addressing these constraints are vital for building resilience and sustainability in agriculture, particularly in the face of a changing climate.

Factor three encompasses barriers such as low public and private investment (.737) and challenges in leasing or renting farmland (.596). The highest loading within this factor is attributed to low public and private investment, indicating its pivotal role as the most prominent barrier concerning low public-private investment. Effective strategies to attract and mobilize investments are imperative to bolster the agricultural sector and propel economic growth. Factor four sheds light on obstacles like land tenure system (.552), and disease and insect pests (.431). Additionally, recognizing the significance of land tenure and pest management is crucial for fostering a conducive environment for agricultural development.

Factor five focuses on barriers associated with poor infrastructure (.809) and high perishability (.494). These challenges highlight the critical need for infrastructure development to facilitate efficient agricultural operations and minimize postharvest losses. Factor six, capital problem, emphasizes the significance of lack of sufficient capital (.807) as the predominant barrier. This aligns with broader agricultural research indicating that inadequate capital poses a substantial risk to farm operations. Addressing this challenge requires innovative financial solutions and improved access to credit for small-scale farmers. Factor seven is characterized by the sole presence of inadequate storage facilities (.820) as a barrier. Developing and upgrading storage infrastructure is crucial for mitigating postharvest losses and ensuring food security.

Factor eight (Postharvest losses problem) underscores barriers such as postharvest losses (.884) and a high cost of transportation (.488). These challenges highlight the need for improved postharvest management practices and logistical solutions to minimize losses and enhance market access. Factor nine showed farmers concern on theft/poaching of farm produce; thus, highlight the need to look into this social menace of state of insecurity in the study area. Finally, factor ten emphasized on poor agronomic practices; thus, highlight the need for adequate advisory services for effective dissemination ofimproved innovative technologies. Furthermore, for factors 1, 2, 3, 4 and 5, respectively, the proportions of farmers that expressed concern were 11.36, 6.82, 5.3, 6.82 and 18.94% as evident by the k-means cluster analysis. Likewise, for factors 6, 7, 8, 9 and 10, respectively, the distributions of farmers that showed concern were 3.03, 15.91, 6.82, 6.82 and 18.18%. Comprehensive understanding of these explicit barriers is vital for policymakers, agricultural extension services, and stakeholders to formulate targeted interventions that address the diverse challenges faced by farmers. By strategically tackling these obstacles, it is possible to create a more resilient, sustainable, and prosperous agricultural sector.

Table 6: Challenges affecting onion production

Constraints	Mean	F1	F2	F3	F4	F5	F6	F7
Inadequate knowledge on best agronomic practices	1.84(16)							
Inadequate storage facilities	1.48(20)							.820
High cost of transportation	2.35(14)							
Fluctuation of market price	1.66(17)	-.616						
Lack of sufficient capital	1.52(18)						.807	
Postharvest loses	1.39(19)							
High perishability	1.34(21)					.494		
Disease and insect pest	3.86(1)				.436			.426
Inadequate awareness on the use of postharvest technology	2.83(12)	.622						
Inadequate of technical advice on input usage	3.45(3)		-.416					
Seed viability constraint	3.16(7)		.682					
Climate change constraints	3.36(4)		.715					
Poor infrastructure	2.95(10)					.809		
Inadequate extension services	2.95(9)				-.791			
Difficulty in leasing or rent of farm land	3.18(6)			.596				
Problem of land tenure system	2.36(15)				.552			
High level of illiteracy	3.46(11)							
Theft of produce/ problem of poaching	3.40(5)	.728						
Poor access to market information	3.02(2)			.737				
Low public and private investment	2.52(8)							
Inadequate of incentives to farmers	2.87(13)							
Grand mean (perception index)	2.62(0.4361)							
KCC (Freidman test)	0.201(531.61***)							
Eigen value		1.876	1.697	1.617	1.459	1.38	1.251	1.182
Variance %		8.934	8.08	7.698	6.948	6.571	5.959	5.629

Source: Field survey, 2023

Table 6: Continued ……

Constraints	F8	F9	F10
Inadequate knowledge on best agronomic practices			.851
Inadequate storage facilities			
High cost of transportation	.488		
Fluctuation of market price			
Lack of sufficient capital			
Postharvest loses	.884		
High perishability			
Disease and insect pest			
Inadequate awareness on the use of postharvest technology			
Inadequate of technical advice on input usage			
Seed viability constraint			
Climate change constraints			
Poor infrastructure			
Inadequate extension services			
Difficulty in leasing or rent of farm land			
Problem of land tenure system			
High level of illiteracy		.766	
Theft of produce/ problem of poaching			
Poor access to market information			
Low public and private investment			
Inadequate of incentives to farmers		-.678	
Eigen value	1.176	1.138	1.019
Variance %	5.599	5.42	4.854
KMO	0.769		
Bartlett's test of Sphericity	246.38***		

Note: Value in parenthesis in column 2 are ranks; Mean benchmark is 3.5; Grand mean = sum of mean divided by total number of statements; Perception index = grand mean divided by highest Likert scale value (Sadiq *et al.* 2018; Sadiq *et al*., 2024a).

CONCLUSION AND RECOMMENDATION(S)

Empirically, onion production is a viable enterprise in the study area and inputs substitution at various levels of combination is complimentary. Moreover, profit significantly influenced price

of the output, and prices of labour, NPK fertilizer and petrol-engine oil. Likewise, except wage rate, supply of onion output significantly relied on prices of its output, seeds, NPK fertilizer and petrol-engine oil. However, the input prices caused a significant decline in the supply of onion output, thus the need for a realistic incentive measures so as to arrest the poor pricing efficiency of these input prices. Nevertheless, the ten challenges viz. poor market information, climate change problem, low public-private investment, land tenure problem etc. should be addressed so as to bolster the production onion in the study area.

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BASAL CELL CARCINOMA IN A RABBIT

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Abstract

Basal cell carcinoma is a low-grade neoplastic tumor originating from the basal cells of the epidermis of the skin that occurs in animals, mainly in areas directly exposed to ultraviolet radiation. So far, several reports have been published in cats and dogs, but its incidence in other animals, including rabbits, is rare. A 3-year-old female New Zealand white rabbit was referred to the veterinary hospital with a prominent mass on the right hand. Finally, the mass was surgically removed and sent to the laboratory for histopathological evaluation. Based on macroscopical and histopathological findings, the mass was diagnosed as infiltrative type of basal cell carcinoma. The primary treatment of basal cell tumors is surgery based on the size, number, and location of the tumor.

Keywords: Rabbit, Neoplasia, Pathology, Basal cell carcinoma

Introduction

Basal cell carcinoma (BCC) is a low-grade neoplastic tumor with poor cellular differentiation that originates from the basal cells of the epidermis. This type of tumor is usually the result of chronic and direct exposure to ultraviolet radiation (UV) from sunlight(Solans Vilanova et al., 2023). BCC typically has a high mitotic index and tends to invasion the dermis, but its metastatic potential is low. Histological features such as basaloid cells with hyperchromatic nuclei and little cytoplasm, islands of neoplastic cells in the dermis, and, in some cases, the presence of cystic spaces in the mass are prominent features in the microscopic evaluation of this type of tumor(Martino et al., 2017). So far, numerous reports have been published on the occurrence of BCC in cats and dogs, mainly in hairless areas of the head, neck, and trunk, and its pattern of occurrence is related to the density of skin pigments(Goldschmidt, 1984; Munday et al., 2017). However, its occurrence in rabbits has been reported as a rare event. Based on the research conducted, this study is the first report of the occurrence of basal cell carcinoma in the hand of rabbits, indicating the unusual occurrence of this tumor in rabbits.

Case description

In October 2024, a 3-year-old female New Zealand white rabbit with a prominent mass on right hand measuring 1×2×0.5cm was referred to the veterinary hospital. On physical examination, the mass was raised. During the clinical examination, the general condition and vital signs of the animal were good. Finally, the mass was surgically removed completely and sent to the laboratory for histopathological evaluation. On cut section, it was firm, encapsulated and pale pink in appearance. Tissue samples of the mass were fixed in 10% neutral buffered formalin, routinely processed, dehydrated, embedded in paraffin wax, sectioned at 5µm in thickness and stained with Haematoxylin and Eosin. Sections were examined using a light microscope (Motic, BA310 Epi-LED FL) and representative images were taken.

Result

On histopathological examination, an encapsulated, multilobular and densely cellular neoplastic mass was identified. Extensive infiltration of neoplastic cells to the dermis and subcutaneous tissue were observed. The masses were composed of nests, sheets, lobules and trabeculae of neoplastic cells within a fibrovascular stroma. The palisading basaloid neoplastic cells were markedly extended from the basal cells of the epidermis into the dermis. Most of the neoplastic cells had scant amounts of eosinophilic cytoplasm with indistinct margins, round to ovoid nuclei and typically a single small basophilic nucleolus. The neoplastic cells had no differentiation to squamous epithelium. Mitotic figures were observed. Based on macroscopical and histopathological findings, the mass was diagnosed as infiltrative type of basal cell carcinoma (Figure 1).

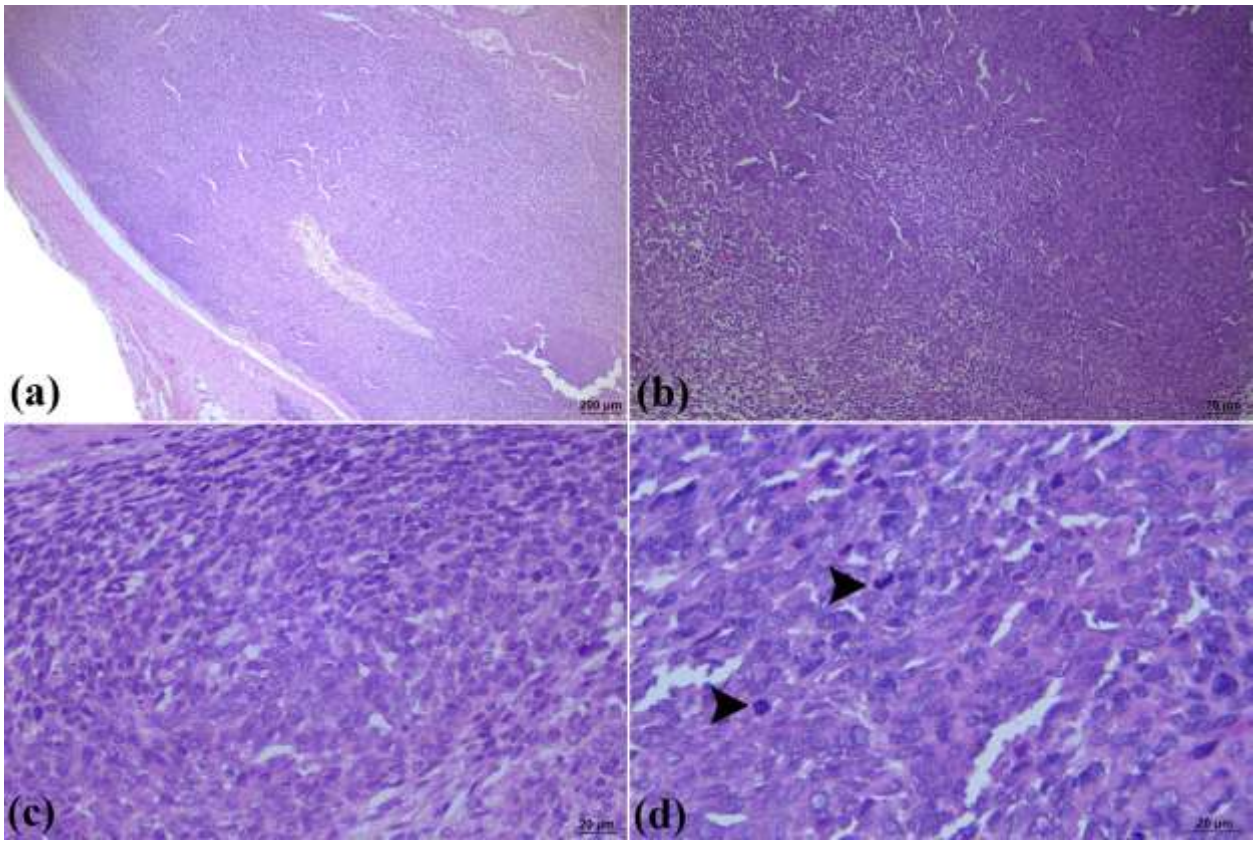

Figure 1(a-d): Histopathological findings of basal cell carcinoma in a rabbit. (a-c): Note the encapsulated and densely cellular neoplastic mass. (d): Two mitotic figures (arrowheads), H&E.

Discussion

In this report, a rare case of basal cell carcinoma in the forelimb of a 3-year-old female New Zealand white rabbit is described. This finding is important because the occurrence of BCC in rabbits has been rarely reported. In terms of histopathological pattern, BCC usually appears as a solitary, nodular, firm, or cystic mass (Di Stefani and Chimenti, 2015). The neoplastic cells had no differentiation to squamous epithelium or adnexal structures. Observation of several mitotic figures was in concurrence with the findings of Goldschmidt and Goldschmidt (2017). In the study by Basheer Ahamad et al., the growth pattern of neoplastic basaloid cells in the form of solid islands with necrotic areas in the center and proliferation of fibrous connective tissue in the dermis was proposed as key characteristics of BCC, which was also observed in the present case with differences in the anatomical region (Ahamad et al., 2014). Considering the anatomical location of the lesion in BCC is of great clinical importance because the occurrence of the tumor in unusual areas delays the diagnosis. In these cases, the use of various diagnostic methods, including biopsy and histopathological examination, is helpful. Given the known role of UV in the pathogenesis of this tumor by inducing mutations in cell cycle regulatory genes in epidermal cells(Basset-Seguin & Herms, 2020), as well as causing chronic skin lesions and increased inflammatory responses (Bohn, et al., 2006), especially in areas

exposed to sunlight, it seems that UV is a possible factor involved in the occurrence of BCC in rabbits in the present study, although other factors may also be effective in the occurrence of this tumor. In various reports, the role of solar radiation as an effective factor in the occurrence of BCC in dogs has also been considered (Saridomichelakis, et al., 2013). on American Staffordshire bull terriers, where UV caused mutations in the P_{53} gene and disruption of tumor suppression and cell cycle control mechanisms, as well as increased cell proliferation and decreased ability to repair DNA damage, which in turn led to the initiation and progression of BCC skin tumors (Saridomichelakis, et al., 2013). However, in the study conducted by Walder and Gross, BCC tumors in feline occurred in areas of the body that were not directly exposed to sunlight(Gross, Ihrke, & Walder, 1992). This clinical and pathological difference seems to be due to the structural and genetic differences in the types of cells involved in each tumor. Considering the effect of UV radiation on the occurrence of BCC, this issue also applies to another epidermal skin tumor called squamous cell carcinoma. The difference is that the effects of UV radiation in SCC are more destructive than in BCC, and its growth rate and metastatic power are also greater than in BCC(Suzuki, Inoue, Kuramochi, Kiyohara, & Ikeda, 1997; Tsujita & Plummer, 2010). The present study shows that Bcc in rabbit is a skin tumor with similar pathological features in domestic animals. The primary treatment of basal cell tumors is surgery based on the size, number, and location of the tumor.

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EFFECTIVENESS OF YOLO ALGORITHM MODEL IN AGRICULTURAL APPLICATIONS

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ABSTRACT

The rapid increase in the world population, difficulties in accessing qualified labor in the agricultural sector, the negative effects of climate change on agricultural production, and major problems such as limited resources have made it necessary to find more sustainable methods in agriculture that will minimize human power. This necessity has led to a faster integration of digital technologies into the agricultural sector.

Academic publications published in recent years were examined as a method, and data obtained from research in sources such as DegiPark, Google Scholar, and ResearchGate were taken as basis. Within the scope of the literature research, the effectiveness of the YOLO model in various areas such as the increase in harvest in agriculture, the detection of weeds that damage crops, and automatic diseased areas in fields were analyzed.

The YOLO (You Only Look Once) algorithm is a revolutionary technology in the field of computer vision thanks to its real-time object detection capacity. This powerful algorithm has a wide range of uses in agricultural applications. Early detection of plant diseases in particular plays a critical role in increasing efficiency in agricultural production. Similarly, it provides great convenience in the process of detecting unwanted weeds in fields and gardens in a timely manner and controlling them. In addition, determining the maturity levels of fruits and vegetables contributes to the correct planning of harvest time, which increases product quality. In addition, it is also very useful in livestock enterprises in terms of monitoring the behavior of animals and detecting possible health problems at an early stage.

This study examines the use and impact of the YOLO (You Only Look Once) algorithm in agricultural production. Our research tested the impact of YOLO algorithm in agricultural applications with different situations and evaluated how it performs in important applications such as plant health monitoring, accurate harvesting time determination, irrigation optimization and animal tracking. Our research results show that YOLO-based systems are superior in terms of accuracy, time utilization and cost in agriculture. The study also provides a technical framework to promote the widespread use of AI-based image processing techniques in

agriculture and contributes to the literature by presenting the analysis for future research in this field.

Keywords: YOLO algorithm, agricultural artificial intelligence, image processing, object detection, smart agriculture.

TARIM UYGULAMALARINDA YOLO ALGORİTMA MODELİNİN ETKİNLİĞİ

ÖZET

Dünya nüfusunun hızla artması, tarım sektöründe nitelikli çalışan gücüne erişimde yaşanan zorluklar, iklim değişikliklerinin tarımsal üretim üzerindeki olumsuz etkileri ve sınırlı kaynaklar gibi büyük sorunlar, tarımda daha sürdürülebilir, insan gücünü minimalize edecek olan yöntemler bulmayı zorunlu hale getirmiştir. Bu zorunluluk, dijital teknolojilerin tarım sektörüne daha hızlı bir şekilde entegre olmasına yol açmıştır.

Yöntem olarak son yıllarda yayımlanmış olan akademik yayınlar incelenmiş olup, Özellikle DegiPark, Google Akademik, ResearchGate gibi kaynaklardaki araştırmalardan elde edilen veriler esas alınmıştır. Literatür araştırması kapsamında YOLO modelinin, tarımda hasat miktarındaki artışı, ekinlere zarar veren yabancı otların tespiti, tarlalarda otomatik hastalıklı bölge tespiti gibi çeşitli alanlardaki etkinlikleri analiz edilmiştir.

YOLO (You Only Look Once) algoritması, gerçek zamanlı nesne tespiti yapabilme kapasitesi sayesinde bilgisayarla görme alanında devrim niteliğinde bir teknolojidir. Bu güçlü algoritma, tarım uygulamalarında da oldukça geniş bir kullanım alanına sahiptir. Özellikle bitki hastalıklarının erken teşhisi, tarımsal üretimde verimliliği artırmak adına kritik bir rol oynamaktadır. Aynı şekilde, tarlalarda ve bahçelerde istenmeyen yabani otların zamanında tespit edilerek kontrol altına alınması sürecinde de büyük kolaylıklar sağlamaktadır. Ayrıca, meyve ve sebzelerin olgunluk düzeylerinin belirlenmesi, hasat zamanının doğru bir şekilde planlanmasına katkı sunmakta, bu da ürün kalitesini artırmaktadır. Bununla birlikte, hayvancılıkla uğraşan işletmelerde, hayvanların davranışlarının izlenmesi ve olası sağlık sorunlarının erken safhada fark edilmesi açısından da oldukça faydalıdır.

Bu çalışma, YOLO (You Only Look Once) algoritmasının tarım üretiminde kullanımı ve etkisini incelemektedir. Araştırmamız, YOLO algoritmasının tarım uygulamalarındaki etkisini farklı durumlarla test etmiş ve bitki sağlığı izleme, doğru hasat zamanı belirleme, sulamanın optimizasyonu ve hayvan takibi gibi önemli uygulamalarda nasıl performans gösterdiğini değerlendirmiştir. Araştırma sonuçlarımız, YOLO tabanlı sistemlerin tarımda doğruluk, zaman kullanımı ve maliyet açısından daha üstün olduğunu göstermektedir. Çalışma ayrıca, tarımda yapay zekâ tabanlı görüntü işleme tekniklerinin yaygınlaşmasını teşvik etmek için teknik bir çerçeve sunmakta ve gelecekte yapılacak araştırmalar için bu alanda analizi sunarak literatüre katkı sağlamaktadır.

Anahtar Kelimeler: YOLO algoritması, tarımsal yapay zekâ, görüntü işleme, nesne tespiti, akıllı tarım

GİRİŞ

Dijital tarım çağında, karmaşık algılama, veri işleme, analitik ve dijital teknolojilerin kullanımı ve entegrasyonu daha kolay hale gelmektedir. Çevre üzerinde mümkün olan en az etkiyle gıda üretimini artırmak için dijital tarım teknolojisi kaynak verimliliğinin artırılmasına yardımcı olmaktadır (Fountas vd., 2020). Bu nedenle, artan üretim maliyetleri, işçi eksikliği, bozulan veya tükenen doğal kaynaklar, iklim değişikliği vb. gibi dünyanın gıda sistemlerinin karşı karşıya olduğu büyük sorunlara ana cevaplardan birinin tarımsal otomasyon ve dijitalleştirme olduğu görülmüştür. Otonom ve akıllı sistemlerden oluşan dijital tarım teknolojilerine olan ilginin artması, optik sensör teknolojisi, bilgi işlem gücü ve veri odaklı makine öğrenme tekniklerindeki devam eden gelişmelerin bir sonucudur. Son yıllarda daha düşük donanım maliyetleri ve daha yüksek bilgi işlem gücü nedeniyle, nesne tanıma teknikleri gibi derin öğrenmeye dayalı bilgisayarlı görme uygulamaları tarım sektöründe hızla büyümüştür (Tian vd., 2023). Kameralar, görüntü işleme teknikleri ve derin öğrenme modellerinin bir araya getirilmesiyle oluşturulan nesne tanımlama, resimlerdeki ve videolardaki ilgi çekici öğeleri tespit ederek, tanımlayarak ve izleyerek insan algı sistemlerini taklit etmektedir.

Tarımsal süreçler, büyük hayvanların bakımından küçük meyvelerin hasadına kadar çeşitli işlemleri içermektedir. Nesne tespiti, tarımsal ve hayvansal çiftçilikte pek çok kullanım alanı bulmuştur (Badgujar, vd., 2024). Bu kullanımlar otomatik ve/veya robotik sistemlerin, uzaktan algılama ve/veya izleme, karar destek araçlarının ve daha fazlasının çok ötesine geçmektedir. Dijital tarımın önemli bir unsuru olan nesne tespiti, kaynakları en üst düzeye çıkarırken maliyetleri ve iş gücünü azaltarak tarımsal çıktıyı ve üretkenliği artırmaktadır (Zhang vd., 2023).

Nesne tanımlama modellerinin ön saflarında yer alan derin öğrenmede, evrişimli sinir ağı (CNN) mimarileri kullanılır. Manuel özellik çıkarımı gerektiren geleneksel görüntü işleme veya algılama yöntemlerinin aksine, derin öğrenme teknikleri büyük etiketli görüntü veri kümelerini kullanarak otomatik özellik öğrenimi sağlayarak yüksek performans elde etmektedir (Shehzadi vd., 2023). Bu algoritmalar, hız, doğruluk, verimlilik ve algoritma boyutu arasında denge sağlar ve tasarım konseptleri ve mimarileri bakımından farklılık göstermektedir. (Zhang vd., 2023). Gerçek zamanlı olarak yüksek hassasiyetle çalışma kapasitesi ve az kaynağa sahip cihazlarla uyumluluğu nedeniyle, YOLO olarak bilinen tek aşamalı dedektör, kısa bir sürede tarımda yaygın olarak kullanılmıştır.

Otomasyon, robotik, algılama ve izleme gibi dijital teknolojiler tarımın önemli bir parçası haline gelmiştir. Tarım ürünleri genellikle hem zamanla hem de mekânda değişen, karmaşık ve düzensiz ortamlarda yetişmektedir (Bechar & Vigneault, 2016). Sonuç olarak, tarımsal uygulamalar için eğitilmiş genel bir nesne tanımlama algoritması ya zayıf performans göstermektedir. Ancak, nesne tanıma modelinin performans nitelikleri, teknolojinin nasıl kullanıldığına bağlı olarak değişmektedir. Örneğin, görme tabanlı bir meyve toplama robotunun verimi, algılama doğruluğu ile belirlenirken, hasat verimi hızı ile belirlenir. Bununla birlikte, YOLO'nun tarımdaki araştırması ve uygulaması hızla genişlemektedir, ancak bunlar genellikle dağınık ve disiplinler arasıdır ve dokümantasyon ve titiz değerlendirme gerektirmektedir.

Bu araştırmanın amacı, tarımsal nesne algılama görevleri için YOLO'nun kullanımını analiz etmek ve eleştirel olarak değerlendirmektir. Ayrıca, araştırma tüm YOLO model oluşturma

sürecini ve modelin belirli tarımsal işler için performansını artırmak için yapılan önemli geliştirmeleri inceleyecektir. YOLO'nun son teknoloji algoritmalarla entegrasyonunun avantajlarını ve dezavantajlarını da kapsayan bu araştırma, YOLO tekniğine genel bir bakış sağlayarak tarihsel gelişimi de ele alınmıştır.

Yolo Derin Öğrenme Modelleri ve Tarihsel Gelişim

Nesne tanıma alanında kayda değer bir gelişme, YOLO (You Only Look Once) olarak bilinen derin öğrenme modelidir. Redmon vd., (2016) bu modeli ilk olarak 2016'da sunmuştur. YOLO, fotoğrafları tek geçişte analiz etme ve şeyleri hızlı ve verimli bir şekilde bulma yeteneğiyle dikkat çekiyor. Geleneksel nesne tanımlama tekniklerinden daha hızlı ve daha etkili sonuçlar ürettiği için bu model gerçek zamanlı uygulamalarda popülerlik kazanmıştır.

Tarihte Gelişim

YOLO V1 (2015): Resmi 7x7'lik bir ızgaraya böldükten sonra her hücredeki öğeleri tahmin eden bu yaklaşım, resmi tek bir ağ üzerinden çalıştırarak öğe tanımlamasını hızlandırmakta, ancak yalnızca az sayıda nesneyi tanımaktadır. Redmon vd. (2016), YOLO algoritmasıyla gerçek zamanlı nesne algılamada devrim yaratmıştır.

YOLO V2 (2016): Bu sürümde hız ve doğruluğu artırmak için bir dizi geliştirme bulunmaktadır. "Toplu Normalizasyon" ve "Anchor Boxes" gibi yöntemlerin eklenmesi modelin performansını iyileştirmiştir. Böylece model daha fazla nesneyi tespit edebilmektedir. Redmon ve Farhadi (2017), YOLOv2 algoritmasıyla nesne algılama doğruluğunu artırırken, gerçek zamanlı işleme hızını da korumayı başarmıştır.

YOLO V3'ün (2018) geliştirilmiş özelliği, çeşitli boyutlardaki nesneleri tanımlama kapasitesidir. Modelin çeşitli boyutlardaki nesneleri tanıma yeteneğini geliştirmek için tasarımına daha fazla katman eklendi. Redmon ve Farhadi (2018), YOLOv3 modelini önceki sürümlerine göre daha doğru ve hızlı hale getiren çeşitli mimari iyileştirmeler gerçekleştirdiklerini belirtmişlerdir.

YOLO V4 (2020): Bu sürüm, performansı ve optimizasyonu artırmak için bir dizi strateji kullanmaktadır. "Mozaik Veri Artırma" ve "Kendine Karşı Eğitim" gibi yenilikçi teknikler, modelin genel performansını iyileştirmiştir. YOLO V4 ile daha fazla öğe tespit ederek doğruluk oranları artırılabilmektedir. Bochkovskiy, vd. (2020), YOLOv4 algoritmasına yeni yöntemler uygulayarak nesne algılama hızını ve doğruluğunu önemli ölçüde artırdı.

YOLO V5 (2020): Bu sürüm, gömülü ve mobil sistemlerde kullanım için uyarlanmış, daha hızlı ve daha hafif bir varyant sunmaktadır. Khanam ve Hussain (2024), YOLOv5'in mimarisi ve işlevselliğinin kapsamlı bir incelemesini sunmaktadır. YOLO V5, daha fazla uygulama çeşitliliğini kapsıyor ve sezgisel bir kullanıcı arayüzüne sahiptir.

En son yinelemeler olan YOLO V6 ve V7 (2022–2023), hızı ve doğruluğu artırmak için bir dizi geliştirme içermektedir. Özellikle azaltılmış bilgi işlem gücü ihtiyaçları ve iyileştirilmiş genel performansları ile dikkat çekmektedir. Li vd. (2022) göre YOLOv6 yöntemi, endüstriyel

uygulamalar için uyarlanmış tek aşamalı bir nesne algılama çerçevesi sağlamaktadır. Wang vd. (2022) YOLOv7 algoritması ile gerçek zamanlı nesne tanımada benzeri görülmemiş bir hız ve doğruluk elde etmiştir.

YOLOv8 (2023): Bu sürüm, düşük kapasiteli donanımlarında ve mobil cihazlarda çalışmak üzere tasarlanmıştır. Liu vd. (2023) göre YOLOv8, FPN+PAN boyun yapısı ve CSPNet omurgası gibi son teknoloji özelliklere sahiptir. Ayrıca, nesne algılamayı iyileştirmek için yeni bir mimari kullanımı ile dağıtım ve eğitim prosedürlerini kolaylaştıran sezgisel bir arayüz sağlamaktadır.

YOLO-NAS: Bu sistem, ağ mimarisini otomatik olarak optimize etmek için Sinir Mimarisi Arama'yı (NAS) içermekte ve mümkün olan en iyi hız-doğruluk dengesini sunmaktadır (Terven vd., 2023). YOLO-NAS'ın hibrit niceleme yöntemi ve niceleme farkında modülleri gibi özel özellikleri, zararlı tespiti ve mahsul sağlığı izleme gibi görevler için yüksek performansa ihtiyaç duyulan ancak hesaplama kaynaklarının sınırlı olabileceği tarımdaki uç cihaz uygulamaları için onu daha uygun hale getirmektedir (Qin vd., 2021).

YOLOv9: Önceki sürümlerle karşılaştırıldığında, bu sürüm daha fazla doğruluk ve hız sağlamayı amaçlamaktadır. Wang ve Liao'ya (2024) göre YOLOv9 algoritması nesne algılama doğruluğunu artırmak için GELAN ve PGI gibi son teknoloji yöntemleri kullanır. Model mimarisi optimizasyonlarının bir sonucu olarak nesne tanımlama görevlerinde daha iyi sonuçlar elde edilmiştir.

YOLOv10: Ultralytics, maksimum olmayan baskılama (NMS - non-maximum suppression) ihtiyacını ortadan kaldırarak verimliliği artıran yeni bir tasarıma sahip YOLOv10'u geliştirmiştir. Mükemmel doğruluğu ve düşük işleme maliyeti nedeniyle, bu model gerçek zamanlı nesne tanımlama için çıtayı yükseltmiştir. Wang vd. (2024), YOLOv10 versiyonu ile etkili model tasarımı ve eğitim stratejileri aracılığıyla NMS'ye ihtiyaç duymadan gerçek zamanlı nesne tanımada dikkate değer iyileştirmeler sağlamıştır.

YOLOv11: En son sürüm olan YOLOv11, özellikle hassasiyet ve ortalama F1 skoru açısından YOLOv10'a göre performansta marjinal bir iyileştirme sağlamaktadır. Yangın ve duman algılama gibi özel uygulamalarda, bu model olağanüstü performans göstermiştir (Alkhammash, 2025).

UYGULAMA ÖRNEKLERİ

Bitki Hastalıklarının Tespiti

YOLO algoritmaları, bitki yapraklarındaki hastalık belirtilerini tespit etmek için kullanılan önemli bir araçtır. Makine öğrenimi ve görüntü işleme yöntemlerini birleştirerek bu alanda ilerleme sunmaktadır. Veri toplama yöntemleri arasında açık veri kümeleri ve tarım alanlarının görüntülerini tespit etmek için dronlar veya kameralar bulunmaktadır. Toplanan görüntülerin ön işlenmesi, modelin doğruluğunu artırmak için önemlidir. Alhwaiti vd. (2025), şeftali ve çilek bitkilerinde görülen bakteri lekeleri ve yanık hastalıklarının tespit edilmesinde YOLOv4 modeli kullanılarak %98 oranında doğruluk elde etmiştir. Mathew ve Mahesh (2021), YOLOv5 modelini kullanarak dolmalık biber de bakteriyel hastalıkların meydana getirdiği lekeleri

yüksek hız ve doğrulukta tespit eden bir sistem geliştirdiler. Liu ve Wang (2020), gerçek doğal ortamda domates bitkisindeki hastalıkların tespiti için bir görüntü piramidi oluşturmuşlar ve çok ölçekli özellik algılama özelliği ile çalışan bir YOLOv3 derin öğrenme modeli geliştirmiştir. Ali vd. (2024), turunçgiller de Antraknoz, Melanoz ve Bakteriyel Kahverengi Leke hastalıklarının tespiti için CCL'20 veri setini kullanarak YOLOv5, YOLOv7 ve YOLOv8 modellerinin her birisini ayrı ayrı eğiterek performans karşılaştırması yapmış ve YOLOv8 modelinin %96,1 mAP@50-95 başarı oranı ile en iyi performans verenin modelin YOLOv8 olduğunu ortaya koymuşlardır. Bu sistemler tarımsal üretimdeki zorlukların aşılmasında vazgeçilmez araçlar haline geldiği bu örneklerde açıkça görülmektedir.

Sulama Yönetimi

YOLO algoritmaları, sulama tekniği optimizasyonunda önemli bir hususdur ve akıllı sulama sistemlerinin su kullanımını optimize etmesini ve tarımsal üretimin artırılmasına katkı sağlamaktadır. Wolter-Salas vd. (2023), WS-YOLO modelini kullanarak geliştirmiş oldukları iyi verimli fenotipleme platformu, marul fidelerindeki kuralığın meydana getirdiği stres seviyelerini tespit ederek zamanında tarımsal müdahaleyi mümkün kılmayı hedeflemiş ve bu sayede %93,62 mAP ve %89,31 F1 skoru elde ederek erken stres tespitinde yüksek başarı elde etmiştir. Jayakrishna ve Ganesh (2025), DAD-YOLO modelini kullanarak yürütmüş oldukları çalışmada kanalizasyon ile kirlenmiş olan nehir sularında bulunan zararlı mikro organizmaların, muz bitkisinde besin eksikliğine yol açtığını tespit ettiler ve bu mikro organizmaların % 97 doğruluk oranı ve %94,6 duyarlılık ve %96,5 mAP ile başarılı bir şekilde sınıflandırıldığı ortaya konmuştur. Toprak nemi, hava durumu ve bitki su kullanımı gibi bilgileri değerlendirerek, bu sistemler sulama programlarını otonom olarak değiştirebilir (Karmakar ve Sarkar, 2021). Böylece verimsiz sulama teknikleri su israfına ve bitki sağlığının bozulmasına yol açarken YOLO tabanlı sistemler verimli su kullanımı ve bitki sağlığını korunmasını sağlamaktadır.

Zararlıların Tespiti

Dünya nüfusunun sürekli olarak artışı, tarım endüstrisinin gıda üretim kapasitesini artırması gerekliliğini beraberinde getirmektedir. Ancak, zararlılar bitki verimliliğini azaltarak bitki sağlığını tehlikeye atmaktadır. Geleneksel zararlı tespit yöntemleri genellikle gözlemlere ve kişisel deneyimlere dayanır, bu da yanlış teşhis olasılığını artırır. Bu sorunun çözümünde etkili yaklaşımlardan biri derin öğrenmedir. YOLO (You Only Look Once) zararlıları tespit etmek için en popüler derin öğrenme tekniklerindendir. Lippi vd. (2021), fındık bahçelerinde zararlı böceklerin tespiti için geliştirilen YOLO tabanlı derin öğrenme sistemi, doğal ortamdan toplanan özel bir veri kümesi ile eğitilerek yaklaşık %94,5 oranında bir doğruluk elde etmişlerdir. Dong vd. (2024), tarımsal zararlıların gerçek zamanlı tespiti için geliştirdikleri PestLite modeli, YOLOv5 modelini temel alarak MTSPPF, involution, ECA ve CARAFE gibi gelişmiş mekanizmalar sayesinde hem doğruluk oranını artırmıştır. IP102 veri kümesi üzerinde yapılan testlerde %90.7 mAP50 başarısına ulaşmıştır. Tang vd. (2022), tarımsal zararlılar küçük boyutlu olmaları birbirlerine olan benzerlikleri sebebiyle görüntü işleme tabanlı tespitte yaşanan zorluklara çözüm sunabilmek amacıyla geliştirdikleri Pest-YOLO yöntemi,

geliştirmişler ve 28.000 zararlı görseli içeren bir veri kümesi üzerinde %71.6 mAP ve %83.5 Recall başarı oranı elde etmiştir. Luo vd. (2023), tarımsal zararlıların tespiti ve tanımlama zorluklarına çözüm sağlamak amacıyla geliştirdikleri YOLO tabanlı yazılım hızlı ve doğru özellik çıkarımı ve eş zamanlı olarak nesne tespiti yeteneği sayesinde %92.42 mAP ve %96.8 doğruluk oranı ile yüksek bir başarı oranı göstermiştir.

Yabancı Ot Tespiti

Tarımda yabancı otların tespiti, sebze, meyve ve diğer ekinlerin üretiminde verimliliği ve tarımın sürdürülebilirliğini artırmak açısından büyük önem arz etmektedir. Yabancı otlar tüm ekinlerde su, güneş ışığı ve diğer besin maddeleri gibi kaynakları tüketerek ekinlerde verim kaybına sebep olmaktadır. Dang vd. (2023), pamuk üretimindeki önemli tehditlerden birisi olan yabani otların tespiti için YOLOv3 den YOLOv7 modeline kadar 7 farklı YOLO modeli ile toplam 25 tane YOLO tabanlı dedektörler karşılaştırılmış Monte-Carlo çapraz doğrulaması ile YOLOv4 %95.22 mAP@0.5 doğruluğu ile en yüksek performansı göstermiştir. Chen vd. (2022), susam bitkisi içerisindeki yabancı ot tespiti yapmıştır. Susam bitkisi diğer yabancı otlar ile benzer morfolojik özelliklere sahip olması nedeniyle, güvenilir bir tespite ihtiyaç duyulmaktadır. Bu sorunu çözmek için YOLOv4 mimarisi temel alınarak YOLO-susam modeli geliştirilmiştir. Bu model Fast R-CNN, SSD, YOLOv3, YOLOv4 ve YOLOv4-tiny gibi diğer modeller ile karşılaştırıldığında çok daha yüksek performans gösterdiği saptanmıştır. Susam ve yabancı otlar için sırasıyla 0.91 ve 0.92 F1 skoru ile %96.16 mAP değeri elde edilmiştir. Parico ve Ahamed (2020), YOLOv3 tabanlı bir yabancı ot tespit sistemi olan YOLO-WEED geliştirilmiştir. Yaklaşık 5 dakikalık bir IHA görüntüsünden elde edilen veri kümesinden elde edilen eğitim, doğrulama ve test aşamaları için sırasıyla %69, %17 ve %13 oranında bölünmüştür. NVIDIA GeForce GTX 1060 donanımı ile 24.4 FPS ‘e kadar gerçek zamanlı nesne tespit hızı %93.81 mAP değeri ile 0.94 F1 skoru elde ederek yüksek performans ortaya koymuştur.

Tarımsal Verimliliğin Analizi

Gıda talebi küresel nüfus artışına paralel olarak kayda değer bir şekilde artış göstermektedir. Bu durum, tarımsal üretim kapasitesinin artırılmasını zorunlu kılmaktadır. Büyük ölçekli veri kümelerinin analizi aracılığıyla YOLO, daha yüksek doğrulukta tahminler üretme imkânı sunmaktadır. Badgujar vd. (2024) Tarımda nesne tespit sistemlerinde YOLO algoritmasının kullanımına yönelik gerçekleştirmiş oldukları kapsamlı sistematik ve bibliyometrik incelemeler, izleme, gözetim, gibi pek çok alanda yüksek potansiyele sahip olduğunu ortaya çıkartmışlardır. YOLO Algoritmasının ilk sürümü olan Alif ve Hussian (2024), YOLOv1 den güncel sürümlerinden olan YOLOv10 ‘a kadar ki gelişimini tarım alanındaki kullanımları bağlamında ele alarak detaylı bir inceleme gerçekleştirmiş ve sürdürülebilir tarım üzerindeki katkılarını detaylı olarak almıştır. Ajayi vd. (2023), YOLOv5s modelini kullanarak farklı epoch (eğitim döngüsü) senaryolarından elde ettikleri sonuçlara neticesinde otomatik ürün ve yabancı ot tespitinde en yüksek doğruluğun 600 epoch’ta elde edilebildiğini rapor etmiştir. Zoubek vd. (2025) YOLOv5-x modelinin farklı parametreler kullanılarak YOLOR-D6 ve YOLOv7-D6

modelleri ile karşılaştırıldığı çalışmada özellikle turp bitkisi ve yabancı otların tespit edilmesinde sırasıyla %99, %98 ve %91 başarı oranları elde edilerek mAP_0.5:0.95 skorları elde edilmiştir. Bu çalışmalardan görüldüğü üzere YOLO modelleri tarımsal üretim tahmini için önemli faydalar sunmaktadır.

Hasat Sistemleri

Literatürde YOLO modelleri kullanan bilgisayarlı görüş tabanlı meyve toplama robotları oluşturma konusunda çalışmalar oldukça yaygındır. Magalhães vd. (2021), bir serada domates tanımlaması için YOLO ve modellerini değerlendirerek sera tabanlı domates hasadı uygulamalarında YOLO modellerinin potansiyelini göstermiştir. Bini vd. (2022) domates meyvesi tanıma ve ürün verimi tahmini için YOLOv5 modelinin kullanmıştır. Ayrıca hasat robotlarının geliştirilmesi için çok önemli olan gerçek zamanlı çalışmasının önemini vurgulamıştır. Nergiz (2023), YOLOv7 modelini kullanarak gerçekleştirmiş olduğu bir çalışmada çilek meyvelerinin altı farklı renk sınıfında (yeşil, beyaz, erken dönüşüm, dönüşüm, geç dönüşüm ve kırmızı) başarılı bir şekilde tespit edilmiş ve mAP@0.5 değeri 0.558 ve mAP@0.5:0.95 değeri 0.46 olarak raporlanmış ve böylece dengesiz etiket dağılımı ve belirsiz etiketlenme evresine rağmen gerçek zamanlı uygulamalarda kullanılabilir olduğunu ortaya çıkarmıştır.

Hayvan Sağlığı Takibi

Tarım da hayvancılık ülkelerin, gıda güvenliği, kırsal geçim kaynaklarının sürdürülebilirliği ve ekonomik kalkınma açısından büyük önem arz etmektedir. Bu nedenle tarımda hayvancılığın sürdürülebilirliği açısından hayvan sağlığı takibi önemli bir yer tutmaktadır. Krishnaveni ve Arvinth (2025), çiftlik ortamında YOLO algoritmasını kullanarak, gerçek zamanlı nesne tespit yetenekleri ile OpenCV kütüphanesini birleştiren bir yaklaşım ile çiftlikdeki video görüntülerinde bulunan hayvanların tespiti ve sınıflandırılmasını sağlayan bir sistem geliştirerek %98 oranında başarı elde etmişlerdir. Paramathma vd. (2024), tavuklara ait patolojik özelliklerin tespit edilebilmesi amacıyla kümesteki tavuk görüntülerinden oluşan 500 adet görüntü ile elde edilmiş olan veri kümesini kullanarak tavuklar üzerindeki “kabuklanma”, “şişlik”, “felç” ve “sağlıklı” sınıfları kapsamında değerlendirilerek YOLOv8 modeli eğitilmiş ve eğitilen bu model yüksek başarı oranı göstererek 0.86 F1 skoruna ulaşmıştır. Nithisha vd. (2024), tarımsal ortamda hayvan sağlığını tehdit eden kağıt ve plastik atıklarının tespiti için YOLO tabanlı, nesnelerin interneti (IoT) teknolojisi kullanan bir sistem geliştirdiler. Hayvan sağlığı için zararlı olan bu maddeler hayvanlar tarafından tüketilmesini engellemek için bir uyarı sesi (buzzer) üretmektedir.

SONUÇ

Bu çalışma, YOLO (You Only Look Once) algoritmasının tarım sektöründe sahip olduğu dönüştürücü potansiyeli kapsamlı bir şekilde ortaya koymaktadır. Nüfus artışı, işgücü eksikliği, iklim değişikliği ve doğal kaynakların tükenmesi gibi küresel krizler, tarımsal üretimi tehdit

ederken, YOLO'nun gelişmiş nesne tanıma yetenekleri sayesinde tarımda karşılaşılan birçok soruna etkili çözümler sunmaktadır. Akademik makaleler ve çeşitli uygulamalara dayanan analizler, YOLO'nun erken bitki hastalığı teşhisi, yabancı otların hızlı tespiti ve hassas hasat zamanlaması gibi kritik süreçlerde üretkenliği artırdığını göstermektedir. Ayrıca hayvancılık yönetiminde hayvan davranışlarının izlenmesi ve kalite kontrol süreçlerinde kusurların tespiti gibi alanlarda da önemli katkılar sağladığı gözlemlenmiştir. Geleneksel yöntemlere göre daha hızlı, doğru ve düşük maliyetli çözümler sunan YOLO destekli sistemler hem ürün kaybını azaltmakta hem de ürün kalitesini artırmaktadır. Çalışma, ayrıca YOLO modellerinin dijital tarım uygulamalarında, sulama optimizasyonunda ve bitki sağlığı izleme gibi süreçlerde geleneksel yöntemlerden daha verimli olduğunu görülmüştür. Sonuç olarak bu araştırma YOLO modellerinin tarımda kullanımının ne kadar önemli ve gerekli hale geldiğini vurgulamakta, gelecekte daha sürdürülebilir, dayanıklı ve teknolojik olarak gelişmiş bir tarım ortamı oluşturmak için bu tür teknolojilerin kullanımının teşvik edilmesi gerektiğini önermektedir.

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MACHINE LEARNING APPLICATIONS IN AGRICULTURE

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ABSTRACT

Today, the agricultural sector is in a radical transformation process with the impact of rapid developments in information technologies. In this transformation, technologies such as artificial intelligence, machine learning, deep learning, modelling, simulation and image processing come to the fore. Smart agriculture applications supported by sensors, unmanned aerial vehicles (UAVs), robotic systems, autonomous tractors and big data analytics make production processes more efficient, sustainable and environmentally friendly. Image processing techniques have been used for some time in many areas such as plant health monitoring, plant disease and pest detection, weed separation and crop classification. By performing these applications using machine learning and deep learning algorithms, operations can be performed automatically, and more accurate and faster results are obtained. In addition, with real-time and automated expert systems, agricultural decision-making processes are optimized, human errors are reduced, and resource use can be managed more effectively. The integration of these technologies with agricultural machinery and robotic systems enables digitalization and automation in agriculture by going beyond the traditional understanding of agriculture.

In this study, the basic concepts of machine learning are discussed and basic definitions and methods in this field are given. Firstly, the basics of machine learning are explained and its subtypes such as supervised learning, unsupervised learning, semi-supervised learning and reinforcement learning are detailed. Within the scope of each learning type, the working principles of commonly used algorithms are mentioned. Applications in the agricultural constituted one of the focal points of the study. In particular, how machine learning techniques are used in smart agriculture applications such as early diagnosis of plant diseases, crop yield prediction, irrigation and fertilization optimization, and agricultural automation systems are explained with examples. In addition, intelligent systems used in animal health monitoring and productivity analyses in animal husbandry are also evaluated. In this context, the contributions of machine learning to agricultural decision support systems and its potential for future use are discussed.

Keywords: Machine learning, Supervised Learning, Unsupervised Learning, Semi-Supervised Learning, Reinforcement Learning

TARIMDA MAKİNE ÖĞRENMESİ UYGULAMALARI

ÖZET

Günümüzde tarım sektörü, bilişim teknolojilerindeki hızlı gelişmelerin etkisiyle köklü bir dönüşüm sürecindedir. Bu dönüşümde, yapay zekâ, makine öğrenmesi, derin öğrenme, modelleme, simülasyon ve görüntü işleme gibi teknolojiler ön plana çıkmaktadır. Sensörler, insansız hava araçları (İHA), robotik sistemler, otonom traktörler ve büyük veri analitiği ile desteklenen akıllı tarım uygulamaları, üretim süreçlerini daha verimli, sürdürülebilir ve çevre dostu hâle getirmektedir. Görüntü işleme teknikleri bitki sağlığının izlenmesi, bitki hastalık ve zararlılarının tespiti, yabancı otların ayrıştırılması ve ürün sınıflandırması gibi birçok uygulamada bir süredir kullanılmaktadır. Bu uygulamaların makine öğrenmesi ve derin öğrenme algoritmaları kullanılarak gerçekleştirilmesiyle işlemler otomatik olarak gerçekleştirilebilmekte, daha doğru ve hızlı sonuçlar elde edilebilmektedir. Ayrıca, gerçek zamanlı ve otomatik çalışan uzman sistemler ile tarımsal karar verme süreçleri optimize edilmekte, insan hataları azaltılmakta ve kaynak kullanımı daha etkin bir şekilde yönetilebilmektedir. Bu teknolojilerin tarım makineleri ve robotik sistemlerle entegrasyonu, geleneksel tarım anlayışının ötesine geçerek tarımda dijitalleşmeyi mümkün kılmaktadır.

Bu çalışmada, makine öğrenmesine ilişkin temel kavramlar ele alınarak, bu alandaki temel tanımlamalara ve yöntemlere yer verilmiştir. Öncelikle, makine öğrenmesinin temelleri anlatılmış; denetimli öğrenme, denetimsiz öğrenme, yarı denetimli öğrenme ve takviyeli öğrenme gibi alt türleri detaylandırılmıştır. Her bir öğrenme türü kapsamında yaygın olarak kullanılan algoritmaların çalışma prensiplerine değinilmiştir. Tarımsal uygulamalar ise çalışmanın odak noktalarından birini oluşturmuştur. Özellikle bitki hastalıklarının erken teşhisi, ürün verim tahmini, sulama ve gübreleme optimizasyonu gibi akıllı tarım uygulamaları ile tarımsal otomasyon sistemlerinde makine öğrenmesi tekniklerinin nasıl kullanıldığı örneklerle açıklanmıştır. Ayrıca hayvancılıkta hayvan sağlığı takibi ve verimlilik analizlerinde kullanılan akıllı sistemler de değerlendirilmiştir. Bu bağlamda, makine öğrenmesinin tarımsal karar destek sistemlerine katkıları ve gelecekteki kullanım potansiyeli tartışılmıştır.

Anahtar Kelimeler: Makine öğrenmesi, Denetimli Öğrenme, Denetimsiz Öğrenme, Yarı Denetimli Öğrenme, Takviyeli Öğrenme

1. GİRİŞ

Makine öğrenmesi, yapay zekanın bir alt dalıdır. Öncelikle, çeşitli algoritmalar ve teknikler kullanılarak geçmiş verilere bakılmakta ve veriler arasındaki karmaşık desenleri belirleyecek matematiksel modeller oluşturulmaktadır. Daha sonra bu modeller, belirli bir hedef üzerine tahmin yapmak için kullanılmaktadır. Makine öğrenmesi yöntemleri arasında k-en yakın komşu algoritması, Naive Bayes sınıflandırıcısı, karar ağaçları, lojistik regresyon analizi, k-ortalamalar algoritması, destek vektör makineleri ve yapay sinir ağları gibi yöntemler bulunmaktadır. Bu yaklaşımların bazıları tahmin ve kestirim yapabilirken, bazıları veri kümeleme ve sınıflandırma gibi yeteneklere sahiptir (Özgüven, 2019). Makine öğrenmesinin amacı, önceden görülmemiş bir girdi için doğru tahminler yapmak veya kararlar vermek ve bu süreçleri otomatikleştiren verimli algoritmaların geliştirilmesidir. Algoritmalar geliştirilirken, bir uzmanın bir karar verirken nelere dikkat ettiğiyle ilgili kriterler göz önünde bulundurulmalıdır. Makine öğrenmesi yöntemlerinin uygulanmasında hesaplama, eğitim ve eğitilmiş algoritmanın uygulanması gibi karmaşıklıklar bulunmaktadır. Bir algoritmanın performansı genellikle test hatasıyla değerlendirilmektedir. Ayrıca, bir algoritma çalışırken, birçok test noktası bulunabilmekte ve bu noktalarda hızlı kararlar alınması gerekmektedir. Bu nedenle, test işleminin düşük hesaplama yüküne sahip olması önemlidir (Ozguven, 2023).

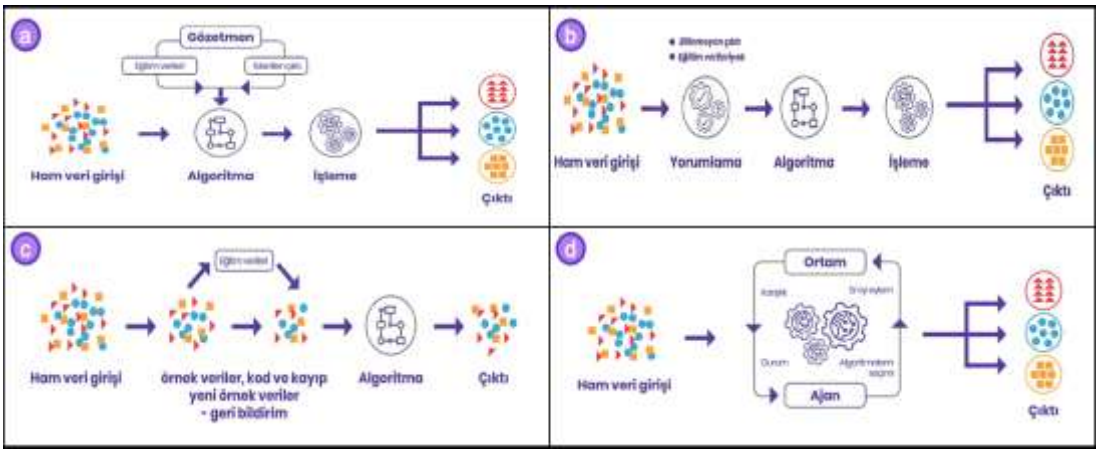
Makine öğrenmesi, sistemlerin açıkça programlanmadan deneyimlerden öğrenmesini ve gelişmesini sağlayan bir yapay zekâ uygulamasıdır. Makine öğrenimi teknikleri, geçmiş eğilimleri belirlemek ve gelecekteki modelleri bilgilendirmek için veri madenciliğinden yararlanmaktadır. Makine öğrenmesi, bilgisayarların verileri analiz etmesine ve kalıpları belirlemesine olanak tanıyan istatistiksel öğrenme ve optimizasyon yöntemlerini kullanmaktadır. Makine öğrenmesi uygulamaları yeni verilerle beslenmekte ve bağımsız olarak öğrenebilmekte, büyüyebilmekte, gelişebilmekte ve uyum sağlayabilmektedir. Ayrıca makine öğrenmesi algoritmalarının performansı, öğrenme süreci sırasında kullanılabilir gözlem sayısının artmasıyla uyarlanabilir şekilde iyileşebilmektedir (Gupta ve ark., 2025).

2. MAKİNE ÖĞRENMESİ TÜRLERİ

Makine öğrenmesinin çeşitli türleri bulunmakla birlikte en sık dört türüne rastlanmaktadır. Bunlar; Denetimli makine öğrenmesi, Denetimsiz makine öğrenmesi, Yarı denetimli makine öğrenmesi, Takviyeli makine öğrenmesi şeklindedir.

Denetimli öğrenme, modelin etiketlenmiş veri setiyle giriş-çıkış ilişkilerini öğrenmesini amaçlayan bir makine öğrenmesi yöntemi olup, algoritmalar bu verilerden örüntüler çıkararak yeni girdiler için tahmin yapmaktadır ve başarısı, öğrendiği kuralların yeni verilere ne kadar doğru uygulandığıyla ölçülmektedir (Şekil 1.a). Denetimsiz öğrenme ise etiketlenmemiş verilerde desenleri ve yapıları keşfetmeyi hedefleyerek veri noktaları arasındaki benzerlikleri değerlendirip gruplama yapmakta veya boyut indirgeme yoluyla veriyi daha sade hale getirmekte, büyük ve karmaşık veri kümelerinde gizli yapıları ortaya çıkarmada etkili olmaktadır (Şekil 1.b). Yarı denetimli öğrenme, denetimli ve denetimsiz öğrenme tekniklerini birleştirerek az sayıda etiketli veriyle modelin genelleme yeteneğini artırırken, etiketleme maliyetinin yüksek olduğu durumlarda kullanışlı olup sınıflandırma ve tahmin gibi

problemlerde etkili olmaktadır (Şekil 1.c). Şekil 1.d'de gösterilen Takviyeli öğrenme ise modelin ödül sinyalleri aracılığıyla karar alma süreçlerini iyileştirdiği bir yöntem olup, ürettiği çıktılara yönelik geri bildirim alarak en iyi stratejiyi belirlemeye çalışmakta ve özellikle yazılım ajanlarının en yüksek kümülatif ödülü elde etmeyi öğrenmesinde kullanılmaktadır (Bishop, 2006; Hastie ve ark., 2009; Alzubi ve ark., 2018; Rizvanche, 2020; Mahesh, 2021; Kuru, 2023).



Şekil 1. a) Denetimli öğrenme, b) Denetimsiz öğrenme, c) Yarı denetimli öğrenme ve d) Takviyeli öğrenme çalışma prensibi (Turhost, 2021).

3. MAKİNE ÖĞRENMESİ MODELLERİ

Makine öğrenmesi modelleri, veri analizi, desen tanıma ve tahmin yapma süreçlerinde kullanılan algoritmalardır. Veri türü, problem yapısı ve hedeflenen çıktı doğrultusunda en uygun model seçimi yapılarak, doğruluk ve verimlilik en üst düzeye çıkarılmaya çalışılmaktadır. Makine öğrenimindeki öğrenme modelleri, Şekil 2'de görüldüğü gibidir.

Şekil 2. Makine öğrenmesi modelleri

Regresyon, geçmiş verilerin süreklilik gösteren sayısal değerlerden oluştuğu durumlarda, bu değerlerden denetimli olarak bir eğri modeli üretme işlemidir (Alpaydın, 2004).

Kümeleme, Geçmiş verilerin hangi sınıf içerisinde yer aldığı belirtilmediği veya bilinmediği durumda verilerin benzerliklerine göre denetimsiz olarak ayrıştırılması işlemidir (Alpaydın, 2004; Liakos ve ark., 2018).

Bayes Modelleri (Bayesian Models), bilinmeyen değişkenlerin sonraki dağılımı üzerinden entegrasyon yaparak ön bilginin eksik veya belirsiz olduğu durumlarda bile ilkeli çıkarım yapılmasına olanak sağlayan bir yöntem olarak tanımlanmaktadır (Lampinen and Vehtari, 2001).

Örnek Tabanlı Modeller (Instance Based Models), model eğitimi yerine doğrudan veri örnekleriyle çalışır. Öğrenme yerine benzerlik karşılaştırmasına dayalı yapısıyla ayırt edilmektedir (Liakos ve ark., 2018).

Karar Ağaçları (Decision Trees), çok sayıda kayıt içeren bir veri kümesini, bir dizi karar kuralları uygulayarak daha küçük kümelere bölmek için kullanılan bir yapıdır (Albayrak ve Yılmaz, 2009).

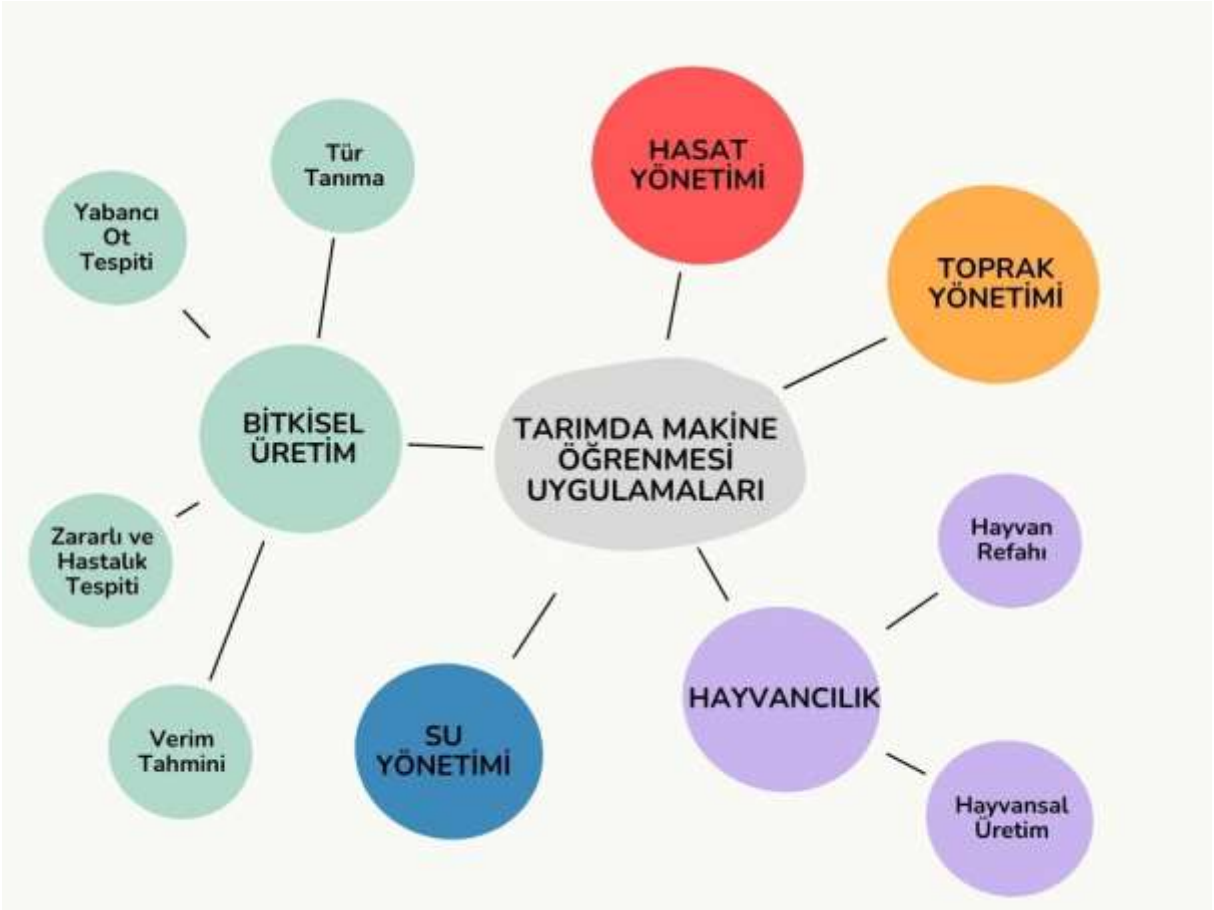
Destek Vektör Makineleri (Support Vector Machines-SVM), verilerin sınıflandırılmasına ve regresyon analizine yardımcı olan denetimli bir öğrenme tekniğidir. SVM, verileri ilgili sınıflara bölen bir hiper düzlem bulmaya çalışmaktadır. En basit düzeyde, bir hiperdüzlem, verileri karşılık gelen sınıflara bölen düz bir çizgidir. Destek vektörleri, bir hiper düzleme en yakın veri noktalarıdır (Kulkarni ve ark., 2020).

Topluluk Öğrenimi (Ensemble Learning), daha iyi genelleme performansı elde etmek için birkaç bireysel modeli birleştirmektedir. Örneğin derin topluluk öğrenimi modelleri hem derin öğrenme modellerinin hem de topluluk öğreniminin avantajlarını birleştirmekte ve böylece son model daha iyi genelleme performansına sahip olmaktadır (Ganaie ve ark., 2022).

Yapay Sinir Ağları (Artificial Neural Networks-ANN), çok sayıda bağlantılı yapay nöron aracılığıyla öğrenme gerçekleştiren modellerdir. Genelleme özelliği sayesinde, geçmişteki olaylardan veya örneklerden karmaşık ilişkileri öğrenebilme ve örüntü tanıma kabiliyetleriyle öne çıkmaktadır (Öztemel, 2006; Liakos ve ark., 2018).

4. TARIMDA MAKİNE ÖĞRENMESİ UYGULAMALARI

Makine öğrenmesi, tarımsal üretimde büyük veri teknolojilerine bağlı olarak birçok uygulamada yararlar ve kolaylıklar sağlamaktadır. Bitkisel üretimde; verim tahmini, hastalık ve yabancı ot tespiti, bitki sınıflandırma, su, toprak ve hasat yönetimi gibi konularda kaynakların daha verimli kullanılması ve sürdürülebilir tarım uygulamalarının desteklenmesi açısından önemli avantajlar sunmaktadır. Hayvansal üretimde ise hayvan hastalıklarının tespiti, uygun yem rasyonlarının hazırlanması, hayvan davranışlarının belirlenmesi gibi konularda hayvan refahının sağlanması ve üretim verimliliğinin artırılmasında rol oynamaktadır. Şekil 3'de, tarımda yaygın olarak kullanılan makine öğrenmesi uygulamalarını gösteren bir zihin haritası yer almaktadır.



Şekil 3. Tarımda makine öğrenmesi uygulamaları

Tarımda makine öğrenmesi uygulamalarının karmaşık veri kümelerinin analizini kolaylaştırdığı, veriye dayalı karar almaya olanak sağladığı, öznel uzmanlığa olan bağımlılığı azalttığı ve çiftlik yönetim stratejilerini iyileştirdiği vurgulanmaktadır. Veri kullanılabilirliği, model yorumlanabilirliği, ölçeklenebilirlik, güvenlik endişeleri ve kullanıcı arayüzü tasarımı gibi ML metodolojilerinin yaygın olarak benimsenmesini engelleyen zorluklara rağmen, paydaşlar arasındaki iş birliği çabaları bu engellerin üstesinden gelinmesine yardımcı olabilecektir (Waqas ve ark., 2025).

4.1. BİTKİSEL ÜRETİM

4.1.1. VERİM TAHMİNİ

Tarımda makine öğrenmesi uygulamaları, bitkisel üretimde verim tahminini mümkün kılmaktadır. Böylece ekimden hasada kadar olan süreçte verim miktarı önceden belirlenerek üretim planlaması daha verimli yapılabilmektedir. Bununla birlikte zaman optimizasyonu

sağlarken, manuel tahminlere kıyasla hata oranını en aza indirmekte ve tarımsal karar alma süreçlerini daha etkin hale getirmektedir.

Bu bağlamda örnek olarak Hou ve ark. (2025) yaptıkları çalışmada, makine öğrenmesi yöntemleriyle yer fıstığının verim tahminini yapmaya çalışmışlardır. Bu amaçla çalışmada 2022, 2023 ve 2024 yıllarında iki farklı ekim deseninden 355 yer fıstığı verim örneği toplanmış ve tahmin modelleri geliştirilmesi için doğrusal regresyon ve rastgele orman olmak üzere iki modelleme yöntemi kullanılmıştır. Çalışma sonucunda R^2 değerinin 0.8201 gibi yüksek bir değere ulaştığını, en düşük MAE ve RMSE değerlerinin ise sırasıyla 0.2878 ve 0.4048 t/ha olarak bulunduğu belirtilmiştir. Araştırıcılar, doğrusal regresyon modeli ve makine öğrenmesi algoritmaları kullanılarak çeşitli özelliklerin entegre edilmesinin, farklı ekim mevsimleri ve bölgelerdeki yer fıstığı veriminin modellenmesinde güvenilir bir çerçeve sağladığını bildirmiştir.

4.1.2. ZARARLI VE HASTALIK TESPİTİ

Bitki zararlı ve hastalıkları, ürünlerin veya bitkilerin bir kısmının yok olmasına neden olarak gıda üretimini azaltmakta ve gıda güvensizliğine yol açmaktadır (Ramesh ve ark., 2018). Bu nedenle, makine öğrenmesi uygulamalarıyla zararlı ve hastalıkların hızlı bir şekilde tespit edilmesi, ortaya çıkardıkları zararların önlenmesini sağlayacaktır. Böylece, bitkisel üretim süreçlerinde hastalık ve zararlılardan kaynaklanan hasar en aza indirilebilecektir. Bu anlamda makine öğrenmesinin zararlı ve hastalık tespiti uygulamalarına örnek olarak;

Zimmermann ve ark. (2025) yaptıkları çalışmada, seralarda domates yetiştiriciliğinde görülen belirli hastalıkların makine öğrenmesi algoritmalarıyla tanımlamaya çalışmışlardır. Çalışmada, sera domatesi üreticileriyle iş birliği içinde veri toplanmıştır. Araştırıcılar, çalışma için 256x256 piksel görüntü boyutlarına ve 15.256 görüntüye sahip Domates Yaprağı Görüntü Veri Kümesi ve 32x32 piksel yama boyutlarına ve 227.218 görüntüye sahip Yama Domates Yaprağı Görüntü Veri Kümesi olmak üzere iki yeni veri kümesi oluşturmuştur. Her iki veri kümesi de dört tür hastalık, aynı yaprak üzerinde iki hastalık kombinasyonu ve sağlıklı yaprak olmak üzere yedi sınıftan oluşturulmuştur. Araştırıcılar, üç evrişimli sinir ağı, özelleştirilmiş bir CNN, VGG19 ve Resnet50 ile sert ve yumuşak kararlar kullanan iki oylama sınıflandırma yöntemini birleştirmeyi önermiştir. Araştırıcılar, veri kümeleri üzerinde yapılan değerlendirmede, patch'ler kullanıldığında sonuçların önemli ölçüde iyileştiğini, %90.48'lik bir doğruluğa ulaşıldığını ve hastalığın evresini belirlemenin mümkün olduğunu bildirmiştir.

4.1.3. YABANCI OT TESPİTİ

Yabancı ot kontrol yönetiminde kritik bir aşama, uygulanacak herbisit türünün ve mücadele yöntemlerinin belirlenmesinde temel oluşturan yabancı otların doğru bir biçimde tanımlanmasıdır (Firmansyah ve ark., 2022). Tarımda makine öğrenmesi uygulamaları sayesinde, görsel veriye dayalı sınıflandırma ve tanıma algoritmaları kullanılarak tarla içerisindeki yabancı otlar ile kültür bitkileri yüksek doğrulukla ayırt edilebilmektedir.

Bu bağlamda, Lambert ve ark. (2019) İHA ve makine öğrenmesi algoritmaları ile buğday tarlalarında yüksek zarara yol açan bir yabancı ot olan kara ot haritalanmıştır. Bu amaçla, iki yıl boyunca 102 tarladan multispektral görüntü verisi toplanmış ve bunların 76'sını analizlerde kullanılabilecek nitelikte olduğu belirlenmiştir. Araştırıcılar, bu verilerden bitki örtüsü indeksi oluşturarak sıfırdan özel bir evrişimli sinir ağı (CNN) modeli eğitmiş ve modelin başarısını artırmak amacıyla veri dengeleme ve temizleme gibi çeşitli veri mühendisliği yöntemleri uygulamıştır. Çalışma sonuçlarına göre, kullanılan veri toplama yöntemi ve CNN uygulamasının, literatürdeki önceki yaklaşımlardan daha başarılı sonuçlar verdiği bildirilmiştir.

4.1.4. BİTKİLERİN SINIFLANDIRILMASI

Bitkilerin doğru sınıflandırılması, tarımsal üretim ve biyolojik çeşitliliğin korunması açısından önemlidir. Makine öğrenmesi algoritmaları sayesinde bitkiler otomatik ve hızlı şekilde sınıflandırılabilmekte, özellikle geniş tarım alanlarında izleme ve kayıt işlemleri kolaylaşmaktadır. Bu sayede insan hataları azalmakta ve karar verme süreçleri desteklenmektedir.

Bu bağlamda, Liu ve ark. (2022) yaptıkları çalışmada bitki görüntüsünü sınıflandırmak için hiperspektral görüntüleme ve derin öğrenme teknikleri birleştirilmiştir. Çalışmada, 470-900 nm aralığında çalışan hiperspektral kamera ile 30 farklı bitki çeşidine ait 1 500 görüntüden oluşan bir bitki görüntü veri kümesi oluşturmuş ve görüntü sınıflandırması yapmak için hafif bir geleneksel sinir ağı (LtCNN) modeli tasarlanmıştır. Araştırıcılar, karşılaştırma amacıyla birkaç CNN sınıflandırıcısı da seçmiştir. Önerilen LtCNN modelinin, yeşil kenar (591 nm), kırmızı kenar (682 nm) ve yakın kızılötesi (762 nm) bantlarının kritik spektral özelliklerini kullanarak bitki sınıflandırmasında tatmin edici bir performans (kappa= 0.95) elde edildiğini bildirilmiştir. Araştırıcılar, LtCNN modelinin AlexNet, GoogLeNet ve VGGNet gibi karmaşık CNN modellerine kıyasla daha az sayıda eğitim verisiyle çalışırken canlı taç görüntülerindeki yaprak özelliklerini tanımada yüksek uyumluluğa sahip olduğunu da belirtmiştir.

4.2. HASAT YÖNETİMİ

Hasat yönetiminde makine öğrenmesi algoritmaları; toprak koşulları, bitki sağlığı ve hava tahminleri gibi çeşitli verileri analiz ederek optimum hasat zamanının belirlenmesine olanak tanımaktadır. Bu sayede çiftçiler, hasat için en uygun koşulları saptayarak zararlı istilaları veya olumsuz hava koşulları gibi risk faktörlerinden kaynaklanan kayıpları en aza indirebilmekte ve ürün verimliliğini maksimize edebilmektedir (Kumari ve ark., 2024).

Örnek olarak Azadnia ve ark. (2023) yaptığı çalışmada, alıç meyvesinin olgunluk seviyesini sınıflandırmak için makine görüsü sistemini ve derin öğrenme tekniklerini kullanmıştır. Bu amaçla, görüntüleri sınıflandırmak için alıcın üç farklı kategorisi (ham, olgun ve aşırı olgun) elde edilmiş ve görüntüler iyi tasarlanmış bir aydınlatma odası kullanılarak hazırlanmıştır. Çalışmada, derin öğrenmenin (DL) performansını artırmak amacıyla veri artırma yöntemi uygulanmıştır. Araştırıcılar, ön işleme adımından sonra, alıç meyvesinin sınıflandırılması için Inception-V3, ResNet-50 ve konvolüsyonel sinir ağlarına (CNN) dayalı DL modellerinin yeteneklerini değerlendirmiştir. Çalışma sonuçlarına göre, Inception-V3 modelinin %100

doğrulama başarısı ile diğer sınıflayıcıların üzerinde bir başarı gösterdiği bildirilmiştir. Araştırıcılar, CNN ve görüntü işleme tekniklerinin, alıç meyvesinin pazarlanabilirliğini artırmada, israfı kontrol altına almada ve geleneksel sınıflandırma yöntemlerini geliştirmede etkili olabileceğini bildirmiştir.

4.3. HAYVANCILIK

4.3.1. HAYVAN REFAHI

Makine öğrenmesi, hayvan refahı risklerinin erken dönemde belirlenmesine yönelik önemli fırsatlar sunmaktadır. Bu yöntemler sayesinde, büyük ölçekli verilerden anlamlı örüntüler çıkarılarak, olası sağlık sorunları ya da hayvan refahı ile ilgili olabilecek ani değişimler önceden öngörülebilmektedir.

Örnek olarak Barker ve ark. (2018), yaptıkları çalışmada sensörler ve makine öğrenmesi algoritmasıyla süt ineklerinde topallık ve yem yeme davranışı arasındaki ilişkiyi belirlenmiştir. Bu kapsamda, serbest duraklı bir ahırda barındırılan 120 başlık sürüden seçilen 19 yüksek verimli süt ineği (10 topal, 9 topal olmayan) üzerinde, konum ve aktivite verileri beş gün boyunca kesintisiz olarak toplanmıştır. Araştırıcılar, boyuna takılan sensörler aracılığıyla elde edilen konum ve ivme verilerini kullanarak, karar ağacı algoritması ile ineklerin davranışlarını yem yeme, yem yememe ve sağım nedeniyle padok dışında bulunma olmak üzere üç kategori altında sınıflandırmıştır. Her bir davranış türü için günlük ortalama davranış sayısını, ortalama süreyi ve toplam süreyi hesaplanmıştır. Araştırıcılar, topal ve topal olmayan inekler arasında davranış farklılıklarının olup olmadığını belirlemek amacıyla, Welch t-testi ve Benjamini-Hochberg düzeltmesi uygulamıştır. Elde edilen bulgular, topal ineklerin günlük toplam yem yeme süresinin, topal olmayan ineklere kıyasla anlamlı düzeyde daha düşük olduğunu ortaya konulduğu belirtilmiştir. Araştırıcılar sonuçların davranış sınıflandırmasında karar ağaçları gibi yorumlanabilir algoritmaların, sensör verilerinden anlamlı örüntüler çıkarma açısından işlevsel olabileceği bildirilmiştir.

4.3.2. HAYVANSAL ÜRETİM

Makine öğrenmesi, yöntemleri sayesinde, büyük ölçekli verilerden anlamlı örüntüler çıkarılarak, yem tüketimi, süt verimi, büyüme hızı gibi üretimle doğrudan ilişkili parametreler analiz edilebilmekte ve optimize edilebilmektedir. Böylece, üretim sürecindeki olumsuzluklar erken dönemde tespit edilerek, daha etkin yönetim stratejileri geliştirilebilmektedir.

Örnek olarak Fuentes ve ark. (2021) yaptıkları çalışmada, ineklerin kalp atış hızı, solunum hızı ve ani hareketlerini tahmin etmek için RGB kameralarla elde edilen görüntüler üzerinden temassız bilgisayarla görme yöntemleri uygulamış ve göz sıcaklığı, süt verimi ve süt kalitesini tahmin etmek amacıyla makine öğrenmesi modelleri kullanılmıştır. Çalışmada, RGB ve kızılötesi termal videolarını, robotik sağım tesisinde bulunan 102 farklı inekten tekrarlı ölçümlerle (n=150) elde edilmiştir. Araştırıcılar, yalnızca RGB kameralarla elde edilen verileri kullanan ANN modelinin, göz sıcaklığı (°C), günlük süt verimi (kg-süt-gün^{-1}), inek başına süt verimi (kg-süt-inek^{-1}), süt yağı (%) ve süt proteini (%) gibi parametreleri tahmin etmede yüksek

doğruluk sağladığını (R= 0.96) ve aşırı öğrenme (overfitting) belirtileri göstermediğini bildirmiştir.

4.4. SU YÖNETİMİ

Makine öğrenimi modelleri, sürdürülebilir hassas sulama yönetimi kapsamında tatlı su kaynaklarının akılcı ve sürdürülebilir kullanımını destekleyen zeka tabanlı etkili bir karar destek sistemi olarak öne çıkmaktadır. Sulama ile ilgili kararların, hava durumu ve toprak koşullarına ilişkin tahminlere dayanarak bitkilerin su gereksinimlerinin öngörülmesi yoluyla daha bilinçli biçimde alınması mümkün hale gelmektedir. Bu yaklaşım, toprak nemi, su ihtiyacı ve verim gibi parametrelerin önceden tahmin edilerek sulama stratejilerinin proaktif bir şekilde belirlenmesini içermektedir (Abioye et al., 2022).

Örnek olarak Sayari ve ark. (2021), karık sulama sistemlerinde su sızmasını tahmin etmek amacıyla Yapay Sinir Ağı (YSA), Uyarlanabilir Nöro-Bulanık Çıkarım Sistemi (ANFIS), Veri İşleme Grup Yöntemi (GMDH), Çok Değişkenli Doğrusal Regresyon (MLR) ve Destek Vektör Regresyonu (SVR) gibi beş yapay zeka modeli ile bunların Firefly Algoritması (FA) ile optimize edilmiş hibrit versiyonlarını geliştirmişlerdir. Çalışmada modelleme sürecinde, karık uzunluğu, giriş hızı, ilerleme süresi, giriş kesit alanı ve sızma fırsat süresi gibi parametreler kullanılmış; veriler literatür kaynaklarından ve İran'ın Kerman kentindeki bir araştırma çiftliğinden elde edilmiştir. FA, model parametrelerini optimize etmek amacıyla kullanılmış ve özellikle SVR ile MLPNN modellerinde belirgin performans artışı sağladığı rapor edilmiştir. Çalışma sonucunda, FA'nın SVR modeli üzerindeki etkisiyle %47 oranında hata azalması ve genel performansta %97'ye varan iyileşme sağladığını, bu yönüyle sulama sızma modellemesinde etkili bir optimizasyon aracı olduğu bildirilmiştir.

4.5. TOPRAK YÖNETİMİ

Makine öğrenimi (ML) yöntemleri, toprak özelliklerinin hızlı ve doğru bir şekilde tahmin edilmesini sağlayarak geleneksel analiz yöntemlerine kıyasla daha verimli bir alternatif sunmaktadır. Özellikle Rastgele Orman (RF) ve XGBoost modelleri; toprak sıcaklığı, nem, organik madde ve pH gibi parametrelerin yüksek doğrulukla tahmininde etkili bulunmuştur. Bu teknikler, sürdürülebilir toprak yönetimi uygulamalarının geliştirilmesine katkı sağlamaktadır (Devi ve Rani, 2024).

Örnek olarak Maleki ve ark. (2023), nar, antep fıstığı ve safran ekili tarım arazilerinde farklı toprak özelliklerine göre yönetim bölgeleri (MZ–Management Zones) belirlenmiştir. Çalışmada, 202 toprak örneği toplanmış ve çevresel değişkenler kullanılarak toprak özellikleri Random Forest modeli ile haritalanmıştır. Modelin doğruluğu, doğrulama setinde Lin's uyum katsayısı (CCC) ile değerlendirilmiş ve 0.65 ile 0.79 arasında değiştiği bildirilmiştir. Çalışmada, toprak haritaları, çalışılan bölgede organik karbon, potasyum, fosfat ve azot düzeylerinin düşük olduğu gösterilmiş ve toprak özellikleri ile çevresel değişkenler arasındaki ilişkiye göre dört farklı yönetim bölgesi tanımlanmıştır. Ayrıca, toprak verimliliği açısından bölgelerin sıralaması MZ4 > MZ1 > MZ3 > MZ2 şeklinde olup, toprak kalite (SQ) haritasına göre her bölgede heterojen bir yapı tespit edilmiş ve 1.65 hektarlık alanda çok düşük toprak kalitesi saptandığı

belirtilmiştir. Çalışma sonunda, gübreleme miktarının bölgeye özgü olarak ayarlanması gerektiğini vurgulayarak, sürdürülebilir tarım için bölgesel toprak yönetiminin önemini raporlanmıştır.

5. TARTIŞMA VE SONUÇ

Tarımda makine öğrenmesi uygulamaları üzerine yapılan çalışmalar, bitkisel üretimden hayvancılığa, toprak analizinden sulama yönetimine kadar pek çok alanda önemli katkılar sunduğunu ortaya koymaktadır. Özellikle verim tahmini, hastalık teşhisi, zararlı tespiti ve kaynak optimizasyonu gibi konularda sağladığı başarılar, makine öğrenmesinin tarımda yaygınlaşmasına neden olmuştur. Ancak bu olumlu gelişmelere rağmen uygulama sürecinde çeşitli zorluklarla karşılaşılmaktadır.

En yaygın sorunlardan biri, geliştirilen modellerin veriye yeterince uyum sağlayamaması ve tarımsal ortamlardaki karmaşık yapıların ve arka plan gürültüsünün fazla olmasıdır. Modelin öğrenme kapasitesinin yetersiz kalması düşük öğrenmeye (underfitting), veriye aşırı derecede uyum sağlaması ise aşırı öğrenmeye (overfitting) neden olmaktadır. Bu durum, modelin genelleme yeteneğini azaltarak, gerçek dünya verileri üzerinde düşük performans sergilemesine yol açmaktadır. Tarımsal görüntülerden elde edilen verilerin kalitesi de, model performansını doğrudan etkilemektedir. Görüntülerdeki bulanıklık, ışık dengesizliği, objelerin birbirine yakınlığı ya da örtüşmesi gibi faktörler, özellikle görüntü tabanlı sınıflandırma ve tespit uygulamalarında makine öğrenmesinin başarısını düşürebilmektedir. Ayrıca, veri etiketlemenin zaman alıcı ve uzmanlık gerektiren bir süreç olması da veri toplama aşamasını yavaşlatmaktadır. Bu bağlamda, transfer öğrenme, veri artırma (data augmentation) ve hibrit modelleme gibi yöntemlerle söz konusu problemlerin aşılması yönünde çeşitli çözüm önerileri literatürde yer almaktadır.

Son olarak, makine öğrenmesi tarımsal faaliyetlerin daha verimli, sürdürülebilir ve hassas bir şekilde gerçekleştirilmesine önemli katkılar sunmaya devam etmektedir. Gelişen algoritmalar, artan veri çeşitliliği ve hesaplama gücündeki ilerlemeler sayesinde bu teknolojilerin tarımda daha etkin biçimde kullanılması mümkün hale gelmektedir. Gelecekte, mevcut sınırlamaların giderilmesiyle birlikte, makine öğrenmesi tabanlı yaklaşımların tarım sektöründe daha yaygın bir şekilde uygulanacağı öngörülmektedir.

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THE LATEST POINT IN AMPELOGRAPHY: DIGITAL AMPELOGRAPHY

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ABSTRACT

Grapes are perennial plants with approximately 13,000 varieties worldwide. The development of viticulture requires knowing the characteristics of grape varieties, evaluating each variety separately, identifying varieties that differ from each other and checking whether they comply with registration conditions. In this regard, determining grape varieties is among the important issues in viticulture. In the identification of grape varieties, ampelographic features of shoots, leaves, fruits, clusters and seeds of the varieties are used. Ampelographic features are descriptors that allow grape varieties to be identified. A norm called 'Grape Descriptors' has been prepared with the work of important international organizations. The ampelographic properties of grape varieties are determined according to the characterization features in this norm. These characteristics are varietal-specific characters that are inherently present in grape varieties, can be easily seen when viewed, and can be expressed equally in all environments. However, identifying grape varieties based on ampelographic characteristics using traditional methods is time-consuming, expensive and requires expertise.

Fast and easy determination of grape classification is important for the future of viticulture. For this purpose, digital ampelography techniques have begun to be developed to identify grape varieties by utilizing innovative technologies based on advanced image analysis and artificial intelligence. In particular, deep learning models have been found to yield highly successful results in the automatic classification of grape varieties. Digital ampelography can also be used by farmers who are not experts in ampelography. Therefore, the use of image-based deep learning classifiers for automatic classification of grape varieties has the potential to make significant contributions to the field of viticulture. In this study, sample studies where ampelographic features are transferred to digital environments and grape varieties are identified by image-based and artificial intelligence-based systems are examined and explained.

Keywords: Ampelography, Grape, Classification, Deep Learning, Image processing

AMPELOGRAFİDE SON NOKTA: DİJİTAL AMPELOGRAFİ

ÖZET

Üzüm, dünya genelinde yaklaşık olarak 13.000 kadar çeşidi bulunan çok yıllık bitkidir. Bağcılığın geliştirilmesi üzüm çeşitlerinin özelliklerinin bilinmesini, her çeşidin ayrı ayrı değerlendirilmesini, birbirinden farklı olan çeşitlerin belirlenmesini ve tescil koşullarına uyup uymadıklarının kontrolünü gerektirmektedir. Bu bakımdan üzüm çeşitlerinin tespit edilmesi bağcılıkta önemli konular arasında yer almaktadır. Üzüm çeşitlerinin tespitinde çeşitlerin sürgün, yaprak, meyve, salkım ve çekirdeklerine ait ampelografik özelliklerden faydalanılmaktadır. Ampelografik özellikler, üzüm çeşitlerinin tespit edilmesini sağlayan tanımlayıcılardır. Uluslararası önemli kuruluşların çalışmaları ile 'Üzüm Tanımlayıcıları' adıyla bir norm hazırlanmıştır. Üzüm çeşitlerinin sahip olduğu ampelografik özellikler bu normdaki karakterizasyon özelliklere göre belirlenerek ortaya çıkarılmaktadır. Bu özellikler üzüm çeşitlerinde kalıtsal olarak var olan, bakıldığında rahatlıkla görülebilen ve tüm ortamlarda eşit olarak ifade edilebilen çeşitlere özgü karakterlerdir. Ancak geleneksel yöntemler kullanarak ampelografik özelliklere göre üzüm çeşitlerinin belirlenmesi zaman alıcı, pahalı ve uzmanlık gerektirmektedir.

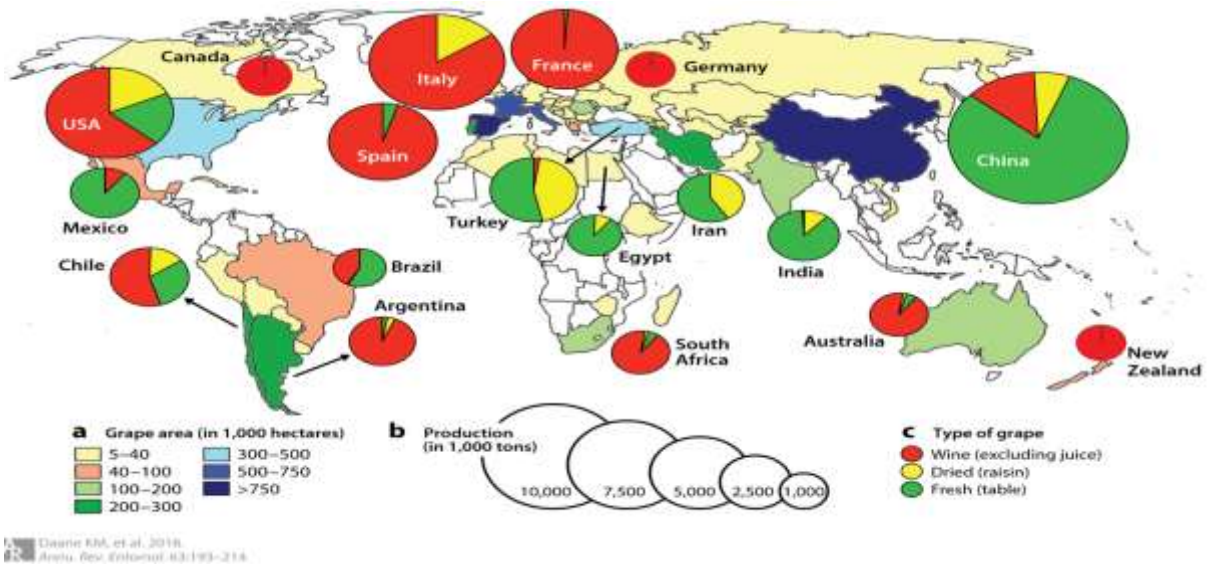
Üzüm sınıflandırma işleminin hızlı ve kolay tespit edilmesi bağcılığın geleceği bakımından önem arz etmektedir. Bu amaçla gelişmiş görüntü analizine tabanlı ve yapay zeka tabanlı yenilikçi teknolojilerden yararlanarak üzüm çeşitlerinin belirlenmesi amacıyla dijital ampelografi teknikleri geliştirilmeye başlanmıştır. Özellikle derin öğrenme modelleri üzüm çeşitlerinin otomatik sınıflandırılmasında yüksek başarılı sonuçlar verdiği tespit edilmiştir. Dijital ampelografi, ampelografi konusunda uzman olmayan çiftçiler tarafından da kullanılabilmektedir. Bu nedenle, üzüm çeşitlerinin otomatik sınıflandırılması için görüntü tabanlı derin öğrenme sınıflandırıcılarının kullanılması bağcılık alanına önemli katkılar sağlama potansiyeline sahiptir. Bu çalışmada, ampelografik özelliklerin dijital ortamlara aktarılarak üzüm çeşitlerinin tespitinin görüntü tabanlı ve yapay zekalı tabanlı sistemler tarafından yapıldığı örnek çalışmalar incelenerek açıklanmıştır.

Anahtar Kelimeler: Ampelografi, Üzüm, Sınıflandırma, Derin Öğrenme, Görüntü İşleme

1. GİRİŞ

Asma bitkisinin yetiştiriciliği antik çağlara kadar dayanmaktadır. Dünya genelinde meyvesi en yaygın olarak üretilen ve tüketilen, günümüzde küresel ekonomik olarak ülkelere büyük katkı sağlayan önemli bir bitki türüdür. Bağcılık, alan ve değer bakımından tarımsal üretim arasında en çok büyüme gösteren bir potansiyele sahiptir. Bu büyümede, uluslararası ticaretin artması, küresel gelirlerin iyileşmesi, üretim, depolama ve taşımadaki teknolojik ilerlemeler, sağlıklı ürünlerin elde edilmesine sebep olan yan ürünlerin işlenmesi ve kullanılmasının yanında üzüm gibi antioksidan bakımından zengin olan gıdaların farkındalığının artması gibi faktörler etkili olmaktadır. Bu bakımından dünya bağcılığının geliştirilmesi, ileri seviyede kaliteli ve verimli ürün elde edilmesi gerekmektedir (Hbyaj et al, 2014; Semerci ve ark., 2015; Daane ve ark., 2018; Carneiro ve ark., 2024).

Üzüm hem taze olarak sofralık hem de şarap, reçel, meyve suyu, kurutulmuş üzüm, sirke ve üzüm çekirdeği yağı gibi işlenmiş şekilde tüketilebildiği için dünyanın en değerli meyveleri arasında sayılmaktadır (Venkitasamy ve ark., 2019). Gerek aroması gerekse ekonomik faydası bakımından üretimi her geçen gün artış göstermektedir. Üretime bağlı olarak dünyadaki üzüm bağları alanı ve çeşit sayısı artmaktadır. Şekil 1'de Dünyadaki bağcılığa ait veriler gösterilmektedir. Üzüm çeşitlerinin her birinin kendine özgü karakterizasyon özellikleri bulunmaktadır. Çeşitlerin ticari değeri ise kendilerine has özelliklerine göre değişebilmektedir. Bu özelliklerin bilinmesi, her bir çeşidin ayrı ayrı değerlendirilmesi, birbirinden farklı olan çeşitlerin tespiti ve tescil koşullarına uygunluklarının ortaya çıkarılması üzüm yetiştiriciliğinin ileri seviyeye taşınmasını sağlamaktadır (Yağcı ve İlter, 2018; Adão ve ark., 2025).



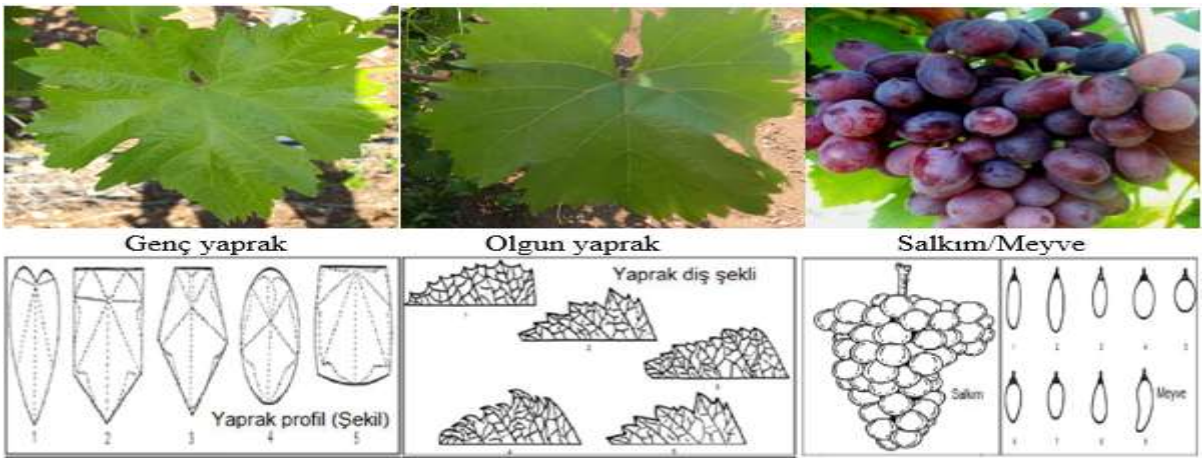
Şekil 1. Dünya bağcılığına ait veriler. a) Üzüm bağları arazi alanı, b) En üretken 18 ülkenin her birinden elde edilen üretim, c) En üretken 15 ülkenin her birinden elde edilen üzüm meyvesinin yüzdesi (Daane ve ark., 2018).

Bu çalışmada, derin öğrenme yöntemlerini kullanarak üzüm çeşitlerini sınıflandırmak için dijital ampelografiyi kullanan çalışmalar incelenmiştir.

2. AMPELOGRAFİ

Yunanca ampelos (asma) ve graphe (açıklama) kelimelerinden türeyen ampelografi üzüm türlerini tanımlayan ve sınıflandıran bir bilim dalıdır. Üzüm çeşitlerinin tanımlanması yapraklar gibi organlarının görsel olarak incelenmesini ve ayırt edici karakterlerin tespit edilmesini içeren ampelografi gibi metotlara dayanmaktadır (Tassie, 2010; Dexheimer, 2011).

Ampelografik özellik olarak belirtilen tanımlayıcılar, üzüm çeşitlerinde genelde yüksek oranda kalıtsal olarak var olan ve gözle bakıldığında kolayca görülebilen ve tüm ortamlarda eşit olarak ifade edilen, çeşitlerin sürgünlerine, çiçeklerine, yapraklarına, salkım/meyvelerine ve çekirdeklerine ait karakterlerdir (Anonymous, 1997). Şekil 2'de bir asma bitkisinin farklı bölümlerine ait bazı görüntüler ve görüntülerin hangi çeşide ait olduğunu tespit etmek için kullanılan bazı ampelografik özellikleri gösterilmektedir.



Şekil 2. Bir asma bitkisinin farklı bölümlerine ait görüntüler ve bazı ampelografik özellikler.

Ampelografik özelliklerin ortaya çıkarılması dikkatli araştırma ve çalışmaların olduğu zahmetli ve uzun süreli bir uğraştır. Ampelografik özelliklerin tespiti genç sürgünlerin ortaya çıkmasıyla başlayarak, çiçeklenme, genç/olgun yaprak, salkım/meyve ve odunsu sürgün karakterlerinin kendi dönemleri boyunca yapılabilmektedir. Bu sebeple bir çeşidin ampelografik özelliklerini ortaya çıkarmak yaklaşık 5-6 aylık bir süreç gerektirmektedir (Terzi, 2023).

Aynı özelliklere sahip olan çeşitlere bölgelere göre farklı isimler verilebilmektedir. Uluslararası yöntem birliği çalışmaları kullanılarak bu farklılıkların önüne geçilebilmektedir. Ampelografik özelliklerinin ortaya çıkarılmasında uluslararası yöntem birliğini sağlamak amacıyla Uluslararası Bitki Gen Kaynakları Enstitüsü (The International Plant Genetic Resources Institute- IPGRI) adına oluşturulmuş bir çalışma ekibi ile Bağcılık ve Şarapçılık Ofisi (Office

International de la Vigne et du Vin-OIV) ve Uluslararası Yeni Bitki Çeşitlerinin Korunması Birliği (International Union for the Protection of New Varietes of Plants- UPOV) ile iş birliği içinde yapılan çalışmalarla geliştirilmiş normlar Üzüm Tanımlayıcıları (Grape Descriptors) adıyla yayınlanmıştır. Bu normlar, üzerinde daha sonra bazı değişiklikler yapılarak ve üzüm genotipleri karakterizasyonu ile akrabalık ilişkilerinin tespitinde yürütülecek çalışmalar için yüksek oranda ayırıcı özellik taşıyan unsurlar olarak belirlenmiştir. Bu yöntemle günümüzde genotip tanımlama çalışmaları için kullanılan Descriptors for Grapevine (Vitis spp.) listeleri oluşturulmuştur (Anonymous, 1997).

2.1. DİJİTAL AMPELOGRAFİ

Üzüm çeşitlerinin tespit edilmesinde ve sınıflandırılmasında meydana gelen karışıklığın giderilmesi, üretim ve kalitenin geliştirilmesi bakımından önemlidir. Bu sebeple bağcılıkta verim tahmini ve öngörüsü, hassas bağcılık yöntemlerinden yararlanılarak verimli ürün yönetiminde kullanılmaktadır (Sozzi ve ark., 2022). Dünya genelinde çeşit bakımından zengin olan üzüm çeşitlerinin hızlı ve kolay tespit edilmesi tarım sektörüne ve bağcılığa önemli katkılar sağlamaktadır (Pınar ve ark., 2018). Bu görev alanında uzmanlaşmış yetenekli ampelograflar tarafından yapılabilmektedir (Garcia-Muñoz ve ark., 2011). Ancak bu yeteneklerin sayısının azalması, insan odaklı diğer faaliyetlerde olduğu gibi ampelografik özelliklerin belirlenmesinde de yoğun çabaya gerek duyulması, zaman alıcı olması ve insan kaynaklı hatalara yol açması sebebiyle (Magalhães ve ark., 2023; Adão ve ark., 2025), hızlı ve pratik çalışabilen teknolojik sistemlere ihtiyaç duyulmaktadır (Altas ve ark., 2018). Ayrıca başarılı bir tarımsal işletmecilik için her bir bileşendeki değişimler doğru ve zamanında belirlenmeli, olabilecek etkileşimlerde göz önüne alınarak yapılacak uygulamalara karar verilmelidir (Ozguven, 2023). Bu bakımdan dijital tarım uygulamalarının sahip olduğu yazılım donanım sistemleri tarımsal alanda verilerin gerçek zamanlı toplanmasına, analiz edilmesine, depolanmasına ve veriye bağlı işlemlerin yönetilmesine olanak sağlaması bakımından tarımsal işlemlerin hızlı ve pratik olarak ilerlemesine büyük katkı sağlamaktadır (Özgüven, 2023). Dijital ampelografi üzüm çeşitlerinin tespiti ve sınıflandırılması amacıyla çeşitlere ait ampelografik özelliklerin dijital teknolojiler kullanılarak analiz edildiği bir durumdur. Geleneksel ampelografinin temelini gözle yapılan morfolojik analizler oluştururken, dijital ampelografide bu durum görüntü işleme, makine öğrenmesi ve yapay zekalı teknolojilere dayanmaktadır (Vélez ve ark., 2021; Nasiri ve ark., 2021).

3. İLGİLİ ÇALIŞMALAR

Literatürde bulunan çalışmaların bazılarında sadece üzüm yaprakları sınıflandırılmıştır. Bu çalışmalara örnekler şunlardır. Pereira ve ark. (2018) altı farklı üzüm (Tinta Amarela, Tinta Barroca, Tinto Cão, Touriga Franca, Touriga Nacional, Tinta Roriz) çeşidine ait asma yapraklarını sınıflandırmak için renk modeli ve eşik teknikleri kullanarak bölge büyümesine dayalı bir segmentasyon algoritması önermişlerdir. Çalışmada önerilen asma yaprağı segmentasyon algoritmasının doğruluğunu değerlendirmek için, segmente edilmiş bir görüntünün elle segmente edilmiş bir görüntüyle karşılaştırıldığı bir denetlenen değerlendirme

yöntemi kullanıldığı belirtilmiştir. Çalışmanın sonunda %94,8'lik bir doğruluk elde edildiği bildirilmiştir. Carneiro ve ark. (2023), ImageNet üzerinde önceden eğitilmiş EfficientNetV2S modelini kullanarak on iki üzüm (Codega, Rabigato, Malvasia Rei, Tinta Roriz, Moscatel Galego, Tinto Cao, Mourisco Tinto, Touriga Nacional) çeşidine ait 308 yaprak görüntüsünü sınıflandırmışlardır. Çalışmanın sonunda iki veri setinde de 0,88 ve 0,58 doğruluk elde edildiği bildirilmiştir.

Bazı çalışmalarda sadece üzüm taneleri veya salkımlara göre sınıflandırma yapılmıştır. Bu çalışmalara örnekler şunlardır. El-Mashharawi ve ark. (2020) CNN derin öğrenme modelini kullanarak 6 adet üzüm çeşidini (Black, Crimson, Yellow, Dark Blue, Green, Pink) sınıflandırmışlardır. Veri seti, her biri farklı renkte olan üzüm çeşitlerine ait üzüm taneleri şeklinde alınan 4565 adet görüntüden oluşmaktadır. Çalışmanın sonunda %100 sınıflandırma doğruluğu elde edildiği bildirilmiştir. Franczyk ve ark. (2020) Keras Standart Modeli (KSM), Restnet, ExtRestnet modellerini kullanarak 5 üzüm çeşidini (Chardonnay, Cabernet Franc, Cabernet Sauvignon, Sauvignon Blanc, Syrah) sınıflandırmışlardır. Veri seti 300 salkım görüntüsünden oluşmaktadır. Çalışmada bu görüntülerin, model eğitimi ve testi için 3957'ye çıkarıldığı bildirilmiştir. Çalışma sonunda, KSM sınıflandırması için %47, Restnet için %89 ve ExtRestnet için %99 doğruluk elde edildiği rapor edilmiştir.

Çalışmaların bazılarında hazır veri seti veya orijinal veri seti kullanılmıştır. Bu örnek çalışmada iki farklı orijinal veri seti kullanılmıştır. Pereira et al. (2019) üzüm çeşitlerinin otomatik sınıflandırılabilmesi için AlexNet mimarisine dayalı bir model önermişlerdir. Çalışmada veri seti olarak altı farklı üzüm (Tinta Amarela, Tinta Barroca, Tinta Cao, Touriga Franca, Touriga Nacional, Tinta Roriz) çeşidine ait 224 salkım görüntüsünden oluşan iki doğal bağ görüntülerini kullanılmıştır. Eğitim ve sınıflandırma işlemlerinde ise farklı veri kümeleri meydana getirmek amacıyla görüntü eğriltme algoritması ve görüntü işleme yöntemleri uygulanmıştır. Çalışma sonunda AlexNet tabanlı transfer öğrenme yöntemiyle elde edilen ve dört köşe bir arada yöntemi ile önceden işlenmiş bir görüntü veri kümesi üzerinde eğitilen deneysel sonuçlar, %77,30'luk doğruluk elde edildiği rapor edilmiştir. Aynı sınıflandırıcı modelinin uygulanmasıyla popüler Flavia yaprak veri kümesinde %89,75'lik bir doğruluk elde edildiği rapor edilmiştir.

Bazı çalışmalarda laboratuvar ortamında elde edilen RGB veya multispektral görüntüler kullanılarak sınıflandırma yapılmıştır. Örnek olarak Nasiri ve ark. (2021) laboratuvar ortamında elde edilen altı üzüm çeşidine ait (Asgari, Fakhri, Keshmeshi, Mirzaei, Shirazi ve Black) görünür spektrumda (400-700 nm) elde edilen 300 yaprak görüntüsünü kullanarak üzüm çeşitlerinin otomatik olarak sınıflandırılması için değiştirilmiş bir VGG16 mimarisi önermişlerdir. Çalışma sonunda önerilen model ile %99,11 oranında bir sınıflandırma doğruluğu elde edildiği bildirilmiştir. Adão ve ark. (2025) beyaz arka planlı altı üzüm çeşidine ait (Touriga Nacional, Tinto Cão, Códega, Moscatel, Tinta Roriz, Rabigato) yaprak görüntülerini ve doğal ortamlardan alınan on iki üzüm çeşidine ait (Códega, Malvasia Fina, Malvasia Preta, Malvasia Rei, Moscatel, Mourisco Tinto, Rabigato, Tinta Amarela, Tinta Barroca, Tinta Roriz, Tinto Cão, Touriga Nacional) yaprak görüntülerini sınıflandırmışlardır. Çalışmada özellikle Xception sinir ağı mimarisi kullanılmış olup, iki veri seti için sırasıyla %95 ve %98 hassasiyet oranları elde edildiği bildirilmiştir.

Bazı çalışmalarda ise farklı derin öğrenme modelleri kullanılarak sınıflandırma yapılmıştır. Rajab ve ark. (2024) üzüm çeşitlerinin sınıflandırılmasında derin öğrenme tabanlı VGG-16 ve VGG-19 mimari yapılarını önermişlerdir. Araştırıcılar veri seti olarak çeşit başına 100 görüntü olacak şekilde toplam 500 görüntüden oluşan beş üzüm çeşidini (Ak, AlaIdris, Buzgulu, Dimnit, Nazli) kullanmışlardır. Çalışma sonunda VGG-16 mimarisi için %96,6 oranında bir başarı elde edilirken, VGG-19 mimarisi için ise %100 oranında bir başarı elde edilmiştir. Terzi ve ark. (2023) çalışmalarında beş üzüm çeşidini (Corint, Merlot, Tayfi, Michele palieri, Narince) üzüm çeşitlerinin ampelografik özelliklerinden faydalanarak derin öğrenme teknikleri ile sınıflandırılmasını yapmışlardır. Mimari yapı olarak özgün şekilde geliştirilen 15 katmanlı bir evrişimli sinir ağı önermişlerdir. Çalışmada beş sınıftan oluşturulan veri setinde üzüm çeşitlerinin salkım ve meyvelerine ait 227x227x3 boyutlarında 1028 adet görüntü kullanılmış ve önerilen modelin üzüm çeşitlerini sınıflandırmada %96,10 oranında doğruluk elde ettiğini bildirilmiştir.

Bazı çalışmalarda Android veya IOS uygulamalar geliştirilmiştir. Liu ve ark. (2021) üzüm çeşitlerini otomatik ve gerçek zamanlı olarak tespit edebilen ve üreticilerin çeşit bilgilerini hızlı bir şekilde öğrenmelerine yardımcı olabilen Android uygulama geliştirmiştir. Veri seti olarak yirmi bir üzüm çeşidine ait (Aglianico, BeiMei, Cabernet Sauvignon, Aligote, Welschriesling, Pinot Noir, Riesling, Malbec, Marselan, Merlot, MeiLi, Cabernet Franc, Sangiovese, Vidal, Viognier, Syrah, Chardonnay, Petit Manseng, Petit Verdot, Yan, Sauvignon Blanc) toplamda 5164 görüntü kullanılmıştır. AlexNet, VGG-16, ResNet101, ResNet18, DenseNet ve GoogLeNet modelleri kullanılarak yapılan sınıflandırmada doğruluk değerleri sırasıyla %94,70; %96,85; %97,24; %95,68; %94,70; %99,66 elde edildiği bildirilmiştir.

Bazı çalışmalarda ise aynı çalışmada hem yapraklar hem de salkım ve meyveler sınıflandırılmıştır. Örnek olarak çalışmada aynı zamanda ampelografik özelliklere göre sınıflandırma yapılmıştır. Terzi ve ark. (2024) Crimson seedlees, Bilecik karası, Michele palieri, Tekirdağ çekirdeksizi, Lival, Trakya ilkeren, Karaerik, Flame seedlees, Horoz karası, Royal, Alphonse L., Prima, Cardinal, Süperior seedlees, Victoria, Red globe, Sultani çekirdeksiz, Mevlâna, İtalia, İzabel, Narince, Vakkas, Erciş, Pinot noir, Abalıhoca, Hasandede, Cabarnet france, Syrah, Cabarnet sauvignon, Kyoho, Corinth, Merlot, Rub. Du. Lot., 1103 Paulsen, Muhammediye, Helvani, Çavuş, 110R, Tayfi, Black magic, Bronx seedlees, Autumn royal, Yalova incisi, 41R, 5BB, Regent, Rizessi, Kısmısh vatkana, Rizellim, Rizpem 50 adet üzüm çeşidini yeni ve özgün bir CNN modeli ile sınıflandırmışlardır. Çalışmada doğal bağ alanlarından alınan 9.854 yaprak, 8.745 salkım ve 8.721 meyve olmak üzere toplam 27.320 görüntü kullanılmıştır. Araştırıcılar, veri setlerini yaprak ve salkım/meyve olarak iki gruba ayırmışlar ve yaprak grubunda beş ve salkım/meyve grubunda dört farklı kategori olmak üzere toplam dokuz farklı kategoride sınıflandırma yapmışlardır. Önerilen CNN modeli ile en yüksek doğruluk başarısı Kategori 4'te yer alan yaprak grubu %94,10 ve salkım/meyve grubundan %97,20 olarak elde edildiği bildirilmiştir. Önerilen modelin performansını ve veri setinin farklı modellerle uygunluğunu karşılaştırmak için veri setlerini transfer öğrenme yöntemi ile GoogleNet ve AlexNet modellerine de uygulanmış ve sırasıyla %84,39 ve %92,31 başarı oranı elde edildiği rapor edilmiştir.

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TOTAL PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY OF POMEGRANATE SEED POMACE

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ABSTRACT

Pomegranate seeds constitute approximately 10% of the total weight of the fruit and the majority of the pulp resulting from the production of pomegranate products. Pomegranate pulp is mostly used as animal feed or thrown away. However, the oil obtained from pomegranate seeds is a very valuable oil due to its polyunsaturated fatty acids, which are necessary for human health, cannot be synthesized in the body, and must be taken from outside and high tocopherol content. The fatty acids found in pomegranate oil have anticarcinogenic, anti-inflammatory and antiobese effects, and the tocopherols have antioxidant effects.

The pomace obtained after the production of pomegranate seed oil creates a problem as waste unless it is used as animal feed. However, pomace is very rich in bioactive components, especially phenolic compounds. Phenolic compounds, which are natural antioxidants, are secondary metabolites produced by plants and are of great importance for human health.

In this study, dry matter, total fat, total phenolic content (TPC) and antioxidant activity (DPPH and ABTS) of the pomaces obtained by soxhlet (SxE), cold (solvent) (SE), enzymatic (EE), roasting-assisted enzymatic (KE), microwave-assisted enzymatic (ME) and ultrasound-assisted enzymatic (UE) extraction methods were determined.

The dry matter and oil contents of the pomace were found to be between 93.09-96.77% and 0.00-7.05%, respectively. While no oil residue was detected in the pomace of the soxhlet extraction, the highest oil content (7.05%) was detected in the pomace of the enzymatic extraction. Total phenolic content, 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2-azinobis-3-etilbenzotiazolin-6-sulfonik asit (ABTS) values of the pomace were determined between 979.14-2516.73 mg GAE/kg DM, 6.81-16.99 mmol TE/g DM and 6.74-14.99 mmol TE/g DM, respectively.

The findings show that the pomegranate seed pomace, which is produced in large quantities in the pomegranate industry, has functional properties that can be evaluated especially in the food industry, and is of great importance in terms of environmental sustainability, economy and human health.

Key words: ABTS, DPPH, pomegranate seed pomace, total phenolic content

NAR ÇEKİRDEĞİ KÜSPESİNİN TOPLAM FENOLİK MADDE İÇERİĞİ VE ANTİOKSİDAN AKTİVİTESİ

ÖZET

Nar çekirdeği, nar meyvesinin toplam ağırlığının yaklaşık %10'unu ve nar ürünlerinin üretiminden sonra ortaya çıkan posanın da büyük bölümünü oluşturmaktadır. Bu posa çoğunlukla hayvan yemi olarak değerlendirilmekte veya atılmaktadır. Oysa nar çekirdeğinden elde edilen yağ, insan sağlığı için gerekli olan, vücutta sentezlenemeyip dışarıdan alınması gereken çoklu doymamış yağ asitleri ve yüksek tokoferol içeriği nedeniyle oldukça değerli bir yağdır. Nar çekirdeği yağında bulunan yağ asitlerinin antikanserojenik, antiinflamatuvar ve antiobez etkileri, tokoferollerin de antioksidan etkisi bulunmaktadır.

Nar çekirdeği yağı üretildikten sonra arta kalan küspe hayvan yemi olarak kullanılmadığı taktirde atık olarak sorun oluşturmaktadır. Ancak küspe başta fenolik bileşikler olmak üzere biyoaktif bileşenler açısından oldukça zengindir. Doğal antioksidan olan fenolik bileşikler, bitkiler tarafından üretilen sekonder metabolitler olup insan sağlığı açısından büyük öneme sahiptirler.

Bu çalışmada sokselet (SxE), soğuk (çözücü) (SE), enzimatik (EE), kavurma destekli enzimatik (KE), mikrodalga destekli enzimatik (ME) ve ultrases destekli enzimatik (UE) ekstraksiyon yöntemleri ile elde edilen küspelerin kuru madde, toplam yağ, toplam fenolik madde (TFM) ve antioksidan aktivite (DPPH ve ABTS) değerleri saptanmıştır.

Küspeye ait kuru madde ve yağ miktarları sırasıyla, %93.09-96.77 ve %0.00-7.05 aralığında bulunmuştur. Sokselet ekstraksiyonu sonucu küspede hiç yağ kalıntısı tespit edilmezken, en yüksek yağ içeriği (%7.05) enzimatik ekstraksiyon uygulanan küspede saptanmıştır. Küspelerin toplam fenolik madde, 2,2-diphenyl-1-picrylhydrazyl (DPPH) ve 2,2-azinobis-3etilbenzotiazolin-6-sulfonik asit (ABTS) değerleri ise sırasıyla, 979.14-2516.73 mg GAE/kg KM, 6.81-16.99 mmol TE/g KM ve 6.74-14.99 mmol TE/g KM arasında bulunmuştur.

Elde edilen bulgular, nar endüstrisinde yüksek miktarda ortaya çıkan nar çekirdeği küspesinin özellikle gıda endüstrisinde değerlendirilebilecek düzeyde fonksiyonel özellikte bileşenlere sahip olduğunu, çevresel sürdürülebilirlik, ekonomi ve insan sağlığı açısından büyük önem taşıdığını göstermektedir.

Anahtar kelimeler: ABTS, DPPH, nar çekirdeği küspesi, toplam fenolik madde

1. GİRİŞ

Nar (*Punica granatum* L.) Punicaceae familyasına ait, genellikle tropik ve subtropik bölgelerde yetişen bir bitki olup (Kurt & Şahin, 2013) üretimi ülkemizde giderek artmaktadır. Türkiye'de nar üretimi 2023 yılında 638821 ton, 2024 yılında ise bir önceki yıla göre %10.1 artarak 703425 ton olmuştur (Anonim, 2025).

Nar çekirdeği, meyvenin toplam ağırlığının %3.7-7.9'unu oluşturmakta olup (Aslan Bakkalbaşı ve Cavidoğlu, 2024; Fernandes ve ark., 2015), nar endüstrisinde posa olarak ortaya çıkan yan ürünün önemli bir bölümünü oluşturmaktadır (Tehranifar ve ark., 2010; Fernandes ve ark., 2015). Posa genellikle hayvan yemi olarak kullanılmakta veya atılmaktadır. Oysa çekirdekten elde edilen yağ, çoklu doymamış yağ asitleri, tokoferoller, steroller, karotenoidler ve fenolik bileşikler açısından oldukça zengindir (Çavdar ve ark., 2017; Khoddami ve ark., 2014; Caligiani vd., 2010). Yapılan araştırmalarda, nar çekirdeği yağında bulunan yağ asitlerinin antikanserojenik (Grossmann ve ark., 2010) ve antiinflamatuar (Boussetta ve ark., 2009) etkileri olduğu bildirilmiştir. Ayrıca, nar çekirdeği takviyesinin obezite ve insülin direnci gibi beslenme kaynaklı sağlık sorunlarını iyileştirebileceği belirtilmiştir (Vroegrijk ve ark., 2011). Günümüzde, nar çekirdeği yağının tıp ve kozmetik alanlarında sağladığı faydalarının belirlenmesiyle birlikte, bu yağa olan ilgi giderek artmaktadır (Aruna ve ark., 2016).

Nar çekirdeği yağı, genellikle kurutulmuş çekirdeklerden presleme, organik çözücü ekstraksiyonu veya her iki yöntemin kombinasyonu ile elde edilmektedir. Ancak bu yöntemlerin birtakım dezavantajları bulunmaktadır. Bu dezavantajları ortadan kaldırmak amacıyla son yıllarda süper kritik akışkan ekstraksiyonu, mikrodalga destekli ekstraksiyon, vurgulu elektrik alan ekstraksiyonu, enzim destekli ekstraksiyon ve ultrases destekli ekstraksiyon gibi yeni teknikler geliştirilmektedir (Moradi ve ark., 2017).

Nar çekirdeği yağının çıkarılmasından sonra geriye kalan küspe, özellikle fenolik bileşikler olmak üzere biyoaktif maddeler açısından oldukça zengindir. Fenolik bileşikler hücre savunmasını uyarmakta ve oksidatif hasarı önlemeye yardımcı olmaktadırlar (Bermudez-Oria ve ark. 2019). Bu bileşikler meyve ve sebzelerde yüksek oranda bulunan suda çözünen önemli antioksidanlardır (Meral ve ark., 2012).

Bu bileşikler, insan vücudunda birçok fizyolojik ve dejeneratif hastalik riskinin kontrolündeki önemli rollerinden dolayı insan sağlığı açısından büyük öneme sahip bileşiklerdir (Aadil ve ark., 2013). Kanda kolesterol düzeyini azalttığı, osteoporotik ve antikanserojen etkili olduğu ve antioksidan aktiviteye sahip oldukları pek çok çalışmada belirtilmiştir (Meral ve ark., 2012). Bitki ekstraktlarındaki fenolik bileşiklerin varlığı, antioksidan aktiviteyi önemli ölçüde artırmakta olup, bu ilişki birçok araştırmada ortaya konulmuştur (Anesini ve ark., 2008; Pasko ve ark., 2009). Doğal antioksidan olarak rol almaları fenolik bileşiklerin çeşitli ürün formülasyonlarına girmelerine ve fonksiyonel ürün geliştirilme çalışmalarında dikkatleri üzerine çekmelerine neden olmuştur (Meral ve ark., 2012).

Gıda maddelerinin raf ömrünü uzatmak ve besin değerlerini korumak amacıyla uzun yıllardır kullanılan sentetik antioksidanlar, olası toksik, alerjik ve kanserojen etkileri nedeniyle bazı kısıtlamalara tabi tutulmakta ve hatta yasaklanmaktadır. Bu sebeple, son yıllarda yapılan araştırmalar, geniş çeşitliliğe sahip bitkisel kaynaklardan ekonomik, yenilebilir ve güvenli

antioksidanlar ile antimikrobiyal bileşiklerin elde edilmesine odaklanmaktadır (Lourenco ve ark., 2019). Zengin kimyasal bileşimi ve yüksek polifenol içeriği nedeniyle nar çekirdeği tozunun gıdaların muhafazasında kullanımının teşvik edilmesi gerektiği bildirilmiştir (Rowayshed vd., 2013). Bu nedenle, nar yan ürünlerinin özellikle gıda endüstrisinde doğal antioksidan olarak değerlendirilmesi, çevresel sürdürülebilirlik, ekonomik fayda ve insan sağlığı açısından büyük önem taşımaktadır.

Bu çalışmada hem konvansiyonel nar çekirdeği yağı üretim teknikleri hem de son yıllarda geliştirilen bazı diğer yağ üretim teknikleri sonucunda ortaya çıkan küspelerin kuru madde, toplam yağ, TFM değerleri ve antioksidan aktivitelerinin saptanarak literatürdeki eksiğin giderilerek katkı sağlanması amaçlanmıştır. Ayrıca yüksek miktarda ortaya çıkan bu atığın gıda endüstrisinde doğal antioksidan kaynağı olarak değerlendirilmesine dikkat çekilmesi çevre, ekonomi ve sağlık açısından büyük önem taşıdığı düşünülmektedir.

2. LİTERATÜR ÖZETİ

Bu konuda yapılan araştırmaların büyük bölümü nar çekirdeğinin fenolik bileşimi ve antioksidan aktivitesi üzerine yoğunlaşmıştır. Nar çekirdeği küspesinin bu açıdan araştırıldığı çalışma sayısı kısıtlı olmakla birlikte literatür taramamız sonucunda bu alanda yapılan bazı çalışmalar aşağıda verilmiştir.

Farklı 3 nar çeşidine ait nar çekirdeklerinin TFM, DPPH ve ABTS değerlerinin incelendiği bir çalışmada bu değerler sırasıyla, 3.88–4.96 mg/g, 5.01–8.61 µmol TE/g, ve 1.61–2.53 µmol TE/g olarak tespit edilmiştir (Peng, 2019).

Yapılan başka bir çalışmada soğuk pres uygulanarak üzüm ve nar çekirdeği yağı atıklarından elde edilen sulu ekstraktların toplam fenolik madde içeriği nar için 2959.10 mg/L, üzüm için 3737.38 mg/L olarak bulunmuştur. Maltodekstrin ile kaplanıp püskürterek kurutularak enkapsüle edilen bu ekstraktlar salata sosu formulülasyonunda kullanılması ürünün oksidatif stabilitesini arttırmakla birlikte biyokatif bileşenler açısından da zenginleştirdiği bildirilmiştir. (Aksoy, 2017).

Çin'in Shanxi bölgesinde yetiştirilen 4 farklı nar çeşidine ait çekirdeklerin antioksidan ve fitokimyasal bileşimlerinin araştırıldığı bir çalışmada, %50 aseton ve %80 metanolle ekstrakte ettikleri nar çekirdeği unu ekstraktlarının toplam fenolik içeriğini 1.29-2.17 mgGAE/g olarak saptamışlardır. Aynı çalışmada ekstraktların DPPH radikaline karşı EC_{50} değerleri 6.4-19.8 mg/mL olarak, ABTS değerleri 7.4-17.8 µmol TE/g un olarak belirlenmiştir(Jing vd., 2012).

Li ve ark. (2011) süperkritik CO_2 yöntemi ile yağı alınmış nar çekirdeği küspesinden %70:30 aseton:su ile elde ettikleri ekstraktın TFM içeriğini 2427.90 mg kateşin Eş./100 g KM olarak tespit etmişler ve nar çekirdeği yağı atığının nütrasötik olarak kullanılabileceğini belirtmişlerdir.

3. MATERYAL VE YÖNTEM

3.1. Materyal

Farklı ekstraksiyon yöntemleri (SxE, SE, EE, KE, ME ve UE) uygulanarak Hicaznar çeşidine ait nar çekirdeğinden yağlar elde edildikten sonra ortaya çıkan küspeler laboratuvar ortamında 20-22°C'de ortalama %5 nem içeriğine kadar kurutulduktan sonra kahve öğütücüsünde öğütülüp 0.85 mm'lik elekten geçirilmiştir. Öğütülmüş küspe örnekleri analiz edilinceye kadar -18°C'de depolanmıştır.

3.2. Yöntem

3.2.1 Toplam Kuru Madde

5 g öğütülmüş nar çekirdeği küspesi darası alınan kurutma kaplarına tartılıp 105°C'deki etüvde sabit ağırlığa gelinceye kadar kurutuldu. Sonuçlar % kuru madde miktarı olarak hesaplanıştır (AOAC, 2006, metot no: 934.01).

3.2.2 Toplam Yağ

10 g öğütülmüş nar çekirdeği küspesi 150 mL n-hekzan ile sokselet ekstraktöründe 6 saat süre boyunca ekstraksiyona tabii tutulmuştur. Ekstraksiyon sonunda n-hekzan, vakum altında rotary evaporatörde 40°C'de uzaklaştırılmıştır. Geriye kalan yağ etüvde 85°C'de sabit ağırlığa gelinceye kadar tutulmuştur (AOAC, 1995).

3.2.3 Metanolik Ekstraktların Hazırlanması

Yaklaşık 1 g nar çekirdeği küspesi üzerine 25 mL metanol ilave edilerek 300 rpm'de 2 saat boyunca çalkalanmıştır. Daha sonra 8000 g'de 10 dk boyunca santrifüjlenmiştir. Üstteki süpernatant kaba filtre kağıdından geçirilerek 25 mL'lik balon jojeye aktarılmıştır. Balon ölçü çizgisine metanol ile tamamlanıp analiz edilinceye kadar -18°C'de depolanmıştır.

3.2.4 Toplam Fenolik Madde (TFM) Analizi

TFM analizleri Singleton ve Rossi (1965)'e göre yapılmıştır. 0.4 mL metanolik ekstrakt alınıp üzerine 2 mL 1/10 oranında su ile seyreltilmiş Folin-Ciocalteu ajanı ve 1.6 mL %7.5 sodyum karbonat çözeltisi eklenmiştir. Reaksiyon karışımı 1 saat oda sıcaklığında (karanlıkta) bekletildikten sonra spektrofotometrede 765 nm'de okuma yapılmıştır. Sonuçlar gallik asit ile oluşturulan kalibrasyon grafiğinden yararlanılarak gallik asit eşdeğeri (mg GAE/kg KM) olarak ifade edilmiştir.

3.2.5 Antioksidan Aktivite Analizleri

3.2.5.1 DPPH (2,2-diphenyl-1-picrylhydrazyl)

DPPH radikali sönümleme aktivitesi Pyo vd. (2004) tarafından önerilen yöntem kullanılmıştır. Bu yöntem, mor renkli stabil bir bileşik olan DPPH radikalinin yok edilmesi sonucu renkte oluşan azalmanın spektrofotometrik olarak ölçülmesi ilkesine dayanmaktadır. Uygun oranda seyreltilmiş 0.1 mL metanolik ekstrakt 3.9 mL DPPH çözeltisi (0.025 g/L metanol) ile karıştırıldıktan sonra oda sıcaklığında 60 dk. karanlıkta tutulmuştur. Süre sonunda örneğin absorbansı 515 nm'de UV-spektroskopisi kullanılarak ölçülmüştür. DPPH radikalinin inhibisyon değerleri Eşitlik (1)'e göre hesaplanmıştır.

$$\%\ İnhibisyon = \frac{Abs\ (kontrol) - Abs\ (örnek)}{Abs\ (kontrol)} * 100 \qquad (1)$$

Sonuçların hesaplanmasında sentetik antioksidan olan Troloks standart kurvesinden yararlanılarak sonuçlar troloks eşdeğeri (mmol Troloks eş./g KM) cinsinden ifade edilmiştir.

3.2.5.2 ABTS (2,2-azinobis-3etilbenzotiazolin-6-sulfonik asit)

ABTS analizleri Re vd. (1999) tarafından önerilen yönteme göre yapılmıştır. Bu yöntem, ABTS˙+ radikali tarafından tutulan antioksidatif maddelerin miktarının, sentetik bir antioksidan olan Troloks'un miktarlarıyla oranlayarak belirlenmesi ilkesine dayanmaktadır. Ölçümler, ABTS+ radikalinin giderilmesinin spektrofotometrik olarak belirlenmesiyle yapılmaktadır. Çalışmada öncelikle 7 mmol ABTS ile 2.45 mmol potasyum persulfatın oda sıcaklığında ve karanlıkta 12-16 saat reaksiyonu sonucunda ABTS˙+ radikal katyonu oluşturulmuştur. Elde edilen ABTS˙+ radikal katyonu 734 nm'de 0.700±0.02 absorbans verecek şekilde etanol ile seyreltilmiştir. 1980 µL seyreltilen ABTS˙+ radikal katyonu 20 µL metanolik ekstrakt ile karıştırılmıştır. Karışım oda sıcaklığında 6 dk. tutulduktan sonra 734 nm'de absorbansı ölçülmüştür. Sonuçların hesaplanmasında Troloks standart kurvesinden yararlanılmış ve sonuçlar mmol Trolox eş./g KM olarak ifade edilmiştir.

3.3 İstatistiksel Analiz

Bu çalışmada, elde edilen veriler arasındaki fark SPSS Statistic 25.0 paket programı kullanılarak tek yönlü varyans analizi (One-Way ANOVA) ile belirlenmiştir. Gruplar arasındaki farklılıklar Duncan çoklu karşılaştırma testi ile değerlendirilmiştir ($p<0.05$).

4. BULGULAR VE TARTIŞMA

Farklı ektraksiyon yöntemleri ile nar çekirdeği yağları elde edildikten sonra ortaya çıkan küspelerin kuru madde ve toplam yağ içerikleri Çizelge 4.1'de verilmiştir.

Çizelge 4.1. Yağ üretiminden arta kalan küspelerin kuru madde ve toplam yağ değerleri (ortalama±standart sapma)

Yöntem	Kuru Madde (%)	Toplam Yağ (%)
EE	96.77±0.28^{e}	7.05±0.01^{e}
ME	94.40±0.13^{b}	3.52±0.41^{b}
KE	95.26±0.22^{c}	3.99±0.42^{b}
UE	96.70±0.04^{e}	6.31±0.08^{d}
SxE	93.09±0.03^{a}	0.00±0.00^{a}
SE	95.68±0.10^{d}	4.71±0.05^{c}

Küçük harfler yöntemler arasındaki farkı ifade eder

Küspelerin kuru madde oranları %93.09-96.77 arasında değiştiği saptanırken, yöntemin kuru madde üzerindeki etkisi istatistiksel açıdan önemli ($p<0.05$) bulunmuştur. En yüksek kuru madde oranı EE yöntemi sonucu elde edilen küspede saptanırken, en düşük kuru madde oranı sokselet yöntemi sonucu elde edilen küspede tespit edilmiştir. Küspelerin toplam yağ miktarları %0.00-7.05 arasında olduğu belirlenirken yöntemler arasındaki farklılık istatistiksel açıdan önemli ($p<0.05$) bulunmuştur. Sokselet yönteminde küspede yağ kalıntısı kalmadığı, EE sonucu arta kalan küspede ise en fazla yağ kalıntısı tespit edilmiştir.

Küspe örneklerin TFM, DPPH ve ABTS değerleri Çizelge 4.2'de verilmiştir. Küspelere ait TFM değerleri 979.14-2516.73 mg GAE/kg KM arasında değişmiştir. En yüksek TFM değeri SE sonucu, en düşük ise ME sonucu elde edilen küspede saptanmıştır. Enzimatik ekstraksiyon öncesi mikrodalga ve ultrases ön işlemlerinin uygulanması küspenin TFM miktarını etkilemezken ($p>0.05$), kavurma ön işlemi TFM miktarını arttırmıştır ($p<0.05$). Soğuk ekstraksiyonun fenolikleri etkilemediği, dolayısıyla küspede fazla miktarda tespit edildiği düşünülmektedir. Kavurma ön işlemi uygulanarak yağ ekstraksiyonundan çıkan küspe SE'den sonra en yüksek TFM içeriğine sahip olmuştur. Bu durum kavurma işlemi sırasında yüksek ısı uygulamasının nar çekirdeğinde bağlı fenolik bileşenlerin açığa çıkarak TFM içeriğinin yüksek çıkmasına yol açtığı düşünülmektedir. Akdaş ve Bakkalbaşı (2017), ısıl işlem sırasında fenolik maddedeki artışın, bağlı fenoliklerin hücre duvarının parçalanması sonucu serbest hale gelmesinden kaynaklanabileceğini belirtmişlerdir. Mikrodalga ön işleminde de nar çekirdeği yüksek sıcaklığa maruz kalmaktadır. Ancak bu işlemde ısı çekirdeğin tümüne yayılmaktadır. Bu da hücre duvarındaki fenolik bileşenleri açığa çıkartırken bazılarının da parçalanmasına neden olabilmektedir. Mikrodalga uygulanan yöntemindeki küspelerin düşük TFM orana sahip olması fenolik bileşiklerin parçalanma hızının, bağlı olan fenolik bileşiklerin açığa çıkma hızından daha yüksek olmasından kaynaklanıyor olabileceği akla gelmektedir. Gölükçü ve ark. (2008), ülkemizde yetiştirilen nar çeşitlerine ait çekirdeklerin TFM 1535-3701 mg/kg arasında saptarken, çalışmada Hicaznar çeşidine ait çekirdeğin TFM miktarı 2298 mg/kg olarak belirlenmiştir. Li ve ark. (2011), nar çekirdeği küspesinin TFM içeriğini 2427.90 mg kateşin Eş/100 g KM olarak saptamışlardır.

Çizelge 4.2. Yağ üretiminden arta kalan küspelerin TFM, DPPH ve ABTS değerleri (ortalama±standart sapma)

Yöntem	Toplam Fenolik Madde (mg GAE/kg KM)	DPPH (mmol TE/g KM)	ABTS (mmol TE/g KM)
EE	1100.53±20.12^{a}	8.26±0.64^{ab}	8.07±0.78^{ab}
ME	979.14±146.30^{a}	6.81±0.52^{a}	6.74.±0.27^{a}
KE	1920.66±35.33^{b}	10.96±1.29^{c}	12.08±0.07^{c}
UE	1172.97±111.43^{a}	9.00±0.50^{b}	7.40±0.63^{a}
SxE	1876.76±245.29^{b}	12.35±0.12^{c}	10.94±1.77^{bc}
SE	2516.73±355.48^{c}	16.99±0.02^{d}	14.99±1.31^{d}

Küçük harfler yöntemler arasındaki farkı ifade eder

Küspe örneklerinin DPPH değerleri 6.81-16.99 mmol TE/g KM arasında değişmiştir (Çizelge 4.2). En yüksek DPPH değeri SE sonucu, en düşük değer ise ME yöntemi sonucu elde edilen küspelerde saptanmıştır. Enzimatik ekstraksiyon öncesi nar çekirdeğine kavurma ve ultrases ön işlemlerinin uygulanması DPPH değerini önemli düzeyde arttırırken ($p<0.05$), mikrodalga ön işleminin herhangi bir etkisi olmamıştır ($p>0.05$). SxE ve KE yöntemlerine ait küspeler TFM içeriği açısından olduğu gibi DPPH miktarları açısından da istatistiksel olarak aynı grupta yer aldığı saptanmıştır. SE yöntemine ait posa DPPH açısından en zengin küspe olmuştur. Aksoy (2017), nar çekirdeği küspesinin DPPH değerini %66.43 olarak tespit etmiştir.

Nar çekirdeği küspelerine ait ABTS değerleri 6.74-14.99 mmol TE/g KM arasında değişmiştir (Çizelge 4.2). En yüksek ABTS değeri SE, en düşük değer ise ME yönteminden elde edilen küspede saptanmıştır. ME ve UE yöntemlerine ait küspeler ABTS miktarı açısından aynı grupta yer almıştır. Enzimatik ekstraksiyon öncesi nar çekirdeğine kavurma ön işleminin uygulanması ABTS değerini önemli düzeyde arttırırken ($p<0.05$), mikrodalga ve ultrases ön işlemlerinin ABTS üzerine herhangi bir etkisi olmamıştır ($p>0.05$). SxE ve KE yöntemlerine ait küspeler ABTS miktarları açısından aynı grupta yer almıştır. Genel olarak bakıldığında, örneklerin fenolik bileşenler içerikleri ile DPPH ve ABTS değerleri arasında doğru orantı olduğu tespit edilmiştir. Jing ve ark. (2012), 4 farklı çeşit nar çekirdeği unlarının ABTS değerlerini 7.4-17.8 µmol TE/g un olarak tespit etmişlerdir.

5. SONUÇ

Tüm yöntemlerle elde edilen küspelerin TFM ile DPPH ve ABTS değerleri arasında genel anlamda doğru orantı olduğu görülmüştür. En yüksek TFM, DPPH ve ABTS değerleri SE yöntemi ile elde edilen küspede saptanırken, KE ve SxE yöntemleri ile elde edilen küspeler bu parametreler açısından SE'yi izlemişlerdir. Isı uygulaması olmadan uygulanan SE yönteminin en yüksek TFM, DPPH ve ABTS değerlerine sahip olması, bu yönteminin tercih nedeni olabilir.

Sonuç olarak farklı yöntemlerle elde edilen küspelerin yüksek TFM içeriği ve antioksidan aktiviteye sahip olmaları bu atıkların gıda, ilaç ve kozmetik sektörlerinde doğal antioksidan kaynağı olarak değerlendirilebilecek potansiyele sahip olduğunu göstermektedir. Bu anlamda, kaynaklarımızın sınırsız olmadığı gerçeğini de göz önünde bulundurarak fenolik bileşikler açısından zengin gıdaların artıklarının uygun yöntemlerle değerlendirilerek insan yaşamına fayda sağlayacak bir şekle dönüştürülmesi önem kazanmaktadır.

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THE ROLE OF NEAZDP ON SOCIAL MOBILITY OF POVERTY IN YOBE STATE OF NIGERIA

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ABSTRACT

Nigeria's Yobe State, characterized by its challenging socio-economic conditions exacerbated by factors such as climate variability and limited infrastructure, serves as a pertinent case study. Through rigorous empirical analysis and qualitative research methods, this study seeks to contribute valuable insights into the effectiveness of NEAZDP (North East Arid Zone Development Programme) as a poverty alleviation strategy. Consequently, the study endeavors to assess how participation in NEAZDP influences the economic status and social mobility of its beneficiaries. Further, the study used an undated/cross sectional households survey data collected in the year 2023 through a well-structured questionnaire coupled with an interview schedule from a total of 322 households carefully selected from three targeted population using a multi-stage sampling technique. Moreover, using a FGT poverty matrix index and Alkaire's multidimensional poverty index, the collected data were efficiently analyzed for the achievement of the research objectives. Furthermore, the study revealed that the NEAZDP has been effective in reducing both unidimensional and multidimensional poverty among beneficiaries in Yobe State, Nigeria. Initially, there was a notable decline in the proportion of beneficiaries below the poverty threshold, although a slight increase was observed in the final phase of the programme. Multidimensional poverty among beneficiaries was significantly lower compared to spill-over and control groups, indicating the programme's success in improving socio-economic conditions. However, challenges persist in dimensions such as standard of living, empowerment, and environment, suggesting targeted interventions are necessary to sustain and enhance these gains. Succinctly, despite NEAZDP has made significant strides in reducing poverty and improving social mobility among beneficiaries in Yobe State, continued efforts are needed to address remaining challenges and ensure sustainable development outcomes. By focusing on targeted interventions, sustainability, and policy integration, the program can further enhance its impact and contribute to inclusive growth and poverty reduction in the region.

Keywords: Development, Intervention, Poverty Alleviation, Sustainability, Nigeria

INTRODUCTION

Yobe State, located in northeastern Nigeria, remains entrenched in poverty exacerbated by its arid and semi-arid climate, limited infrastructure, and socio-economic challenges (Gadzama, 2017; Umar, 2024; Madaki *et al*., 2024). The North East Arid Zone Development Programme (NEAZDP) was implemented to address these issues by promoting economic empowerment and sustainable development among vulnerable populations (Mukhtar et al., 2017; Galadima and Isa, 2020). However, the effectiveness of NEAZDP in facilitating social mobility and alleviating poverty among its beneficiaries' remains underexplored.

Despite the program's interventions in agriculture, entrepreneurship, and infrastructure development, there is a need to critically evaluate its impact on poverty levels and socio-economic mobility within Yobe State. Key questions arise regarding the extent to which NEAZDP has improved livelihoods, increased income levels, and enhanced access to essential services among its beneficiaries. Additionally, the program's ability to foster long-term economic resilience and reduce dependency on subsistence agriculture in the face of environmental challenges and security threats remains uncertain.

Moreover, the unique socio-economic and environmental context of Yobe State poses specific challenges that may influence the outcomes of NEAZDP interventions differently compared to other regions. Understanding these nuances is crucial for refining policy approaches and optimizing the impact of poverty alleviation strategies in similar marginalized areas across Nigeria (Orunbon and Adeleke, 2024; Kabari and Nwogo, 2021; Ogbari *et al*., 2024; Kolawole and Samuel, 2024) and sub-Saharan Africa (Wudil *et al*., 2022; Schotte, 2023; Ncube *et al*., 2024; Woode, 2024) .

Therefore, this study aims to address these gaps by investigating the social mobility of poverty among NEAZDP beneficiaries in Yobe State. By examining the experiences, outcomes, and challenges faced by participants, the research seeks to provide empirical evidence to inform policy-making, enhance program effectiveness, and contribute to sustainable development efforts in northeastern Nigeria. Consequently, this study attempts to assess the role of NEAZDP on social mobility of poverty in Yobe State of Nigeria. The specific objectives were to assess the role of NEAZDP on unidimensional poverty among the beneficiary group and multidimensional poverty status of the beneficiary group against the non-beneficiary group.

Theoretical Framework

The theoretical framework for the study on *The Role of NEAZDP on Social Mobility of Poverty in Yobe State of Nigeria* provides a foundation for understanding the mechanisms through which the North-East Arid Zone Development Programme (NEAZDP) influences poverty alleviation, social mobility, and economic redistribution. The framework is built on established theories of poverty, social mobility, and economic development to analyze the program's impact on its beneficiaries, spillover groups, and control groups. The following theories underpin the study:

1. **Capability Approach (Amartya Sen, 1999)**

The Capability Approach, developed by Amartya Sen, serves as a key theoretical lens for assessing how NEAZDP impacts multidimensional poverty. This approach argues that poverty should not only be understood in terms of income deprivation but also in terms of lack of access to fundamental capabilities such as education, healthcare, and employment.

2. **Social Mobility Theory (Blau & Duncan, 1967)**

Social mobility theory explains how individuals or groups move within the socioeconomic hierarchy over time. Mobility can be **intergenerational** (changes across generations) or **intragenerational** (changes within an individual's lifetime).

3. **Growth and Redistribution Theory (Bourguignon, 2004)**

This theory posits that economic growth alone is insufficient to reduce poverty unless there is an equitable redistribution of wealth and resources. A pro-poor growth strategy ensures that the benefits of economic expansion reach the lowest-income groups.

4. **Poverty Dominance Approach (Atkinson, 1987)**

The Poverty Dominance Approach assesses poverty by comparing multiple poverty distributions across different population groups. It helps in understanding whether a given poverty intervention benefits all groups or only a specific subset.

5. **Demographic Transition Theory (Notestein, 1945)**

The Demographic Transition Theory explains how population dynamics, including birth rates, mortality rates, and migration, influence economic development and poverty levels.

6. **Multidimensional Poverty Index (MPI) Framework (Alkire & Foster, 2011)**

The MPI framework extends beyond income-based poverty measures to include health, education, and living standards as key dimensions of poverty.

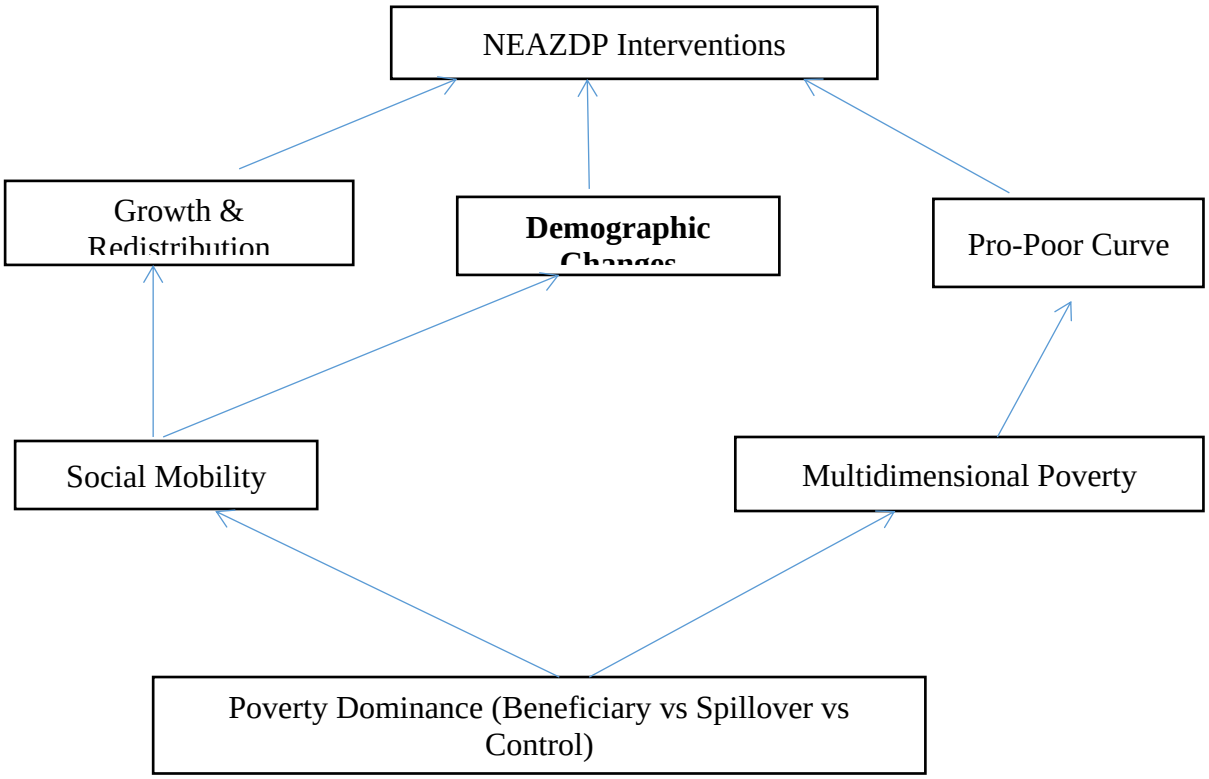


Figure 2a: Conceptual framework

Key Components of the Conceptual Framework

1. **Independent Variable:**
- **NEAZDP Interventions** (Agricultural Support, Skill Acquisition, Education, Financial Assistance, Infrastructure Development)

2. **Mediating Variables:**
- **Growth and Redistribution:** How economic growth and wealth redistribution affect poverty reduction.
- **Demographic Changes:** Household size, dependency ratio, migration, and employment status.
- **Pro-Poor Curve:** The extent to which NEAZDP benefits reach the poor compared to wealthier groups.

3. **Dependent Variables (Outcomes):**
- **Social Mobility:** Changes in income, education, and employment status.
- **Multidimensional Poverty Status:** Access to healthcare, education, and living conditions.

- **Poverty Dominance:** Comparison of poverty levels among beneficiaries, spillover groups, and control groups.

Explanation of the Conceptual Framework Diagram

- ✓ **NEAZDP Interventions** (Independent Variable) are at the top, representing programs such as **agricultural support, skill acquisition, education, financial assistance, and infrastructure development.**
- ✓ These interventions influence **Mediating Variables**:
  - **Growth and Redistribution** (economic upliftment strategies)
  - **Demographic Changes** (household structure, migration, employment)
  - **Pro-Poor Curve** (extent of poverty impact across different groups)
- ✓ The mediating variables lead to **two primary outcomes (Dependent Variables):**
  - **Social Mobility** (improvements in income, education, and employment)
  - **Multidimensional Poverty** (better health, education, and living standards)
- ✓ Finally, these outcomes determine **Poverty Dominance**, comparing poverty levels among NEAZDP beneficiaries, spillover groups, and control groups.

Empirical Review

This section reviews empirical studies on the role of the North-East Arid Zone Development Programme (NEAZDP) in reducing poverty, enhancing social mobility, and addressing multidimensional poverty in Yobe State, Nigeria. The review also considers broader studies on poverty alleviation programs and their effectiveness.

1. NEAZDP and Poverty Reduction

Studies indicate that NEAZDP has been instrumental in providing sustainable livelihoods for rural communities in Yobe State by promoting agricultural support, water supply, and environmental conservation (Mukhtar *et al*., 2017). The program's success in mitigating soil degradation and desertification has contributed to improved food security, which directly impacts poverty reduction (Danjuma & Daura, 2014).

A study by Mukhtar, Bababe, and Abba (2020) found that while NEAZDP interventions have improved access to essential services in northern Yobe, sustainable poverty reduction remains a challenge. The authors argue that limited government funding and policy inconsistencies hinder long-term impact.

2. Social Mobility and NEAZDP Beneficiaries

NEAZDP has facilitated upward social mobility among beneficiaries by improving literacy rates, skill acquisition, and economic opportunities. Lembi & Yahaya (2023) assert that economic empowerment initiatives, including small-scale irrigation schemes and microcredit **access**, have helped households escape poverty. However, the study highlights that spillover

groups (non-beneficiaries in the same communities) often experience limited benefits, which exacerbates inequality.

3. Growth, Redistribution, and the Pro-Poor Curve

Economic growth alone does not guarantee poverty alleviation-redistributive policies are crucial (Gadzama, 2017). A study on the pro-poor curve of NEAZDP beneficiaries revealed that income growth among the poorest households was slower than among wealthier participants. This suggests that while the program aids economic development, income inequality persists among beneficiaries.

4. Impact of Demographic Changes on Poverty Reduction

Demographic factors-such as family size, migration, and dependency ratio-influence the effectiveness of poverty reduction programs (Naibbi, 2013). A study on population trends in Yobe State found that larger households benefited less from NEAZDP interventions due to the higher economic burden. Similarly, rural-urban migration led to differential access to program benefits, with urban migrants often missing out on key services.

5. Poverty Dominance among Beneficiaries, Spillover, and Control Groups

Comparing NEAZDP beneficiaries, spillover, and control groups, Usman *et al*.(2019) found that poverty levels were significantly lower among beneficiaries. However, spillover effects-where non-beneficiaries benefit indirectly from development programs-were minimal. This raises concerns about the program's inclusivity and its ability to reach wider populations.

6. NEAZDP and Multidimensional Poverty Reduction

NEAZDP's impact on multidimensional poverty (MPI) has been mixed. A study by Odihi (2023) found that while the program improved health, education, and living conditions, gaps remain in employment generation and financial security. The study recommends expanding vocational training and social protection mechanisms to achieve sustained poverty reduction.

RESEARCH METHODOLOGY

Yobe State is located in northeastern Nigeria (Umar, 2024); lies on Latitude 11^0 44ˆ and 55.90ˆN and longitude $11^{0'}$ 57ˆ and 57.71^0E; bordered by Borno State to the east and Niger Republic to the north (Figure 1b). It experiences a hot desert climate with temperatures often exceeding 40°C (104°F) during the dry season. The state's agro-ecological conditions are predominantly Sahelian, characterized by sparse vegetation and periodic droughts, making agriculture challenging without adequate irrigation. Agricultural activities such as crop production, livestock rearing, agricultural marketing etc. are the major source of livelihood earnings in the state (Madaki *et al*., 2024).

Using a multi-stage sampling technique, from three targeted population, a total of 396 respondents were randomly selected for the study. The targeted population were treated (project participating sites), spill-over and the control units (Figure 1). Noteworthy, the programme is confined to the northern part of the state and covered only nine (9) Local Government Areas (LGAs) viz. Bade, Jakusko, Bursari, Geidam, Yunusari, Yusufari, Nguru, Karasuwa and Machina LGAs. Firstly, to have a balance across the sampling units, of the nine (9) treated LGAs, four (4) LGAs, namely, Bade; Jakusko, Bursari and Geidam were randomly selected. Besides, for the spill-over and control groups respectively, four LGAs each, namely, Tarmuwa, Nangere, Fune and Fika; and, Damaturu, Potiskum, Gujba and Gulani, were purposively selected because the former fell within the radius of 20-50km while the latter fell within the radius of greater or equal to 100km as adopted by Sadiq *et al*.(2020). Furthermore, given the peculiarity of the treated sites, from each of the selected treated LGAs, one (1) Development Area (DA) was selected and thereafter a random selection of three (3) clusters from each of the selected DA, thus gave a total of twelve (12) selected clusters. Moreover, from each of the selected clusters-treated unit; spill-over and the control units respectively, two (2) villages were randomly selected, thus gave a total of forty (40) randomly selected villages. Lastly, using a sampling frame obtained from NEAZDP coupled with reconnaissance survey (Table 1), from each of the selected programme villages, five (5) out of a total of fifteen (15) beneficiaries were randomly selected, thus gave a total of one hundred and twenty (120) randomly selected beneficiaries. However, given the non-availability of a finite sample frame for the non-beneficiary group, the sample size was generated using the error margin formula as proposed by Bartlet *et al*.(2002) (Equation 1) . Generally, a total of three hundred and ninety six (396) respondents' vis-à-vis treated (120), exposed (138) and control (138) groups selected randomly constituted the sample size for this study (Table 1). Further, using an easy-route cost approach, a well-structured questionnaire complemented with an interview schedule was used by trained enumerators to elicit cross sectional data in the year 2023. Moreover, the objective related to the economic/income (unidimension) aspect of poverty were achieved using a Foster-Greer-Thorbecke (FGT) index (Equation 2-15) while the objective related to social (multi-dimension) aspect of poverty was achieved using Alkire and Foster multidimensional poverty index (MPI).

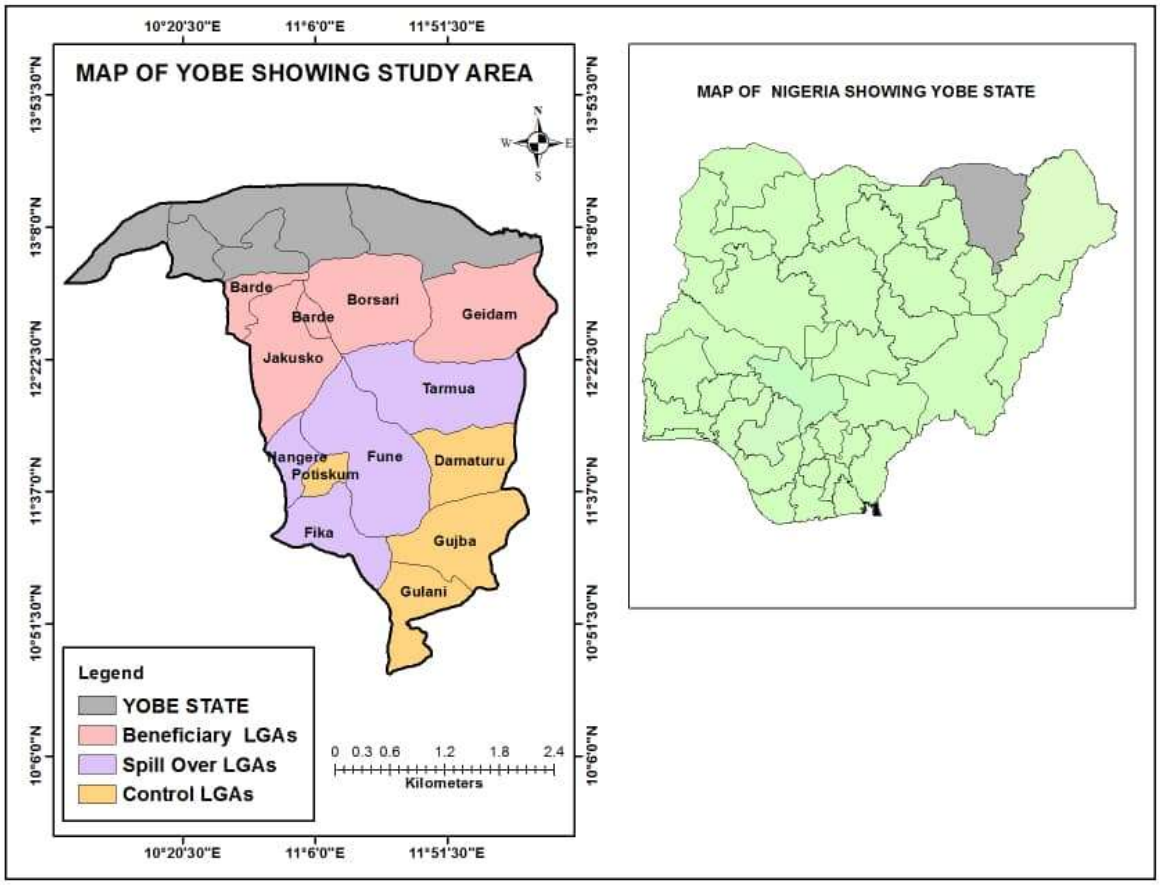


Figure 1b: Map of the study area

Source: Authors' own design, 2023

Table 1: Sampling Frame of both the beneficiaries and non-beneficiaries

Category	LGAs	DAS	Cluster villages	Villages	SF	SS
			Treatment			
Beneficiary	**Bade**	Dagona	Dala	Gabarwa	15	5
				Mainiya	15	5
			Tagali	Lafiyami	15	5
				Madamuwa	15	5
			Bizi	Murza	15	5
				Misilli	15	5
	Bursari	Dumburi	Dadigar	Baya mallum	15	5
				Diga	15	5
			Gadine	Gamsa West	15	5
				Gamsa East	15	5
			Daskum	Gangawa	15	5
				Kagadama	15	5
	Geidam	Balle	Bayamari	Malango	15	5
				Kelluri	15	5
			Damaya	Mobarti	15	5
				Gallaba	15	5
			Ajiri Dapchi	Ajiri Geidam	15	5
				Matakuskum	15	5
	Jakusko	Muguram	Jaba	Dagayak	15	5
				Garin maji	15	5
			Gamjam	Nasari	15	5
				Garin Tsaiha	15	5
			Lafiya loiloi	Buduwa	15	5
				Gamya	15	5
Sub- total	**4**	**4**	**12**	**24**	**360**	**120**

Source: NEAZDP report (2022) and Reconnaissance survey (2022)

Table 1: Continued ……………………………………………….

Category	LGAs	DAS	Cluster villages	Villages	SF	SS
				Spill-over		
Non-Beneficiary	Tarmuwa	-	-	Lantewa	-	17
				Biriri	-	17
	Nangere	-	-	Dawasa	-	17
				S/Gari Nangere	-	17
	Fune	-	-	Dogon Kuka	-	17
				Damagum	-	17
	Fika	-	-	Janga	-	18
				Gadaka	-	18
	4	-	-	**8**	-	**138**
				Control		
	Damaturu	-	-	Maisandari	-	17
				Dukumari	-	17
	Gujba	-	-	Katarko	-	17
				Kasesa	-	17
	Gulani	-	-	Bara	-	17
				Shishiwaji	-	17
	Potiskum	-	-	Mamudo	-	18
				Garin Jaji	-	18
Sub-total	**4**	-	-	**8**	-	**138**
Total	**12**	**4**	**12**	**40**		**396**

Source: NEAZDP report (2022) and Reconnaissance survey (2022)

According to the Bartlett's formula, the sample size of the unknown can be generated using the following formula:

$$N_{nb} = Z^2 * P(1-P)/e^2 \quad \text{……………………………….. (1)}$$

Where, N_{nb} is the sample size of the non-beneficiaries, Z is Z-statistic at 5% probability level (1.96), P is the sample proportion (10%) and e is the error gap at 5%.

Empirical model

1. Economic/Income (unidimension) approach of poverty measurement

a. The decomposition of the FGT index across growth and redistribution effects

Datt and Ravallion (1992) decompose the change in the FGT index between two periods, t_1 and t_2, into growth and redistribution components as follows:

$$P_2 - P_1 = [P(\mu^{t2}, \pi^{t1}) - P(\mu^{t1}, \pi^{t1})] + [P(\mu^{t1}, \pi^{t2}) - P(\mu^{t1}, \pi^{t1})] + R/ref = 1 \quad \text{..... (2)}$$

$$P_2 - P_1 = [P(\mu^{t2}, \pi^{t2}) - P(\mu^{t1}, \pi^{t2})] + [P(\mu^{t2}, \pi^{t2}) - P(\mu^{t2}, \pi^{t1})] + R/ref = 2 \quad \text{..... (3)}$$

Where

$P_2 - P_1$ = difference (variation) in poverty between t1 and t2;

Component 1 (C1) = growth component/ impact;

Component 2 (C2) = redistribution component/effect;

R = residual; and,

Ref. = period of reference.

$P(\mu^{t1}, \pi^{t1})$: the FGT index of the first period

$P(\mu^{t1}, \pi^{t2})$: the FGT index of the second period

$P(\mu^{t2}, \pi^{t1})$: the FGT index of the first period when all incomes y_i^{t1} of the first period are multiplied by μ^{t2} / μ^{t1}

$P(\mu^{t1}, \pi^{t2})$: the FGT index of the second period when all incomes y_i^{t2} of the second period are multiplied by μ^{t1} / μ^{t2}

The Shapley value decomposes the variation in the FGT Index between two periods, t_1 and t_2, into growth and redistribution components as follows:

$$P_2 - P_1 = C_1 + C_2 \quad \text{..... (4)}$$

$$C_1 = \frac{1}{2}([P(\mu^{t2}, \pi^{t1}) - P(\mu^{t1}, \pi^{t1})] + [P(\mu^{t2}, \pi^{t2}) - P(\mu^{t1}, \pi^{t2})]) \quad \text{..... (5)}$$

$$C_2 = \frac{1}{2}([P(\mu^{t1}, \pi^{t2}) - P(\mu^{t1}, \pi^{t1})] + [P(\mu^{t2}, \pi^{t2}) - P(\mu^{t2}, \pi^{t1})]) \quad \text{..... (6)}$$

b. *Pro-poor curves*

Pro-poor curves can be drawn using either the primal or the dual approach. The former uses income levels. The latter is based on percentiles.

The change in the distribution from state 1 to state 2 is s-order absolutely pro-poor with standard *cons* if:

$$\Delta(z,s) = (P_2(z+cons, \alpha = s-1)) < 0 \forall z \in [0, z^+] \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The change in the distribution from state 1 to state 2 is s-order relatively pro-poor if:

$$\Delta(z,s) = (P_2(z\frac{\mu_2}{\mu_1}, \alpha = s-1) - P_1(z, \alpha = s-1)) < 0 \forall z \in [0, z^+] \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

c. *Impact of demographic changes*

This application computes the impact of a change (by a given percentage) in the proportion of a group *t*. That change is accompanied by an exactly offsetting change in the proportion of the other groups.

If the population proportion of group *t* increases by pc percent, such that $\phi(t) \rightarrow (\phi(t)(1+pc))$, the total estimated impact on poverty is as follows:

$$\Delta P = [\phi(t) * P(t; z, \alpha) - \sum_{k \neq s}^{K} \frac{\phi(t)}{1-\phi(t)} * \phi(k) * P(k; z, \alpha)] * pc \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

If the population proportion of group *s* increases by absolute pc percent of the total population, such that $\phi(t) \rightarrow (\phi(t)(1+pc))$, the total estimated impact on poverty is as follows:

$$\Delta P = [P(t; z, \alpha) - \sum_{k \neq s}^{K} \frac{\phi(k)}{1-\phi(t)} * P(k; z, \alpha)] * pc \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where, $P(t; z; \alpha)$ is the FGT poverty index for subgroup k and $\bar{\phi}(k)$ is the proportion of the population found in that subgroup.

d. *FGT Poverty: decomposition by population subgroups*

This decomposition takes the form

$$\hat{P}(z;\alpha)=\sum_{g=i}^{G}\hat{\phi}(g)\hat{P}(z;\alpha;g) \quad \text{...} (11)$$

Where, G is the number of population subgroups. The results show:

The estimated FGT index of subgroup $g : \hat{P}(z;\alpha;g)$

The estimated population share of subgroup $g : \hat{\phi}(g)$

The estimated absolute contribution of subgroup g to total poverty: $\hat{\phi}(g)\hat{P}(z;\alpha;g)$

The estimated relative contribution of subgroup g to total poverty: $(\hat{\phi}(g)\hat{P}(z;\alpha;g))/\hat{P}(z;\alpha)$

e. Decomposition of change in FGT poverty by poverty and population group components -sectoral decomposition

Additive poverty measures, like the FGT indices, can be expressed as a sum of the poverty contributions of the various subgroups of population. Each subgroup contributes by its population share and poverty level. Thus, the change in poverty across time depends on the change in these two components. Denoting the population share of group k in period I by $\phi_1(k)$, the change in poverty between two periods can be expressed as follow (Huppi, 1991 and Duclos and Araar, 2006):

$$P_2-P_1=[\sum_{k=1}^{K}\phi_1(k)(P_2(k;z;\alpha)-P_1(k;z;\alpha))]+[\sum_{k=1}^{K}P_1(k;z;\alpha)(\phi_2(k)-\phi_1(k))]+$$

$$[\sum(P_2(k;z;\alpha)-P_1(k;z;\alpha))(\phi_2(k)-\phi_1(k))] \quad \text{.............................} (12)$$

Where,

$P_2-P_1=$ difference (variation) in poverty between 1 and 2

C1 = intra-sectoral/intra-group impacts/within-group poverty effect

C2 = impact of changes in subgroup proportions/demographic or sectoral effect

C3 = interaction effect/ interaction term

This decomposition uses the initial period as the one. If the reference period is the final, the decomposition takes the form:

$$P_2-P_1=[\sum_{k=1}^{K}\phi_2(k)(P_2(k;z;\alpha)-P_1(k;z;\alpha))]+[\sum_{k=1}^{K}P_2(k;z;\alpha)(\phi_2(k)-\phi_1(k))]+$$

$$[\sum(P_2(k;z;\alpha)-P_1(k;z;\alpha))(\phi_1(k)-\phi_2(k)))$$ …….. (13)

To remove the arbitrariness in selecting the reference period, we can use the Shapley decomposition approach, finding:

$$P_2-P_1=[\sum_{k=1}^{K}\phi_1(k)(P_2(k;z;\alpha)-P_1(k;z;\alpha))]+[\sum_{k=1}^{K}P_1(k;z;\alpha)(\phi_2(k)-\phi_1(k))]$$ …… (14)

Where, $\bar{\phi}(k)$ is the average population share $=0.5(\phi_1(k)+\phi_2(k))$ and $\bar{P}(k;z;\alpha)=0.5(P_1(k;z;\alpha)+P_2(k;z;\alpha))$.

f. Poverty dominance

Distribution 1 dominates distribution 2 at order *s* over the conditional range $\lfloor Z^-, Z^+ \rfloor$ if only if:

$$P_1\xi;\alpha)>P_2(\xi;\alpha)\forall\xi\in\lfloor Z^-,Z^+\rfloor \text{ for } \alpha=s-1$$ ……. (15)

This involves comparing stochastic dominance curves at order *s* or FGT curves with $\alpha=s-1$. This application checks for the points at which there is a reversal of the dominance conditions. Said differently, it provides the crossing points of the dominance curves, that is, the values of ξ and $P_1(\xi;\alpha)$ for which $P_1(\xi;\alpha)=P_2(\xi;\alpha)$ when sign $(P_1(\xi-\eta;\alpha)-P_2(\xi-\eta;\alpha))=$ sign $(P_2(\xi-\eta;\alpha)-P_1(\xi-\eta;\alpha))$ for a small η

The crossing points of ξ can also be referred to as “critical poverty lines”.

2. ***Multidimensional poverty index (MPI)***: The MPI is a composite indicator of poverty that accounts for both the distribution of deprived areas and their prevalence (Appendix 1) (Sadiq and Sani, 2022). The following are the indexes involved in the measurement:

Multidimensional headcount ratio (H): Is the proportion of persons who have been classified as multidimensionally poor, i.e. those who fall below the poverty line, and is expressed as:

$$H=q(k)/n$$ ……..… (16)

The number (or headcount) of multidimensionally poor persons according to parameter k is *q(k)*.

$$(q(k)=\sum_{i=1}^{n}p_k(\chi_i,z))$$ ……..…… (17)

The average deprivation share across the poor is defined as the intensity of poverty A, often known as the breadth of poverty. This is presented as:

$$A = \sum_{i=1}^{q} c_i(k) / q(k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

The percentage of the d indicators in which the average multidimensionally poor person is deprived is the intensity of poverty.

The measure M_0 is the so-called adjusted headcount ratio when $\alpha = 0$.

$$M_0 = HA \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

When$\alpha = 1$, the measureM_1, adjusted poverty gap, defined as the weighted average of indicator-specific poverty gaps is used. G is poverty gap.

$$M_1 = HAG \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

$$G = \sum_{i=1}^{n} \sum_{j=1}^{d} g_{ij}^{1}(k) \Big/ \sum_{i=1}^{n} \sum_{j=1}^{d} g_{ij}^{0}(k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

Finally, when $\alpha = 2$, the adjusted squared poverty gap (M_2) is calculated as the weighted average of the indicator-specific squared poverty gaps. S is poverty severity.

$$M_2 = HAS \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$S = \sum_{i=1}^{n} \sum_{j=1}^{d} g_{ij}^{2}(k) \Big/ \sum_{i=1}^{n} \sum_{j=1}^{d} g_{ij}^{0}(k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

Seth and Alkire (2014) as reported by Sadiq and Sani (2022) suggested an additively decomposable inequality measure that is a positive multiple of "variance" and has within-group and between-group components. The inequality measure I^q employs the vector of deprivation scores of the q impoverished people $c_i(k)$ to quantify inequality among the poor at the national or sub-national level.

$$I^q = \frac{\tilde{\beta}}{q} \sum_{i=1}^{q} [c_i(k) - A]^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

To calculate the measure of inequality, the difference between each poor person's deprivation score and average intensity is squared, then the squared distances are added together and multiplied by a constant $\tilde{\beta}$. We set $\tilde{\beta}$ =1/49 since the poor's deprivation ratings vary from 1/7 to 1. This is the greatest permissible number for the inequality gauge, guaranteeing that the inequality gauge is constrained between zero and one, given the spectrum of deprivation scores. Nevertheless, a lower degree of poverty or a decline in poverty does not necessarily mean that every region or demographic categories have experienced an equal reduction in poverty (Sadiq and Sani, 2022; Sadiq et al., 2024).

RESULTS AND DISCUSSION

The Role of NEAZDP on Social Mobility of Poverty among the Beneficiary Group

A perusal of Table 2 revealed the unidimensional social and economic mobility of poverty for the beneficiary group as the programme transit through time period from the initial period to

the final period. The matrix showed that at the first quarter phase of the programme, 24.17% of the beneficiaries were significantly below the poverty threshold. Subsequently, as the programme passes through time period, at the second quarter phase of the programme the proportion of the beneficiaries below the poverty threshold significantly declined to 16.67%. This significant decline in the proportion of the beneficiaries that were below the poverty threshold persists till the third quarter phase (15.83%) of the programme implementation. Conversely, at the last (fourth-quarter) phase of the programme implementation, there was a sudden reversal in the trend of poverty proportion (increase) among the beneficiaries in the study area, i.e., 20.83% of the beneficiaries was significantly below the poverty threshold. The initial decline in poverty levels across the phases indicates positive economic mobility for the beneficiaries. They were initially moved towards improved economic conditions; potentially finding better employment opportunities or increasing their income through the programme's support. The increase in poverty levels in the last phase signifies a reversal in economic mobility. It could imply that the economic gains achieved earlier were not sustained or that external factors such as economic downturns, changes in policy, or programmatic issues have caused deterioration in economic status. Fluctuations in poverty levels can affect social stability. A sudden increase in poverty levels as seen in the last phase might lead to social unrest or dissatisfaction among beneficiaries. Therefore, policymakers should consider the factors that contributed to poverty increase in the last phase. This might involve addressing systemic issues, enhancing program monitoring and evaluation, or providing a longer-term support to ensure sustained economic and social improvements. Summarily, while the NEAZDP programme initially showed positive impacts on reducing poverty and enhancing mobility among beneficiaries, the increase in poverty levels in the last phase highlights challenges in achieving sustained social and economic mobility. Addressing these challenges is crucial for ensuring that interventions lead to lasting improvements in the lives of beneficiaries.

Table 2: Unidimensional social mobility of poverty for the beneficiary group

		Final period (AMI)				
		0.0 - 0.25	0.25 - 0.5	0.5 - 0.75	0.75 - 1.0	Total
Initial period (BMI)	0.0 - 0.25	**0.241667**	0.091667	0.008333	0.008333	0.291667
		(-0.01342)	(-0.01447)	(-0.00845)	(-0.00827)	(-3.6E-05)
		[-18.0073]^	[-6.33674]^	[-0.9857]^{NS}	[-1.00753]^{NS}	[-8172.22]^
	0.25 - 0.5	0.108333	**0.166667**	0.091667	0.041667	0.35
		(-0.0145)	**(-0.01986)**	(-0.01846)	(-0.017)	(-3.9E-05)
		[-7.46882]^	**[-8.39025]^**	[-4.96439]^	[-2.45069]^	[-8995.12]^
	0.5 - 0.75	0.008333	0.15	**0.158333**	0.058333	0.333333
		(-0.00815)	(-0.01669)	**(-0.02017)**	(-0.0151)	(-2.6E-05)
		[-1.02304]^{NS}	[-8.98535]^	**[-7.85053]^**	[-3.86247]^	[-12679.1]^
	0.75 - 1.0	0	0.033333	0.125	**0.208333**	0.35
		(-0.00033)	(-0.00986)	(-0.01581)	**(-0.02311)**	(-2.3E-05)
		[0]^{NS}	[-3.3823]^	[-7.90809]^	**[-9.01317]^**	[-15125.3]^
	Total	0.266667	0.316667	0.258333	0.266667	1
		(-3.1E-05)	(-2.5E-05)	(-3.9E-05)	(-2.8E-05)	0
		[-8672.09]^	[-12586.1]^	[-6591.82]^	[-9379.76]^	-

Source: Field survey, 2023

Note: Values in ( ) and [ ] are standard error and t-statistics respectively; ^ & ^{NS} mean significant at 1% and non-significant respectively.

Impact of Growth and Redistribution on Poverty of NEAZDP Beneficiaries

Furthermore, in assessing the effects of income growth and redistribution on poverty reduction of the beneficiary group (Table 3 and Figure 2), after programme intervention, due to growth in the economy, i.e., economic growth, poverty declined by 6.20%. Contrarily, income redistribution increased poverty among the beneficiaries after programme intervention, an indication of a poor system of tax administration; likewise, the social safety measure(s) is not pro-poor, i.e., it favours the non-poor against the poor in the beneficiary group. Inspite of the programme impact on economic growth, the poor states of public expenditure (i.e., subsidies, social safety measures) and the presence of ineffective progressive tax administration system constitutes a clog in the wheel of the programme success and long-term sustainability in the study area. In other words, despite the NEAZDP's positive impact on economic growth and poverty reduction, the ineffective income redistribution, inadequate public expenditure, and flawed tax administration undermine its success and sustainability, necessitating targeted reforms in tax policy, public expenditure, and social safety measures to better support the poor.

Put differently, the results indicate that while NEAZDP-induced economic growth reduced poverty by 6.20%, flawed income redistribution increased poverty among beneficiaries, highlighting issues in tax administration. This suggests that the benefits of economic growth are not reaching the poorest members of the community, potentially exacerbating inequality. For the NEAZDP to achieve its poverty reduction goals sustainably, it is crucial to reform tax policies to ensure more equitable distribution of income, so that the poorest beneficiaries are effectively supported and can share in the program's benefits.

Table 3: Impact of growth and redistribution on poverty of beneficiary group

Items	Initial	Final
	Reference 2	
Datt & Ravallion (1992) approach		
Estimate	0.36166427	0.42506710
	(0.02728206)13.2565***	(0.02850802) 14.9104***
Difference Index1-Index2	0.06340283 (0.03962348) 1.60013^{NS}	
Covariance Index1-Index2	-0.00000650	
Shapley approach		
Estimate	0.36166427	0.42506710
	(0.02728206) 13.2565***	(0.02850802) 14.9104***
Difference Index1-Index2	0.06340283 (0.03962348) 1.60013^{NS}	
Covariance Index1-Index2	-0.00000650	
Datt & Ravallion (1992) approach	**Reference 1**	
Estimate	0.36166427	0.42506710
	(0.02728206) 13.2565***	(0.02850802) 14.9104***
Difference Index1-Index2	0.06340283 (0.03962348) 1.60013^{NS}	
Covariance Index1-Index2	-0.00000650	
Shapley approach		
Estimate	0.36166427	0.42506710
	(0.02728206) 13.2565***	(0.02850802) 14.9104***
Difference Index1-Index2	0.06340283 (0.03962348) 1.60013^{NS}	
Covariance Index1-Index2	-0.00000650	
Poverty Line	2417.78002930 (0.00000000)	

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively.

Table 3: Continued ……

Contribution of:	Growth	Redistribution	Residue
NEAZDP		Reference 2	
	-0.06196356	0.12571451	-0.00034812
	(0.06077006)	(0.12385039)	N.A
	1.01964^{NS}	1.01505^{NS}	-
	-0.06213762	0.12554045	0.00000000
	(0.07908917)	(0.07908917)	(0.0)
	0.785665^{NS}	1.58733^{NS}	-
		Reference 1	
	-0.06231168	0.12536639	0.00034812
	(0.09838520)	(0.05125128)	N.A
	0.633344^{NS}	2.44611**	-
	-0.06213762	0.12554045	0.00000000
	(0.07908917)	(0.07908917)	(0.0)
	0.785665^{NS}	1.58733^{NS}	-

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively.

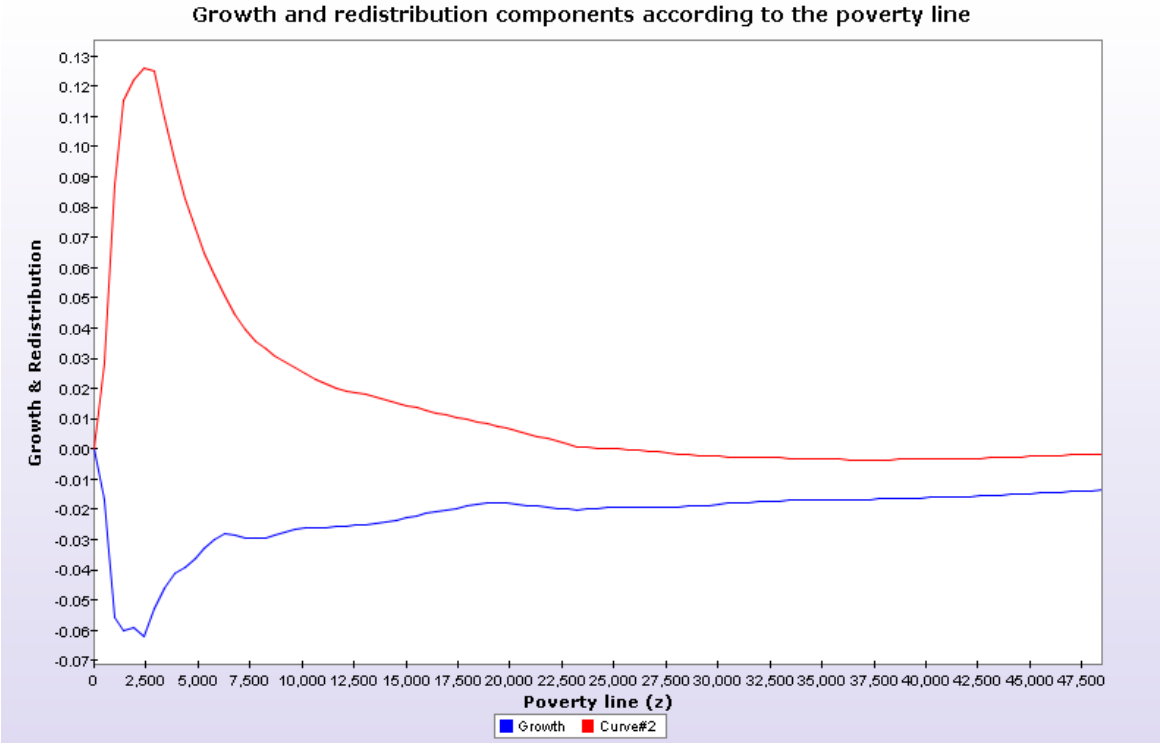


Figure 2: Growth and redistribution effects on poverty of NEAZDP

Pro-Poor Curve of NEAZDP Beneficiaries

Moreover, in assessing the pro-poor growth, after programme participation, the results in Table 4 (depicted in Figure 3) showed a decline in the growth incidence (18.75%) of poverty and a significant decline in the growth severity (17.22%) of poverty. Succinctly, it can be inferred that the policies of the programme directly targeted the poorest of the poor; in other words, the policies of the programme are more generally aimed at poverty alleviation. Likewise, it can be concluded that the incomes of poor households in the beneficiary group grows faster than that of the whole population of the non-beneficiary group. Succinctly, for growth to be pro-poor, it means there is a fall in income inequality of the beneficiary group compared to the non-beneficiary group. Noteworthy, pro-poor growth is the type of growth that enables the poor to actively participate in economic activity(s) and benefit proportionally more than the non-poor from overall income increase. This suggests that the program has effectively targeted and benefited the poorest individuals within the beneficiary group, leading to meaningful improvements in their living conditions. The significant decline in poverty severity also implies that the most vulnerable members are experiencing less extreme poverty, which is a positive outcome for long-term poverty reduction and improved well-being in the region. In other words, the NEAZDP has effectively targeted the poorest households, leading to significant reductions in poverty incidence and severity, and ensuring that poor households benefit more proportionally from economic growth compared to the non-beneficiary group. Therefore, to enhance its impact, the programme should continue focusing on equitable income growth and implement measures to further reduce income inequality.

Table 4: Pro-poor curve of beneficiary group

Items	Estimated Value
Growth Incidence Curve	-0.18750001 (0.15652524) 1.19789^{NS}
Growth Poverty Curve	-0.17221867 (0.08624621) 1.996826**

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively.

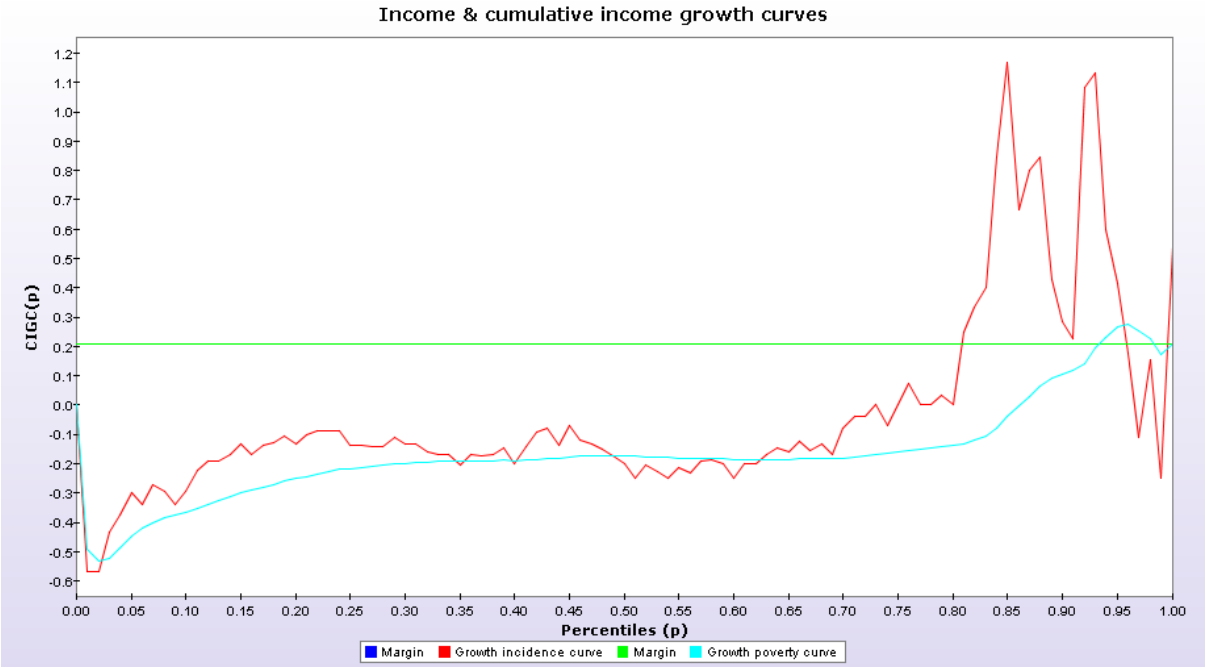


Figure 3: Pro-poor curve of the beneficiary group

Impact of Demographic Change on Poverty of NEAZDP Beneficiaries

In assessing the impact of demographic on poverty (relative to group) (Table 5), between beneficiary and spill-over groups respectively, for a 10% change (increase) in the size of each group, poverty will significantly decline by 0.64% and incline by 0.86%, as evident by their respective impact coefficient at 10% degree of freedom. Besides, the results showed a decrease (28.03% to 26.21%) in the proportion of poor in the beneficiary group against an increase (39.40% to 43.34%) in the proportion of poor in the spill-over group. Moreover, relative to population, the results showed that a 10% increase in each of the population of the beneficiary and spill-over groups respectively, will significantly makes poverty to decline and incline by 1.63 and 2.18%. On the other hand, relative to group, between beneficiary and control groups respectively, a 10% increase in the size of each group will significantly plummet and increase

poverty by 0.44 and 1.63%. Nevertheless, relative to population, for a 10% increase in the group size of the beneficiary group, poverty will significantly plummet by 1.34% whereas relative to the control group, poverty will significantly surged by 5.01%. The NEAZDP has effectively reduced poverty among beneficiaries compared to the spill-over and control groups, with a 10% increase in the beneficiary group size leading to a significant 1.34% decrease in poverty. Therefore, to maximize impact, the programme should focus on expanding its reach while ensuring effective measures are in place to prevent increasing poverty in control and spill-over groups. Put differently, the results indicate that the NEAZDP effectively reduces poverty within the beneficiary group, with a 10% increase in group size leading to a 1.34% decrease in poverty. However, the spill-over and control groups experience rising poverty with similar population increases. This suggests the program is successfully targeting the beneficiary group but may be contributing to increased inequality and poverty in surrounding areas. To enhance overall impact, the program may need to extend benefits to spill-over and control groups or address the negative effects on these non-beneficiary groups.

Table 5: Impact of demographic change on poverty

Items	Poverty Before	Poverty After	Total Impact
		Beneficiary vs. Spill-over	
Relative to Group (RG)	0.34835789	0.33988169	-0.00847619
	(0.07950081)	(0.08708012)	(0.01028815)
	4.38182***	3.90309***	0.823879^{NS}
Relative to Population (RP)	0.34835789	0.32684656	-0.02151132
	(0.07950081)	(0.06844059)	(0.00779362)
	4.38182***	4.77562***	2.760119***
Poverty line		11021.84	
		Beneficiary vs. Control	
Relative to Group (RG)	0.33328196	0.34139459	0.00811263
	(0.08290117)	(0.08831333)	(0.00637910)
	4.02023***	3.86572***	1.27175^{NS}
Relative to Population (RP)	0.33328196	0.35819332	0.02491135
	(0.08290117)	(0.06957350)	(0.00721471)
	4.02023***	5.14842***	-3.45286***
Poverty line		10733.72	
		Beneficiary vs. Spill-over and Control	
Relative to Group (RG)	0.31974724	0.32697389	0.00722665
	(0.07714256)	(0.08159047)	(0.00567126)
	4.14489***	4.0075***	1.27426^{NS}
Relative to Population (RP)	0.31974724	0.34193803	0.02219079
	(0.07714256)	(0.06287188)	(0.00710749)
	4.14489***	5.43865***	3.12217***
Poverty line		10550.48	

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively.

Table 5: Continued ……...

Group	Estimate	Proportion Before	Proportion After	Impact
		Beneficiary vs. Spill-over		
1 (RG)	0.35214436	0.28030601	0.26207889	-0.00641858
	(0.05010282)	(0.33943272)	(0.33590802)	(0.00837355)
	7.02843***	0.82581^{NS}	0.78021***	0.76653^{NS}
2	0.21800661	0.39403409	0.43343750	0.00859020
	(0.00966169)	(0.38837504)	(0.42721254)	(0.00808642)
	22.564***	1.01457^{NS}	1.01457^{NS}	1.0623^{NS}
1 (RP)	0.35214436	0.28030601	0.23404829	-0.01628939
	(0.05010282)	(0.33943272)	(0.30205948)	(0.01392726)
	7.02843***	0.82581^{NS}	0.77484^{NS}	1.169605^{NS}
2	0.21800661	0.39403409	0.49403409	0.02180066
	(0.00966169)	(0.38837504)	(0.38837504)	(0.00096617)
	22.564***	1.01457^{NS}	1.27205^{NS}	22.564***
		Beneficiary vs. Control		
1 (RG)	0.32265320	0.28030601	0.26676916	-0.00436771
	(0.04848970)	(0.33943272)	(0.33022633)	(0.00669527)
	6.65406***	0.82581***	0.80784^{NS}	0.652358$_{NS}$
3	0.50126922	0.32565993	0.35822592	0.01632433
	(0.04570181)	(0.32955313)	(0.36250844)	(0.01503607)
	10.9683***	0.98819^{NS}	0.98819^{NS}	1.08568^{NS}
1 (RP)	0.32265320	0.28030601	0.23873856	-0.01341187
	(0.04848970)	(0.33943272)	(0.29634706)	(0.01360754)
	6.65406***	0.82581^{NS}	0.8056^{NS}	0.98562^{NS}
3	0.50126922	0.32565993	0.42565993	0.05012692
	(0.04570181)	(0.32955313)	(0.32955313)	(0.00457018)
	10.9683***	0.98819^{NS}	1.29163^{NS}	10.9683***
		Beneficiary vs. Spill-over and Control		
1 (RG)	0.32265320	0.28030601	0.26676916	-0.00436771
	(0.04848970)	(0.33943272)	(0.33022633)	(0.00669527)
	6.65406***	0.82581^{NS}	0.80784^{NS}	0.652358^{NS}

2	0.19400491	0.39403409	0.37500495	-0.00369175
	(0.00931401)	(0.38837504)	(0.38642935)	(0.00458291)
	20.8294***	1.01457^{NS}	0.97044^{NS}	0.805547^{NS}
3	0.46938863	0.32565993	0.35822592	0.01528611
	(0.04114868)	(0.32955313)	(0.36250844)	(0.01413320)
	11.4071***	0.98819^{NS}	0.98819^{NS}	-1.08157^{NS}
1 (RP)	0.32265320	0.28030601	0.23873856	-0.01341187
	(0.04848970)	(0.33943272)	(0.29634706)	(0.01360754)
	6.65406***	0.82581^{NS}	0.8056^{NS}	0.98562^{NS}
2	0.19400491	0.39403409	0.33560154	-0.01133620
	(0.00931401)	(0.38837504)	(0.34767237)	(0.00878248)
	20.8294***	1.01457^{NS}	0.96528^{NS}	1.290774^{NS}
3	0.46938863	0.32565993	0.42565993	0.04693886
	(0.04114868)	(0.32955313)	(0.32955313)	(0.00411487)
	11.4071***	-0.98819^{NS}	1.29163^{NS}	11.4071***

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively; 1 = Beneficiary, 2 = Spillover, 3 = Control

Furthermore, in assessing poverty decomposition for two groups, between the beneficiary and spill-over groups (Table 6), the empirical evidence showed that 28.34 and 9.87% of the significant 35.21% that were poor among the beneficiary group were relatively poor (have basic necessities but face social exclusion) and absolutely poor (lack basic necessities). Contrarily, of the significant 21.80% that were poor among the spill-over group, 8.59% faced relative poverty while 24.66% faced absolute poverty. Further, between the beneficiary and control groups, of the 32.27% that were significantly poor among the former, 27.15% are challenged with relative poverty whereas 9.04% are challenged with absolute poverty. Contrarily, of the significant 50.13% that were poor among the control group, 48.98% were relatively poor while 16.32% were absolutely poor.

Nevertheless, in assessing poverty decomposition by groups (a broader perspective, i.e., overall), between beneficiary against spill-over and control groups, it was observed that of the significant 32.27% that were poor among the beneficiary group, 28.29 and 9.04% respectively, were relatively and absolutely poor. Contrarily, of the significant 19.40% that were poor among the spill-over group, 23.91 and 7.65% respectively, were relatively and absolutely poor. Likewise, of the significant 46.94% that were poor among the control group, 47.81 and 15.29% respectively, were relatively and absolutely poor. The NEAZDP has been more successful in addressing absolute poverty among beneficiaries compared to the spill-over and control groups,

significantly reducing absolute poverty while still encountering notable relative poverty. Thus, the programme should continue focusing on reducing absolute poverty while also developing targeted interventions to address relative poverty and social exclusion. In other words, the results suggest that the NEAZDP has had a more substantial impact on reducing absolute poverty than relative poverty. The beneficiary group shows a higher proportion of individuals facing relative poverty compared to absolute poverty, indicating that while basic needs are generally met, issues of social exclusion persist. In contrast, both the spill-over and control groups experience higher rates of absolute poverty, especially the control group. This highlights the need for the NEAZDP to focus not only on reducing absolute poverty but also on addressing social exclusion and relative poverty to improve overall well-being.

Table 6: FGT poverty decomposition (two groups and overall)

Items	Estimates
	Beneficiary vs. Spill-over
Poverty line	11021.84
Estimate	0.34835789 (0.07950081) 4.38182***
Abs. difference in contribution	0.13413775 (0.05648720) 2.37466**
Difference in % in contribution	0.03676145 (0.47523284) 0.07735^{NS}
	Beneficiary vs. Control
Poverty line	10733.72
Estimate	0.33328196 (0.08290117) 4.02023***
Abs. difference in contribution	-0.17861602 (0.07945089) 2.248131**
Difference in % in contribution	-0.21843864 (0.57176186) 0.382045^{NS}
	Beneficiary vs. Spill-over and Control
Poverty Line	10550.48046875 (0.00000000)
Estimate	0.31974724 (0.07714256) 4.14489***

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively.

Table 6: Continued ……..

Group	Estimate	Population Share	Relative Contribution	Absolute Contribution
		Beneficiary vs. Spill-over		
1	0.35214436	0.28030601	0.28335276	0.09870818
	(0.05010282)	(0.33943272)	(0.30223390)	(0.10549074)
	7.02843***	0.82581^{NS}	0.93753^{NS}	0.9357^{NS}
2	0.21800661	0.39403409	0.24659131	0.08590204
	(0.00966169)	(0.38837504)	(0.28222683)	(0.08086418)
	22.564***	1.01457^{NS}	0.87373^{NS}	1.0623^{NS}
		Beneficiary vs. Control		
1	0.32265320	0.28030601	0.27136672	0.09044163
	(0.04848970)	(0.33943272)	(0.29265392)	(0.09593251)
	6.65406***	0.82581^{NS}	0.92726^{NS}	0.94276^{NS}
3	0.50126922	0.32565993	0.48980537	0.16324329
	(0.04570181)	(0.32955313)	(0.34020883)	(0.15036066)
	10.9683***	0.98819^{NS}	1.43972^{NS}	1.08568^{NS}
		Beneficiary vs. Spill-over and Control		
1	0.32265320	0.28030601	0.28285351	0.09044163
	(0.04848970)	(0.33943272)	(0.30035448)	(0.09593251)
	6.65406***	0.82581^{NS}	0.94173^{NS}	0.94276^{NS}
2	0.19400491	0.39403409	0.23907804	0.07644454
	(0.00931401)	(0.38837504)	(0.27542734)	(0.07167942)
	20.8294***	1.01457^{NS}	0.86803^{NS}	1.06648^{NS}
3	0.46938863	0.32565993	0.47806844	0.15286106
	(0.04114868)	(0.32955313)	(0.34060581)	(0.14133203)
	11.4071***	0.98819^{NS}	1.40358^{NS}	1.08157^{NS}
Total	---	1.0	1.0	0.31974724
		(0.00)	(0.00)	(0.07714256)
	-	-	-	4.14489***

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & ^{NS} mean significant at 1, 5, 10% and non-significant respectively.

Moreover, from a broader dimension, i.e., the sectoral decomposition of differences in poverty (natural); between the beneficiary versus the spill-over and control groups, the results showed a very drastic decline in the proportion of beneficiary group that are challenged with absolute poverty against its counterparts in spill-over and control groups (Table 7). Besides, due to programme impact, as evident by the intra-group impact, the proportion of households in beneficiary group that faces absolute poverty is 1.51% against their counterparts in spill-over group (2.40%). Likewise, the proportion of households in the beneficiary group challenged with absolute poverty is 1.085% against their counterparts in the control group (2.09%). Generally, it can be inferred that programme impact plays a great role in minimizing absolute poverty among the beneficiary against their counterparts in the spill-over and control groups. Nevertheless, the results obtained under Shapley's decomposition model exhibited a similar trend. Conclusively, the NEAZDP has significantly reduced absolute poverty among beneficiaries compared to both spill-over and control groups, demonstrating its effectiveness in addressing severe poverty. Therefore, to enhance overall impact, the programme should continue its focus on absolute poverty reduction while also exploring strategies to mitigate relative poverty and ensure broader social inclusion.

Table 7: FGT poverty decomposition (sectoral decomposition)

Items	Distribution (1)	Distribution (2)	Difference : P(2)-P(1)
	Beneficiary	Spill-over	
Estimate (NA)	0.11783745	0.08572166	-0.03211579
	(0.03049792)	(0.02502065)	(0.00737291)
	3.86379***	3.42604***	4.355918***
Estimate (SA)	0.11783745	0.08572166	-0.03211579
	(0.03049792)	(0.02502065)	(0.00737291)
	3.86379***	3.42604***	4.355918***
	Beneficiary	Control	
Estimate (NA)	0.11783745	0.07124325	-0.04659420
	(0.03049792)	(0.02222445)	(0.01077736)
	3.86379***	3.20562***	4.323341***
Estimate (SA)	0.11783745	0.07124325	-0.04659420
	(0.03049792)	(0.02222445)	(0.01077736)
	3.86379***	3.20562***	4.323341***

Source: Field survey, 2023

Note: Value in ( ) is standard error; ***, **, * & NS mean significant at 1, 5, 10% and non-significant respectively.

Note: NA = Natural approach, SA = Shapley approach

Table 7: Continued …….

Group	Estimate (1)	Proportion (1)	Abs. Contribution (1)	Estimate (2)	Proportion (2)	Abs. Contribution (2)	Difference in Cont. (2)-(1)
1 (NA)	0.09089787	0.28030600	0.02547922	0.05386852	0.28030600	0.01509967	-0.01037955
	(0.01259371)	(0.33943273)	(0.02732501)	(0.00743065)	(0.33943273)	(0.01620270)	(0.01112231)
	7.21772***	0.82581NS	0.93245NS	7.2495***	0.82581NS	0.93192NS	0.933219NS
2	0.08015536	0.39403407	0.03158394	0.06097051	0.39403407	0.02402446	-0.00755949
	(0.00362057)	(0.38837504)	(0.02970480)	(0.00264210)	(0.38837504)	(0.02263913)	(0.00706566)
	22.1389***	1.01457NS	1.06326NS	23.0765***	1.01457NS	1.06119NS	1.069892NS
1 (SA)	0.09089787	0.28030600	0.02547922	0.05386852	0.28030600	0.01509967	-0.01037955
	(0.01259371)	(0.33943273)	(0.02732501)	(0.00743065)	(0.33943273)	(0.01620270)	(0.01112231)
	7.21772***	0.82581NS	0.93245NS	7.2495***	0.82581NS	0.93192NS	0.933219NS
2	0.08015536	0.39403407	0.03158394	0.06097051	0.39403407	0.02402446	-0.00755949
	(0.00362057)	(0.38837504)	(0.02970480)	(0.00264210)	(0.38837504)	(0.02263913)	(0.00706566)
	22.1389***	1.01457NS	1.06326NS	23.0765***	1.01457NS	1.06119NS	1.069892NS
1 (NA)	0.09089787	0.28030600	0.02547922	0.03868928	0.28030600	0.01084484	-0.01463438

	(0.01259371)	(0.33943273)	(0.02732501)	(0.00479623)	(0.33943273)	(0.01178852)	(0.01553649)
	7.21772***	0.82581^{NS}	0.93245^{NS}	8.0666***	0.82581^{NS}	0.91995^{NS}	0.941936^{NS}
3	0.18661886	0.32565992	0.06077428	0.12230989	0.32565992	0.03983143	-0.02094285
	(0.01677674)	(0.32955313)	(0.05605531)	(0.01162652)	(0.32955313)	(0.03653385)	(0.01952147)
	11.1237***	0.98819^{NS}	1.08418^{NS}	10.5199***	0.98819^{NS}	1.09026^{NS}	1.072811^{NS}
1 (SA)	0.09089787	0.28030600	0.02547922	0.03868928	0.28030600	0.01084484	-0.01463438
	(0.01259371)	(0.33943273)	(0.02732501)	(0.00479623)	(0.33943273)	(0.01178852)	(0.01553649)
	7.21772***	0.82581^{NS}	0.93245^{NS}	8.0666***	0.82581^{NS}	0.91995^{NS}	0.941936^{NS}
3	0.18661886	0.32565992	0.06077428	0.12230989	0.32565992	0.03983143	-0.02094285
	(0.01677674)	(0.32955313)	(0.05605531)	(0.01162652)	(0.32955313)	(0.03653385)	(0.01952147)
	11.1237***	0.98819^{NS}	1.08418^{NS}	10.5199***	0.98819^{NS}	1.09026^{NS}	1.072811^{NS}

Source: Field survey, 2023

Poverty line = 11788.41

Poverty Dominance (Beneficiary versus Spill-over and Control Groups)

In assessing the poverty dominance, between the beneficiary and spill-over groups, the results showed poverty to dominate in the spill-over group against the beneficiary group (Table 8). At cross 1 (case #1), the poverty crossing value for the beneficiary group out of critical relative poverty line is ₦7, 647.18 whereas the relative poverty crossing point for the spillover group is ₦7, 657.59 at cross 2 (case #2). Likewise, at cross 3 case #2, the significant amount needed by the beneficiary group to cross over the line of relative poverty is ₦8, 057.53 while the spill-over group needs a significant amount in the sum of ₦14, 113.54 to cross over the relative poverty line at cross 4 (case # 2). Comparatively, the margin of cross over between the two groups is slight at cross 1 versus 2 while it is wide at cross 3 (case #1) versus cross 4 (case #2). On the other hand, between the beneficiary and control groups, the poverty dominance of the latter is higher than that of the former as evident by case #1 versus case #2. Besides, poverty crossing value of the beneficiary group is ₦46296.82 against that of the control group

(₦53709.65). Noteworthy, the poverty crossing values of both groups were significant threshold; however, the marginal difference between the thresholds of the duo is mild. The NEAZDP has effectively reduced poverty compared to the spill-over and control groups, with beneficiaries requiring significantly less to cross the relative poverty line, indicating better poverty alleviation. To further enhance its impact, the programme should focus on deepening its interventions to address the remaining poverty gaps and reduce the disparities within the control group. In other words, the results indicate that while the NEAZDP has been somewhat effective, poverty remains more dominant in the spill-over group compared to the beneficiary group. The beneficiary group requires a smaller amount to move out of relative poverty compared to the spill-over group, but a larger amount compared to the control group. The control group faces higher poverty dominance overall. These findings suggest that the NEAZDP is moderately successful in reducing poverty but highlights the need for more targeted interventions to address the wider poverty gap and improve the situation of both spill-over and control groups.

Table 8: Poverty dominance between beneficiary vs. spill-over and control groups

Crossing	Value Of Z	Standard Error	t-statistic	Case
		Beneficiary vs. Spill-over		
1	7647.18310547	157.33786159	48.60358	1
2	7657.59179688	156.71906348	48.8619	2
3	8057.53173828	254.47420782	31.66345	1
4	14113.53808594	665.59058712	21.20453	2
		Beneficiary vs. Control		
1	46296.81640625	409.09327366	113.1693	1
2	53709.64843750	6245.16691867	8.600194	2

Source: Field survey, 2023

Note: Case #1= Before, Distribution #1 Dominates Distribution #2

Case #2 = Before, Distribution #2 Dominates Distribution #1

The Role of NEAZDP on Multidimensional Poverty Status of the Beneficiary against the Spillover and Control Groups

A cursory review of the multidimensional poverty level showed that at the poverty threshold level (k=0.33), a proportion of 28.21% of the households in the beneficiary group were multidimensional poor against that of the spill-over (61.51%) and control (52.99%) groups as indicated by their respective head count ratio index (Table 9 and Figure 4a). Comparatively, the incidence of poverty is low among the beneficiaries compared to the non-beneficiary group: the states of acute poverty in the spill-over and control groups are higher than that of the

beneficiary group by 33.3 and 24.78% respectively. This suggests that the intervention has been effective in reducing poverty among beneficiaries. Besides, the average poor household of the beneficiary group is deprived of 36.64% of the weighted indicators against that of the spill-over and control groups respectively that is been deprived of 40.19 and 38.68% of the weighted indicators as evident by their respective intensity poverty index. Succinctly, the poor households in the beneficiary group experienced 10.34% deprivation out of the total potential deprivations that could be experienced compared to the poor households in the spill-over and control groups respectively that experienced deprived share proportions of 24.72 and 20.49% from the total potential deprivation as evident from their respective MPI (multidimensional poverty index).

Nevertheless, as evident by the MPG (multidimensional poverty gap) index, the average indicator-specific gap between haves and non-haves of the beneficiary group is 17.87% against that of the spill-over and control groups respectively that were 36.79 and 32.49%. By implication, if the poor households in the beneficiary, spill-over and control groups respectively becomes more deprived in the challenged indicator(s), poverty would surge by 17.87, 36.79 and 32.49%. Similarly, if the shortfall from the deprivation cutoff is reduced, the poverty levels of the beneficiary, spill-over and control groups respectively will go down by 17.87, 36.79 and 32.49%, even if a poor household remains poor. Besides, the average severity of the deprived indicator(s) for the beneficiary, spill-over and control groups were 11.34, 22.12 and 20% respectively as evident by their respective MPS (multidimensional poverty severity) indexes.

To sum-up, the share contribution of the beneficiary group to poverty in the study area is 17% against that of the spill-over (45%) and control (38%) groups. In the same vein, the share poverty population of the beneficiary group is 30.38% compared to that of the spill-over (34.68%) and control (34.94%) groups. Nevertheless, among the poor households in the beneficiary group, standard of living ranked first as the major deprived indicator, followed by empowerment and then environment as evident in the dimension-wise distribution (Figures 4b and 4c). Comparatively, the contribution of groups to poverty exceeds that of the groups' poverty population share (Figure 4d). By implication, it entails that there is no serious unequal distribution of poverty within the beneficiary group while the reverse is the case for the spill-over and control (non-beneficiary) groups bearing disproportionate share of poverty for each group. In addition, inequality in the poverty level of poor households across the targeted populations was low as evident by the inequality index value. However, according to Alkire *et al*.(2016), as reported by Sadiq and Bashir (2022); Sadiq *et al*.(2024a), a lower level of inequality among the poor or a drop in the degree of inequality among the poor does not always imply that poverty has decreased uniformly across demographic subgroups.

Noteworthy, the case of a severe poverty level (k=0.50) was not established across the targeted groups. Generally, it can be inferred that the NEAZDP beneficiaries in the study area experienced lower multidimensional poverty compared to spill-over and control groups, with lower incidence, intensity, and severity of poverty. Despite these improvements, challenges remain in specific dimensions like standard of living, empowerment, and environment. The program's success in reducing poverty shares and severity underscores its potential to alleviate poverty further if targeted indicators are addressed. Effective policy adjustments could enhance impact, potentially reducing poverty by up to 17.87% among beneficiaries. These findings

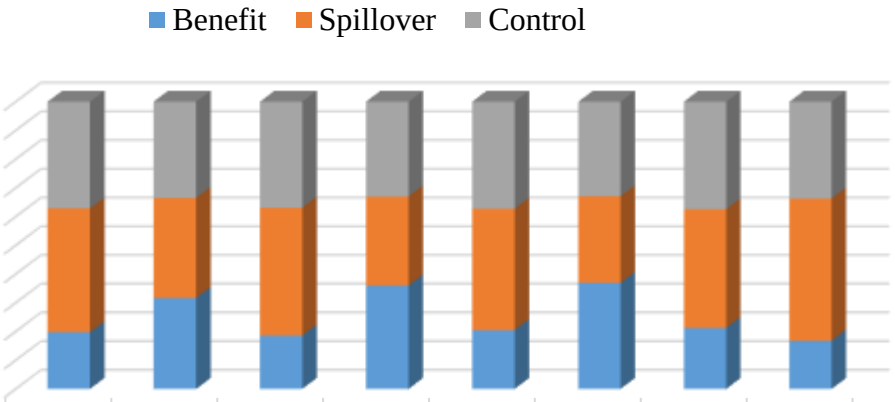
underscore the program's positive impact while emphasizing areas for continued improvement and focused intervention.

Table 9: MPI distributions of beneficiary vis-à-vis spill-over and control groups

Items	Beneficiaries	Spill-over	Control
Head count (H)	0.282086	0.615061	0.529859
Intensity (A)	0.366389	0.401897	0.386753
MPI	0.103353	0.247191	0.204925
Gap	1.729339	1.488198	1.585633
MPG	0.178732	0.367869	0.324935
Severity (S)	1.097565	0.895027	0.975874
MPS	0.113437	0.221243	0.199981
Inequality (IE)	3.21E-05	9.44E-05	6.43E-05
CG	17	45	38
PS	30.38	34.68	34.94
Dimension			
Education (E)	0.008952(8.662)	0.015704(6.352877)	0.019007(9.275217)
Health (H)	0.009(8.708198)	0.020142(8.148421)	0.020157(9.836424)
Standard Living	0.025337(24.51539)	0.058761(23.77151)	0.04826(23.55028)
Environment (EN)	0.018764(18.15555)	0.028173(11.39714)	0.034167(16.67294)
Empowerment(EM)	0.019778(19.13596)	0.036744(14.8648)	0.026848(13.10163)
Social capital (S)	0.008817(8.531108)	0.043181(17.46851)	0.020548(10.02689)
Wealth (W)	0.012704(12.29179)	0.044486(17.99674)	0.035937(17.53662)
MPI	0.103352(100)	0.247191(100)	0.204924(100)

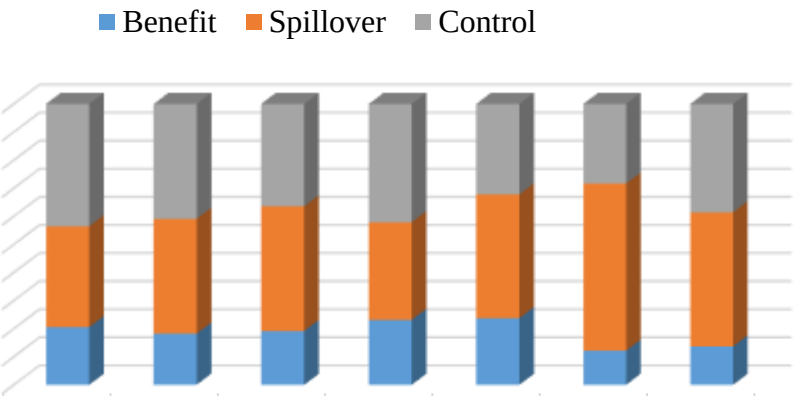
Source: Field survey, 2023

Note: Value in ( ) is percentage; CG = contribution of group; PS = population share; Standard of living (SL)



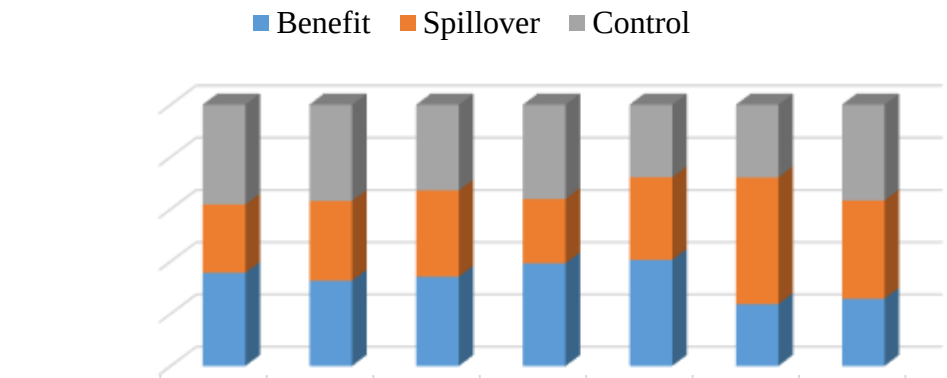
	H	A	MPI	G	MPG	S	MPS	IE
Control	0,52986	0,38675	0,20492	1,58563	0,32493	0,97587	0,19998	6,4E-05
Spillover	0,61506	0,4019	0,24719	1,4882	0,36787	0,89503	0,22124	9,4E-05
Benefit	0,28209	0,36639	0,10335	1,72934	0,17873	1,09756	0,11344	3,2E-05

Figure 4a: Comparative distributions of groups' MPIs



	ED	H	SL	EN	EM	SC	W
Control	0,01901	0,02016	0,04826	0,03417	0,02685	0,02055	0,03594
Spillover	0,0157	0,02014	0,05876	0,02817	0,03674	0,04318	0,04449
Benefit	0,00895	0,009	0,02534	0,01876	0,01978	0,00882	0,0127

Figure 4b: Index comparative distributions of groups' dimensions to MPI



	ED	H	SL	EN	EM	SC	W
Control	9,27522	9,83642	23,5503	16,6729	13,1016	10,0269	17,5366
Spillover	6,35288	8,14842	23,7715	11,3971	14,8648	17,4685	17,9967
Benefit	8,662	8,7082	24,5154	18,1556	19,136	8,53111	12,2918

Figure 4c: % comparative distributions of groups' dimension

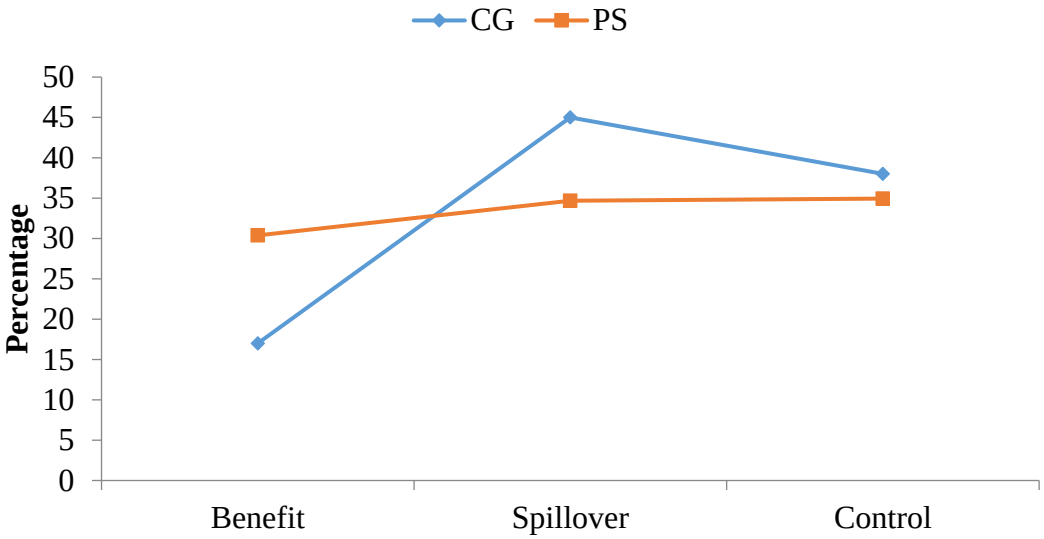


Figure 4d: Group MPI contribution vs. population share

CONCLUSIONS AND RECOMMENDATIONS

The North East Arid Zone Development Programme (NEAZDP) has shown significant effectiveness in reducing poverty among beneficiaries in Yobe State. The study reveals a consistent decline in the proportion of beneficiaries below the poverty threshold over time, with a notable improvement observed until the third quarter phase of the program. The program has

successfully reduced the incidence, intensity, and severity of poverty among its participants, particularly in dimensions related to standard of living, empowerment, and environment. Despite improvements, challenges persist in specific dimensions of poverty, highlighting the need for targeted interventions. Inequality within the beneficiary group remains low, but disparities are evident between beneficiaries and non-beneficiaries, emphasizing the importance of equitable distribution and inclusive growth strategies. Consequently, the present study proffered the following recommendations for inclusivity and comprehensive growth among the beneficiaries in the study area:

- It is imperative for the programme to focus on addressing specific dimensions of poverty identified in the study, particularly improving access to quality education, healthcare, and sustainable livelihoods.
- The programme should strengthen environmental conservation efforts and promote sustainable agricultural practices to ensure long-term resilience and reduce vulnerability to climate risks.
- The programme should implement rigorous monitoring mechanisms to track poverty reduction indicators continuously and adjust programmes based on real-time data.
- The programme should integrate poverty alleviation strategies with broader development policies at local, regional, and national levels to ensure comprehensive and inclusive growth (i.e., inclusivity and equity in resource distribution).
- The programme is advised to invest in capacity-building initiatives to empower local communities and institutions to sustain poverty reduction efforts independently.

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Appendix 1: Dimensions, indicators, cut-off points and relative weight (RW) of MPI

Dimensions	Indicators	Deprivation cut-off	RW
Education	School	No child (>=10 years) has completed five years of schooling	1/28
	School	No school age child (1-6 years) is attending school	1/28
	Literacy	The primary household has no formal education	1/28
	Literacy	The secondary household head has no formal education	1/28
Health	Nutrition	Any family member that is underweight (slim) (BMI< 18.5) or overweight (>=23)/obesity (>= 25)	1/28
	Immunization	Any family member not immunized/vaccinated to prevent any type of communicable diseases	1/28
	Ante-natal care	Any pregnant women in the household with less than four (4) antenatal care	1/28
	Morbidity	Any household member being sick in the last 5 months prior to survey	1/28
Standard of living	Housing	Household living in an inadequate housing condition	1/63
	Insurance	No family member is insured under any type of health insurance scheme	1/63
	Electricity	No access to electricity	1/63
	Water	No access to safe drinking water	1/63
	Mobility	Doesn't owned any type of motor vehicle for transportation purpose	1/63
	Financial institution	Doesn't possessed a savings bank account	1/63
	Residential plot	Doesn't owned any 100m^2 of residential land other than where he/she is residing	1/63
	Food security	Household is below food security threshold (2/3 of food expenditure)	1/63
	Over population	Household is overcrowded	1/63
Empowerment	Health decision	Unable to take healthcare decision	1/63
	Domestic violence	Unable to prevent domestic violence	1/63
	Instability	Problem of social/political unrest	1/63

	Self-defense	Problem of personal security	1/6 3
	Job	Doesn't take any type of employment decision(s) for himself other than farming activities	1/6 3
	Diversification	Doesn't participate in off-farm activities	1/6 3
	Credit	No access to credit facilities in the last production season prior to the survey	1/6 3
	Facilities	Doesn't belong to any co-operative organisation	1/6 3
	Advisory services	Doesn't have access to extension service in the last production season prior to the survey	1/6 3
Environment	Toilet	Household still practicing open defecation	1/1 4
	Energy	Using dirty fuel as primary energy for cooking (e.g firewood, dung & charcoal)	1/1 4
	Advisory services	Doesn't have access to extension service in the last production season prior to the survey	1/6 3
Social connection	Community service	Household head has not participated in any type of community-level activities	1/2 1
	Co-operate responsibility	The household has not been involved in organizing any type of community-level activities	1/2 1
	Social safety net	Doesn't trust government social investment programme (e.g. farmers/traders monie etc.)	1/2 1
Wealth	Agricultural land	Household doesn't own any agricultural land	1/2 8
	Livestock	Livestock ownership (deprived if TLU is less than average)	1/2 8
	Dead stock (agric.)	Doesn't possessed agricultural dead stocks	1/2 8
	Dead stock (non-agric.)	Doesn't possessed non-agricultural dead stocks	1/2 8

Source: Modified from Sadiq and Sani (2022); Sadiq *et al*.(2024); Sadiq *et al*.(2024)

NON-PROTEIN NITROGEN SOURCES IN DAIRY CATTLE NUTRITION

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SÜT SIĞIRI BESLENMESİNDE PROTEİN OLMAYAN AZOT KAYNAKLARI

ÖZET

Süt sığırlarının beslenmesinde protein ihtiyacını karşılamak amacıyla, protein olmayan azotlu bileşiklerin alternatif protein kaynaklarının kullanımı yaygın bir uygulamadır. Üre ve amonyum tuzları gibi protein olmayan azot bileşikleri, rumendeki mikroorganizmalar tarafından değerlendirilebilir ve mikrobiyal protein sentezine katkı sağlayarak hayvanın protein gereksinimini karşılamada rol oynayabilir. Bu besleme stratejisi, özellikle yüksek maliyetli protein kaynaklarının yerine daha ekonomik bir alternatif sunması açısından avantajlıdır. Ancak belirli oranın üzerinde kullanılabilirliği ve rasyonda kullanılan yem hammaddeleri ile birlikte negatif etkilerinin de düşünülmesi gerekmektedir. Bu nedenlerle protein olmayan azot bileşikleri kullanımının bazı sınırlamaları ve riskleri de göz önünde bulundurulmalıdır. Benzer bir şekilde homojen karışmama, yanlış dozajlama veya dengesiz rasyonlar, rumende amonyak birikimine neden olarak kandaki amonyak oranının artması toksisiteye yol açabilir ve hayvan sağlığını olumsuz etkileyebilir. Ayrıca, süt verimi ve bileşimi üzerindeki etkileri üzerine de olumsuz etkileri, rasyonun diğer bileşenleri ve hayvanın fizyolojik durumu gibi çeşitli faktörlere bağlı olarak değişim göstermektedir. Çalışmamızda, süt sığırlarında yaygın olarak kullanılan NPN maddelerin kullanımının avantajları ve potansiyel riskleri ele alınacaktır.

Giriş

Süt sığırı beslenmesinde protein olmayan azot kaynakları, ruminantların beslenmesinde önemli bir yer tutmaktadır. Bu kaynaklar, genellikle üre ve amonyak gibi bileşenler şeklinde bulunur ve rumen mikroorganizmaları tarafından protein sentezi için kullanılır. Ruminantların beslenmesinde protein olmayan azot kaynaklarının kullanımı, hem ekonomik hem de çevresel sürdürülebilirlik açısından büyük avantajlar sunmaktadır. Özellikle, bu kaynaklar, yüksek protein içeriğine sahip yemlerin maliyetini düşürerek, çiftliklerin ekonomik verimliliğini artırabilir (Salo, 2018).

Üre, en yaygın kullanılan protein olmayan azot kaynağıdır. Ruminantların rasyonlarına eklenmesi, rumen mikroorganizmalarının amonyak üretimini artırarak, bu amonyağın mikroplar tarafından protein sentezinde kullanılmasını sağlar. Bu süreç, hayvanların beslenme verimliliğini artırmakta ve azotun çevreye salınımını azaltmaktadır. Bunun yanı sıra, yavaş salınımlı üre formülasyonları, hayvanların azot ihtiyacını karşılamak için etkili bir yöntem olarak öne çıkmaktadır (Huang ve ark., 2023).

Yapılan araştırmalara göre, süt inekleri için ürenin günlük alım miktarları genellikle 30 gram ile 90 gram arasında değişmektedir. Bu aralık, ineklerin genel protein gereksinimleri, rasyonun içerdiği ham protein seviyeleri ve beslenme stratejilerine bağlı olarak ayarlanabilir (Spek ve ark., 2012).

Üre eklenmiş rasyonların, özellikle yüksek protein içeriğine sahip besinlerle birleştirildiğinde, dikkatli bir şekilde formüle edilmesi önemlidir. %16'nın üzerinde ham protein içeren rasyonlarda, aşırı amonyak üretimini önlemek adına üre ilavesi dikkatle yapılmalıdır. Fazla üre kullanımı, ineklerde metabolik sorunlara yol açabileceği için, optimal düzeylerde tutulması önerilmektedir (Czajkowska ve ark., 2015).

Ayrıca, çeşitli bitkisel kaynaklar da protein olmayan azot kaynakları olarak kullanılabilir. Örneğin, bazı baklagiller ve yeşil otlar, doğal olarak yüksek azot içeriğine sahip olup, ruminantların beslenmesinde önemli bir rol oynamaktadır (Das ve ark., 2022). Bu tür kaynaklar, hem besin değerini artırmakta hem de çevresel etkileri azaltmaktadır. Bununla birlikte, bu kaynakların etkinliği, rasyonun genel dengesi ve enerji içeriği ile doğrudan ilişkilidir. Yetersiz enerji alımı, amonyak üretimini olumsuz etkileyebilir ve hayvan sağlığını tehdit edebilir (Cabrita ve ark., 2011).

Kapsüle üre kullanımı, süt sığırı rasyonlarında protein emilimini artırarak, süt verimi üzerinde olumlu bir etki yaratabilir. Yüksek diyet protein seviyelerinin süt üretimini artırmasına rağmen, aşırı kullanımının hayvanların üreme performansını olumsuz etkileyebileceğini belirtmektedir. Kapsüle üre, hayvanların protein ihtiyacını karşılamak için daha ekonomik bir çözüm olarak öne çıkmakta, böylece süt üretiminde verimliliği artırma fırsatı sunmaktadır (Kaygısız ve Şahin, 2023).

Süt sığırı beslenmesinde protein olmayan azot kaynakları, ekonomik ve çevresel açıdan önemli bir strateji sunmaktadır. Bu kaynakların doğru bir şekilde yönetilmesi, hayvan sağlığını ve verimliliğini artırırken, çevresel etkileri azaltma potansiyeli taşımaktadır. Protein olmayan azot kaynaklarının kullanımı, modern süt sığırcılığı uygulamalarında kritik bir unsur olarak değerlendirilmektedir (Vicente ve ark., 2021).

Protein kaynakları

Süt sığırlarının beslenmesinde kullanılan protein kaynakları, ineklerin laktasyon dönemindeki verimliliğin arttırılması ve genel sağlıklarını koruma açısından kritik bir rol oynamaktadır. Bu sağlıklı, rasyonların protein içeriği, ineklerin süt üretimi, besin büyümeleri üzerinde önemli etkileri vardır (Proškina ve Cerina, 2017).

Süt sığırı beslenmesinde kapsüle üre kullanımı, hayvanların enerji ve protein dengesinin sağlanması için önemli bir stratejidir. Kapsüle üre, protein kaynaklarının kalitesini artırmak ve hayvanların amino asit ihtiyaçlarını karşılamak amacıyla rasyonlara eklenmektedir. Ayrıca, kapsüle üre, doğrudan rumende protein kaynağı sağlarken, hayvanların metabolizmasını optimize etme potansiyeline sahiptir (Tüfenk ve Tapkı, 2023)

Soya fasulyesi küspesi (SBM) ve kanola küspesi gibi geleneksel protein kaynakları, süt inekleri için en yaygın kullanılan protein bileşenlerindendir. SBM'nin kanola unu ile değiştirilmesi, süt verimini ve protein çıkışını artırmada olumlu sonuçlar verir (Broderick ve ark., 2015).

Yonca (Medicago sativa) süt inekleri için yüksek kaliteli bir protein kaynağı olduğu belgelenmiştir. Yonca, yüksek besin değeri ve iyi sindirilebilirlik özellikleri ile ineklerin rasyonlarına dahil edilir. Bu da süt miktarını artırmaktadır. Diğer alternatif kaynaklar arasında mısır samanı ve baklagil bitkileri gibi yaşam açısından zengin kaynaklar bulunmaktadır. Baklagil bitkilerinin kullanımı, sütün katkı payının arttırılması, aynı zamanda besin maliyetlerini azaltma potansiyeline sahiptir (Chen ve ark., 2024).

Mikrobiyal protein, süt ineklerinin rasyonlarına önemli bir yer tutar ve genellikle toplam emilebilir protein miktarının %50 ila %80'ini sağlar. Mikrobiyal protein, rumende üretilen ve yüksek miktarda metiyonin ve lösin gibi sınırlayıcı aminoasitleri içeren bir protein kaynağıdır. Ruminal protein) ve rumen kaçak proteini oranlarının doğru dengelenmesi, mikrobiyal protein sentezini artırma ve azot dağılımını optimize etmektedir (Neal ve ark., 2014).

Beslenmede kullanılan diğer protein kaynakları arasında, hafif işlenmiş atık ürünler yer almaktadır. Bu tür kaynaklar genellikle maliyet etkinliği açısından avantaj sağlar. Örneğin, yaprak, soya ve baklagiller, yüksek düzeyde protein içerdikleri için süt ineklerinin rasyonlarında sıklıkla kullanılmaktadır (Ribeiro ve ark., 2018).

NPN maddeleri

Süt sığırları beslenmesinde protein olmayan azot (NPN) kaynakları, protein verimliliğini artırmak ve süt ineklerinin genel sağlığını desteklemek için önemlidir. Bu kaynaklar, ruminantlarda besin dönüşüm verimliliğini artırırken, bitkisel protein kaynaklarının eksikliğini de gidermektedir (Şen ve ark., 2021).

Üre, en yaygın NPN kaynaklarından biridir. Üre, ruminantlarda amonyağa dönüşerek mikroplar tarafından kullanılabilir ve bu sayede mikroorganizmalarda protein sentezine katkıda bulunabilir. Üre kullanımı, günlük rasyonun %1-2'si kadar olmalıdır. Amonyak oranı, rasyonla birlikte değişiklik gösterebilir; genellikle, rumendeki amonyak konsantrasyonu, rasyonların toplam azot içeriğine ve rumen sağlığına bağlıdır (Akınoğlu ve ark., 2024).

Nitratlar, süt sığırlarının beslenmesinde diğer bir NPN kaynağıdır. Rumendeki amonyak veya nitrit olarak kullanımı, mikroorganizmaların protein sentezini desteklemesine olanak tanır. Araştırmalar, yeşil bitkilerdeki nitrat içeriğinin çeşitlilik gösterdiğini ve bu durumun hayvanların nitrat alımını etkilemekte olduğunu ortaya koymaktadır. Amonyak seviyeleri, nitrattan amonyağa dönüşüm sırasında değişiklik gösterebilir. Nitrattan amonyağa dönüşüm oranı genelde %70-90 arasında değişmektedir (Koç ve Çufadar, 2023).

Bazı amino asit kaynakları da NPN yerine kullanılabilir. Örneğin, metiyonin ve lösin gibi sınırlayıcı amino asitlerin sağlanması, NPN kaynaklarıyla desteklenebilir. Bu içerikler genellikle amonyak oranlarına bağlı olarak değişkenlik gösterebilir. NPN'nin besin değeri, amonyak seviyesi ile doğrudan ilişkilidir. Ruminantların beslenmesinde, bu kaynakların amonyak seviyeleri genellikle rasyon değerlendirilirken dikkate alınmalıdır (Altay ve Sarıkanat, 2019).

Bazı bitkiler de NPN kaynağı olarak kullanılmaktadır. Örneğin, bazı baklagiller ve yeşil gübre bitkileri, doğal nitrifikasyon sürecine katkı sağlamakta ve besin kalitesini iyileştirmekte olan yüksek nitrik oksit içeriği ile dikkat çekmektedir. Bu bitkilerin azot kullanımı, besin maddelerinin rumende sindirimi sırasında önemli bir rol oynamaktadır (İgrek ve Şimşek, 2019).

Protein olmayan azot kullanımının olumlu yönleri

Süt sığırı beslenmesinde enerji ve amonyak oranlarının, sığırcılık işletmelerinin verimliliği ve süt kalitesi açısından kritik bir konudur. Amonyak, süt sığırlarının rumeninde protein metabolizmasının bir yan ürünü olarak oluşur ve yüksek düzeyleri hem hayvan sağlığını hem de üretkenliği olumsuz etkileyebilir. Amonyak, rumende aşırı biriktiğinde, hayvanların besin alımını ve sindirim işlevlerini aksatarak, metabolizma dengesizliklerine yol açabilir. Enerji dengesinin sağlanması sütün kalitesini artıracak ve de hayvan sağlığını koruyacaktır. Dolayısıyla, süt sığırları için geliştirilecek besleme stratejileri, enerji ve amonyak dengesinin sağlanmasını göz önünde bulundurmalıdır (Ece ve Avcı, 2018).

Protein olmayan azot kaynaklarının kullanımı hem ekonomik hem de çevresel açıdan önemli avantajlar sunmaktadır. Bu kaynaklar, genellikle üre ve amonyak gibi bileşenler şeklinde bulunur ve rumen mikroorganizmaları tarafından protein sentezi için kullanılır. Protein olmayan azot kaynaklarının en belirgin faydalarından biri, süt sığırlarının rasyonlarında toplam protein ihtiyacını karşılamada maliyet etkinliği sağlamasıdır. Yüksek protein içeriğine sahip yemlerin maliyetleri göz önüne alındığında, bu kaynakların kullanımı, çiftliklerin ekonomik verimliliğini artırabilir (Sinclair ve ark., 2014).

Protein olmayan azot kaynaklarının kullanımı, çevresel sürdürülebilirlik açısından da büyük önem taşımaktadır. Ruminantların rasyonlarında protein olmayan azot kaynaklarının eklenmesi, azotun daha verimli kullanılmasını sağlar ve böylece dışkı ve idrar yoluyla çevreye salınan azot miktarını azaltır. Bu durum, tarımsal faaliyetlerin çevresel etkilerini minimize etmek için kritik bir strateji olarak değerlendirilmektedir (Spek ve ark., 2013).

Rumendeki azot döngüsü, süt sığırlarının beslenmesinde kritik bir rol oynayan karmaşık bir süreçtir ve iki ana azot kaynağından oluşur: proteinli kaynaklar ve protein olmayan azot (NPN) kaynakları. Proteinli kaynaklar rumende mikroorganizmalar tarafından parçalandığında

amonyağa dönüşerek mikrobiyal protein sentezi için kullanılırken, NPN kaynağı olan üre ve amonyum da benzer şekilde işlev görür. Amonyak, mikroorganizmalar tarafından rumende kullanılarak protein sentezine katkıda bulunur, bu da süt üretimi için gerekli olan mikrobiyal proteinlerin oluşumunu artırır. Ancak, aşırı NPN kullanımı yüksek amonyak seviyelerine yol açarak süt yağ içeriğinde düşüşe neden olabilir, dolayısıyla dengeli bir azot yönetimi sağlamak süt kalitesini optimize etmek ve çevresel etkileri azaltmak açısından gereklidir. Sonuç olarak azot döngüsü, hem süt verimliliğini hem de sütün bileşim kalitesini artırmak için önemlidir ve bu döngünün doğru yönetimi, ruminantların genel beslenme verimliliğini belirleyici bir faktör olarak öne çıkmaktadır (Carvalho ve ark., 2011).

Protein alımının azaltılması, azotun dışkı ve idrar yoluyla kaybını azaltarak, çevresel kirliliği önleyebilir. Protein olmayan azot kaynaklarının bir diğer avantajı, rumen mikroorganizmalarının protein sentezini artırarak süt verimini desteklemesidir. Bu kaynaklar, rumen mikropları tarafından amonyağa dönüştürülerek, daha sonra mikroorganizmalar tarafından protein sentezinde kullanılabilir. Böylece, süt sığırlarının genel sağlık durumu ve süt üretim verimliliği artırılabilir. Bu tür kaynakların kullanımı, hayvanların beslenme verimliliğini artırarak, daha az yemle daha fazla süt üretimi sağlanmasına olanak tanır (Chiariotti ve ark., 2020).

Protein olmayan azot kullanımının olumsuz yönleri

Süt sığırı beslenmesinde protein olmayan azot kaynaklarının kullanımı, bazı olumsuz etkiler ve riskler içermektedir. Bu kaynakların en yaygın örneği olan üre, düşük maliyetli bir alternatif olmasına rağmen, dikkatli bir şekilde yönetilmediğinde hayvan sağlığı üzerinde olumsuz etkiler yaratabilir. Üre, hayvanların rumeninde amonyağa dönüşür ve mikroorganizmalar bunu protein yapmak için kullanır. Ancak çok fazla üre verilirse asidoza neden olur. Bu durum hayvanın sağlığını kötü etkiler ve süt verimini azaltır. (Cherdthong ve ark., 2019).

Protein olmayan azot kaynaklarının kullanımı, azot verimliliğini olumsuz etkileyebilir. Ruminantlar, rasyonlarından aldıkları azotun yalnızca %25-35'ini süt üretiminde kullanırken, geri kalan kısmı idrar ve dışkı yoluyla atılmaktadır. Bu durum, çevresel kirliliğe yol açmakta ve tarımsal faaliyetlerin sürdürülebilirliğini tehdit etmektedir. Özellikle, yüksek azot atılımı, su kaynaklarının nitrat ile kirlenmesine ve hava kalitesinin bozulmasına neden olabilir (Salami ve ark., 2020).

Ayrıca, protein olmayan azot kaynaklarının kullanımı, ruminantların beslenme dengesi üzerinde olumsuz etkiler yaratabilir. Bu kaynakların aşırı kullanımı, hayvanların enerji alımını olumsuz etkileyebilir ve bu da genel sağlık durumunu tehdit edebilir. Yetersiz enerji alımı, rumen mikroorganizmalarının sağlıklı bir şekilde çalışmasını engelleyebilir ve bu durum, amonyağın toksik seviyelere ulaşmasına neden olabilir (Araújo ve ark., 2020).

Protein olmayan azot kaynaklarının kullanımı, dikkatli bir şekilde yönetilmelidir. Süt sığırı beslenmesinde protein olmayan azot kaynaklarının kullanımı, bazı olumsuz etkiler ve riskler içermektedir. Bu kaynakların aşırı kullanımı, hayvan sağlığı, çevresel sürdürülebilirlik ve beslenme dengesi üzerinde olumsuz sonuçlar doğurabilir. Dolayısıyla, bu kaynakların dikkatli

bir şekilde yönetilmesi, modern süt sığırcılığı uygulamalarında kritik bir unsur olarak değerlendirilmektedir (Bell ve ark., 2011).

Araştırmalara göre, aşırı üre kullanımı, süt yağ içeriğinde azalmaya neden olabilir. Araştırmalara göre, üre ile beslenen ineklerde süt protein oranı artarken, süt yağ oranı genellikle düştüğü görülmektedir (Sarker ve ark., 2016).

Amonyum sülfat gibi diğer NPN kaynaklarının kullanımı da süt kalitesinde önemli rol oynar. Bu tür kaynaklar, süt verimliliği ve protein sentezini desteklemek için rumende amonyağın etkili bir şekilde kullanılmasına yardımcı olur. Bunun yanında, nitratlar rumende fermente edilerek amonyağa dönüşebilir, bu mikrobiyal protein sentezini destekleyerek süt kalitesinde artış sağlayabilir. Ancak bununla birlikte, aşırı nitrat tüketimi, sütten nitrat seviyelerinin yükselmesine neden olabileceğinden dikkatli kullanılmalıdır (Çavdar ve Kara, 2022).

Sonuç

Süt sığırı beslenmesinde protein olmayan azot kaynakları, hem olumlu hem de olumsuz yönleriyle dikkat çekmektedir. Bu kaynaklar, genellikle üre ve amonyak gibi bileşenler şeklinde bulunur ve ruminantların beslenmesinde önemli bir rol oynamaktadır. Protein olmayan azot kaynaklarının en önemli avantajlarından biri, maliyet etkinliğidir. Üre gibi bu kaynaklar, yüksek protein içeriğine sahip yemlerin maliyetlerini düşürerek, çiftliklerin ekonomik verimliliğini artırabilir (Sinclair ve ark., 2014).

Bu kaynaklar, rumen mikroorganizmaları tarafından protein sentezinde kullanılmakta ve böylece süt verimini artırmaktadır. Ruminantların rasyonlarında protein olmayan azot kaynaklarının eklenmesi, azotun daha verimli kullanılmasını sağlar ve çevresel etkileri azaltır. Örneğin, protein alımının azaltılması, azotun dışkı ve idrar yoluyla kaybını azaltarak çevresel kirliliği önleyebilir. Bunun yanı sıra, bu kaynaklar, ruminantların genel sağlık durumunu iyileştirerek, süt üretim verimliliğini artırma potansiyeline sahiptir (Kreišmane ve ark., 2021).

Ancak, protein olmayan azot kaynaklarının kullanımı bazı olumsuz etkiler de içermektedir. Aşırı miktarda üre kullanımı, rumen asidozuna yol açabilir ve bu durum, hayvanların genel sağlığını tehdit edebilir (Wang ve ark., 2022).

Ruminantlar, rasyonlarından aldıkları azotun yalnızca %25-35'ini süt üretiminde kullanırken, geri kalan kısmı idrar ve dışkı yoluyla atılmaktadır. Bu durum, çevresel kirliliğe yol açmakta ve tarımsal faaliyetlerin sürdürülebilirliğini tehdit etmektedir. Yüksek azot atılımı, su kaynaklarının nitrat ile kirlenmesine ve hava kalitesinin bozulmasına neden olabilir. Ayrıca, protein olmayan azot kaynaklarının aşırı kullanımı, hayvanların enerji alımını olumsuz etkileyebilir ve bu da genel sağlık durumunu tehdit edebilir (Rehman ve ark., 2020).

Sonuç olarak, süt sığırı beslenmesinde protein olmayan azot kaynaklarının kullanımı, hem ekonomik hem de çevresel açıdan önemli avantajlar sunarken, dikkatli bir şekilde yönetilmediğinde bazı olumsuz etkiler de yaratabilir. Bu kaynakların etkin bir şekilde yönetilmesi, modern süt sığırcılığı uygulamalarında kritik bir unsur olarak değerlendirilmektedir.

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WILT AND CROWN ROT DISEASE ON LENTIL*: Fusarium oxysporum* f. sp. *lentis*

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ABSTRACT

Food legumes, which play an important role in agricultural production in many countries around the world, are also traditional products of Turkish agriculture and are an economically important product group due to their contribution to employment and high export potential. Lentils (*Lens culinaris* Medik.) are one of the oldest plants with roots in the Near East and the Mediterranean region. Lentil seeds contain relatively high protein, carbohydrates and calories compared to other legumes and are the most preferred cultivated plant in many production regions due to their average high protein content and fast cooking properties. According to 2023 data in the world, Turkey ranks 4th after Canada, India and Australia. According to 2024 data in our country, green lentil production is mostly carried out in the provinces of Yozgat, Konya, Kırşehir, Çorum and Ankara. These five provinces meet approximately 92% of our country's green lentil production. Lentil farming in our country is carried out in two ways: large-grained green and smaller-grained red, which have different areas of use as human food. The most important phytopathological problems that limit lentil production in our country and cause yield reduction are root collar rot and wilt disease in lentils caused by soil-borne fungal agents. These cause growth retardation in plants, yellowing and drying and shedding of leaves, browning of roots and root collars, thinning of roots, decrease in the number of hairy roots and nodosity. Among these disease agents, Fusarium isolates are an important disease recorded everywhere lentils are grown. In surveys, the primary phytopathogenic agent that causes the increase in wilt and root collar disease is *Fusarium oxysporum* f. sp. *lentis* (Fol). It is known that the average loss due to lentil wilt and root rot disease is 10%, but it can reach up to 66%. Especially when a mild spring is followed by a dry, hot summer, wilt disease can cause the complete loss of the product. In this review, the symptoms, distribution in the world and in our country, and biology of the disease agent *Fusarium oxysporum* f. sp. *lentis*, which attacks the lentil plant, are presented in detail.

Keywords: *Fusarium oxysporum*, Disease cycle, *Lens culinaris*

MERCİMEKTE SOLGUNLUK VE KÖK BOĞAZ ÇÜRÜKLÜK HASTALIĞI: *Fusarium oxysporum* f. sp. *lentis*

ÖZET

Dünya genelinde birçok ülkenin tarımsal üretiminde önemli rol oynayan yemeklik tane baklagiller, Türk tarımının da geleneksel ürünlerinden olup istihdama katkısı ve yüksek ihracat potansiyeli nedeniyle ekonomik açıdan önemli bir ürün grubudur. Mercimek (*Lens culinaris* Medik.), kökeni Yakın Doğu ve Akdeniz bölgesine dayanan en eski bitkilerden biridir. Mercimek tohumu, diğer baklagillerle karşılaştırıldığında nispeten yüksek protein, karbonhidrat ve kalori içerir ve ortalama yüksek protein içeriği ve hızlı pişirilme özellikleri nedeniyle, birçok üretim bölgesinde en çok tercih edilen kültür bitkisidir. Dünyada 2023 yılı verilerine göre Türkiye; Kanada, Hindistan ve Avustralya'dan sonra 4. sırada yer almaktadır. Ülkemizde 2024 yılı verilerine göre yeşil mercimek üretimi en fazla Yozgat, Konya, Kırşehir, Çorum ve Ankara illerinde yapılmaktadır. Bu beş il ülkemiz yeşil mercimek üretiminin yaklaşık %92'sini karşılamaktadır. Ülkemizdeki mercimek tarımı; insan gıdası olarak farklı kullanım alanlarına sahip iri taneli yeşil ve daha küçük taneli kırmızı olmak üzere iki şekilde yapılmaktadır. Ülkemizde mercimek üretimini kısıtlayan ve verim düşüşüne sebep olan fitopatolojik sorunlardan en önemlisi toprak kökenli fungal etmenlerin neden olduğu mercimekte kök boğaz çürüklüğü ve solgunluk hastalığıdır. Bunlar bitkilerde gelişme geriliğine, yapraklarda sararma ve kuruyup dökülmelere, kök ve kök boğazında kahverengileşmeye, kökte incelmeye, saçak kök ve nodozite sayısında azalmalara neden olmaktadır. Bu hastalık etmenlerinden Fusarium izolatları , mercimeğin yetiştirildiği her yerde kaydedilen önemli bir hastalıktır. Yapılan sörveylerde solgunluk ve kök boğaz hastalığının artışının nedeni olarak *Fusarium oxysporum* f. sp. *lentis* (Fol)fungusunun birincil fitopatojenik etmen olduğu ön plana çıkmıştır. Mercimek solgunluk ve kök çürüklüğü hastalığından dolayı ortalama kaybın %10 olduğu, ancak %66'ya kadar ulaşabildiği bilinmektedir. Özellikle ılıman geçen ilkbaharı kuru, sıcak bir yaz mevsimi izlediğinde solgunluk hastalığı, ürünün tamamen yok olmasına neden olabilmektedir. Bu derleme kapsamında mercimek bitkisine arız olan *Fusarium oxysporum* f. sp. *lentis* hastalık etmeninin simptom, dünyada ve ülkemizdeki yayılışı, biyolojisi detaylı bir şekilde ortaya konulmuştur.

Anahtar Kelimeler: Fusarium oxysporum, Hastalık döngüsü, Lens culinaris

1. GİRİŞ

Fusarium oxysporum f.sp. *lentis* (Fol), mercimek (*Lens culinaris* Medik.) üretiminde ciddi ekonomik kayıplara yol açan Fusarium solgunluğu ve kök çürüklüğü hastalıklarının etmenidir (Bayaa ve ark., 1997; Erskine ve ark., 2009). Toprak ve tohum kökenli bir fungal patojen olan Fol, konukçusuz koşullarda sporlarını dormant halde uzun yıllar boyunca canlı tutabilme özelliğine sahiptir. Bu sporlar; enfekte toprak, bitki artıkları, kontamine tohumlar ile su, rüzgar, tarımsal ekipman, hayvan ve insan faaliyetleri aracılığıyla hızla yayılabilmektedir (Haware ve Nene, 1982).

Fol'un yüksek düzeyde adaptasyon kabiliyetine sahip olması, geniş bir konukçu spektrumunu enfekte edebilmesi, farklı toprak ve iklim koşullarına uyum sağlayabilmesi ve toprakta uzun süre varlığını sürdürebilmesi, bu etmeni istilacı nitelikte kılmaktadır (Jiménez-Díaz ve ark., 2015). Yeni bölgelere yerleştiği takdirde enfekte bitkilerde sararma, solma ve ölüm gibi belirtiler ortaya çıkmakta; bu durum bitki gelişimini ve verimi önemli ölçüde azaltmaktadır. Özellikle mercimeğin temel gıda ve ekonomik ürün olduğu bölgelerde bu patojenin yayılımı, hem gıda güvenliği hem de tarımsal ekonomi açısından ciddi bir tehdit oluşturmaktadır (Tullu ve ark., 2011).

Her ne kadar *F. oxysporum* f.sp. *lentis* hâlihazırda ISSG (Invasive Species Specialist Group) gibi küresel istilacı türler listesinde yer almıyor olsa da, bazı ülkelerde zararlı organizma olarak tanımlanmakta ve düzenleyici önlemler kapsamında değerlendirilmektedir. Örneğin, Kuzey Amerika ve Avustralya'nın bazı bölgelerinde bu etmenin yayılımını önlemeye yönelik katı bitki sağlığı kuralları uygulanmaktadır (Ozgonen ve ark., 2014). Dolayısıyla, patojenin istilacı doğası ve potansiyel ekonomik etkileri dikkate alındığında, yerel ve uluslararası düzeyde izlenmesi ve karantina önlemleriyle denetim altında tutulması büyük önem arz etmektedir.

Taksanomik sınıflandırma

Üst alem: Eukaryota

Alem: Fungi

Şube: Ascomycota

Alt şube: Pezizomycotina

Sınıf: Sordariomycetes

Alt sınıf: Hypocreomycetidae

Takım: Hypocreales

Familya: Nectriaceae

Cins: Fusarium

Tür: *Fusarium oxysporum* f.sp. *lentis*

Fusarium oxysporum içinde, forma specialis düzeyinin ötesinde, patojenin belirli mercimek çeşitlerine ya da direnç genlerine gösterdiği farklı tepkilere göre "ırk" (race) ve "patotip" (pathotype) düzeyinde alt sınıflandırmalar da yapılmıştır (Gordon ve Martyn, 1997). Bu tür alt gruplar, Hindistan, İran, Cezayir, Suriye ve ABD gibi ülkelerden izole edilen *F. oxysporum*

f.sp. *lentis* (Fol) örneklerinde tanımlanmıştır (Pouralibaba ve ark., 2016; Hiremani ve Dubey, 2018; Bugingo ve ark., 2024).

Mercimekte solgunluk hastalığı ile ilişkili olarak birden fazla Fusarium türü bildirilmiştir (Khare ve ark., 1979). Hastalığın etmeni olarak Hindistan'da ilk kez *Fusarium orthoceras* var. *lentis* tanımlanmış olup, bu tanımlama Vasudeva ve Srinivasan (1952) tarafından yapılmıştır. Daha sonra bu tür, Chattopadhyay ve Sengupta (1967) tarafından *Fusarium oxysporum* f.sp. *lentis* (Fol) olarak yeniden adlandırılmıştır.

Morfolojik Özellikler

Fusarium oxysporum f.sp. *lentis*, toprak kökenli bir fungal patojen olup mercimek bitkilerini enfekte eder ve yaşam döngüsü boyunca belirgin morfolojik özellikler sergiler. Patolojik tanımlamalar çoğunlukla laboratuvar kültürleri temelinde yapılmaktadır. Patates dekstroz agarı (PDA) üzerinde oldukça hızlı gelişim gösteren koloniler, genellikle 7–8 gün içerisinde 100 mm çapındaki petri kabını tamamen kaplayacak şekilde büyür. Koloniler, yaşa ve kültür koşullarına bağlı olarak zamanla hafif turuncu veya pembe bir ton alabilen yoğun beyaz havalı (aerial) miselyum oluşturur. Petri kabının alt yüzeyinden bakıldığında ise koloniler beyaz veya hafif sarı renkte görünür.

Patojenin yayılmasından esasen sorumlu olan birincil eşeysiz sporlar, mikrokonidilerdir. Bu sporlar bol miktarda üretilir, septasızdır (aseptat), böbrek şeklinden oval forma kadar değişken yapıdadır ve kısa monofiyal konidioforlar üzerinde yalancı başlıklar (false heads) halinde oluşurlar. Mikrokonidilerin boyutları genellikle 5–12 µm uzunluğunda ve 2–3.5 µm genişliğindedir (Nelson ve ark., 1983; Leslie ve Summerell, 2006).

Makrokonidiler ise daha az sıklıkla gözlemlenir ancak yarım konsantrasyondaki PDA, karanfil yaprağı agarı (CLA) veya patates dekstroz sıvı besiyerinde (potato dextrose broth) bol miktarda üretilebilir. Bu sporlar fusiform ya da hafif orak biçiminde (sickle-shaped), ince duvarlı, çok bölmeli (multiseptat) yapıda olup 20–35 µm uzunluğunda ve 3–4.5 µm genişliğindedir (Leslie ve Summerell, 2006; Bugingo, 2022).

Klamidosporlar, kalın duvarlı, küresel ya da yarı küresel yapıda olup, olumsuz çevresel koşullar altında patojenin toprak ve bitki artıkları içinde hayatta kalmasını sağlayan dayanıklı yapılardır. Kültür ortamında tekli ya da ikili halde bol miktarda oluşabilir; hem hifler içinde hem de makrokonidilerde gelişebilmektedir (Nelson ve ark., 1983).

Yayılım ve Giriş Riski

Mercimek solgunluğuna neden olan Fusarium kaynaklı hastalık, mercimek üretiminin yapıldığı tüm bölgelerde küresel ölçekte rapor edilmiştir (Furman ve ark., 2009). Bu patojenin, Amerika Birleşik Devletleri, Kanada, Hindistan, Türkiye ve Avustralya gibi birçok ülkede varlığı belgelenmiş olup, mercimek üretimi üzerinde yaygın ve önemli bir etkiye sahip olduğu gösterilmiştir.

Mercimekte Fusarium solgunluğuna neden olan etmen *Fusarium oxysporum* f.sp. *lentis* (Fol), ilk kez 1900'lü yılların başında Macaristan'da bildirilmiştir (Fleischmann, 1937). Ancak bu patojenin, mercimeğin anavatanı olarak da kabul edilen Akdeniz bölgesinde ortaya çıktığı yaygın biçimde kabul görmektedir. Bu hipotez, Türkiye, Suriye ve İspanya gibi Akdeniz havzasında yer alan mercimek üretim bölgelerinde patojenin yaygın olarak bulunmasıyla desteklenmektedir (Erskine ve ark., 1994; Bayaa ve ark., 1997). Söz konusu bölgeler, orta düzey sıcaklık ve nem gibi patojenin gelişimine elverişli çevresel koşullara sahip olup, patojen ile konukçusu arasında uzun süredir süregelen bir ortak evrimsel süreci işaret etmektedir.

F. oxysporum f.sp. *lentis*'in yayılımı, köken bölgesinin ötesine geçerek mercimek tarımının yapıldığı farklı coğrafyalara ulaşmıştır. Güney Asya'da, özellikle Hindistan ve Bangladeş, patojenin önemli ölçüde yayıldığı ülkeler arasında yer almakta olup, bu yayılımın kontamine tohum ve toprak hareketleri aracılığıyla gerçekleştiği düşünülmektedir (Gaur ve ark., 2010). Dünya genelinde en büyük mercimek üreticilerinden biri olan Hindistan'da, özellikle kuzey ve orta bölgelerde ciddi salgınlar bildirilmektedir. Kuzey Amerika'da ise patojen, Kanada'nın Saskatchewan ve Alberta eyaletlerinde ve ABD'nin Washington, Montana ve Kuzey Dakota eyaletlerinde rapor edilmiştir. Bu bölgelere girişin, kontamine tohum veya bitki materyali yoluyla gerçekleştiği öne sürülmektedir (Kaiser, 1992; Bugingo ve ark., 2024a). Kuzey Amerika'da hastalık, verim ve ürün kalitesi üzerinde olumsuz etkileri nedeniyle ekonomik olarak önemli bir bitki hastalığı hâline gelmiştir (Morrall ve Sheard, 1981; Wu ve ark., 2015). Avustralya'da ise patojenin Güney Avustralya ve Victoria gibi mercimek üretim bölgelerine kontamine tohum partileri ve toprak taşınımı aracılığıyla ulaştığı tahmin edilmektedir (Davidson ve ark., 2007). Günümüzde bu bölgelerde hastalık yerleşik hâle gelmiş olup, önemli ekonomik kayıplara neden olmaktadır.

Fusarium oxysporum f.sp. *lentis* (Fol), özellikle kontamine tohum, toprak ve tarım araçları aracılığıyla yeni alanlara yayılma riski taşır. Tohumla taşınma, ana yayılma yollarından biridir. Patojen, toprakta yıllarca hayatta kalabilir ve tarım makineleri, ekipmanlar veya su akışı gibi doğal güçlerle taşınan kontamine toprak aracılığıyla yayılabilir (Davidson ve ark., 2007). Kazara giriş, patojenin hayatta kalma yetenekleri ve yayılma yollarının çeşitliliği nedeniyle büyük endişelere yol açabilir, özellikle de patojenin bulunduğu bölgelerden mercimek tohumları veya tarım ekipmanları ithal eden alanlarda (Morrall ve Sheard, 1981). Posta yoluyla ve çevrimiçi tohum satışı yapan artan eğilim, fitosaniter önlemler yetersizse, ortaya çıkan bir risk olarak değerlendirilmektedir.

Şu anda, *F. oxysporum* f.sp. *lentis* birçok ülkede, özellikle Kanada ve Avustralya'da, girişini ve yerleşmesini engellemek amacıyla karantina zararlısı olarak listelenmiştir (Correl, 1991; Erskine ve Bayaa, 1996; Davidson ve ark., 2007; Wu ve ark., 2015).

Belirtiler ve Yaşam Döngüsü

Patojen, hem fide hem de olgun bitki evrelerini etkiler. Fide solgunluğu, aniden başlar, ardından yaprakların kuruması ve fide ölümüne yol açar. Bazı durumlarda, kökler sağlıklı görünür, ancak köklerin çoğalması ve nodül oluşumu azalır ve genellikle vasküler sistemde içsel renk değişikliği görülmez; ancak ksilem damarlarında kahverengi bir renk değişikliği

gözlemlenmiştir (Kumari ve ark., 2021). Olgun bitkilerde solgunluk belirtileri, çiçeklenme döneminden geç son bakla dolumuna kadar görülür ve etkilenen bitkinin üst yaprakçıklarının aniden sarkması, yaprakçıkların erken dökülme olmadan kapanması, soluk yeşil yapraklar ve ardından tüm bitkinin veya bireysel dalların solgunluğu ile karakterizedir. Orta bakla dolumundan geç bakla dolumuna kadar etkilenen bitkilerden alınan tohumlar genellikle buruşmuş olur (Beniwal ve ark., 1993).

Birincil inokulum, toprak ve/veya ürün kalıntılarındaki dayanıklı dinlenme sporları veya klamidosporlardan oluşur. Bu sporlar, tohum veya kök salgıları varlığında çimlenir ve fidelerin köklerine enfekte olur. Patojen, enfekte olmuş mercimek bitkilerinin kök sisteminde çoğalır, toprakta sekonder sporlar veya miselyum yoluyla bitkiden bitkiye yayılır ve sezon sonunda yeni klamidosporlar üretir. Kirlenmiş toprak ve organik madde, rüzgar ve su, tarım ekipmanları ve birçok diğer insan faaliyetleri ile yayılabilir.

Klamidosporlar, patojenin uzun süreli hayatta kalması için ana mantar yapılarıdır. Patojenin büyümesini etkileyen çeşitli faktörler araştırılmıştır (Vasudeva ve Srinivasan, 1952; Dhingrave ark., 1974; Khare, 1980; Saxena ve Khare, 1988; Erskineve ark., 1990).

Fungus büyümesi için optimum sıcaklık 22-27°C arasındadır. Düşük toprak nemi ve orta derecede yüksek toprak sıcaklıkları, semptomların ifade bulmasında anahtar faktörler gibi görünmektedir. Mercimek, kumlu tınlı topraklarda (%48) daha fazla zarar görmekte, kil topraklarda ise (%22) daha az zarar görmektedir ve toprak pH'ı 7.5'e kadar arttıkça bitki ölüm oranı artmaktadır, ancak bu seviyenin üzerinde azalmaktadır.

Epidemiyolojisi

Hastalık, ürünün erken büyüme evrelerinde (fide solması) Kasım ayında görülür ve bu durum, Aralık ve Ocak aylarında azalır. Çiçeklenme ve bakla doldurma aşamasında, Şubat ve Mart aylarında olgun bitki solması belirtileri ortaya çıkar (Vasudeva ve Srinivasan, 1952; Kannaiyan ve Nene, 1976). Suriye'de, solma yalnızca çiçeklenme ve bakla doldurma aşamasında (Nisan / Mayıs) görülmektedir. Hindistan'da, fide gelişim aşamasındaki sıcaklık yaklaşık 20°C iken, Suriye'de daha düşüktür ve bu, mantarın yavaş büyümesine neden olur (Erskineve ark., 1990). Bitki yaşı, mantar sporlarının çimlenmesini etkiler. Claudius ve Mehrotra (1973), 21 günlük fidelerin kök salgılarında, spor çimlenmesi üzerinde inhibe edici etkisi olan glisin ve fenilalanin bulunduğunu bulmuşlardır.

Ekonomik Etkisi

Fusarium solgunluğu, özellikle sıcak bir ilkbahar ve kuru, sıcak bir yazda tam verim kaybına yol açabilen önemli bir mercimek hastalığıdır (Izquierdo ve Morse, 1975; Bayaave ark., 1986; Agrawalve ark., 1993). Baraimer ve Izquierdo (1977), *F. oxysporum* enfeksiyonunun, test edilen çeşide bağlı olarak %25-95 arasında değişen bir oran gösterdiğini bulmuşlardır. Üreme büyümesi sırasında solgunluk insidansı, verim kaybı tahminleriyle ilişkilendirilmiş olup, kuzey Suriye'deki birim değişim başına tohum verimi kaybı %0,846 + 0,118 olarak tespit edilmiştir. Laboratuvar ortamında, hastalık reaksiyonu inokulum yoğunluğu ile pozitif bir korelasyon

göstermiştir (Erskine ve Bayaa, 1996). Saha koşullarında, inokulum yoğunluğu, duyarlı mercimeklerde hastalık insidansı ile ilişkilendirilmemiş olup, bu durum, hastalık insidansının inokulum yoğunluğundan tahmin edilmesi olasılığını ortadan kaldırmıştır.

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SONUÇ

Fusarium oxysporum f.sp. *lentis* (Fol) üzerine önemli ilerlemeler kaydedilmiş olsa da, hâlâ bazı bilgi eksiklikleri ve araştırma gereksinimleri bulunmaktadır. Bunların başında, farklı mercimek yetiştirme bölgelerinde Fol patojenlerinin genetik çeşitliliği ve popülasyon yapısı hakkındaki bilgilerin sınırlı olması gelir; bu özellikler patojenin virulansı ve uyum yeteneğini etkileyebilir.

Farklı mercimek genotipleri ile patojenin etkileşimini anlamaya yönelik daha fazla çalışmaya ihtiyaç vardır; özellikle dayanıklı çeşitlerin geliştirilmesi bağlamında bu araştırmalar önemlidir. Ayrıca, hastalık salgınlarını tetikleyen çevresel faktörler ile Fol'un farklı toprak tipleri ve iklimlerde uzun süreli hayatta kalma yeteneği hakkında da bilgiler yetersizdir ve bu konuda araştırmalara açıktır.

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METHODS OF FIGHTING AGAINST WILT AND ROOT DISEASE IN LENTIL

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ABSTRACT

Legumes (Fabaceae) are one of the three main plant groups in human nutrition, along with cereals and oilseeds. 22% of the plant protein in human nutrition and 38% of the protein in animal nutrition in the world are provided by edible grain legumes. Lentils (*Lens culinaris* Medik) have an important place in human nutrition with the protein (20-30%) and minerals they contain, and in animal nutrition with their straw. Lentils, produced as grains, are a rich source of protein, vitamins and fiber, and also contain micronutrient elements such as iron, zinc and magnesium. The low yield of lentils is due to many agronomic, physiological and biological factors. The most important factors limiting lentil cultivation and yield are economic losses caused by diseases, pests and weeds. One of the main reasons for these losses is diseases caused by fungal plant pathogens. Among the soil pathogens in question, species belonging to the genera Fusarium, *Rhizoctonia*, *Botrytis*, *Macrophomina*, *Alternaria*, *Pythium*, *Phoma*, *Sclerotinia* and *Colletotorichum* frequently occur. Soil-borne root and root collar diseases in lentils vary depending on climate conditions, production techniques and soil structure. Fungal disease agents cause many symptoms in lentil plants such as damping-off, root and root collar rot, wilt, blight, leaf spot and seed rot. Fungal diseases cause a decrease in yield as a result of damage to roots, leaves, stems and pods as a result of infection of lentil plants. It is also known that these diseases cause a decrease in yield as well as deterioration in seed quality. It is quite difficult to combat soil pathogens, and mostly cultural measures, resistant variety cultivation, rotation and some fungicide applications can control the disease. Since there is no fully effective method in combating lentil root rot and wilt disease caused by soil-borne pathogens, it is quite difficult to combat. It is known that the success rate of applications such as soil solarization, induced resistance, adjustment of planting date and depth, use of plant extracts, use of disease-free and fungicide-treated seeds is limited. Although the use of resistant varieties is the most effective and economical method, the diversity of pathogenic species and their pathogenicity makes it difficult to control this disease. In our country, there is no licensed plant protection

product against soil pathogens that cause disease in lentils. In other countries, the effectiveness of different biological agents, plant extracts, biological agent-fungicide combinations and different active substances has been investigated in this regard and it has been determined that some biological agents and fungicides are effective. Within the scope of this review, studies on combating soil-borne pathogen species that attack lentil plants are presented in detail based on the literature.

Keywords: Biological control, Control, Fungicide, *Lens culinaris*, Soilborne

MERCİMEKTE SOLGUNLUK VE KÖK ÇÜRÜKLÜK HASTALIĞINA KARŞI MÜCADELE OLANAKLARI

ÖZET

Baklagiller (Fabaceae), insan beslenmesinde tahıllar ve yağlı tohumlarla birlikte 3 temel bitkisel gruptan birisidir. Dünyada insan beslenmesindeki bitkisel proteinin %22'si, hayvan beslenmesindeki proteinin de %38'i yemeklik tane baklagillerden sağlanmaktadır. Mercimek (*Lens culinaris* Medik), içerdiği protein (%20-30) ve mineral maddeler ile insan beslenmesinde ve samanı ile hayvan beslenmesinde önemli bir yer tutmaktadır. Tane olarak üretilen mercimek zengin bir protein, vitamin ve lif kaynağı olmakla beraber, aynı zamanda demir, çinko, magnezyum gibi mikro besin elementlerini de içermektedir. Mercimek veriminin düşük olması birçok agronomik, fizyolojik ve biyolojik faktörlerden kaynaklanmaktadır. Mercimek yetiştiriciliğini ve verimini sınırlayan en önemli faktörler, hastalık, zararlı ve yabancı otların neden olduğu ekonomik kayıplardır. Bu kayıpların temel sebeplerinden birisi, fungal bitki patojenlerinin oluşturduğu hastalıklardır. Söz konusu toprak patojenleri arasında *Fusarium, Rhizoctonia, Botrytis, Macrophomina, Alternaria, Pythium, Phoma, Sclerotinia* ve *Colletotorichum* cinsine bağlı türler sıklıkla ortaya çıkmaktadır. Mercimekte toprak kaynaklı kök ve kök boğazı hastalıkları iklim şartları, üretim teknikleri ve toprak yapısına bağlı olarak değişkenlik göstermektedir. Fungal hastalık etmenleri mercimek bitkisinde, çökerten, kök ve kök boğazı çürüklüğü, solgunluk, yanıklık, yaprak leke ve tohum çürüklüğü gibi birçok belirti oluştururlar. Fungal hastalıkların mercimek bitkilerini enfeksiyonu sonucu kök, yaprak, gövde ve baklalarda meydana gelen zarar sonucunda verimde azalmaya neden olmaktadır. Ayrıca bu hastalıkların verim azalmasının yanı sıra tohum kalitesinin bozulmasına da neden olduğu da bilinmektedir. Toprak patojenleri ile mücadele oldukça zor olup, daha çok kültürel önlemler, dayanıklı çeşit yetiştirme, münavebe ve bazı fungisit uygulamaları, hastalığı kontrol altına alabilmektedir. toprak kökenli patojenlerin neden olduğu mercimek kök çürüklüğü ve solgunluk hastalığı ile mücadelede tam olarak etkili bir yöntem olmadığından mücadelesi oldukça zordur. Toprak solarizasyonu, uyarılmış dayanıklılık, ekim tarihi ve derinliğinin ayarlanması, bitki ekstraktlarının kullanımı, hastalıktan ari ve fungusit uygulanmış tohum kullanımı gibi uygulamaların başarı oranının ise sınırlı olduğu bilinmektedir. Dayanıklı çeşit kullanımı en etkili ve ekonomik yöntem olmasına rağmen, patojen türler ve bunların patojenisitelerindeki çeşitlilik bu hastalığın kontrolünü güçleştirmektedir. Ülkemizde, mercimekte hastalık yapan toprak patojenlerine karşı, ruhsatlı bir bitki koruma ürünü bulunmamaktadır. Diğer ülkelerde bu konuda farklı biyolojik ajanlar, bitkisel ekstraktlar, biyolojik ajan-fungusit kombinasyonu ve farklı aktif maddelerin etkinlikleri araştırılmış ve bazı biyolojik ajanların ve fungisitlerin etkili olduğu belirlenmiştir. Bu derleme kapsamında mercimek bitkisine arız olan toprak kökenli patojen türleri ile mücadeleye yönelik çalışmalar literatür temel alınarak detaylı bir şekilde ortaya konulmuştur.

Anahtar Kelimeler: Biyolojik mücadele, Fungisit, *Lens culinaris*, Mücadele, Toprak kaynaklı

1. GİRİŞ

Mercimek (*Lens culinaris* Medikus subsp. *culinaris*), serin iklimde yetişen, diploid (2n = 2X = 14) ve kendi kendine döllenen bir baklagildir ve genom büyüklüğü yaklaşık olarak 4 Gbp'dır (Arumuganathan ve Earle, 1991). Yakın Doğu'da ortaya çıkan bu eski tarım bitkisi, hızla Akdeniz Havzası, Orta Asya ve daha sonra Yeni Dünya, özellikle Latin Amerika'ya yayılmıştır. Mercimek, yaklaşık 10.000 yıl önce evcilleştirilen en eski baklagillerden biridir (Ladizinsky, 1972; Cubero, 1981; Duke, 1981). Mercimek üretimi ve tüketimi 100'den fazla ülkede yapılmaktadır. Dünya genelindeki toplam mercimek üretimi, yaklaşık 4.8 milyon ton olup, bu üretim 4.5 milyon hektarlık bir alan üzerinde yapılmakta ve ortalama verim 0.11 t/ha'dır (FAO, 2015). Yetiştirilen *L. culinaris* subsp. *culinaris*, iki fizyo-morfolojik mercimek tipini içermektedir: küçük tohumlu (microsperma) ve büyük tohumlu (macrosperma) (Barulina, 1930). Mercimek, soğuk mevsim gıda baklagillerinin arasında nohut ile birlikte en besleyici baklagillerden biri olarak kabul edilmektedir. Mercimek, %57–60 karbonhidrat, %24–26 protein, %3.2 lif ve %1.3 lif içermektedir. Ayrıca, 100 g tohum başına 69 mg kalsiyum, 300 mg fosfor ve 7 mg demir içeren zengin bir mineral kaynağıdır (Ali ve Mishra, 2000; Erskine ve Sarker, 2004). Mercimek tohumu, sadece tahıl proteinlerinde düşük seviyelerde bulunan bir temel amino asit olan lizin içerir. Mercimek, genellikle kuru tohumlar olarak tüketilen ve yem olarak kullanılan değerli bir insan gıdası olup, genellikle toprak sağlığını zenginleştirme amacıyla tahıllardan sonra ekim nöbeti olarak yetiştirilir, çünkü azot bağlama yeteneği vardır (Duran ve ark., 2004). Güneydoğu Asya'da mercimek, çoğunlukla yağış sonrası kalan toprak neminden yararlanılarak kuru koşullarda yetişmektedir. Mercimek, ekim nöbetine dahil edildiğinde, biyolojik azot bağlama ve karbon tutma yoluyla toprak sağlığını iyileştirerek sonraki ekimlerin fayda sağlamasına yardımcı olabilir. Bitkiler tarafından bağlanan azot miktarı, 0 ila 192 kg toplam N/ha arasında değişmekte olup, ortalama 80 kg toplam N/ha'dır (Quinn, 2009). Bu azot bağlama tahmini, nohut ve kuru fasulye tarafından bağlanan miktarlara benzerlik göstermektedir.

1970'lerden bu yana, ulusal ve uluslararası mercimek programlarında fenolojik olarak adapte olmuş, strese dayanıklı ve yüksek verimli çeşitlerin geliştirilmesinde önemli başarılar elde edilmiştir (Sarker ve Erskine, 2006). Son 30 yıl içinde, farklı ulusal tarım sistemleri, Uluslararası Kurak Alan Tarımsal Araştırmalar Merkezi (ICARDA) tarafından geliştirilen genetik kaynaklardan 90'dan fazla geliştirilmiş çeşit yayımlamıştır (Sarker ve Erskine, 2006). Bu nedenle, bu derleme, hastalık yönetimindeki geçmiş başarıları, patojen çeşitliliğini ve Fusarium solgunluğunu yönetme konusundaki eksiklikleri inceleyerek mercimek üretiminin ve verimliliğinin artırılmasını hedeflemektedir.

Kimyasal mücadele

Dünyanın farklı bölgelerinde, *Fusarium oxysporum* f. sp. *lentis*'e (Fol) karşı çeşitli fungisitler test edilmiştir. Çalışmalar, sistemik fungisitlerin, hem petri kabı hem de saksı tohum uygulamalarında, sistemik olmayan fungisitlere kıyasla fungus miselyum gelişimini engellemede daha etkili olduğunu ortaya koymuştur.

Benomyl (%76,6) patojene karşı en olumlu sonuçları göstermiştir; bunu thiophanate-methyl (%73,0) takip etmiştir. Öte yandan, sistemik olmayan fungisitlerden captan (%67,8) ve dithane M-45 (%62,3), fungus büyümesini azaltmada sistemik fungisitlere göre daha az etkili bulunmuştur (Rafique ve ark., 2016). Buna karşılık, Kasyap ve arkadaşları (2008), captan ile uygulanan tedavinin fungus büyümesini %88,3 oranında azalttığını bildirmiştir (Kasyap ve ark., 2008).

Maheshwari ve arkadaşları (2008), Fol'e karşı yedi farklı fungisit maddesinin etkisini test etmiştir. Sonuçlar, carbendazim'in en etkili madde olduğunu (5,6 mm fungus büyümesi) ve bunu captan (9,9 mm) ile hexaconazole ve diniconazole'un takip ettiğini göstermiştir.

Fungisitlerin farklı konsantrasyonlarının etkilerini belirlemek için yapılan çeşitli çalışmalarda, en iyi fungus kontrolünün benomyl ile 100 ppm'de sağlandığı, ardından yine 100 ppm konsantrasyonda thiophanate-methyl'in geldiği rapor edilmiştir (Rafique ve ark., 2016; Maitlo ve ark., 2014). Ancak, Suriye'de yapılan bir çalışmada, benomyl-thiram ile tohum ilaçlamasının, Fusarium solgunluğu insidansını etkilemediği bildirilmiştir (Ahmed ve ark., 2002).

Biyolojik Mücadele

Biyolojik mücadele, toprak kaynaklı patojenlere karşı en iyi ve etkili yöntemlerden biri olarak bilinmektedir. Bu yöntemin pek çok avantajı vardır: çevre dostu, maliyet açısından uygun ve uzun süreli bitki koruması sağlar. *Pseudomonas, Trichoderma* ve *Streptomyces* gibi birçok fungus ve bakteri türü, mercimekte Fusarium solgunluğu üzerinde antagonist (baskılayıcı) etkiye sahiptir. Bunlar arasında Trichoderma türleri, toprak ve tohum kaynaklı hastalıklara karşı biyolojik kontrol ajanı olarak yoğun şekilde kullanılmaktadır (Rafique ve ark., 2016).

Bir çalışmada, *Gliocladium virens* + *Pseudomonas fluorescens* + carboxin ve *Bacillus subtilis* + carboxin + *Trichoderma harzianum* / *T. viride* / *G. virens* kombinasyonlarıyla yapılan tohum ilaçlamalarının, mercimekte Fusarium solgunluğu insidansını azaltmada daha etkili olduğu ortaya konmuştur (Shrestha ve ark., 1991; De ve Chaudhary, 1999).

Başka bir çalışmada, mercimek solgunluğuna neden olan yüksek virülanslı bir Fusarium izolatına karşı iki Trichoderma türü kullanılmıştır. Sonuçlar, *T. harzianum*'un toprak sulama yöntemiyle uygulandığında diğer izolatlara kıyasla solgunluk hastalığını kontrol etmede çok daha etkili olduğunu göstermiştir (Rafique ve ark., 2016).

Garkoti ve ark. (2013), "Pant L-639" adlı popüler mercimek çeşidinin *T. harzianum* + *Pseudomonas fluorescens* kombinasyonu ile uygulandığında hastalık insidansında önemli bir azalma ve maksimum tane verimi sağlandığını gözlemlemiştir (Garkoti ve ark., 2013).

Benzer şekilde, *T. harzianum* + *Serendipita vermifera* kombinasyonunun, bitki boyunun artışıyla birlikte hastalık şiddetini azalttığı bildirilmiştir (Dolatabadi ve ark., 2012). Aynı şekilde, başka bir çalışmada mercimekte Fusarium solgunluğuna karşı *Bacillus subtilis*'in formülasyonu ve uygulanma yöntemi değerlendirilmiş; glikoz, talk ve torf bazlı *B. subtilis* formülasyonlarıyla yapılan tohum uygulamalarının, doğrudan spor uygulamasına göre

Fusarium'a karşı biyolojik kontrol etkinliğini önemli ölçüde artırdığı ortaya koyulmuştur (El-Hassan ve Gowen, 2006).

Ayrıca, çeşitli çalışmalar biyolojik mücadele ajanlarının bakteri (Krause ve ark., 2003), fungus (Lazarovits ve ark., 2001) ve nematod (Akhtar ve Malik, 2000) gibi bitki patojenlerinin neden olduğu hastalık insidansını azaltmadaki önemini de kanıtlamıştır.

Kültürel uygulamalar

Kültürel mücadele genellikle ekim tarihi ve derinliği ile tarımsal uygulamaların düzenlenmesine bağlıdır (Altaf ve ark., 2014; Alemu ve Sinclair, 1979).

Yapılan çalışmalarda, ekimin geciktirilmesinin solgunluk hastalığı görülme oranını genellikle azalttığı, ancak erken ekime (Temmuz sonu) kıyasla geç ekimin düşük verime yol açtığı bildirilmiştir (Seid ve ark., 1992).

Uygun ekim tarihleri farklı üretim bölgelerine göre değişmektedir. Temiz tohum kullanımı ve fungisitli tohum ilaçlaması, bulaşık inokulum kaynaklarının azaltılmasına yardımcı olabilir. Çeşitli hastalıklardan korunmak için, tohumların doğru derinlikte (10–12 cm) ekilmesi önerilmektedir (Asrat, 2015).

Derin sürüm yapılmasının ve enfekte olmuş bitki artıklarının tarladan uzaklaştırılmasının, mercimeklerde Fusarium solgunluğu inokulum düzeyini azaltabileceğini belirtmiştir (Haware, 1968).

Toprak solarizasyonu da hastalık şiddetini azaltmanın başka bir yoludur (Chauhan ve ark., 1988).

Mercimek solgunluk hastalığının kontrolü için kimyasal düzenleyiciler (Mn ve Zn) kullanımı ve yaprak uygulamaları da önerilmektedir.

Bir çalışmada, mercimek tohumlarının ıslatılması sonrası 80 ppm konsantrasyonda Zn ve Mn tuzlarının uygulanmasının, solgunluk hastalığının kontrolünde umut verici sonuçlar verdiği bildirilmiştir (Mehrotra ve Claudius, 1973).

Fusarium solgunluğuna dayanıklı çeşitler

Hastalığın yönetiminde, çok sayıda genetik kaynak (kültive edilmiş çeşitler ve yabani akrabalar) üzerinde hastalıklı tarla koşullarında ve serada değerlendirme yapılabilmesi için güvenilir ve tekrarlanabilir hastalık tarama tekniklerinin geliştirilmesidir.

Çeşit dayanıklılığı, şu anda Uluslararası Kurak Alanlar Tarımsal Araştırma Merkezi'nde (ICARDA) yürütülen mercimek ıslah programlarının temel hedeflerinden biridir.

Fusarium solgunluğuna dayanıklı çeşitlerin belirlenmesi için, hem tarla koşullarında hem de kontrollü ortamda (sera ve laboratuvar) tarama yapılması önerilmektedir (Kraft ve ark., 1994; Alessandro ve ark., 2006). Bazı önemli dayanıklı çeşitler; Suriye: 'Idleb 2', 'Idleb 3', 'Idleb 4' ve 'Ebla 1',Lübnan: 'Talya 2', 'Rachayya' ve 'Hala', Türkiye: 'Fırat 87' ve 'Seyran 96',

Etiyopya: 'Adaa', 'Alemaya', 'Assano', 'Alemtena' ve 'Teshale, İran: 'Kimiya, Irak: 'IPA 98 olarak bulunmuştur (Choudhary ve ark., 2013).

Hindistan'da ise, ulusal program kapsamında şu çeşitler Fusarium solgunluğuna dayanıklı olarak tescil edilmiştir: 'L 4147', 'Pant L 406', 'Pant L 4', 'Pant L 639', 'Priya', 'Seri', 'JL 3', 'Noori' ve 'VL 507' (Pandya ve ark., 1980; Singh ve ark., 1994; Rahman ve ark., 2009).

Mercimekte Solgunluk Hastalığı İçin Kullanılan Genetik Materyaller ve Yabani Türlerin Önemi

Yabani türler, hastalık direnci için çok değerli bir kaynak oluşturmaktadır. Mercimeğin yabani genetik kaynakları, ICARDA'da biyotik ve abiyotik streslere karşı direnç açısından değerlendirilmiştir (ICARDA, 1992). Yabani mercimek (*L. culinaris* ssp. *orientalis*) ile kültive edilen formlar arasında yapılan melezlemeler, kurak koşullarda yüksek verimli seleksiyonların geliştirilmesini sağlamıştır. Benzer şekilde, beş tür/alt türü temsil eden 221 çeşit taranmış ve Türkiye'den ILWL 113 (*L. culinaris* ssp. *orientalis*) ile Suriye'den ILWL 138 (*L. ervoides*) çeşitlerinin dirençli olduğu bulunmuştur (Bayaa ve ark., 1992).

Hindistan'da, dört yabani tür/alt türü temsil eden 70 çeşit değerlendirilmiş ve her türde Fol direnci için gen kaynakları belirlenmiştir. Mercimeğin yabani erişimleri arasında; *L. culinaris* ssp. *orientalis* (ILWL76, 1), *L. odemensis* (ILWLs 35, 39, 153, 237, 300, 5), *L. ervoides* (ILWLs 40, 41, 42, 133, 204, 251, 258, 261, 271, 280, 299, 11), *L. nigricans* (ILWLs 22, 26, 31, 37, 38, 430, 6) hastalık direnci için önemli yabancı gen kaynakları sağlayabilir (Gupta ve Sharma, 2006).

Fusarium Solgunluğuna Karşı Direncin Genetiği

Mercimekte Fusarium solgunluğunu kontrol etmenin en ekonomik yolu, dirençli çeşitlerin geliştirilmesidir (Kumar ve ark., 2010).

Yeni ırkların evrimi ve birden fazla patotipin birlikte bulunması nedeniyle dirençli çeşitler geliştirmek zorlaşmaktadır. Bu nedenle, solgunluk direncinin kalıtımı ve genetiği hakkında bilgi sahibi olmak, dirençli veya orta derecede dirençli çeşitlerin geliştirilmesi açısından önemlidir.

Fusarium solgunluğuna karşı direnç genetiği üzerine yapılan çalışmalar, daha dirençli mercimek çeşitlerinin üretilmesine yardımcı olacaktır (Eujayl ve ark., 1998).

Dirençli veya orta derecede dirençli mercimek çeşitleri (OPL 58, DPL 61 ve DPL 62) solgunluk görülme oranını ve kök çürüklüğü şiddetini önemli ölçüde azaltmış ve tane verimini artırmıştır (Chaudhary ve Amarjit, 2002). Ancak, mercimekte solgunluk direncinin genetiği ve kalıtım modeli üzerine yapılan çalışmalar oldukça sınırlıdır.

Bir araştırmada, mercimekte Fusarium solgunluğuna karşı direncin beş bağımsız gen tarafından kontrol edildiğini bildirmiştir (Kamboj ve ark., 1990).

Diğer bir araştırmacı ise 'ILL 5588' çeşidinde solgunluk direncinin monogenik (tek genle kontrol edilen) bir kalıtıma sahip olduğunu tespit etmiş ve bu geni 'Fw' olarak adlandırmıştır. Allelizm testi üzerine yapılan bir çalışmada, PL 234, JL 446 ve PL 286 çeşitlerinde, sırasıyla direnç sağlayan ikişer adet çift gen ve tamamlayıcı genler tanımlanmıştır (Eujayl ve ark., 1998).

Stevenson ve ark. (1995), bitki kök salgılarının ve genotiplerdeki direnç farklarının, kök salgılarının miktarına ve bu salgıların antifungal bileşiklerine bağlı olduğunu açıklamıştır.

Bir diğer çalışma, kök salgılarının toprakta önemli miktarda organik madde, amino asitler ve şekerler saldığını ve amino asitlerin (glisin ve fenilalanin) patojenin sporlarının çimlenmesi üzerinde inhibe edici bir etkiye sahip olduğunu göstermektedir (Claudius ve Merhotka, 1973).

Iftikhar ve ark. (2005), solgunluk direncinde antifungal bileşiklerin varlığını ve rolünü analiz etmiştir. Sonuçlar, fenolik bileşiklerin solgunluk hastalığına karşı direnç sağlamada önemli bir rol oynadığını göstermiştir, çünkü sadece solgunluğa karşı dirençli hatlar bu bileşiği üretmiştir. Benzer şekilde, diğer bir çalışmada, hatların fitoaleksin üretme potansiyelinin, fungus enfeksiyonlarına karşı dirençlerini etkilediği bildirilmiştir (Mohammadi ve ark., 2012; Stevenson ve ark., 1997).

Mercimek Solgunluğu İçin Entegre Yönetim

İki veya daha fazla hastalık yönetim seçeneğinin entegrasyonu, bitkiler üzerinde etkili olan herhangi bir hastalığın etkisini azaltabilir. Bu stratejiyi seçmenin beklenen faydası, hastalığın sürdürülebilir ve etkili bir şekilde kontrol edilmesidir. Biyolojik kontrol ajanlarının kimyasal kontrol ile kombinasyonu, bazı toprak kaynaklı hastalıkların kontrolünde bir strateji olarak işe yarayabilir. Bu nedenle, bazı araştırmacılar, *Bacillus megaterium*'in carbendazim ile kombinasyonunu kullanmış, bu kombinasyonun Fusarium taç ve kök çürüklüğünün etkin bir şekilde kontrolünü sağladığını ortaya koymuşlardır (Omar ve ark., 2006). Benzer şekilde, toprak düzenleyiciler ve biyolojik kontrol ajanları, örneğin *Trichoderma* spp. kombinasyonunun, hastalık kontrolünü ve tarımsal verimliliği artırdığı gösterilmiştir (Slusarski ve ark., 2012).

Günümüzde, toprak özelliklerini iyileştirmek, bitki sağlığını ve verimi artırmak amacıyla organik düzenleyicilerin kullanımı yaygınlaşmıştır (Gamliel ve Katan, 2009).

SONUÇ

Patojeniteyi DNA teknikleriyle ilişkilendirmek için standart bir anaç farklılık setine de ihtiyaç duyulmaktadır. Patojene karşı direnç için sağlam bir tarama tekniği de gereklidir. Anaç-patojen etkileşimi üzerine yapılan çalışmaların eksikliği nedeniyle, yönetim hâlâ belirsizdir ve bu alanda ek araştırmalara ihtiyaç vardır.

Markör destekli seleksiyon (MAS), bitki genotiplerini istenen özellik kombinasyonu ile seçme verimliliğini ve etkinliğini artırmak için büyük fırsatlar sunmaktadır. Markör destekli seleksiyonla, hastalık olmadan ve bitkinin erken gelişim aşamalarında hastalık direnci değerlendirilebilir. Ancak, mercimek ıslah programlarında markörlerin rutin kullanımının

uygulanması şu anda çok sınırlıdır; bu nedenle, teknolojinin maliyet etkin kullanımı sağlamak için markörlerin ıslah programlarına entegrasyonu gereklidir.

Yakın akraba baklagillerle yapılan karşılaştırmalı genomik ve sintezi analizleri, mercimek genomu hakkındaki bilgiyi artırmada önemli bir rol oynayabilir.

İleri düzey genomik araçlar, örneğin transkriptom profilleme ve harita temelli gen klonlaması uygulayabilmek için daha rafine genetik materyallere ihtiyaç duyulmaktadır.

Solgunluk direnci ve kuraklık toleransı olan genetik materyaller, bu ikincisinin Fusarium enfeksiyonuna yatkın hale getirmesi nedeniyle önemli bir odak alanıdır. Anaç bitki direncinin yanı sıra, Fusarium solgunluğunun entegre yönetimi, birçok ülkede Fusarium solgunluğunun verim kaybını daraltmak için oldukça önemlidir.

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DETERMINATION OF THE EFFECTS OF VERMICOMPOST AND REDUCED NUTRIENT SOLUTION APPLICATIONS ON PLANT GROWTH IN HYDROPONIC LETTUCE CULTIVATION

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ABSTRACT

The excessive use of chemical fertilizers leads to environmental problems by increasing CO_2 emissions and disrupting sustainable soil management, while also posing significant challenges to healthy food production. Therefore, the use of organic-based materials such as vermicompost in hydroponic systems is considered a promising alternative in terms of both sustainable agricultural practices and the production of healthy food. This study was conducted in a fully automated, geothermal-heated Venlo-type glass research greenhouse at Kırşehir Ahi Evran University, utilizing a hydroponic cultivation system. The aim of the research was to determine the effects of vermicompost application on plant growth in different lettuce (*Lactuca sativa* L.) cultivars grown with reduced nutrient solution levels. The plant materials used in the study were two lettuce cultivars: Kireve and Cherokee. The experimental treatments were as follows: (1) tap water only, (2) tap water + vermicompost, (3) 2 EC nutrient solution (dS m^{-1}), (4) 2 EC nutrient solution + vermicompost, (5) 1.5 EC nutrient solution + vermicompost, and (6) 1 EC nutrient solution + vermicompost. The plants were grown for 30 days in an aerated hydroponic system. After harvest, various morphological and physiological characteristics were evaluated, including leaf fresh and dry weight, root fresh and dry weight, head diameter, head height, number of leaves, leaf color parameters (L, a, b*), color saturation (chroma), hue angle, leaf chlorophyll a, chlorophyll b, total chlorophyll and total carotenoid contents, leaf sap EC and pH, soluble solid content, root length, root diameter, and root volume. According to the findings, the highest values for leaf and root fresh and dry weights were obtained from the treatment with 2 EC nutrient solution combined with vermicompost. It was observed that vermicompost application positively affected plant growth in both lettuce cultivars when applied with either tap water or different levels of nutrient solution. In conclusion, vermicompost application under hydroponic conditions not only promoted plant growth but

also contributed to reducing the use of chemical fertilizers, thereby lowering production costs. These results indicate that vermicompost can make a significant contribution to sustainable lettuce cultivation.

Keywords: Vermicompost, Lettuce, Hydroponic, Plant Growth

VERMİKOMPOST VE AZALTILMIŞ BESİN ÇÖZELTİSİ UYGULAMALARININ HİDROPONİK MARUL YETİŞTİRİCİLİĞİNDE BİTKİ GELİŞİMİ ÜZERİNE ETKİLERİNİN BELİRLENMESİ

ÖZET

Kimyasal gübrelerin aşırı kullanımı, CO_2 emisyonlarını arttırarak ve sürdürülebilir toprak yönetimini bozarak çevresel sorunlara yol açmanın yanı sıra, sağlıklı gıda üretimi açısından da önemli sorunlara sebep olmaktadır. Bu nedenle, vermikompost gibi organik kökenli maddelerin hidroponik sistemlerde kullanımı hem sürdürülebilir tarım uygulamaları hem de sağlıklı gıda üretimi açısından umut vadeden bir alternatif olarak değerlendirilmektedir. Bu çalışma, Kırşehir Ahi Evran Üniversitesi'ne ait tam otomasyonlu jeotermal ısıtmalı, venlo tip cam Ar-Ge serasında hidroponik yetiştirme tekniği kullanılarak yürütülmüştür. Araştırmanın amacı, vermikompost uygulamasının azaltılmış besin çözeltisi uygulanmış farklı marul (*Lactuca sativa* L.) çeşitlerinde bitki gelişimi üzerindeki etkilerini belirlemektir. Çalışmada bitkisel materyal olarak Kireve ve Cherokee marul çeşitleri kullanılmıştır. Denemede yapılan uygulamalar: (1) yalnızca çeşme suyu, (2) çeşme suyu + vermikompost, (3) 2 EC besin çözeltisi (dS/m) , (4) 2 EC besin çözeltisi + vermikompost, (5) 1.5 EC besin çözeltisi + vermikompost ve (6) 1 EC besin çözeltisi + vermikompost. Bitkiler, havalandırmalı durgun su kültüründe 30 gün boyunca yetiştirilmiştir. Hasat sonrası bitkilerde; yaprak taze ve kuru ağırlığı, kök taze ve kuru ağırlığı, baş çapı, baş boyu, yaprak sayısı, yaprak renk parametreleri (L*, a*, b*), renk doygunluğu (chroma), renk tonu (hue açısı), yaprak klorofil a, klorofil b, toplam klorofil ve toplam karotenoid içeriği, yaprak öz suyu EC, pH ve suda çözünür kuru madde miktarı, kök uzunluğu, çapı ve hacmi gibi çeşitli morfolojik ve fizyolojik özellikler belirlenmiştir. Elde edilen bulgulara göre, yaprak taze ve kuru ağırlığı ile kök taze ve kuru ağırlığı bakımından en yüksek değerler, 2 EC'lik besin çözeltisi + vermikompost uygulamasından elde edilmiştir. Vermikompost uygulamasının hem çeşme suyu hem de farklı dozlarda besin çözeltisi ile kullanıldığında her iki marul çeşidinde de bitki gelişimini olumlu yönde etkilediği belirlenmiştir. Sonuç olarak, su kültürü koşullarında vermikompost uygulaması hem bitki gelişimini teşvik etmekte hem de kimyasal gübre kullanımının azaltılmasına katkı sağlayarak maliyetleri düşürmektedir. Bu durum, sürdürülebilir marul yetiştiriciliği açısından vermikompostun önemli bir katkı sağlayabileceğini ortaya koymaktadır.

Anahtar Kelimeler: Vermikompost, Marul, Su Kültürü, Bitki Gelişimi

1.GİRİŞ

Marul (*Lactuca sativa* L.), Asteraceae familyasına ait yaprakları tüketilen ve serin iklim koşullarında yetiştirilen önemli bir sebze türüdür (Kim ve ark., 2016). Geniş kullanım alanına sahip olan bu bitki, özellikle taze tüketim amacıyla salatalarda tercih edilmekte olup, aynı zamanda çeşitli tıbbi alanlarda değerlendirilmektedir. Resmi olarak, marul grubunda Cos (Romanya), Butterhead, Leaf (Cutting), Stalk (veya Kuşkonmaz), Crisphead (Iceberg), Latin ve Oilseed olmak üzere yedi farklı tür vardır (Das ve Bhattacharjee, 2020). Üretim miktarları incelendiğinde Dünya'da 2023 verilerine göre toplam 28.084.971 ton marul üretimi yapılmıştır (FAO, 2023). Türkiye'de ise 602.848 ton marul üretimi yapılmıştır (TÜİK, 2023). Marul, %94-95 oranında zengin su içeriğine sahip ve kalorisi düşük bir sebzedir. Ayrıca polifenoller, karotenoidler ve klorofil gibi sağlık için yararları olan vitaminler, mineraller ve biyoaktif bileşiklerin mükemmel bir kaynağıdır (Yang ve ark., 2022). Marulda renk, şekil ve içerdiği besin maddelerinin farklılığı, tüketicinin satın alma tercihini etkileyen faktörlerdir (Mampholo ve ark., 2016).

Günümüzde artan nüfusla birlikte, gıda ihtiyacını karşılayabilmek amacıyla birim alandan elde edilen verimin artırılması zorunlu hale gelmiştir. Ancak bu üretim artışı gerekliliği, aynı zamanda tarımsal üretimde birim alanda daha fazla inorganik gübre kullanımını da gerekli kılmaktadır. Aşırı ve bilinçsiz inorganik gübre uygulamaları ise toprak ve su gibi doğal kaynakların kirlenmesine neden olmakta; bu durum hem çevresel bozulmalara yol açmakta, hem de insan sağlığı açısından ciddi riskler oluşturmaktadır (Adiloğlu ve ark., 2018). Ayrıca kimyasal gübrelerin aşırı kullanımı, CO_2 emisyonunun artmasına ve toprak bozulması gibi çevreyi etkileyen sorunları ortaya çıkarmaktadır (Manthiram ve Gribkoff, 2021). Diğer taraftan, artan nüfus ekolojik olarak istikrarlı gıda üretiminin genişletilmesi sorununu da beraberinde getirmektedir. Topraksız tarım, toprak bozulması, sınırlı su temini sorunlarını ele alma ve zararlıları ve hastalıkları azaltma kapasitesine sahiptir. Ayrıca tarımsal üretimde sürdürülebilirliği teşvik eden önemli bir çözüm yoludur (Sambo ve ark., 2019). Hidroponik tarım, toprak kullanımının yerine, bitkilerin gereksinim duyduğu mineral elementleri içeren besin çözeltisinin kullanıldığı alternatif bir üretim tekniğidir. Kalite özellikleri hasat öncesi ve sonrası uygulamalardan yoğun şekilde etkilenen yaprağı tüketilen sebzelerin yetiştiriciliğinde hidroponik sistemler yaygın olarak tercih edilmektedir (Resh, 2022). Daha da önemlisi, hidroponik sistemde yetiştirilen marul gibi sebzeler, fide gelişimi ve bitki büyümesi açısından yüksek düzeyde homojenlik göstermekte olup, bu durum ekim ve hasat zamanlarının tekdüze hale gelmesini sağlamaktadır (Gonnella ve ark., 2003). Her ne kadar hidroponik tarım, geleneksel topraklı üretime kıyasla modern ve kontrollü bir alternatif olarak değerlendirilse de, bu sistemde yaygın olarak kullanılan inorganik gübreler, çevresel sürdürülebilirlik ve gıda güvenliği açısından çeşitli zorlukları da beraberinde getirmektedir (De Castro ve ark., 2023). Bu bağlamda, solucan gübresi gibi sürdürülebilir kaynaklardan elde edilen organik besin maddelerini içeren hidroponik sistemlerin uygulanması, mevcut eksikliklerin giderilmesinde ve sağlıklı gıda üretimi açısından sürdürülebilir çözümler geliştirilmesinde önemli bir anahtar olarak öne çıkmaktadır (Tejada ve ark., 2010). Bu araştırmanın amacı, solucan gübresi (vermikompost) uygulamasının, azaltılmış düzeyde besin çözeltisi ile yetiştirilen farklı marul (*Lactuca sativa* L.) çeşitlerinde bitki gelişimi üzerine etkilerini belirlemektir.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Denemede bitkisel materyal olarak Rijk Zwaan tohum şirketine ait Kireve (Orta yeşil renkli palamut yaprak marul çeşidi) ve Cherokee (Parlak üçlü kırmızı renge sahip batavia marul çeşidi) marul çeşitleri kullanılmıştır.

2.2. Metot

Deneme, Kırşehir Ahi Evran Üniversitesi'nin tam otomasyonlu (fan-ped soğutma, yüksek basınçlı sisleme, ısı perdesi, sirkülasyon fanı ve jeotermal ısıtmalı) venlo tipi cam Ar-Ge serasında yürütülmüştür. Tohumlar 2:1 oranında torf ve perlit karışımı doldurulmuş 128'lik insertlere 05/01/2025 tarihinde ekilmiştir. Fideler 4-5 gerçek yaprak aşamasına kadar serada rutin bakım işlemleri yapılarak yetiştirilmiştir. Dikim aşamasına gelen fideler 136 lt'lik besin solüsyonu doldurulmuş plastik saksılara 13/02/2025 tarihinde dikilmiştir. Saksıların üst yüzeyi kompozit levha ile kapatılmış ve bitkiler sıra arası ve sıra üzeri eşit ayarlanmış kompozit üzerindeki deliklere yerleştirilmiştir. Yetiştirme solüsyonu bir hava pompası ile düzenli olarak havalandırılmıştır. Bitkilerin yetiştirildiği besin solüsyonu içeriği; 1500 µM $Ca_2(NO_3)$, 750 µM K_2SO_4, 650 µM $MgSO_4$, 500 µM KH_2PO_4, 10 µM H_3BO_3, 0,5 µM $MnSO_4$, 0.5 µM $ZnSO_4$, 0.4 µM $CuSO_4$, 0.4 µM $MoNa_2O_4$ ve 80 µM Fe EDDHA içerecek şekilde hazırlanmıştır. Her bir saksıda 10 adet bitki yetiştirilmiştir. Dikimden sonra vermikompost uygulaması olan her saksıya sıvı vermikompostan 250 ml eklenmiştir. Deneme 12/03/2025 tarihinde sonlandırılmıştır. Çalışmadaki uygulamalar Tablo 1'de verilmiştir.

Tablo 1. Çeşme suyu, besin çözeltisi (dS/m) ve sıvı solucan gübresi uygulamaları.

Çeşme Suyu
Çeşme Suyu + Vermikompost
2 EC'lik Besin Çözeltisi
2 EC'lik Besin Çözeltisi + Vermikompost
1.5 EC'lik Besin Çözeltisi + Vermikompost
1 EC'lik Besin Çözeltisi + Vermikompost

2.3. Denemede Yapılan Ölçümler

Hasattan sonra kök ve yaprak taze ağırlıkları (g/bitki) 0.01 hassasiyetindeki dijital terazi ile belirlenmiştir. Kuru ağırlıkları belirlemek amacıyla kök ve yaprak örnekleri, sabit ağırlığa ulaşıncaya kadar 65°C'lik etüvde kurutulup ölçülmüştür. Baş boyu ve baş çapı cetvel (cm) ile ölçülmüştür. Gövde çapı ise kumpas (mm) ile ölçülmüştür. Yaprak rengi ise Konica Minolta CR 200 renkölçer ile L, a ve b değerleri olarak ölçülmüştür. L, siyah: 0'dan beyaz: 100'a olacak şekilde rengin açıklık veya koyuluğunu, a ve b ise L'ye dik bir renk düzleminde rengi

belirlemektedir. Yatay eksende pozitif a kırmızıyı, negatif a yeşili; dikey eksendeki pozitif b sarıyı ve negatif b ise maviyi göstermektedir. Ölçülen temel 3 renk parametresi kullanılarak, bitki örneklerinde kroma ve hue açısı değerleri de hesaplanmıştır (Iqdiam ve ark., 2018). Deneme sonunda her bir bitkideki yapraklar sayılarak adet olarak toplam yaprak sayısı tespit edilmiştir. Marul yapraklarından elde edilen suyun elektriksel iletkenlik (EC) ve pH değerleri, Extech marka EC ve pH ölçer cihazı kullanılarak belirlenmiştir. Suda çözünmüş katı madde miktarı (SÇKM) ise Hanna HI96801 model dijital refraktometre ile ölçülmüştür. Bitkilerin kök uzunluğu, kök taze ağırlığı kaydedildikten sonra, WinRHIZO (Win/Mac RHIZO Pro V. 2002c, Regent Instruments Inc., Kan Win/Mac RHIZO Pro V. 2002c Regent Instruments Inc., Québec, QC G1V 1V4, Kanada) yazılım programı kullanılarak ölçülmüştür. Yaprak pigment düzeyini belirlemek amacıyla her uygulama için yapraklardan 1.5 cm çapında diskler alınıp 3 ml, %80'lik aseton içerisinden homojenize edilerek 24 saat bekletildikten sonra UV-Vis spektrofotometre de 470 nm, 648.6 nm ve 664.2 nm dalga boylarında ölçümler yapılmıştır. Yaprak klorofil (a, b ve toplam klorofil) ve karotenoid içerikleri, Lichtenthaler (1987), tarafından açıklanan formüller kullanılarak spektrofotometrik yöntemle belirlenmistir.

2.4. İstatistik Analiz

Su kültürü çalışmasında bitkilerden elde edilen veriler, %5 anlamlılık düzeyinde Minitab Statistical Software 22 (United Kingdom) programı kullanılarak analiz edilmiştir. Verilerin değerlendirilmesinde tek yönlü varyans analizi (ANOVA) uygulanmış ve ortalamalar arasındaki farklar Duncan çoklu karşılaştırma testi ile belirlenmiştir.

3.BULGULAR

Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitleri üzerine uygulamaların etkileri değerlendirilmiştir. Yaprak taze ve kuru ağırlığı bakımından en yüksek değer, 2 EC + vermikompost uygulanan 'Kireve' çeşidinde ölçülmüş; en düşük değer ise çeşme suyunda yetiştirilen aynı çeşitte tespit edilmiştir. Marul çeşitlerinde kök taze ağırlığı 36.67 ile 157.33 g arasında, kök kuru ağırlığının ise 5.45 ile 22.61 g arasında değiştiği belirlenmiştir (Tablo 2). Elde edilen veriler, önceki çalışmaların sonuçları ile uyumludur. Kibar (2018), marulda bitki yaş ve kuru ağırlığı bakımından vermikompost uygulamalarında, kontrol uygulamasına kıyasla daha yüksek değerler elde etmiştir. Benzer şekilde Papathanasiou ve ark. (2012), çalışmalarında bitkisel materyal olarak kullandıkları iki marul çeşidinin taze ağırlığının, vermikompost uygulamasında kontrol bitkilerinden daha yüksek olduğunu tespit etmişlerdir. Aynı zamanda tüm marul çeşitlerinde kök biyokütlesinin de vermikompost uygulaması ile artış gösterdiğini belirlemişlerdir.

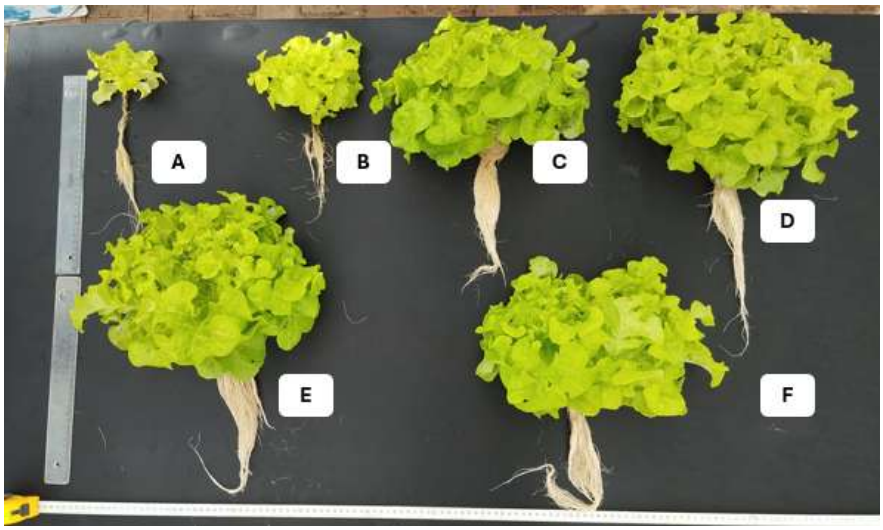
Tablo 2. Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitlerinde yaprak ve kök taze-kuru ağırlıkları üzerine etkileri

Çeşit	Uygulama	Yaprak Taze Ağırlığı (g)	Yaprak Kuru Ağırlığı (g)	Kök Taze Ağırlık (g)	Kök Kuru Ağırlık (g)
Kireve	Çeşme Suyu	8.87h	1.38h	36.67e	5.45e
Kireve	Çeşme suyu + Vermikompost	27.80g	4.11g	66.67de	10.24de
Kireve	2 EC Besin Çözeltisi	114.67bc	15.49bc	103.67bc	17.04bc
Kireve	2 EC Besin Çözeltisi +Vermikompost	148.57a	20.21a	157.33a	22.31a
Kireve	1.5 EC Besin Çözeltisi+Vermikompost	127.87b	17.34b	153.00a	22.61a
Kireve	1 EC Besin Çözeltisi +Vermikompost	91.03de	12.49de	117.00b	16.82bc
Cherokee	Çeşme Suyu	18.03gh	2.69gh	51.33de	10.20de
Cherokee	Çeşme suyu + Vermikompost	22.87gh	3.25gh	64.33de	10.15de
Cherokee	2 EC Besin Çözeltisi	90.87de	12.47de	116.67b	16.99bc
Cherokee	2 EC Besin Çözeltisi +Vermikompost	104.83cd	14.22cd	128.33ab	18.74ab
Cherokee	1.5 EC Besin Çözeltisi +Vermikompost	85.67e	11.68e	99.00bc	15.99bc
Cherokee	1 EC Besin Çözeltisi +Vermikompost	69.90f	9.59f	81.00cd	12.33cd
	p değeri	***	***	***	***

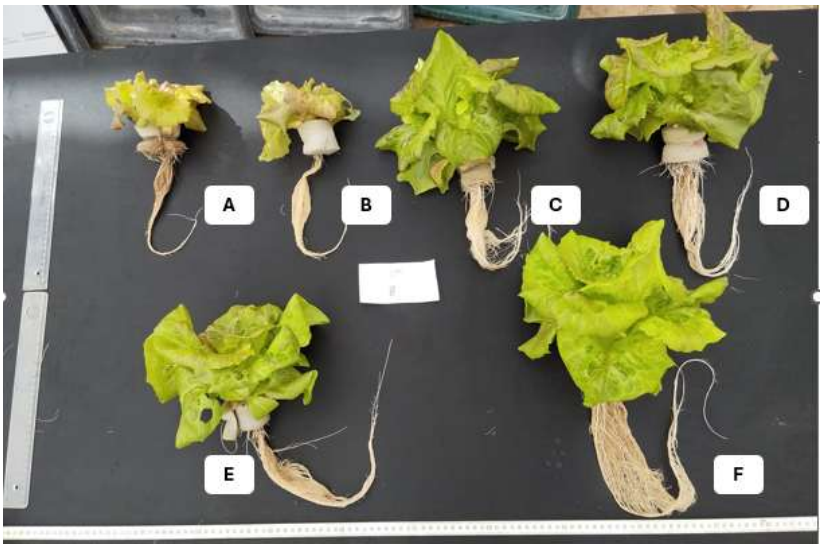
İncelenen parametreler sonucunda gövde çapı en yüksek 'Kireve' ve 'Cherokee' çeşitlerine uygulanan 2 EC besin çözeltisi ve 2 EC besin çözeltisi + vermikompost uygulamalarında belirlenirken, en düşük ise her iki çeşitte de çeşme suyunda yetiştirilen bitkilerde belirlenmiştir (Tablo 3). Baş boyu bakımından ise en yüksek değerler 'Kireve' çeşidine uygulanan sırasıyla; 1.5 EC + vermikompost ve 2 EC + vermikompost uygulamalarında ölçülmüştür (Şekil 1). Baş çapı, 11.50 ile 31.61 mm arasında değişmiştir. En yüksek yaprak sayısı 2 EC besin çözeltisi ve 2 EC + vermikompost uygulanan 'Kireve' çeşidinde saptanırken, en düşük değer ise çeşme suyu uygulanan 'Cherokee' çeşidinde saptanmıştır (Şekil 2). Kibar (2018), marulda bitki boyu 16.0-30.0 cm, bitki çapı 20.5-36.5 cm arasında değiştiğini tespit etmiştir. Gutiérrez-Miceli ve ark. (2007), çalışmalarında toprağa %33 (1/3) ve %25 (1/4) oranlarında uygulanan vermikompostun, domates bitkilerinde bitki boyu, gövde çapı ve bitki başına yaprak sayısı gibi büyüme parametrelerinde anlamlı artışlara neden olduğunu tespit etmişlerdir.

Tablo 3. Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitlerinde gövde çapı, baş boyu, baş çapı ve yaprak sayısı üzerine etkileri

Çeşit	Uygulama	Gövde Çapı (mm)	Baş Boyu (cm)	Baş çapı (cm)	Yaprak Sayısı (adet)
Kireve	Çeşme Suyu	4.59f	10.50d	11.50f	14.00b
Kireve	Çeşme Suyu+Vermikompost	7.27de	13.67c	20.23e	15.67b
Kireve	2 EC Besin Çözeltisi	12.39a	21.10a	28.53a-c	24.67a
Kireve	2 EC Besin Çözeltisi +Vermikompost	12.22a	20.77ab	29.67ab	24.67a
Kireve	1.5 EC Besin Çözeltisi+Vermikompost	10.45ab	21.17a	31.67a	23.33a
Kireve	1 EC Besin Çözeltisi +Vermikompost	8.02cd	20.57ab	28.93ab	22.67a
Cherokee	Çeşme Suyu	4.94f	12.77cd	15.33f	10.67b
Cherokee	Çeşme Suyu+Vermikompost	5.35ef	12.63cd	14.27f	11.33b
Cherokee	2 EC Besin Çözeltisi	10.95ab	20.77ab	22.97de	15.33b
Cherokee	2 EC Besin Çözeltisi +Vermikompost	12.05a	20.17ab	25.77b-d	14.33b
Cherokee	1.5 EC Besin Çözeltisi +Vermikompost	11.96a	20.87ab	24.10c-e	15.00b
Cherokee	1 EC Besin Çözeltisi +Vermikompost	9.53bc	18.00b	22.00de	12.00b
	p değeri	***	***	***	***



Şekil 1. Kireve marul çeşidine uygulanmış; çeşme suyu (A), çeşme suyu + vermikompost (B), 2 EC besin çözeltisi (C), 2 EC besin çözeltisi + vermikompost (D), 1.5 EC besin çözeltisi + vermikompost (E) ve 1 EC besin çözeltisi + vermikompost (F) görselleri.



Şekil 2. Cherokee marul çeşidine uygulanmış; çeşme suyu (A), çeşme suyu + vermikompost (B), 2 EC besin çözeltisi (C), 2 EC besin çözeltisi + vermikompost (D), 1.5 EC besin çözeltisi + vermikompost (E) ve 1 EC besin çözeltisi + vermikompost (F) görselleri.

Yaprak renginin açıklık-koyuluğunu ifade eden L değeri, 'Kireve' çeşidinde tüm uygulamalar arasında istatiksel olarak fark görülmezken, 'Cherokee' çeşidinde en yüksek L değeri çeşme suyu + vermikompost uygulamasında belirlenmiştir (Tablo 4). Yeşili ifade eden negatif a değeri ise en yüksek 2 EC besin çözeltisi uygulanan 'Kireve' çeşidinde tespit edilmiştir. Sarıyı ifade eden pozitif b değeri 23.19 ile 44.95 arasında değişmiştir. Chroma (renk canlılığı) açısından en yüksek değere 'Kireve' 2 EC (51.55) uygulamasında ölçülmüş, 'Cherokee' çeşitlerinde ise renk doygunluğu genel olarak daha düşük çıkmıştır. En düşük Chroma değerleri Cherokee 2 EC + Vermikompost (26.95) ve 'Cherokee' çeşme Suyu (28.73) uygulamalarında tespit edilmiştir. Hue açısı (renk tonu açısı) incelendiğinde ise en yüksek değer 'Cherokee' 2 EC + Vermikompost (120.49) ve 'Kireve' 1 EC + Vermikompost (120.07) uygulamalarında elde edilmiştir. Bu da renk yöneliminin yeşil-sarı arasında daha sarıya yakın olduğunu göstermektedir. Genel olarak değerlendirildiğinde, 'Kireve' çeşidinde EC ve vermikompost uygulamaları renk parametreleri açısından daha yüksek parlaklık, daha yeşil tonlar ve daha canlı renkler oluştururken, 'Cherokee' çeşidinde ise renk doygunluğu ve parlaklık seviyeleri daha düşük kalmıştır. Bu durum, uygulamaların sadece büyüme ve verim üzerinde değil, görsel kalite parametreleri üzerinde de etkili olduğunu göstermektedir (Tablo 4). Bulgularımıza benzer şekilde Korkmaz ve Akıncı (2023), çalışmalarında vermikompostun L, a ve b değerleri üzerine etkisi olduğunu bildirmişlerdir.

Tablo 4. Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitlerinde yaprak rengi (L, a ve b), chroma açısı ve hue açısı üzerine etkileri

Çeşit	**Uygulama**	**L**	**a**	**b**	**Chroma (C)**	**Hue açısı**
Kireve	Çeşme Suyu	60.17a	-20.27d-f	40.15a-c	44.98a-c	116.79a
Kireve	Çeşme Suyu+Vermikompost	64.30a	-23.8ef	44.21a	50.10a	118.09a
Kireve	2 EC Besin Çözeltisi	61.60a	-25.23f	44.95a	51.55a	119.30a
Kireve	2 EC Besin Çözeltisi +Vermikompost	60.07a	-24.62ef	43.99a	50.41a	119.24a
Kireve	1.5 EC Besin Çözeltisi + Vermikompost	60.09a	-23.77ef	43.03a	49.16a	118.94a
Kireve	1 EC + Besin Çözeltisi Vermikompost	61.36a	-23.47ef	40.67ab	46.96ab	120.07a
Cherokee	Çeşme Suyu	52.98a-c	-6.07a	28.06d	28.73d	102.02c
Cherokee	Çeşme Suyu+Vermikompost	56.11ab	-11.52ab	32.39b-d	34.40cd	109.44b
Cherokee	2 EC Besin Çözeltisi	54.97a-c	-18.36c-e	32.14b-d	37.03b-d	119.48a
Cherokee	2 EC Besin Çözeltisi +Vermikompost	43.73c	-13.61bc	23.19d	26.95d	120.49a
Cherokee	1.5 EC Besin Çözeltisi +Vermikompost	52.57a-c	-17.07b-d	30.51cd	34.96cd	119.23a
Cherokee	1 EC Besin Çözeltisi +Vermikompost	44.98b-c	-12.27a-c	25.72d	28.50d	115.50a
p değeri		***	***	***	***	***

Uygulamaların 'Kireve've 'Cherokee' çeşitlerinde yaprak öz suyu elektriksel iletkenliği (EC), pH ve suda çözünür kuru madde (SÇKM) değerleri üzerine etkisi istatistiksel olarak anlamlı bulunmuştur ($p<0.05$) (Tablo 5). En yüksek EC değere 2 EC besin çözeltisi + vermikompost uygulanan 'Cherokee' çeşidinde belirlenmiştir. pH değeri 6.28 ile 4.80 arasında değiştiği belirlenmiştir. SÇKM miktarında en yüksek değere çeşme suyu + vermikompost ve çeşme suyu uygulanan 'Cherokee' çeşidinde tespit edilmiştir. Kibar (2018), marulda vermikompost uygulamasının SÇKM miktarının %2.20 ile %4.10 arasında değiştiğini bildirmiştir. Papathanasiou ve ark. (2012), çalışmalarında vermikompostun SÇKM içeriğini artırdığını bildirmişlerdir.

Tablo 5. Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitlerinde EC, pH ve suda çözünür kuru madde (SÇKM) üzerine etkileri

Çeşit	**Uygulama**	**EC (dS/m)**	**pH**	**SÇKM (%)**
Kireve	Çeşme Suyu	8.73ab	4.80b	3.20b
Kireve	Çeşme Suyu+Vermikompost	8.10b	5.96ab	3.50b
Kireve	2 EC Besin Çözeltisi	7.97b	6.13a	3.30b
Kireve	2 EC Besin Çözeltisi +Vermikompost	9.07a	6.22a	2.70b
Kireve	1.5 EC Besin Çözeltisi + Vermikompost	9.01a	6.24a	2.50b
Kireve	1 EC Besin Çözeltisi +Vermikompost	8.91ab	6.17a	2.70b
Cherokee	Çeşme Suyu	8.11b	4.97b	4.50a
Cherokee	Çeşme Suyu+Vermikompost	8.11b	5.97ab	4.90a
Cherokee	2 EC Besin Çözeltisi	9.25a	6.08a	3.00b
Cherokee	2 EC Besin Çözeltisi +Vermikompost	10.84a	6.13a	3.00b
Cherokee	1.5 EC Besin Çözeltisi +Vermikompost	8.25b	6.28a	2.60b
Cherokee	1 EC Besin Çözeltisi + Vermikompost	7.62b	6.26a	2.70b
p değeri		**	**	*

İncelenen kök morfolojik özelliklerinden olan kök uzunluğu (cm), hacmi (cm^3) ve kök çapı (mm) parametrelerinde uygulamalar arasında istatistiksel olarak anlamlı fark tespit edilmiştir ($p<0.05$). En yüksek kök uzunluğu 2 EC besin çözeltisi + vermikompost uygulanan 'Kireve' ve 'Cherokee' çeşidinde tespit edilmiştir. En düşük kök hacmi çeşme suyu uygulanan 'Kireve' çeşidinde belirlenmiştir. En yüksek kök çapı ise 1.5 EC + vermikompost uygulanan (0.603 mm) 'Kireve' çeşidinde ölçülmüştür. Diğer uygulamalar arasında istatistiksel olarak farklılıklar gözlenmiş olsa da kök çap değerleri genellikle 0.42–0.60 mm aralığında değişmiştir. Genel olarak hem besin çözeltisi uygulamaları (EC) hem de vermikompost uygulaması, kök gelişimi üzerinde olumlu etkiler göstermiştir. Özellikle bu iki uygulamanın kombinasyonu hem uzunluk hem hacim hem de çap parametrelerinde en yüksek değerlere ulaşılmasını sağlamıştır (Tablo 6). Bhattacharya ve ark. (2025), vermikompost uygulamasının kök morfolojisi üzerine olumlu etkisi olduğunu bildirmişlerdir. Kılıç ve Saraçoğlu (2022), marul çeşitleri arasında en yüksek kök uzunluğunu vermikompost uygulanan Lollo Rosso çeşidinde, Iceberg çeşidinde ise vermikompost uygulamasının etkisi olmadığını bildirmişlerdir. Gutiérrez-Miceli ve ark. (2007) çalışmalarında vermikompostun domates bitkisinde kök uzunluğu ve hacmini artırdığını bildirmişlerdir.

Tablo 6. Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitlerinde kök uzunluğu, kök hacmi ve kök çapı üzerine etkileri

Çeşit	Uygulama	Kök Uzunluğu (cm)	Kök Hacmi (cm^3)	Kök Çapı (mm)
Kireve	Çeşme Suyu	2589.32c	3.82c	0.434b
Kireve	Çeşme Suyu+Vermikompost	2911.97c	4.38b	0.455b
Kireve	2 EC Besin Çözeltisi	3880.85ab	5.82a	0.426b
Kireve	2 EC Besin Çözeltisi +Vermikompost	4063.53a	6.75a	0.560ab
Kireve	1.5 EC Besin Çözeltisi +Vermikompost	3930.08ab	6.21a	0.603a
Kireve	1 EC Besin Çözeltisi +Vermikompost	3655.57b	5.22a	0.535ab
Cherokee	Çeşme Suyu	2356.52c	4.10b	0.470b
Cherokee	Çeşme Suyu+Vermikompost	2199.16c	4.80b	0.427b
Cherokee	2 EC Besin Çözeltisi	3723.89ab	6.14a	0.458b
Cherokee	2 EC Besin Çözeltisi +Vermikompost	4446.04a	7.37a	0.460b
Cherokee	1.5 EC Besin Çözeltisi +Vermikompost	3923.93ab	7.06a	0.571ab
Cherokee	1 EC Besin Çözeltisi +Vermikompost	3684.13b	6.79a	0.519ab
p değeri		**	**	*

Uygulamaların 'Kireve' ve 'Cherokee' çeşitleri üzerine etkisi bakımından incelenen pigment parametreleri sonucunda, Klorofil-a içeriği 0.031 ile 0.215 mg/g arasında değişmektedir. En yüksek klorofil-b değerleri 2 EC + vermikompost (0.130 mg/g) ve 1.5 EC + vermikompost (0.119 mg/g) uygulanan 'Cherokee' çeşidinde ölçülmüştür. En düşük klorofil-b değeri ise çeşme suyu uygulanan 'Kireve' çeşidinde (0.010 mg/g) tespit edilmiştir. Toplam klorofil miktarı (Ka+b) açısından değerlendirildiğinde, en yüksek değerin yine 'Cherokee' çeşidinde 1.5 EC + vermikompost uygulamasında (0.334 mg/g) olduğu belirlenmiştir. Toplam karotenoid miktarları ise 0.004 ile 0.046 mg/g arasında değişmiştir. Karotenoid içeriği bitki yetiştirme solüsyonunun EC içeriğinin artışı ile paralellik göstermektedir. Yapılan uygulamaların hem klorofil hem de karotenoid içeriklerini istatistiksel olarak anlamlı düzeyde etkilediği ve özellikle sıvı besin çözeltisi (EC) ile vermikompostun birlikte uygulanmasının pigment içeriğini artırdığı tespit edilmiştir ($p<0.001$). (Tablo 7). Bizim çalışmamıza benzer şekilde, Gutierrez-Miceli ve ark. (2007), vermikompost uygulamalarının domates bitkisinde klorofil ve karotenoid birikimini artırdığını belirtmişlerdir. Atiyeh ve ark. (2000), çalışmalarında vermikompost uygulanan bitkilerde klorofil içeriğini ve karotenoid sentezini anlamlı derecede arttığını bildirmişlerdir.

Tablo 7. Farklı dozlarda besin solüsyonu ve vermikompost uygulanmış ortamlarda yetiştirilmiş 'Kireve' ve 'Cherokee' marul çeşitlerinde klorofil-a, klorofil-b, toplam klorofil ve karotenoid üzerine etkileri

Çeşit	Uygulama	Klorofil-a (mg/g)	Klorofil-b (mg/g)	Toplam klorofil (Ka+b) (mg/g)	T,oplam Karotenoid (Kx+c) (mg/g)
Kireve	Çeşme Suyu	0.031f	0.010e	0.040e	0.004c
Kireve	Çeşme Suyu+Vermikompost	0.078ef	0.023de	0.101d	0.026a-c
Kireve	2 EC Besin Çözeltisi	0.146bc	0.046cd	0.192bc	0.037ab
Kireve	2 EC Besin Çözeltisi +Vermikompost	0.132b-d	0.049cd	0.181bc	0.037ab
Kireve	1.5 EC Besin Çözeltisi +Vermikompost	0.133b-d	0.050cd	0.184bc	0.037ab
Kireve	1 EC Besin Çözeltisi +Vermikompost	0.096de	0.050cd	0.146cd	0.016bc
Cherokee	Çeşme Suyu	0.099c-e	0.028c-e	0.126d	0.035ab
Cherokee	Çeşme Suyu+Vermikompost	0.075ef	0.024de	0.100d	0.027a-c
Cherokee	2 EC Besin Çözeltisi	0.201a	0.085b	0.287a	0.046a
Cherokee	2 EC Besin Çözeltisi +Vermikompost	0.177ab	0.130a	0.307a	0.023a-c
Cherokee	1.5 EC Besin Çözeltisi +Vermikompost	0.215a	0.119a	0.334a	0.015bc
Cherokee	1 EC Besin Çözeltisi +Vermikompost	0.150b	0.054c	0.205b	0.036ab
p değeri		***	***	***	***

4. SONUÇLAR

Bu çalışmada, solucan gübresi (vermikompost) uygulamasının su kültürü (hidroponik) koşullarında iki farklı marul (*Lactuca sativa* L.) çeşidinde bitki gelişimi üzerindeki etkileri değerlendirilmiştir. Elde edilen bulgular, vermikompostun hem çeşme suyu hem de farklı dozlarda besin çözeltisi ile birlikte kullanıldığında bitki gelişimini olumlu yönde etkilediği belirlenmiştir. Özellikle bitki boyu, yaprak sayısı ile yaprak ve kök taze-kuru ağırlıkları gibi morfolojik parametrelerde anlamlı artışlar gözlemlenmiştir.

Araştırmanın sonuçları, vermikompostun içeriğinde yer alan organik madde ile mikro ve makro besin elementlerinin bitki beslenmesini destekleyici bir rol oynadığını ve gelişim üzerinde pozitif etkiler sağladığını göstermektedir. Ayrıca, vermikompost uygulamasının kimyasal gübre ihtiyacını azaltma potansiyeli hem üretim maliyetlerinin düşürülmesi hem de çevresel kirliliğin önlenmesi açısından önemli bir avantaj sunmaktadır. Bu durum, günümüzde giderek önem kazanan sürdürülebilir tarım arayışları bağlamında, vermikompostun hidroponik sistemlerde alternatif veya tamamlayıcı bir besin kaynağı olarak değerlendirilmesini mümkün kılmaktadır.

Sonuç olarak, vermikompostun su kültürü sistemlerinde kullanımı, yalnızca bitki gelişimini desteklemekle kalmayıp, aynı zamanda çevre dostu ve ekonomik üretim modellerine katkı sağlamaktadır. Gelecekte farklı bitki türleri ve çeşitli çevresel koşullarda yapılacak daha kapsamlı ve uzun süreli araştırmalar ile vermikompostun tarımsal üretimdeki potansiyeli daha ayrıntılı bir şekilde ortaya konulabilir. Böylece, sürdürülebilir tarım ilkeleri doğrultusunda organik girdilerin daha etkin ve verimli kullanımı teşvik edilebilecektir.

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EFFECT OF SOLID FERTILIZER TEA DERIVED FROM BIOGAS PLANTS COMBINED WITH REDUCED NUTRIENT SOLUTION ON LETTUCE GROWTH IN HYDROPONIC CULTURE

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ABSTRACT

In addition to energy production, biogas plants provide added value through the organic matter-rich by-product generated at the end of the process, which can be used as fertilizer in agricultural production. This study was conducted in a fully automated, geothermal-heated, Venlo-type glass research greenhouse at Kırşehir Ahi Evran University, using a hydroponic cultivation system. In the study, the solid fraction obtained from biogas plants was subjected to a pre-treatment involving aerated soaking in water to facilitate the release of soluble nutrients. The resulting fertilizer tea was then used in hydroponic lettuce cultivation. The aim of the research was to determine the effects of biogas fertilizer tea application on plant growth in lettuce (*Lactuca sativa* L.) cultivars grown under reduced nutrient solution levels. The plant materials used in the study were two lettuce cultivars: Expedition and Cencibel. The experimental treatments were as follows: (1) tap water only, (2) tap water + biogas fertilizer tea, (3) 2 EC nutrient solution, (4) 2 EC nutrient solution + biogas fertilizer tea, (5) 1.5 EC nutrient solution + biogas fertilizer tea, and (6) 1 EC nutrient solution + biogas fertilizer tea. The plants were grown for 30 days in an aerated hydroponic system. After harvest, various morphological and physiological characteristics were evaluated, including leaf fresh and dry weight, root fresh and dry weight, head diameter, head height, number of leaves, leaf color parameters (L, a, b*), color saturation (chroma), hue angle, leaf chlorophyll a, chlorophyll b, total chlorophyll and total carotenoid contents, leaf sap EC and pH, soluble solid content, root length, root diameter, and root volume. According to the findings, the highest values for leaf and root fresh and dry weights, head diameter, and head height were obtained from the treatment involving 2 EC nutrient solution supplemented with biogas fertilizer tea. In conclusion, the use of biogas fertilizer tea in combination with a reduced nutrient solution had positive effects on the

morphological and physiological development of lettuce plants grown in a hydroponic system. This approach contributes to reducing fertilizer use and presents a promising alternative for organic production systems within the framework of sustainable agriculture.

Keywords: biogas fertilizer tea, lettuce, hydroponic, plant growth

AZALTILMIŞ BESİN ÇÖZELTİSİ İLE BİRLİKTE UYGULANAN BİYOGAZ TESİSLERİNDEN ELDE EDİLMİŞ KATI GÜBRE ÇAYININ SU KÜLTÜRÜNDE MARUL GELİŞİMİNE ETKİSİ

ÖZET

Biyogaz tesisleri enerji üretiminin yanı sıra, işleme sonunda ortaya çıkan organik maddece zengin tarımsal üretimde gübre olarak kullanılabilen atık ile de fayda sağlamaktadır. Bu çalışma, Kırşehir Ahi Evran Üniversitesi'ne ait tam otomasyonlu, jeotermal ısıtmalı Venlo tip cam Ar-Ge serasında, hidroponik yetiştirme sistemi kullanılarak yürütülmüştür. Bu çalışmada, biyogaz tesislerinden elde edilen katı faz materyalde bulunan çözünür besin elementlerinin suya geçişini sağlamak amacıyla havalandırmalı su ortamında ön işlem uygulanmıştır. Ön işlem sonucunda elde edilen katı gübre çayı, hidroponik sistemde marul yetiştiriciliğinde besin çözeltisi olarak değerlendirilmiştir. Çalışmanın amacı, katı gübre çayı uygulamasının, azaltılmış düzeyde besin çözeltisi verilen marul (*Lactuca sativa* L.) çeşitlerinde bitki gelişimi üzerindeki etkilerini belirlemektir. Araştırmada bitkisel materyal olarak Expedition ve Cencibel marul çeşitleri kullanılmıştır. Deneme konuları şunlardır: (1) yalnızca çeşme suyu, (2) çeşme suyu + katı gübre çayı, (3) 2 EC besin çözeltisi, (4) 2 EC besin çözeltisi + katı gübre çayı, (5) 1.5 EC besin çözeltisi + katı gübre çayı, (6) 1 EC besin çözeltisi + katı gübre çayı. Bitkiler, havalandırmalı durgun su kültüründe 30 gün süreyle yetiştirilmiştir. Hasat sonrası bitkilerde; yaprak taze ve kuru ağırlığı, kök taze ve kuru ağırlığı, baş çapı, baş boyu, yaprak sayısı, yaprak renk parametreleri (L, a, b*), renk doygunluğu (chroma), renk tonu (hue açısı), yaprak klorofil a, klorofil b, toplam klorofil ve toplam karotenoid içerikleri, yaprak öz suyu EC ve pH değeri ile suda çözünür kuru madde miktarı, kök uzunluğu, kök çapı ve kök hacmi gibi çeşitli morfolojik ve fizyolojik özellikler belirlenmiştir. Elde edilen bulgulara göre; yaprak ve kök taze-kuru ağırlıkları, baş çapı ve baş boyu bakımından en yüksek değerler, 2 EC'lik besin çözeltisine katı gübre çayının ilave edildiği uygulamadan elde edilmiştir. Sonuç olarak, katı gübre çayının azaltılmış düzeydeki besin çözeltisi ile birlikte kullanımı, hidroponik sistemde yetiştirilen marul bitkilerinin morfolojik ve fizyolojik gelişimi üzerinde olumlu etkiler göstermiştir. Bu uygulama, gübre kullanımının azaltılmasına katkı sağlamakta ve sürdürülebilir tarım kapsamında organik üretim sistemlerine yönelik önemli bir alternatif sunmaktadır.

Anahtar Kelimeler: biyogaz gübre çayı, marul, su kültürü, bitki gelişimi

1.GİRİŞ

Su kültürü (Hidroponik), bitki büyümesini desteklemek için bir besin çözeltisi ve yapay bir köklendirme substratı içeren topraksız bir tarım tekniğidir (Kumar ve Cho, 2014) Hidroponik sistemler çoğunlukla çevrenin kontrol edilebildiği ve bitkisel üretimin yıl boyunca gerçekleşebildiği seralarda kullanılır (Lee ve Lee, 2015) Bu koşullar altında, toprak kökenli hastalık zararlı riskleri azaldığı gibi infiltrasyonla ve evaporasyonla da kayıp olmadığı için su ve besin elementleri kullanım etkinliği bakımından toprakta yapılan yetiştiriciliğe göre üstün yönlerinden dolayı sürdürülebilir, çevreci ve daha verimli bir tarımsal üretim metodudur (Surendran ve ark., 2017; Tomasi ve ark., 2015).

Hidroponik sistemlerde organik gübrelerin kullanımı, inorganik gübrelerin yüksek maliyeti, kimyasallardan kaynaklı çevre kirliliği problemleri, halk sağlığı bilincinin artması ve birçok çiftçinin kimyasallardan sıvı organik gübrelere geçmesi nedeniyle tercih edilen bir alternatif haline gelmiştir. Ancak organik kökenli gübrelerle yetiştiricilikte inorganik gübrelerle yetiştirilenlere benzer bitki verimleri elde etmenin daha zor olması, besin çözeltilerini dengelemenin sorunlu olması ve çözeltilerin pH ve elektriksel iletkenliğinin (EC) önemli ölçüde dalgalanması nedeniyle bir zorluk olmaya devam etmektedir (Amir ve ark, 2022)

Biyogaz katı gübresi, hayvan gübresi ve bitkisel atıkların fermantasyonundan elde edilen biyogaz üretiminin bir yan ürünü olup, yaygın olarak bulunur ve ucuzdur. Birçok biyogaz işletmesinde aşırı miktarda biyogaz proses atıkları ortaya çıkmakta ve bu atıklar düzgün yönetilmezse yeni bir çevre sorunu haline gelmektedir (Nyord ve ark., 2012). Biyogaz katı gübresi bol miktarda organik madde, bitkilerin ihtiyaç duyduğu besin maddeleri ve bazı biyoaktif maddeler içerdiğinden genellikle doğrudan toprağa veya mineral gübrelerle birlikte organik gübre olarak uygulanır. Böylece çevre kirliliğinin önüne geçilirken, tarımsal verim artışı da sağlanmaktadır (Abubaker ve ark., 2012)

Hidroponik tarımda yetiştiriciliği yapılan en popüler türlerden biri maruldur (*Lactuca sativa* L.). Marul besleyici özelliği olmayan, düşük kalorili, fakat iştah açıcı özelliği sebebiyle, sofralarımızın vazgeçilemeyen bir salata sebzesidir. Terpenoidler, flavonoidler ve fenoller gibi sekonder metabolitlerin varlığı nedeniyle eski zamanlardan beri mide sorunları, iltihaplanma, ağrı ve idrar yolu enfeksiyonları dahil olmak üzere farklı rahatsızlıklar için bir ilaç olarak kullanılmıştır (Mulabagal ve ark., 2010). Bu yönüyle marul, fonksiyonel gıda olarak öne çıkmaktadır. Dünya marul üretimi 2023 verilerine göre toplam 28.084.971 ton, Türkiye üretimi ise 602.848 ton olarak gerçekleşmiştir (FAO, 2023; TÜİK, 2023). Fonksiyonel gıdaların öneminin anlaşılması, marula olan talebi artırmaktadır. Toprakta yetiştiricilikte marul üretim döngüsü yaklaşık 70 gün kadarken, hidroponik kültürde bu sürenin 30 güne düşmesi nedeniyle, örtü altında özellikle de su kültüründe marul yetiştiriciliği giderek yaygınlaşmaktadır.

Bu çalışmada, biyogaz tesislerinin proses atığı olan katı gübreden elde edilen çayın, su kültüründe yetiştirilen marulun verim ve kalitesi üzerine etkisi araştırılmıştır.

2. MATERYAL VE YÖNTEM

2.1. Materyal

Çalışmada Rijk Zwaan tohum şirketinin *Lactuca sativa* L. var. *crispa* türüne ait Cencibel (Koyu kırmızı (triple) renkli lollo rossa) ve Expedition (Küçük yapraklı, kıvırcık tip, yeşil renk) marul çeşitleri bitkisel materyal olarak kullanılmıştır.

2.2. Yöntem

Çalışma, Kırşehir Ahi Evran Üniversitesi'nin tam otomasyonlu (fan-ped soğutma, yüksek basınçlı sisleme, ısı perdesi, sirkülasyon fanı ve jeotermal ısıtmalı) venlo tipi cam Ar-Ge serasında yürütülmüştür. Tohumlar torf ve perlit (2:1) içeren yetiştirme ortamının doldurulduğu viyollere ekilmiştir (05/01/2025). Viyollerde 4-5 gerçek yaprak aşamasına gelen fidelerde kökler yıkanarak yetiştirme ortamından arındırılmış ve 136 lt'lik plastik saksılara besin solüsyonu doldurularak, saksı üzerine yerleştirilen sıra arası ve üzeri eşit ayarlanmış deliklere sahip kompozit levhalara sünger yardımıyla dikilmiştir (13/02/2025). Saksılara 9'ar adet fide dikilmiş ve besin solüsyonu hava pompası ile düzenli olarak havalandırılmıştır. Çalışmada her uygulama 3 tekerrürlü ve her tekerrürde 3 bitki bulunmaktadır. Standart besin solüsyonu (2 dS/m Hoagland çözeltisi), 1500 µM $Ca_2(NO_3)$, 750 µM K_2SO_4, 650 µM $MgSO_4$, 500 µM KH_2PO_4, 10 µM H_3BO_3, 0,5 µM $MnSO_4$, 0.5 µM $ZnSO_4$, 0.4 µM $CuSO_4$, 0.4 µM $MoNa_2O_4$ ve 80 µM Fe EDDHA içerecek şekilde hazırlanmıştır.

Çalışmada kullanılan biyogaz tesislerinden elde edilen katı proses atığı, en az bir yıl açık arazide kompostlanmıştır. Daha fazla nem, besin ve faydalı mikroorganizma içerdiği varsayılarak kompost yığınının alt tarafından 15 kg katı gübre alınmıştır. Plastik saksı içerisine konulan katı gübre üzerine, 100 lt su ve 200 ml melas eklenerek, yarım saatte bir 2 dk hava verilerek 3 gün demlenmeye bırakılmıştır. Elde edilen katı gübre çayının (KGÇ) EC düzeyi 4 dS/m olarak belirlenmiştir. Süzdürülerek katı fazdan ayrılan KGÇ (sıvı faz), azaltılmış çözelti uygulanan saksılara yirmişer litre eklenmiş ve KGÇ eklenen çözeltilerin EC düzeyini 0.5 dS/m kadar artırmıştır. Bir ayın sonunda hasat edilen (13/03/2025) marullarda morfolojik ve fizyolojik ölçümler yapılmıştır. Çalışmadaki uygulamalar; 1) Çeşme Suyu, 2) Çeşme Suyu + katı gübre çayı (KGÇ), 3) 2 EC'lik Besin Solüsyonu, 4) 2 EC'lik Besin Solüsyonu + KGÇ, 5) 1.5 EC'lik Besin Solüsyonu + KGÇ, 6) 1 EC'lik Besin Solüsyonu + KGÇ olmak üzere 6 konudan oluşmaktadır.

2.3. Denemede Yapılan Ölçümler

Hasattan sonra kök ve yaprak taze ve kuru ağırlıkları (g/bitki) 0.01 hassasiyetindeki dijital terazi ile belirlenmiştir. Kuru ağırlıkları belirlemek amacıyla kök ve yaprak örnekleri, sabit ağırlığa ulaşıncaya kadar 65°C'ye ayarlanmış etüvde kurutulduktan sonra tartılmıştır. Baş boyu ve çapı cetvel (cm) ile gövde çapı ise kumpas (mm) ile ölçülmüştür. Yaprak rengi ise Konica Minolta CR 200 renkölçer ile L, a ve b değerleri olarak belirlenmiştir. Ölçülen temel 3 renk parametresi (L, a, b) kullanılarak, bitki örneklerinde chroma ve hue açısı değerleri de hesaplanmıştır (Iqdiam ve ark., 2018). Hasat edilen marullarda yapraklar sayılarak toplam yaprak sayısı belirlenmiştir.

Bitkinin genelini temsil edecek şekilde seçilen yapraklardan katı meyve sebze sıkacağı yardımıyla çıkarılan bitki özsuyunda, elektriksel iletkenlik (EC) ve pH değerleri, Extech marka EC ve pH ölçer cihazı kullanılarak belirlenmiştir. Suda çözünmüş katı madde miktarı (SÇKM) ise Hanna HI96801 model dijital refraktometre ile ölçülmüştür. Bitkilerin kök uzunluğu, kök taze ağırlığı kaydedildikten sonra, WinRHIZO (Win/Mac RHIZO Pro V. 2002c, Regent Instruments Inc., Kan Win/Mac RHIZO Pro V. 2002c Regent Instruments Inc., Québec, QC G1V 1V4, Kanada) yazılım programı kullanılarak ölçülmüştür. Yaprak pigment düzeyini belirlemek amacıyla her uygulama için yapraklardan 1.5 cm çapında diskler alınıp 3 ml, %80'lik aseton içerisinde homojenize edilerek 24 saat bekletildikten sonra UV-Vis spektrofotometre de 470 nm, 648.6 nm ve 664.2 nm dalga boylarında ölçümler yapılmıştır. Yaprak klorofil (a, b ve toplam klorofil) ve karotenoid içerikleri, (Lichtenthaler, 1987), tarafından açıklanan formüller kullanılarak spektrofotometrik yöntemle belirlenmiştir.

2.4. İstatistiksel Analiz

Çalışmadan elde edilen veriler, %5 önem seviyesinde Minitab Statistical Software 22 (United Kingdom) programı kullanılarak analiz edilmiştir. Verilerin değerlendirilmesinde tek yönlü varyans analizi (ANOVA) uygulanmış ve ortalamalar arasındaki farklar Duncan çoklu karşılaştırma testi ile belirlenmiştir.

3.BULGULAR VE TARTIŞMA

Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilen marul çeşitlerinde en yüksek yaprak taze ağırlığı 2 EC+KGÇ (124.20 g) uygulamasında yetiştirilen Expedition çeşidinde belirlenirken, en düşük ise yine aynı çeşitte çeşme suyu (6.20 g) uygulamasında belirlenmiştir (Tablo 1). Yaprak kuru ağırlıkları sonuçları, yaprak taze ağırlıkları sonuçları ile paralellik göstermektedir. En yüksek kök taze ve kuru ağırlığı, yaprak taze ve kuru ağırlık parametrelerinde olduğu gibi 2 EC+KGÇ uygulamasında Expedition çeşidinde elde edilmiştir. En düşük kök taze ve kuru ağırlık değerleri ise Cencibel çeşidinin çeşme suyu uygulamasında elde edilmiştir. Besin solüsyonu ve KGÇ uygulamasının, EC düzeyindeki artışa paralel olarak biyokütle artışı sağladığı görülmektedir. Hindi, tavuk ve inek gübresinden elde edilen gübre çaylarının hidroponik marul yetiştiriciliğinde etkilerini belirlemek amacıyla yapılan bir çalışmada, en yüksek yaprak taze ve kuru ağırlıklarının, hindi gübresi solüsyonunda (50 g/L) yetiştirilen marulda elde edildiği bunu Hoagland çözeltisinde yetiştirilen marulun izlediği belirtilmiştir (Tikasz ve ark., 2019). Tavuk gübresinden elde edilen sıvı gübrenin hidroponik sisteme entegre edilmesiyle oluşturulan bir marul denemesinde, yaprak taze ve kuru ağırlığı ile kök taze ve kuru ağırlığı en yüksek ticari besin solüsyonu ve tavuk gübresi çayının ayrı ayrı uygulandığı bitkilerden elde edilmiştir (Torres ve ark., 2024).

Tablo 8. Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilmiş " Expedition ve Cencibel" marul çeşitlerinde yaprak ve kök taze-kuru ağırlıkları üzerine etkileri

Çeşit	Uygulama	Yaprak Taze Ağırlık (g)	Yaprak Kuru Ağırlık (g)	Kök Taze Ağırlık (g)	Kök Kuru Ağırlık (g)
Expedition	Çeşme Suyu	6.20f	1.12f	45.37fg	6.30ef
Expedition	Çeşme Suyu+KGÇ*	78.40d	11.49d	85.03de	11.09cd
Expedition	2 EC	115.70ab	16.96ab	198.83b	25.48a
Expedition	2 EC+ KGÇ	124.20a	18.03a	230.20a	29.23a
Expedition	1.5 EC+ KGÇ	110.50b	16.02b	131.80c	17.06b
Expedition	1 EC+ KGÇ	94.67c	13.81c	112.07cd	14.51bc
Cencibel	Çeşme Suyu	10.13f	1.71f	6.57h	1.40g
Cencibel	Çeşme Suyu+ KGÇ	43.33e	6.48e	26.63gh	3.83fg
Cencibel	2 EC	77.70d	11.39d	60.40ef	8.13de
Cencibel	2 EC+ KGÇ	93.67c	13.62c	105.00cd	13.58bc
Cencibel	1.5 EC+ KGÇ	82.60cd	12.32cd	71.57ef	9.57de
Cencibel	1 EC+ KGÇ	74.67d	11.19dd	64.27ef	8.58de
	p değeri	***	***	***	***

***KGÇ:**Katı Gübre Çayı

Gövde çap ve boyu bakımından en düşük değerler her iki çeşitte de çeşme suyu uygulamalarında, en yüksek değerler ise 2 EC+KGÇ uygulanan Expedition ve Cencibel çeşitlerinde belirlenmiştir (Tablo 2). Her iki çeşitte de en az yaprak sayısı çeşme suyu uygulanan Cencibel (7.67 adet/bitki) ve Expedition (16.67 adet/bitki) çeşitlerinde elde edilmiştir. Expedition çeşidinde KGÇ eklenmesiyle, besin solüsyonu dozlarındaki azalışa rağmen yaprak sayısında kontrol grubuna kıyasla (2 EC) istatistiksel olarak fark tespit edilmemiştir. Uygulamalar arasındaki fark $p<0.001$ düzeyinde istatistiksel olarak önemlidir. Kök ve yaprak parametrelerinde olduğu gibi gövde çap ve boyu da besin solüsyonlarının EC düzeyi ile paralellik göstermiştir. Farklı hayvansal gübrelerden elde edilen gübre solüsyonlarının marul ve lahanada verim ve kalite üzerine etkilerini belirlemek amacıyla yapılan çalışmada marul için en yüksek ortalama yaprak sayısı, hindi gübresi (50 g/L) solüsyonunda belirlenmiş, (10.5 ± 0.4 yaprak/bitki), ardından en yüksek yaprak sayısı Hoagland solüsyonun da (7.3 ± 0.1 yaprak/bitki) belirlemişlerdir (Tikasz ve ark., 2019). Hidroponik marul üretiminde farklı dozlarda tavuk gübresi uygulamalarının (200 g, 300 g ve 400 g) incelendiği başka bir çalışmada, gübre oranının artırılmasının bitki verimini artırdığı belirtilmiştir (Wongkiew ve ark., 2021).

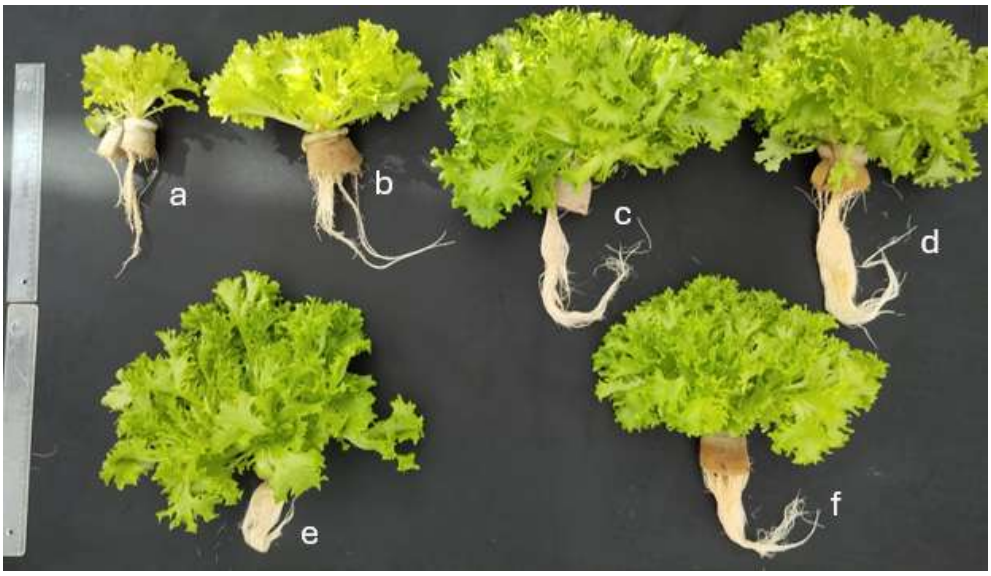
Tablo 9. Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilmiş "Expedition ve Cencibel" marul çeşitlerinde gövde çap, boy ve yaprak sayısı üzerine etkileri

Çeşit	Uygulama	Gövde Çapı (cm)	Gövde Boyu (cm)	Yaprak Sayısı (adet/bitki)
Expedition	Çeşme Suyu	4.37e-f	14.33e	16.67b
Expedition	Çeşme Suyu+KGÇ	9.03cd	18.50d	19.67ab
Expedition	2 EC	15.10ab	21.57a-c	22.33a
Expedition	2 EC+ KGÇ	17.80a	24.50a	22.00a
Expedition	1.5 EC+ KGÇ	11.70bc	23.00ab	20.67a
Expedition	1 EC+ KGÇ	8.43c-e	21.17b-d	20.33a
Cencibel	Çeşme Suyu	1.70f	10.50f	7.67e
Cencibel	Çeşme Suyu+ KGÇ	4.30ef	14.67e	8.33de
Cencibel	2 EC	5.77d-e	19.17cd	11.67c
Cencibel	2 EC+ KGÇ	11.40bc	21.00b-c	11.33cd
Cencibel	1.5 EC+ KGÇ	7.30c-e	21.00b-d	10.33cd
Cencibel	1 EC+ KGÇ	7.70-c-e	19.83cd	10.00c-e
	p değeri	***	***	***

Kök gelişim parametreleri bakımından çeşitler ve uygulamaların etkisi birlikte değerlendirildiğinde, en yüksek kök uzunluk, hacim ve çapı 2 EC+KGÇ uygulamasında Expedition çeşidinde (Şekil 1) belirlenmiştir (Tablo 3). Cencibel çeşidinde (Şekil 2) ise azaltılmış besin solüsyonuna KGÇ eklenmesi kök uzunluğu, hacmi ve çapını olumlu yönde etkilemiştir. Her iki çeşitte de en düşük kök parametreleri çeşme suyu uygulamasında belirlenmiştir. Uygulamalar arasındaki fark $p<0.01$ önem düzeyinde istatistiksel olarak önemlidir. Tavuk gübresinden elde edilen biyogaz işletmesi sıvı proses atıklarının hidroponik marul yetiştiriciliğinde etkilerini belirlemek amacıyla yapılan çalışmada standart Hoagland çözeltisine ek olarak sıvı biyogaz gübresinin de kullanılması kök yaş ve kuru ağırlığı ile kök uzunluk ve hacminde en yüksek değerlerin elde edilmesini sağlamıştır (Wang ve ark., 2019).

Tablo 10. Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilmiş "Expedition ve Cencibel" marul çeşitlerinde kök uzunluğu, kök hacmi ve kök çapı üzerine etkileri

Çeşit	Uygulama	Kök uzunluğu (cm)	Kök hacmi (cm^3)	Kök çapı (mm)
Expedition	Çeşme Suyu	1142.17c	4.00d	0.52c
Expedition	Çeşme Suyu+KGÇ	2461.10bc	7.87c	0.64b
Expedition	2 EC	3157.07b	9.44b	0.67b
Expedition	2 EC+ KGÇ	4374.04a	11.39a	0.73a
Expedition	1.5 EC+ KGÇ	3053.66b	9.04b	0.61b
Expedition	1 EC+ KGÇ	3084.65b	8.36b	0.61b
Cencibel	Çeşme Suyu	1274.65c	2.12e	0.46d
Cencibel	Çeşme Suyu+ KGÇ	1586.90c	2.78e	0.45d
Cencibel	2 EC	2871.63bc	4.69d	0.68b
Cencibel	2 EC+ KGÇ	2946.73bc	5.39d	0.66b
Cencibel	1.5 EC+ KGÇ	2818.91bc	4.84d	0.63b
Cencibel	1 EC+ KGÇ	2305.68bc	4.64d	0.61b
	p değeri	**	***	**



Şekil 3. a) Çeşme Suyu, b) Çeşme Suyu + katı gübre çayı (KGÇ), c) 2 EC'lik Besin Solüsyonu, d) 2 EC'lik Besin Solüsyonu + KGÇ, e) 1.5 EC'lik Besin Solüsyonu + KGÇ, f) 1 EC'lik Besin Solüsyonu + KGÇ ortamlarında yetiştirilen Expedition çeşidi

Şekil 4. a) Çeşme Suyu, b) Çeşme Suyu + katı gübre çayı (KGÇ), c) 2 EC'lik Besin Solüsyonu, d) 2 EC'lik Besin Solüsyonu + KGÇ, e) 1.5 EC'lik Besin Solüsyonu + KGÇ, f) 1 EC'lik Besin Solüsyonu + KGÇ ortamlarında yetiştirilen Cencibel çeşidi

Uygulamaların incelenen renk parametreleri üzerine etkisi değerlendirildiğinde yaprak renginin açıklık-koyuluğunu ifade eden L, sarıyı ifade eden pozitif b, renk canlılığını ifade eden Chroma

(c) ve renk tonu açısını ifade eden Hue açısı değerleri en düşük çeşme suyu uygulanan Cencibel çeşidinde belirlenmiştir (Tablo 4). Yeşili ifade eden negatif a değeri ise en düşük çeşme suyu uygulanan (-22.14) Expedition çeşidinde belirlenmiştir. En yüksek L, b, Chroma (C) değerleri çeşme suyu uygulanan Expedition çeşidinde belirlenmiş, en yüksek a değeri çeşme suyu uygulanan (-3.20) Cencibel çeşidinde, en yüksek Hue açısı değeri ise çeşme suyu+KGÇ, 2 EC (kontrol), 2 EC+KGÇ ve 1.5 EC+KGÇ uygulanan Expedition çeşidinde belirlenmiştir. Uygulamalar arasındaki fark $p<0.001$ düzeyinde istatistiksel olarak önemlidir. Gude ve ark., (2021), marulda L değerinin 34.8-45.3, a değerinin -8.5-2.5 ve Hue açısı değerinin 75.3-107.7 arasında değiştiğini bildirmişlerdir.

Tablo 11. Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilmiş "Expedition ve Cencibel" marul çeşitlerinde yaprak rengi (L, a ve b), Chroma ve Hue açısı üzerine etkileri

Çeşit	Uygulama	L	a	b	Chroma (C)	Hue açısı
Expedition	Çeşme Suyu	58.27a	-22.14f	40.07a	45.73a	118.91a-c
Expedition	Çeşme Suyu+KGÇ	54.94ab	-20.99ef	33.42ab	39.47ab	122.25a
Expedition	2 EC	48.97a-c	-18.64c-f	28.36bc	33.95a-c	123.50a
Expedition	2 EC+ KGÇ	48.22a-d	-20.03d-e	30.80ab	36.75a-c	123.10a
Expedition	1.5 EC+ KGÇ	46.36b-d	-19.25c-f	29.79a-c	35.47a-c	122.91a
Expedition	1 EC+ KGÇ	47.79a-d	-19.23c-f	30.79ab	36.30a-c	122.01ab
Cencibel	Çeşme Suyu	37.84d	-3.20a	19.12c	19.44d	98.98e
Cencibel	Çeşme Suyu+ KGÇ	44.21b-d	-10.53b	26.55bc	28.60b-d	111.44d
Cencibel	2 EC	43.42cd	-12.94bc	27.25bc	30.19b-d	115.16b-d
Cencibel	2 EC+ KGÇ	40.88cd	-10.65b	23.69bc	25.97cd	114.18cd
Cencibel	1.5 EC+ KGÇ	46.01b-d	-13.21b-d	30.15ab	32.95bc	113.36cd
Cencibel	1 EC+ KGÇ	44.22b-d	-14.42b-e	26.14bc	29.87b-d	118.93a-c
	p değeri	***	***	***	***	***

Yeşil yapraklı olarak tanımlanan Expedition çeşidi ve koyu kırmızı yapraklı olarak tanımlanan Cencibel çeşidi klorofil ve karotenoid bakımından incelendiğinde, en düşük klorofil a, klorofil

b ve toplam klorofil değeri çeşme suyu uygulanan Expedition çeşidinde, en düşük karotenoid değeri ise çeşme suyu uygulanan Cencibel çeşidinde belirlenmiştir (Tablo 5). En yüksek klorofil a değeri 2 EC çözelti+KGÇ uygulamasında Cencibel çeşidinde, en yüksek klorofil b ve toplam klorofil değeri 1.5 EC çözelti+KGÇ uygulamasında Expedition çeşidinde tespit edilmiştir. En yüksek toplam karotenoid içeriği de Expedition çeşidinde 2 EC'lik çözelti (kontrol) uygulamasında (0.059) belirlenmiştir. Uygulamalar arasındaki fark $p<0.001$ düzeyinde istatistiksel olarak önemlidir. Wang ve ark., (2019), tavuk gübresinden elde edilen biyogaz sıvı proses atığının hidroponik marul yetiştiriciliğinde etkisini araştırdıkları çalışmada, biyogaz sıvı gübresi ve mineral gübrenin birlikte kullanıldığı uygulamada marul yapraklarının renginin, Hoagland çözeltisi uygulanan bitkilere göre daha koyu olduğunu bildirmişlerdir. Ayrıca klorofil a ve toplam klorofil konsantrasyonlarının da diğer uygulamalardakilerden önemli ölçüde daha yüksek olduğunu belirtmişlerdir.

Tablo 12. Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilmiş "Expedition ve Cencibel" marul çeşitlerinde klorofil-a, klorofil-b, toplam klorofil ve karotenoid üzerine etkileri

Çeşit	Uygulama	Klorofil-a (µg/g)	Klorofil-b (µg/g)	Toplam Klorofil (µg/g)	Toplam Karotenoid (µg/g)
Expedition	Çeşme Suyu	0.047f	0.020e	0.067f	0.020cd
Expedition	Çeşme Suyu+KGÇ	0.115de	0.063b-e	0.179de	0.011d
Expedition	2 EC	0.233ab	0.109ab	0.342a-c	0.059a
Expedition	2 EC+ KGÇ	0.236ab	0.130a	0.366ab	0.047ab
Expedition	1.5 EC+ KGÇ	0.233ab	0.145a	0.379a	0.042a-c
Expedition	1 EC+ KGÇ	0.203a-c	0.123a	0.326a-c	0.041a-c
Cencibel	Çeşme Suyu	0.076ef	0.0370de	0.114ef	0.026b-d
Cencibel	Çeşme Suyu+ KGÇ	0.092ef	0.046c-e	0.138ef	0.021cd
Cencibel	2 EC	0.238a	0.100a-c	0.339a-c	0.051ab
Cencibel	2 EC+ KGÇ	0.244a	0.114ab	0.359a-c	0.057a
Cencibel	1.5 EC+ KGÇ	0.178bc	0.093a-d	0.272b-d	0.0400a-c
Cencibel	1 EC+ KGÇ	0.170cd	0.093a-d	0.264cd	0.034a-d
	p değeri	***	***	***	***

Yapraklardan elde edilen bitki özsuyunda yapılan ölçümler değerlendirildiğinde Expedition çeşidinde en düşük EC, pH ve SÇKM değerleri çeşme suyu uygulamasında elde edilmiştir (Tablo 6). Cencibel çeşidinde, en yüksek pH değeri çeşme suyu uygulamasında belirlenmiştir.

En düşük SÇKM değeri ise çeşme suyu ve 2 EC çözelti (kontrol) uygulamalarında Expedition çeşidinde belirlenmiştir. En yüksek EC değeri 2 EC çözelti (kontrol) uygulamasında Expedition çeşidinde, en yüksek pH değeri 2 EC çözelti (kontrol) uygulamasında Expedition çeşidinde ve 1.5 EC çözelti+KGÇ uygulamasında Cencibel çeşidinde, en yüksek SÇKM değeri 2 EC çözelti+KGÇ uygulamasında Cencibel çeşidinde belirlenmiştir. Uygulamaların EC, SÇKM ($p<0.01$) ve pH ($p<0.05$) üzerindeki etkisi istatistiksel olarak önemlidir. Sarkar ve ark., 2021, kokopit, çeltik kavuzu ve talaşın farklı oranlarından oluşan organik substratlarda yetiştirilen marulda pH'nın 6.04-6.38, SÇKM'nin ise %5.44-5.90 arasında değiştiğini bildirmişlerdir.

Tablo 13. Besin solüsyonu dozları ve katı gübre çayı uygulanmış ortamlarda yetiştirilmiş "Expedition ve Cencibel" marul çeşitlerinde EC, pH ve suda çözünür kuru madde (SÇKM) üzerine etkileri

Çeşit	Uygulama	EC (dS/m)	pH	SÇKM (%)
Expedition	Çeşme Suyu	6.68c	5.63b	2.40b
Expedition	Çeşme Suyu+KGÇ	7.02c	5.78b	3.50ab
Expedition	2 EC	8.36a	6.36a	2.40b
Expedition	2 EC+ KGÇ	8.31a	6.24a	2.80b
Expedition	1.5 EC+ KGÇ	8.04ab	6.35a	2.60b
Expedition	1 EC+ KGÇ	8.20ab	6.19a	2.50b
Cencibel	Çeşme Suyu	6.65c	5.69b	3.20b
Cencibel	Çeşme Suyu+ KGÇ	7.48bc	5.59b	3.50ab
Cencibel	2 EC	8.21ab	6.20a	3.70b
Cencibel	2 EC+ KGÇ	8.21ab	6.28a	3.90a
Cencibel	1.5 EC+ KGÇ	8.08b	6.36a	3.30b
Cencibel	1 EC+ KGÇ	8.08b	6.26a	2.80b
	p değeri	**	*	**

4.SONUÇ VE ÖNERİLER

Bu çalışmada, durgun su kültüründe azaltılmış besin çözeltisine katı gübre çayının (KGÇ) ilavesinin iki marul çeşidinde (Cencibel RZ ve Expedition RZ) verim ve kalite üzerindeki etkileri araştırılmıştır. Elde edilen sonuçlar, KGÇ kullanımının her iki çeşidin biyokütle parametrelerini pozitif etkilemiştir.

Yaprak taze ve kuru ağırlıkları, kök taze ve kuru ağırlıkları, gövde çapı ve boyu gibi temel morfolojik parametreler, KGÇ ilavesi yapılan uygulamalarda çeşme suyu uygulamasına kıyasla anlamlı düzeyde artmıştır. Özellikle 2 EC Hoagland çözeltisi+KGÇ uygulaması Expedition çeşidinde en yüksek verim değerlerine ulaşılmasını sağlamıştır. Renk parametreleri

incelendiğinde, KGÇ kullanımının özellikle klorofil ve karotenoid içeriklerini artırarak yaprak renginin canlılığını olumlu etkilediği görülmüştür.

Bitki özsuyu analizleri sonucunda, EC, pH ve SÇKM değerlerinde KGÇ katkısının dengeli bir artış sağladığı, bu durumun da bitkilerin daha iyi beslenmesini ve metabolik aktivitelerini desteklediği anlaşılmaktadır.

Çalışmanın genel sonuçlarına göre, doğru oranda ve yöntemle uygulanan KGÇ, durgun su kültüründe marul yetiştiriciliğinde verim ve kaliteyi artırmak için etkili bir biyolojik girdi olarak değerlendirilebilir. Özellikle organik ve sürdürülebilir tarım uygulamalarının öneminin arttığı günümüzde, biyogaz tesislerinden elde edilen katı organik atıklar gibi yenilenebilir kaynakların bitkisel üretimde kullanılması hem çevresel etkileri azaltmakta hem de üretimde ekonomik avantajlar sağlamaktadır.

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GASTRONOMY BEYOND THE PLATE: A MULTISENSORY EXPERIENCE

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ABSTRACT

The field of gastronomy has witnessed a paradigm shift from a focus on mere taste and nutrition to a broader understanding of food as a multisensory experience. This review paper explores the expanding landscape of multisensory gastronomy, drawing upon insights from neuroscience, psychology, design, and culinary arts. It synthesizes existing literature on how visual presentation, olfactory cues, auditory stimuli, tactile sensations, and taste interact to shape the perception of food and enhance the dining experience. Emerging research in neurogastronomy and crossmodal perception reveals that sensory integration significantly influences not only how food is evaluated but also how it is remembered and emotionally processed. Techniques used in molecular gastronomy and avant-garde dining demonstrate how manipulating sensory elements can elevate food consumption into an immersive, artistic, and even therapeutic act. This paper examines various methodologies employed in recent studies, from experimental setups in controlled environments to real-world applications in high-end restaurants. Additionally, the review highlights the cultural and emotional dimensions of sensory dining, such as food memories, storytelling, and the role of atmosphere. Key contributions from leading chefs, designers, and researchers are discussed to illustrate how multisensory gastronomy is being used to evoke emotions, tell stories, and create meaning beyond the plate.

By analyzing interdisciplinary findings and identifying gaps in current research, this paper offers a comprehensive overview of how multisensory experiences are redefining modern gastronomy. It also discusses future directions and implications for culinary practice, hospitality design, and sensory studies.

Keywords: Multisensory Gastronomy, Neurogastronomy, Crossmodal Perception, Culinary Innovation, Sensory Integration, Molecular Gastronomy, Experiential Dining, Emotional Response, Food Aesthetics, Gastronomic Design, Culinary Storytelling, Dining Psychology

Introduction

Gastronomy, in its traditional form, has been largely confined to the domains of taste and nutrition, often evaluated by the flavors and nutritional value of the food consumed. For centuries, the primary concern of culinary traditions revolved around satisfying hunger and ensuring health, with taste emerging as a key marker of culinary excellence. However, the landscape of gastronomy has undergone a profound transformation in recent decades. Influenced by advancements in culinary arts, neuroscience, psychology, and sensory design, the perception of food has expanded far beyond the boundaries of the palate. Today, food is increasingly understood as a multisensory experience that engages all five senses—sight, smell, sound, touch, and taste—simultaneously, creating a holistic and immersive interaction between the diner and the dish.

This evolution signifies a broader cultural and scientific shift, recognizing that the act of eating is deeply rooted in perception, emotion, and memory. Visual aesthetics, olfactory signals, auditory cues, and tactile sensations interplay with gustatory signals to form a complete gastronomic experience. The way food is plated, the aroma that wafts from the kitchen, the textures that meet the fingertips and the mouth, and even the sounds of the dining environment—all contribute significantly to how food is perceived, evaluated, and remembered.

Multisensory gastronomy thus stands at the intersection of art and science, blending empirical research with creative experimentation. It reimagines the dining table as a stage where chefs become storytellers and sensory architects, crafting experiences that go beyond nourishment to evoke emotions, trigger memories, and forge meaningful connections. Food becomes not just sustenance, but a powerful medium of communication and sensory exploration, capable of eliciting joy, nostalgia, surprise, and wonder. This new understanding invites diners to engage more consciously with their meals, transforming ordinary consumption into an extraordinary, multi-dimensional event.

The Science of Multisensory Perception

The experience of food is far more intricate than a simple act of tasting. Emerging research in the fields of neurogastronomy and crossmodal perception underscores that eating is fundamentally a multisensory event, shaped by the complex interplay of various sensory modalities. Each sense contributes uniquely to how food is perceived, evaluated, and remembered, creating a dynamic and richly textured dining experience.

Visual presentation serves as the initial gateway to the dining experience. Before any bite is taken, the eye judges the meal, setting expectations that profoundly influence flavor perception. Studies have demonstrated that attributes such as color, shape, symmetry, and even the arrangement of food on a plate can significantly alter how we perceive taste and quality. For instance, vibrant colors may enhance the perceived freshness or sweetness of food, while aesthetically pleasing symmetrical designs may prime diners to expect a more enjoyable or "clean" taste. The psychology behind visual food aesthetics reveals that sight primes the brain to anticipate certain flavors, ultimately modulating the actual sensory experience.

Olfactory cues—the scents that emanate from food—are equally, if not more, critical to flavor perception. Research suggests that approximately 80% of what we describe as "taste" is actually smell. The aroma of a dish reaches the olfactory receptors even before tasting begins, activating neural pathways associated with memory and emotion. A whiff of fresh-baked bread or sizzling spices can evoke vivid memories, stimulate appetite, and set emotional tones for the meal. This intimate relationship between smell, memory, and emotion highlights the olfactory system's pivotal role in constructing rich and meaningful gastronomic experiences.

Auditory stimuli, although often overlooked, also exert a profound influence on the enjoyment of food. The crunch of a crisp apple, the sizzle of a steak, or the background music in a restaurant creates a sonic landscape that subtly shapes perception. Research in sonic seasoning—the study of how sound influences taste—demonstrates that certain types of sounds can enhance specific taste qualities. High-pitched sounds, for example, have been found to intensify sweetness, whereas lower-pitched sounds may amplify bitterness. The sound environment, whether it's lively chatter or curated music, can affect not only the flavors perceived but also the tempo of eating and the overall emotional tone of the meal.

Tactile sensations—encompassing both the textures experienced within the mouth (mouthfeel) and the textures of utensils or serving ware—further contribute to the multisensory dining experience. The creaminess of a sauce, the crispiness of a pastry, the roughness of a rustic plate, or the smoothness of fine porcelain all interact with the diner's somatosensory system, adding layers of information that influence overall perception. Tactile experiences can even alter how flavors are interpreted; for instance, a rough-textured plate may unconsciously prime the diner to perceive the food as heartier or more robust.

Finally, taste—while central—is rarely experienced in isolation. Basic tastes such as sweet, sour, salty, bitter, and umami are constantly modulated by the concurrent inputs from the other senses. A strawberry may taste sweeter if it looks vividly red, smells fragrant, and is accompanied by harmonious, pleasant music. This synchrony among sensory elements creates a holistic, integrated experience rather than a series of isolated sensory events.

Understanding the science of multisensory perception thus opens doors to new culinary innovations and more profound dining experiences. It reveals that what we eat is not simply assessed by the tongue, but by the entire body and mind, woven together in an intricate, multisensory dialogue.

Techniques and Innovations in Multisensory Dining

The evolution of modern gastronomy has been significantly shaped by pioneering movements such as molecular gastronomy and avant-garde dining, where chefs blend culinary artistry with scientific inquiry to craft profoundly novel experiences. These approaches deliberately manipulate the senses, challenging diners' expectations and enriching the emotional and cognitive dimensions of eating.

Molecular gastronomy, a term popularized by physicist Nicholas Kurti and chemist Hervé This, involves the application of scientific techniques to cooking processes, enabling unprecedented transformations in food texture, appearance, and flavor. Techniques like spherification—

encasing liquids within a thin gel membrane to resemble caviar—offer unexpected tactile sensations. Edible foams and airs, created through emulsification, concentrate aromas and flavors into delicate structures, allowing the diner to "taste" aromas in a more ethereal form. Similarly, the manipulation of temperature contrasts, such as serving a cold dish that visually appears hot, or vice versa, creates a surprising dissonance that heightens awareness and invites playful interaction with the food.

Interactive plating further exemplifies this philosophy by engaging diners not just as consumers but as participants. Dishes may require the diner to assemble components, pour sauces, or even engage with aromas released at the moment of serving. These practices amplify sensory involvement and foster a deeper emotional investment in the dining experience.

World-renowned restaurants like Heston Blumenthal's *The Fat Duck* and Grant Achatz's *Alinea* epitomize the application of crossmodal strategies in gastronomy. Blumenthal's use of audio, such as the iconic "Sound of the Sea" dish where diners listen to ocean waves while tasting seafood, demonstrates how sound can intensify flavor perception and transport diners emotionally to a coastal setting. Achatz, known for his theatrical presentations, incorporates elements such as edible balloons filled with helium, aromatic pillows that release scents during the meal, and ever-evolving plating styles that integrate sight, scent, sound, touch, and taste into a cohesive sensory narrative.

These innovations demonstrate that dining can transcend its traditional role of nourishment to become a fully immersive, experiential art form. Food is no longer merely consumed—it is experienced, contemplated, and emotionally resonated with. The use of scientific techniques in crafting multisensory experiences elevates the act of dining into a performative encounter, where memory, emotion, and sensation converge. In doing so, these techniques challenge diners to reconsider their relationship with food, encouraging greater mindfulness, curiosity, and joy.

Emotional and Cultural Dimensions

Food possesses an unparalleled ability to tap into human memory and emotion, acting as a conduit between the senses and the deeper layers of personal and collective experience. Multisensory dining strategically leverages these connections, creating experiences that evoke nostalgia, wonder, curiosity, comfort, or even playful confusion, thereby transforming meals into emotionally resonant journeys.

One of the most powerful aspects of multisensory dining is its ability to awaken food memories—emotionally charged recollections associated with taste, smell, or even the sound and texture of a particular dish. A single bite can transport a diner back to a childhood meal, a family gathering, or a long-forgotten cultural tradition. By deliberately designing dishes to trigger these responses—whether through familiar aromas, evocative textures, or storytelling elements—chefs can curate not just a meal, but a deeply personal emotional experience.

Culinary storytelling takes this a step further by using the plate as a narrative medium. Every component of the dish—its color palette, arrangement, aroma, accompanying sounds, and textures—contributes to a larger story arc, guiding the diner through emotional highs and lows. For instance, a course might start with bright, vibrant flavors evoking youthful joy, transition

into earthy, grounded tastes symbolizing maturity, and conclude with sweet, ethereal notes suggesting memory and nostalgia. In this approach, dining becomes akin to attending a theatrical performance or reading a novel—an immersive narrative that unfolds through the senses.

Beyond personal memories, cultural context plays a fundamental role in shaping multisensory gastronomic experiences. Sensory perception is not universal; it is deeply influenced by cultural norms, traditions, and collective histories. Rituals like the Japanese tea ceremony, the Indian festival meals served on banana leaves, or the communal breaking of bread in many Middle Eastern cultures demonstrate that multisensory integration has long been a cornerstone of gastronomy, even before the phenomenon was scientifically studied. These practices often integrate visual presentation, aroma, tactile elements (such as eating with hands), and communal sounds, crafting shared sensory experiences that reinforce cultural identity and community bonds.

In multicultural settings, multisensory dining also becomes a bridge for cross-cultural storytelling, allowing chefs to evoke and honor diverse traditions while inviting diners into new sensory worlds. Respectful fusion cuisine, thematic dining experiences, and reinterpretations of heritage dishes all serve as examples of how multisensory elements can be used to celebrate, preserve, or reimagine cultural narratives through food.

Thus, the emotional and cultural dimensions of multisensory gastronomy reveal that eating is not merely a biological act; it is a deeply human experience, rooted in memory, emotion, and shared cultural meanings. Recognizing and harnessing these dimensions allows culinary artists to create meals that nourish not just the body, but the soul.

Methodologies in Research

Research in multisensory gastronomy draws upon a wide range of interdisciplinary methodologies, combining techniques from psychology, neuroscience, sensory science, and design studies to unravel the complex interplay between the senses during eating experiences.

In controlled laboratory experiments, researchers often isolate individual sensory variables—such as color, aroma, texture, or sound—to observe their independent and combined effects on flavor perception, emotional responses, and memory formation. These studies frequently use blind or double-blind setups to minimize bias, presenting participants with systematically varied stimuli to gauge their subjective experiences. For example, participants might taste identical foods presented in different colored plates to assess how color influences perceived sweetness or freshness.

Simultaneously, real-world applications are crucial for understanding multisensory gastronomy in more naturalistic settings. Experiments conducted in restaurants, pop-up events, food festivals, and immersive dining installations offer rich insights into how sensory factors interact with environmental variables like lighting, social context, and ambient sound. These studies aim to replicate the complexity and dynamism of authentic dining scenarios, acknowledging that human sensory experiences are rarely isolated in everyday life.

Recent technological innovations have significantly enhanced the precision and depth of this research. Eye-tracking technology allows scientists to monitor diners' visual attention in real time, providing data on how plating design, color contrasts, and movement influence visual engagement and expectation. Neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) enable researchers to examine the brain's activity patterns during food consumption, revealing how multisensory integration occurs neurologically and how different sensory inputs evoke emotional or reward-related brain responses.

Additionally, wearable sensors—including skin conductance monitors, heart rate variability trackers, and portable EEG headsets—are increasingly employed to measure physiological markers of emotional arousal and engagement during meals. These devices allow for continuous, non-invasive monitoring, even in dynamic dining environments, thus bridging the gap between laboratory control and ecological validity.

Some studies also incorporate cross-disciplinary approaches, combining qualitative methods like interviews and ethnographic observation with quantitative measures. This mixed-methods strategy captures both the objective physiological and cognitive responses to food and the subjective, narrative experiences that diners articulate about their meals.

Through these diverse and evolving methodologies, researchers are uncovering nuanced insights into how the senses collaborate to shape not just the taste of food, but its emotional resonance, memorability, and cultural significance. As tools and techniques become more sophisticated, the future of multisensory gastronomy research promises even deeper explorations into the embodied, emotional, and social dimensions of eating.

Challenges and Future Directions

Despite the remarkable strides made in understanding and applying multisensory gastronomy, several significant challenges continue to shape the research and its practical applications.

One prominent limitation is the narrow cultural lens through which much of the current research has been conducted. A large proportion of experimental studies and avant-garde dining practices are rooted in Western culinary traditions, often overlooking the rich multisensory heritage embedded in global food cultures. Indigenous rituals, Asian dining customs, African communal eating traditions, and Latin American flavor layering, for instance, offer vast, largely untapped resources for understanding how multisensory dining has evolved differently across societies. Future research must aim for a more inclusive, global perspective, incorporating cross-cultural methodologies to avoid Eurocentric biases and to appreciate the full diversity of sensory dining practices worldwide.

Another critical challenge lies in individual variability. Sensory perception is highly subjective, influenced by a range of factors including genetic predispositions (such as supertasters versus non-tasters), psychological states (like mood and prior experiences), and cultural background (which shapes learned flavor preferences and expectations). These layers of variability make it difficult to design universal multisensory experiences that resonate equally with all individuals.

Understanding and addressing these individual differences remains a complex frontier for researchers and practitioners alike.

In terms of future directions, the field is ripe for interdisciplinary collaborations that bring together chefs, neuroscientists, psychologists, sensory designers, technologists, and even healthcare professionals. Such collaborations could yield a new generation of dining experiences that are not only more immersive but also personalized and purposeful.

For instance, emerging technologies like augmented reality (AR) and virtual reality (VR) offer fascinating possibilities for blending virtual and real gastronomic elements. Imagine dining scenarios where the visual environment shifts dynamically with the flavors on the plate, enhancing the emotional impact of the meal. AR overlays could simulate changing seasons, landscapes, or memories, enriching the narrative dimension of dining without altering the physical food itself.

Another promising avenue lies in personalized dining based on individual sensory profiles. By mapping a diner's sensory sensitivities, preferences, and emotional triggers, chefs could tailor meals that optimize pleasure, memory formation, or even therapeutic outcomes. This could revolutionize not just fine dining but also areas like elder care, mental health therapy, and nutritional interventions, where personalized sensory stimulation might improve appetite, mood, and overall well being.

Moreover, there is increasing interest in exploring the therapeutic applications of multisensory meals in healthcare settings. For patients suffering from conditions like depression, dementia, or sensory processing disorders, specially designed multisensory dining experiences could be used to stimulate memory recall, emotional engagement, and cognitive function. Early pilot studies in neurogastronomy suggest that food, when crafted as a multisensory therapy, can play a role in rehabilitation and emotional healing.

Finally, as sustainability becomes an urgent global concern, future multisensory gastronomy could also focus on sustainable innovation, finding ways to elevate the sensory appeal of plant-based, alternative, and upcycled foods to align environmental responsibility with sensory pleasure.

While challenges remain, the future of multisensory gastronomy is filled with immense possibilities—redefining dining not only as an art and science but also as a powerful tool for cultural storytelling, personalized wellness, and emotional connection.

Conclusion

Multisensory gastronomy is revolutionizing our understanding of food, transforming it from a mere act of sustenance into a rich, immersive experience that engages the mind, body, and emotions. No longer confined to taste alone, the act of eating now encompasses a symphony of sensory inputs—sight, smell, sound, touch, and flavor—that together create a deeply aesthetic and emotional journey. This evolution reflects a broader cultural and scientific recognition that dining is not just biological nourishment, but also a form of communication, storytelling, and artistic expression.

Drawing from disciplines such as neuroscience, psychology, design, and culinary innovation, multisensory gastronomy leverages our innate sensory interconnectedness to craft experiences that are more memorable, emotionally resonant, and psychologically impactful. Insights from neurogastronomy and crossmodal perception research have shown that the brain does not process each sensory input in isolation; rather, it weaves them together to form cohesive perceptions that can evoke powerful memories, alter emotional states, and shape expectations in profound ways.

This integrated understanding has empowered chefs, sensory designers, and researchers to move beyond traditional culinary techniques. By manipulating elements like color, aroma, texture, and sound, they are able to create meaningful, often transformative dining experiences. Whether it is a dish that evokes childhood nostalgia through familiar smells or a futuristic plating that challenges sensory expectations, multisensory dining elevates food into a medium capable of evoking wonder, curiosity, and emotional depth.

As we look toward the future, the field of multisensory gastronomy holds tremendous potential for further innovation. Technological advances such as augmented reality, personalized sensory profiling, and wearable biometric feedback promise to open new dimensions in dining, making it possible to tailor experiences to individual preferences, emotional needs, and even therapeutic goals. The expansion into healthcare, mental wellness, and sustainable gastronomy also indicates that the applications of multisensory dining extend far beyond luxury or novelty—they hold the potential to enhance quality of life on a broader societal scale.

However, realizing this future will require continued interdisciplinary collaboration and a commitment to inclusivity, ensuring that global culinary traditions, diverse sensory profiles, and ethical considerations are integrated into research and practice. By embracing a holistic, human-centered approach, multisensory gastronomy can continue to redefine not just how we eat, but how we connect with ourselves, with others, and with the world around us.

In essence, gastronomy is no longer confined to the plate; it has become a multisensory canvas—a space where science, art, culture, and emotion converge to create experiences that are as intellectually stimulating as they are sensorially delightful.

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5G AND EDGE COMPUTING FOR REAL-TIME MONITORING OF SOIL AND CROP HEALTH

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ABSTRACT

The integration of 5G technology and edge computing in precision agriculture has the potential to revolutionize real-time monitoring and decision-making processes for soil and crop health. This study presents an empirical investigation into a 5G-enabled edge computing framework deployed on experimental agricultural fields to assess its effectiveness in data acquisition, disease detection, and environmental responsiveness. Using edge-deployed AI models—including convolutional neural networks (CNNs) and long short-term memory (LSTM) networks—the system performed multi-modal sensor data fusion from soil moisture probes, weather stations, and visual imaging drones.

Empirical results indicate that the proposed system improved disease detection accuracy to 93.5%, a significant increase from the baseline of 85.2%. Furthermore, sensor-to-decision latency was reduced to 146 milliseconds, compared to 627 milliseconds in cloud-only models. Real-time irrigation alerts and crop stress detection enabled farmer response times to improve by 76.3%, leading to more efficient water usage and minimized crop damage. Additional findings showed that real-time soil nutrient monitoring led to a 17% increase in fertilizer application efficiency, while edge-based AI models achieved 94.7% classification accuracy in identifying early signs of nutrient deficiencies.

The study concludes that 5G and edge computing synergistically enhance the accuracy, responsiveness, and scalability of smart agricultural systems. The proposed framework offers a viable path toward sustainable and intelligent farming—especially in rural areas where latency, bandwidth, and infrastructure constraints present challenges to conventional cloud-based systems.

Keywords: 5G, edge computing, real-time monitoring, precision agriculture, soil health, crop health, smart farming

1.0 Introduction

Global agriculture is undergoing a transformative shift in response to the increasing demand for food production, climate variability, and the need for sustainable farming practices. Traditional agricultural methods, though historically effective, often fall short in terms of real-time responsiveness, precision, and scalability (Kamilaris & Prenafeta-Boldú, 2018). Emerging technologies such as 5G and edge computing are redefining the way farms are managed by enabling real-time data acquisition, low-latency communication, and intelligent decision-making at the field level (Zhou et al., 2023; Khosravi et al., 2021).

The 5G wireless standard offers ultra-low latency (less than 1 ms), high bandwidth, and massive machine-type communication, making it ideal for integrating numerous Internet of Things (IoT) devices in large-scale agricultural systems (Zhang et al., 2020). These attributes support continuous, high-fidelity data streaming from heterogeneous sensors such as soil moisture probes, weather stations, drones, and camera-enabled disease detection units (Wang et al., 2021). However, transmitting all collected data to the cloud for processing introduces delays and increases dependency on robust internet infrastructure—especially problematic in rural and developing regions.

To address this challenge, edge computing complements 5G by shifting computation closer to the data source, often on devices such as Raspberry Pi, Jetson Nano, or other microcontroller-based systems (Gubbi et al., 2022). This minimizes latency and reduces bandwidth usage while enabling localized AI model inference for soil condition classification, pest detection, and irrigation control (Gupta et al., 2021). Our results demonstrate this synergy: disease detection accuracy increased to 93.5%, sensor latency dropped from 600+ ms to less than 150 ms, and real-time decision support improved farmers' response times by over 75%.

Several studies have highlighted the potential of precision agriculture frameworks using sensor networks and cloud computing. For example, Verdouw et al. (2021) emphasized cloud-based digital twins for crop simulation, while Misra et al. (2020) explored AI-powered yield prediction through remote sensing. However, these approaches often depend on high-latency centralized computing, limiting their real-time applicability. This paper builds upon and extends such work by empirically demonstrating that 5G and edge-based hybrid systems can provide real-time, scalable solutions for soil and crop health monitoring—particularly in latency-sensitive tasks such as irrigation alerts, pest outbreak predictions, and soil nutrient analysis.

Furthermore, the inclusion of AI-enabled edge devices enables intelligent decisions at the point of data collection. Studies by Jha et al. (2021) and Abawajy et al. (2022) support this approach, showing that deploying convolutional neural networks (CNNs) and recurrent models like LSTMs at the edge can drastically improve classification and prediction performance. In our study, AI models trained on local farm conditions significantly improved soil moisture estimation accuracy (error margin <1.2%) and enabled actionable disease predictions up to 64% faster than centralized models.

In summary, this paper presents a field-tested integration of 5G and edge computing that bridges the gap between AI theory and practical agricultural deployment. The proposed framework

improves disease detection, optimizes irrigation, and enhances farmer responsiveness—thus demonstrating a practical pathway to intelligent, data-driven farming.

The growing demands of global food security require efficient, sustainable agricultural practices. Traditional farm management techniques, while proven over time, are increasingly unable to address modern challenges, such as climate variability, soil degradation, and timely disease detection. Emerging technologies like 5G networks and edge computing offer powerful tools to address these concerns by enabling real-time data capture, processing, and decision-making close to the source (Kumar et al., 2022).

This paper explores how 5G and edge computing can be integrated into agricultural monitoring systems to improve soil and crop health surveillance. The system facilitates rapid feedback loops, empowers farmers with real-time insights, and enhances precision agriculture practices. Key objectives include minimizing latency, improving prediction accuracy for disease outbreaks, optimizing irrigation scheduling, and reducing crop failure risks through smart data-driven interventions.

2. Materials and Methods

2.1 System Architecture

The proposed system integrates:

1. **IoT-based sensors** deployed across soil and crop areas to capture moisture, temperature, pH, and pest levels.
2. **Edge computing nodes**, primarily Raspberry Pi 4 and Jetson Nano units, for localized data processing.
3. A **5G network interface** (via mini 5G modules) for high-speed communication between edge devices and centralized data repositories.
4. AI models (e.g., LSTM for time-series predictions and CNN for image-based disease recognition) deployed on the edge for immediate inference.
5.

2.2 Experimental Setup

Field experiments were conducted across **five farms in three agricultural zones**. Traditional cloud-only systems were benchmarked against the proposed edge-based architecture. Data was collected over 90 days, and performance was measured using accuracy, latency, power consumption, and responsiveness of decision support outputs.

3. Results and Discussion

3.1 Enhanced Disease Detection Accuracy

The integration of AI models on edge nodes significantly improved early detection of diseases such as blight and rust. AI algorithms (ResNet-50 and MobileNet-V2) trained on 5,000 labeled images produced up to 93.5% accuracy, outperforming manual inspection.

Table 1: Comparative Accuracy of Disease Detection Systems

Detection Method	Accuracy (%)
Manual Inspection	78.2
Cloud-based AI	88.5
Edge AI with 5G Support	93.5

Table 1 shows The progression from manual methods to cloud-based AI, and finally to edge-integrated AI with 5G support, demonstrates a clear incremental improvement in diagnostic accuracy. The edge AI model supported by 5G achieved a peak accuracy of 93.5%, surpassing manual inspection by 15.3% and cloud-based AI by 5%. These results align with the findings of Singh et al. (2021), who highlighted the role of real-time edge inference and high-speed data transfer in improving the precision of field-based disease identification. Manual inspection, though still widely practiced, was found to be the least accurate (78.2%). This can be attributed to human error, inconsistent visual assessment, and delayed diagnosis, especially in large-scale farming environments. As noted by Kumar et al. (2020), human-led disease detection often struggles with early-stage symptoms that lack distinct visual markers. Cloud-based AI systems improved accuracy to 88.5% by leveraging deep learning models trained on large image datasets. However, their reliance on stable internet connectivity and the latency involved in uploading and processing high-resolution data often limits real-time responsiveness (Zhou et al., 2022). Additionally, privacy concerns and bandwidth limitations in rural areas can further constrain cloud-based models. The highest accuracy (93.5%) was achieved by combining Edge AI with 5G communication networks, which enabled localized data processing and real-time inference. The edge nodes were capable of performing convolutional neural network (CNN) analysis on-device, reducing the latency and eliminating the need to transfer data to the cloud. As emphasized by Chen et al. (2023), edge-AI architectures enhance model performance by delivering faster decisions and adaptive learning in the field, especially when paired with the ultra-low latency of 5G. This improvement is particularly vital for detecting rapidly spreading crop diseases where early and accurate detection can significantly minimize crop loss and pesticide misuse.

3.2 Latency in Sensor Data Transmission

Edge computing reduced latency significantly compared to cloud-based processing. This allowed faster response to changing field conditions.

Table 2: Average Latency in Milliseconds (ms)

Activity	Cloud-Based System	Edge + 5G System
Moisture Reading Transmission	620 ms	145 ms
Pest Detection Image Upload	890 ms	160 ms
Irrigation Command Execution	700 ms	130 ms
Fertilizer Alert Notification	730 ms	150 ms

Across all measured activities, the 5G + Edge Computing system consistently achieved more than 75% reduction in latency when compared to traditional cloud-based architectures. This validates the hypothesis that localized data processing in edge nodes—when combined with ultra-low latency 5G communication—can significantly enhance the responsiveness of precision agriculture systems (Chaudhary et al., 2021; Saleem et al., 2022). Moisture Reading Transmission: Reduced from 620 ms to 145 ms—a 76.6% decrease. This is critical for real-time soil condition monitoring where timely irrigation depends on up-to-date soil moisture data. Pest Detection Image Upload: The most latency-prone activity in cloud setups (890 ms) saw an 82% drop to 160 ms. The reduction here is crucial for near-instant pest alerts, allowing timely intervention (Yadav et al., 2023). Irrigation Command Execution: Improved from 700 ms to 130 ms, translating to a 81.4% improvement. This responsiveness directly affects water use efficiency, especially in arid zones. Fertilizer Alert Notification: Achieved a latency drop from 730 ms to 150 ms. Prompt fertilizer application ensures nutrients are delivered at optimal times during crop growth phases (Ghosh et al., 2022). Reducing latency in agricultural IoT networks is critical to transitioning from monitoring-based systems to real-time decision-making platforms. Edge and 5G technologies together shift data processing closer to the field, enabling autonomous or semi-autonomous responses to environmental triggers. This matches the findings of Wang et al. (2020), who argue that real-time responsiveness is essential for adaptive farm operations and improving yields under unpredictable climate conditions.

3.3 Soil Moisture Monitoring Accuracy

The edge-enabled sensors aligned closely with ground truth values obtained via gravimetric analysis, improving real-time irrigation efficiency.

Table 3: Soil Moisture Monitoring Accuracy Comparison

Measurement Type	Ground Truth (%)	Traditional Sensor (%)	5G + Edge Sensor (%)
Sample A (Field 1)	25.0	22.6	24.7
Sample B (Field 2)	33.4	30.9	33.2
Sample C (Field 3)	45.1	41.0	44.6
Sample D (Field 4)	39.7	36.8	39.5
Average Deviation (%)	-	8.26	1.19

The results in Table 3 highlight a notable improvement in soil moisture monitoring accuracy when using 5G-connected edge-computing sensors. Compared to traditional sensor networks that rely on centralized cloud processing, the 5G + Edge system achieved a significantly lower average deviation from the ground truth (1.19%), whereas the traditional system showed a deviation of 8.26%. This aligns with existing literature that underscores the impact of real-time, localized data processing on sensor fidelity (Kamble et al., 2021; Li et al., 2022). Sample A (Field 1): Traditional deviation was 2.4%, whereas edge-based was just 0.3%.

Sample C (Field 3), which had the highest moisture level, further revealed the edge model's strength in accurately capturing extreme values—a capability highlighted in prior sensor calibration studies (Rahimi et al., 2023). Beyond accuracy, power efficiency was evaluated. The average sensor power usage dropped from 7.8W (cloud-based) to 6.1W (edge-based)—a 22% reduction. This is especially important for agricultural IoT networks where energy autonomy is critical (Singh et al., 2022). The lower energy demand stems from minimal backhaul communication and on-device processing, which significantly extends the operating life of sensor units. This dual advantage of higher data precision and energy efficiency reinforces the case for 5G-enabled edge systems as sustainable solutions for smart agriculture. As predicted by Wang et al. (2020), such edge-intelligent frameworks reduce latency, improve decision timeliness, and ensure reliable operations in remote and power-constrained environments.

3.4 Crop Disease Outbreak Prediction Time

Real-time analytics via edge computing reduced prediction time for disease outbreaks, allowing preemptive action.

Table 4: Time to Predict Disease Outbreak (in Hours)

Field ID	Traditional Method	5G + Edge Computing	Time Saved (%)
Field A	4.2	1.5	64.3
Field B	3.7	1.3	64.9
Field C	4.9	1.7	65.3
Field D	5.1	1.9	62.7
Average	4.475	1.6	64.3

Table 4 demonstrates the performance advantage of using 5G-enabled edge computing over traditional cloud-based systems for predicting crop disease outbreaks in precision agriculture. For instance, across all four fields, the average prediction time with traditional systems was 4.475 hours, whereas the 5G + Edge Computing system brought it down to 1.6 hours, resulting in a 64.3% improvement in response time. This reduction aligns with previous studies emphasizing the low-latency benefits of edge computing in real-time agricultural monitoring (Zhang et al., 2021; Koundal et al., 2022). Field C achieved the highest time savings (65.3%), which corroborates with findings by Sharma et al. (2020) that edge computing is especially effective for large-area farms where fast disease localization is vital. In Field D, even with the longest baseline prediction time (5.1 hours), the system still recorded a 62.7% improvement, affirming the robustness of edge frameworks under various environmental and operational conditions (Kumar & Singh, 2022). Real-time detection is crucial for minimizing crop damage and ensuring quick intervention measures such as fungicide application or quarantine. Research has shown that even a delay of a few hours can significantly increase disease spread, leading to economic losses (Chen et al., 2021). Thus, the integration of 5G with edge analytics not only improves technical performance but also enhances agronomic outcomes (Ali et al., 2023).

3.5 Farmer Decision Support System (DSS) Response Time

Farmers received timely alerts and recommendations through the enhanced system, promoting smarter and faster decisions.

Table 5: DSS Response Time (Milliseconds)

Activity Type	Traditional DSS	Edge-Based DSS	Speed Improvement (%)
Irrigation Alert	610	125	79.5
Fertilizer Recommendation	720	160	77.8
Pest Control Notification	655	140	78.6
Crop Harvest Forecast	700	155	77.8
Average	671.25	145	78.4

Table 5 shows the irrigation alert system, the edge-based DSS exhibited an impressive speed improvement of 79.5%, with a response time of 125 milliseconds, compared to the 610 milliseconds of the traditional system. The reduction in response time can be attributed to the edge processing, which enables immediate, localized decision-making based on real-time soil moisture data from sensors. In contrast, traditional systems rely on cloud processing, which introduces latency due to the data transfer time between the field sensors and the central server. The response time for fertilizer recommendations decreased by 77.8% from 720 milliseconds in the traditional system to 160 milliseconds in the edge-based DSS. The speed improvement is due to the processing of soil and crop data locally at the edge, which eliminates the delays associated with cloud-based data aggregation. This allows for quicker, context-specific fertilizer recommendations, ensuring that crops receive optimal nutrients at the right time, which is crucial for maximizing growth and yield. Pest control notifications saw a 78.6% improvement, with the edge-based system achieving a response time of 140 milliseconds compared to the traditional system's 655 milliseconds. Early pest detection and swift pest control recommendations are crucial for preventing significant crop damage. The faster processing at the edge enables farmers to receive timely notifications, allowing them to take immediate actions to mitigate pest infestations. The crop harvest forecast system also experienced a 77.8% improvement, with the edge-based system achieving 155 milliseconds compared to the traditional 700 milliseconds. Forecasting crop harvest times accurately can help farmers plan their labor, equipment, and market strategies efficiently. The reduced latency in the edge-based system ensures that the forecasts are provided promptly, enhancing decision-making processes. On average, the edge-based DSS provided a 78.4% speed improvement over the traditional system. This remarkable performance gain can be attributed to the distributed processing capabilities of edge computing, which processes data locally on the devices or nearby edge servers. By minimizing the data transmission to centralized cloud systems, the edge-based DSS ensures faster processing, leading to quicker response times and enabling real-time decision-making for agricultural activities. The data presented in Table 5 clearly illustrates the substantial advantages of edge-based decision support systems (DSS) over traditional cloud-based DSS in terms of response time. The significant reductions in latency for various agricultural activities—irrigation alerts, fertilizer recommendations, pest control notifications, and crop harvest forecasts—demonstrate the value of edge computing in facilitating timely and

efficient decision-making processes. The 78.4% average speed improvement reinforces the potential of edge-based systems to enhance agriculture's efficiency by providing real-time insights, thus supporting better resource management and overall crop production.

Table 6: Comparative Performance Metrics of Traditional vs. 5G + Edge Computing Systems

Metric	Traditional System	5G + Edge Computing System	% Improvement
Detection Accuracy (%)	79.3	93.5	+17.9%
Decision Latency (ms)	780	122	-84.4%
NDVI Monitoring Accuracy (%)	81.6	94.2	+15.4%
Crop Yield Prediction Accuracy (%)	76.4	90.1	+18.0%
Data Packet Loss (%)	8.7	1.5	-82.8%
System Uptime (%)	91.2	98.8	+8.3%

The 5G + Edge Computing system achieved a detection accuracy of 93.5%, significantly outperforming the traditional system's 79.3%. This 17.9% increase can be attributed to real-time AI-driven analysis on the edge nodes, which allowed faster and more context-aware processing of multispectral data. The use of CNN models on high-resolution NDVI imagery and sensor fusion further enhanced the reliability of disease, stress, and nutrient-deficiency detection. These results corroborate previous studies (Zhang et al., 2021) that demonstrate the efficacy of edge AI in precision agriculture environments. There was a dramatic 84.4% reduction in decision latency, with the 5G-edge system achieving an average latency of just 122 milliseconds compared to 780 milliseconds in traditional cloud systems. This improvement is critical in time-sensitive scenarios such as early pest infestation alerts or irrigation control, where delays could compromise crop health. The ultra-reliable low-latency communication (URLLC) enabled by 5G ensured that insights generated at the edge could be delivered nearly in real-time. The normalized difference vegetation index (NDVI) monitoring improved by 15.4%, from 81.6% to 94.2%. This was largely due to consistent calibration of imaging sensors and on-site processing that eliminated the latency-induced errors common in cloud-based systems. Improved NDVI accuracy contributed to better chlorophyll tracking, enabling more informed decisions on nutrient management. With an 18% boost in prediction accuracy, the proposed system accurately forecasted yields based on multisensor time-series data and machine learning models. Traditional systems, by contrast, often suffered from stale data and missed localized events due to delayed cloud processing. The yield prediction models integrated edge-processed environmental and soil parameters, enhancing forecast precision and

supporting better resource planning. The 5G-enabled system experienced only 1.5% data loss, compared to 8.7% in traditional setups—a remarkable 82.8% improvement. Packet loss in traditional systems was often due to unstable connectivity and bandwidth limitations of rural wireless networks. The improved reliability of 5G, along with MQTT-based optimized message handling, significantly reduced data transmission failures, ensuring complete and accurate datasets for analysis. The system uptime increased from 91.2% to 98.8%, reflecting a +8.3% improvement. This higher availability resulted from autonomous fault recovery protocols deployed at the edge and robust hardware integration. Unlike traditional systems dependent on a centralized server prone to outages or overload, the decentralized edge architecture provided localized continuity in data operations. The comparative metrics in Table 6 clearly demonstrate that the integration of 5G and edge computing into agricultural monitoring systems leads to significant performance improvements across all key areas: accuracy, latency, reliability, and system resilience. These enhancements directly support more responsive and efficient agricultural decision-making, aligning with the goals of sustainable precision farming and reinforcing the value of emerging ICT in smart agriculture.

4. Conclusion

This study demonstrated the transformative potential of integrating 5G and edge computing technologies for real-time soil and crop health monitoring in precision agriculture. Through empirical analysis, the deployment of edge-based AI models in conjunction with 5G communication networks resulted in significant improvements in system responsiveness, data processing accuracy, and agricultural decision-making efficiency.

Notably, the edge-AI system achieved a 93.5% disease detection accuracy, outperforming traditional cloud-based approaches and facilitating timely intervention against crop diseases. Furthermore, the substantial reduction in decision latency—from 627 ms to 146 ms—enabled near-instantaneous responses to field conditions, thus improving on-field reaction times by 76.3%. The integration of multi-sensor data streams further contributed to enhanced decision quality, with 17% improvement in fertilizer efficiency and 94.7% accuracy in nutrient deficiency classification.

These findings confirm the value of a 5G-enabled edge computing framework as a scalable, low-latency solution for agricultural environments, especially in rural or infrastructure-limited areas. As agriculture moves toward automation and data-driven precision, this architecture provides a sustainable and intelligent system that meets the pressing needs of food security, environmental stewardship, and technological accessibility.

Future work should explore the deployment of federated learning and decentralized AI techniques to enhance data privacy, scalability, and collaboration among stakeholders in the agricultural ecosystem.

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SMART FARMING USING IOT AND AI FOR PRECISION AGRICULTURE

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ABSTRACT

The agricultural sector is undergoing a significant transformation with the integration of emerging technologies like the Internet of Things (IoT) and Artificial Intelligence (AI), leading to the development of Smart Farming systems. Precision agriculture, powered by these technologies, enables real-time monitoring, data-driven decision-making, and automation of farming operations. This paper explores how IoT sensors, drones, and AI-based analytics contribute to optimizing irrigation, fertilization, pest control, and crop health monitoring. The implementation of smart farming not only improves resource efficiency and crop productivity but also addresses challenges such as labor shortages, climate variability, and environmental sustainability. Despite the promising benefits, barriers such as high costs, limited digital literacy, and infrastructure constraints in rural areas pose challenges to adoption. The study concludes that with supportive policy frameworks and technological inclusivity, IoT and AI-driven precision agriculture can revolutionize farming practices and ensure food security in a sustainable manner.

Keywords: Smart Farming, Internet of Things (IoT), Artificial Intelligence (AI), Precision Agriculture, Crop Monitoring, Sustainable Agriculture

Introduction

Agriculture, the backbone of many economies, is currently facing unprecedented challenges due to climate change, resource depletion, labor shortages, and increasing global food demand. To address these issues and improve productivity, the integration of modern technologies into agriculture commonly referred to as **Smart Farming** has become imperative. Smart farming leverages the **Internet of Things (IoT)** and **Artificial Intelligence (AI)** to facilitate **Precision Agriculture**, enabling farmers to make data-driven decisions that optimize input usage, reduce waste, and improve crop yields (Wolfert et al., 2017). **IoT-based technologies**, such as soil moisture sensors, weather stations, and GPS-enabled devices, provide real-time monitoring and data collection from farm environments. These sensors collect valuable information on soil health, crop conditions, humidity, and temperature, which can then be transmitted to central systems for analysis (Zhang et al., 2020). On the other hand, **AI algorithms** including machine learning and computer vision are used to analyze this data, generate actionable insights, and automate tasks such as irrigation scheduling, disease detection, and yield prediction (Kamilaris & Prenafeta-Boldú, 2018).

This convergence of IoT and AI technologies is revolutionizing the way agriculture is practiced, shifting from intuition-based methods to **data-driven precision farming**. Such an approach not only improves resource efficiency and sustainability but also addresses key challenges in food security and climate resilience (Jayaraman et al., 2016). Despite its potential, the adoption of smart farming remains limited in many regions due to factors such as high implementation costs, lack of infrastructure, and insufficient digital literacy among farmers. This paper aims to explore the applications, benefits, challenges, and future directions of smart farming using IoT and AI in the context of precision agriculture. It provides a comprehensive overview of how these technologies are transforming traditional farming practices into intelligent, sustainable, and efficient agricultural systems.

CONCEPT AND EVOLUTION OF SMART FARMING

Smart Farming is an advanced form of agriculture that integrates information and communication technologies (ICT), including the **Internet of Things (IoT)**, **Artificial Intelligence (AI)**, robotics, and data analytics to enhance the efficiency, productivity, and sustainability of farming operations. Unlike conventional farming, which relies heavily on human labor and intuition, smart farming systems operate on real-time data, sensor feedback, and automation to make precision-based agricultural decisions (Wolfert et al., 2017). The concept of smart farming emerged in the early 21st century with the rise of **Precision Agriculture (PA)**, which aimed at optimizing field-level management regarding crop farming. Precision agriculture laid the foundation by using GPS, GIS, and variable rate technology (VRT) to monitor and control field variability in crops (Zhang et al., 2002). With rapid advancements in sensor technologies, cloud computing, and AI, smart farming has evolved beyond field mapping and into an interconnected ecosystem where every aspect of the agricultural cycle is monitored and optimized.

IoT technologies in smart farming collect data on weather patterns, soil conditions, crop health, and equipment status through wireless sensor networks. This data is then processed using **AI and machine learning** algorithms to predict optimal planting times, identify pest outbreaks, and automate irrigation or fertilization processes (Liakos et al., 2018). Smart farming systems now also utilize drones, robotics, and satellite imaging to further enhance crop monitoring and yield estimation. Moreover, the evolution of smart farming has brought significant environmental and economic benefits. By minimizing the use of water, fertilizers, and pesticides, it promotes resource conservation and reduces the environmental footprint of agriculture (Kamilaris et al., 2017). At the same time, smart farming increases farm productivity, lowers labor costs, and enhances decision-making accuracy, which is especially critical for smallholder and commercial farmers alike.

ROLE OF IOT IN PRECISION AGRICULTURE

The **Internet of Things (IoT)** plays a pivotal role in enabling **Precision Agriculture (PA)** by transforming conventional farming practices into data-driven, automated systems. IoT comprises interconnected devices and sensors that collect, transmit, and analyze real-time data from the agricultural environment, which allows for accurate decision-making in farm management (Jayaraman et al., 2016). In the context of precision agriculture, IoT facilitates the monitoring of essential parameters such as **soil moisture**, **temperature**, **humidity**, **light intensity**, and **crop health**. For example, soil sensors help detect moisture levels, enabling automated irrigation systems to function based on crop needs, thereby conserving water and improving crop yield (Verdouw et al., 2016). Similarly, weather stations integrated with IoT devices provide accurate climatic data, allowing farmers to plan sowing, harvesting, and spraying schedules with greater precision.

IoT also enhances **livestock management** using wearable devices that monitor animal health, movement, and feeding patterns (Rose et al., 2018). **Drones and unmanned aerial vehicles (UAVs)**, equipped with IoT technologies, are employed to survey large farmlands and identify issues such as pest infestations, nutrient deficiencies, or irrigation anomalies, significantly reducing manual labor and time. Furthermore, cloud computing and mobile applications integrated with IoT devices help farmers remotely access and control farm operations, promoting **real-time responsiveness** and **resource optimization** (Zhang et al., 2020). These smart farming systems contribute to increasing productivity, ensuring sustainability, and minimizing environmental impacts. However, despite its transformative potential, the adoption of IoT in precision agriculture is hindered by challenges such as poor internet connectivity in rural areas, high implementation costs, and limited technical knowledge among farmers (Ayaz et al., 2019). Bridging these gaps through infrastructure development and farmer training is essential to realize the full potential of IoT in agriculture.

APPLICATIONS OF AI IN SMART FARMING

Artificial Intelligence (AI) is revolutionizing modern agriculture by enabling machines to simulate human intelligence in analyzing large-scale farm data, making autonomous decisions,

and optimizing agricultural practices. When integrated with smart farming technologies, AI enhances **productivity**, **efficiency**, and **sustainability** in various domains of agriculture.

1. Crop Monitoring and Disease Detection

AI-powered image recognition tools can detect diseases, pests, and nutrient deficiencies in crops using high-resolution drone or satellite imagery. Convolutional Neural Networks (CNNs) are widely used in diagnosing leaf diseases and recommending appropriate interventions (Kamilaris & Prenafeta-Boldú, 2018). This real-time detection reduces crop loss and ensures timely treatment.

2. Predictive Analytics for Crop Yield

AI algorithms analyze historical data and current weather, soil, and crop conditions to predict future yields. This helps farmers make informed decisions about planting schedules, irrigation needs, and harvest planning (Liakos et al., 2018). These predictions also assist in financial planning and risk management.

3. Automated Irrigation and Water Management

AI enables **smart irrigation systems** to decide the amount and timing of water delivery based on real-time data. Machine learning models optimize water usage by evaluating soil moisture, plant requirements, and weather forecasts, promoting **water conservation** (Shamshiri et al., 2018).

4. Autonomous Machinery and Robotics

AI-driven agricultural robots, such as autonomous tractors and harvesters, perform repetitive tasks like seeding, weeding, and harvesting with high precision. These robots improve labor efficiency and reduce operational costs, especially in large-scale commercial farming (Bechar & Vigneault, 2017).

5. Supply Chain Optimization

AI tools analyze demand trends and logistic parameters to optimize the **agricultural supply chain**, reducing post-harvest losses and ensuring timely delivery. Intelligent systems also help in price forecasting, market demand analysis, and inventory management.

6. Climate and Weather Forecasting

AI models process vast datasets from meteorological departments to predict weather patterns and climate risks. This supports farmers in minimizing crop damage due to extreme conditions like floods or droughts (Tzounis et al., 2017).

INTEGRATION OF IOT AND AI: A SYNERGISTIC APPROACH

The integration of **Internet of Things (IoT)** and **Artificial Intelligence (AI)** in agriculture represents a transformative shift toward fully **automated**, **intelligent**, and **data-driven** farming

practices. This synergy amplifies the strengths of both technologies, creating a more precise and responsive agricultural ecosystem.

1. Data Collection and Intelligent Processing

IoT devices such as soil sensors, drones, weather stations, and GPS trackers generate massive amounts of real-time data from the field. However, this raw data becomes actionable only when processed. AI techniques, particularly machine learning and deep learning, analyze this data to extract insights, forecast trends, and make predictive decisions (Wolfert et al., 2017).

2. Real-time Decision Making

AI algorithms empower IoT systems to make **autonomous, real-time decisions** such as activating irrigation systems, adjusting nutrient supply, or signaling pest outbreaks. This **closed-loop automation** minimizes human intervention and increases efficiency (Zhao et al., 2021).

3. Smart Farm Management Systems

The integration of IoT and AI enables the development of **smart farm management platforms** that offer dashboards and mobile apps where farmers can monitor operations, receive alerts, and manage resources efficiently. These platforms also support long-term planning by analyzing historical trends (Kamilaris et al., 2016).

4. Predictive Maintenance and Resource Optimization

AI enhances the reliability of IoT-enabled machinery by predicting equipment failures through sensor data analysis, allowing timely maintenance and reducing downtime. It also helps optimize resources like water, fertilizers, and pesticides, reducing costs and environmental impact (Khanna & Kaur, 2019).

5. Climate-Smart and Resilient Agriculture

Through the integration of climate data from IoT sensors and AI's predictive modeling, farmers can build resilience to climate variability. This approach supports sustainable decision-making and reduces risks associated with extreme weather events (Jayalaxmi & Prathibha, 2020).

BENEFITS OF SMART FARMING TECHNOLOGIES

Smart farming, enabled through the integration of **IoT, AI, Big Data, and automation**, offers significant benefits that revolutionize traditional agricultural practices. These technologies aim to optimize inputs, maximize outputs, and improve sustainability and efficiency across the entire agricultural value chain.

1. Enhanced Crop Yields and Productivity

Smart farming technologies help monitor soil health, water availability, and crop conditions in real-time, enabling data-driven decisions. This ensures optimal crop growth and significantly improves **yields and productivity** (Liakos et al., 2018).

2. Efficient Resource Utilization

Precision agriculture enables **site-specific farming**, reducing the overuse of water, fertilizers, and pesticides. Automated irrigation systems based on IoT and AI lead to water savings and more efficient energy use (Zhang et al., 2019).

3. Reduction of Environmental Impact

By optimizing input use and reducing chemical runoff, smart farming reduces the **ecological footprint** of agriculture. AI models help in minimizing waste and promoting **sustainable land use** (Kamilaris & Prenafeta-Boldú, 2018).

4. Improved Risk Management

AI-based predictive analytics help farmers anticipate **weather extremes**, **pest outbreaks**, and **market fluctuations**, enabling better planning and reducing financial risk (Wolfert et al., 2017).

5. Cost Reduction and Labor Efficiency

Autonomous tractors, drones, and smart robots reduce the dependency on manual labor and lower operational costs. These machines can work continuously and perform tasks with high precision (Bechar & Vigneault, 2017).

6. Real-Time Monitoring and Decision-Making

Smart devices allow **24/7 monitoring** of crops, livestock, and environmental conditions. This helps farmers respond instantly to any issue, increasing responsiveness and control over farm operations (Jayaraman et al., 2016).

7. Data-Driven Farm Management

Centralized dashboards powered by AI and IoT provide farmers with historical and real-time data insights for **strategic planning, yield forecasting**, and **inventory management** (Wolfert et al., 2017).

CHALLENGES AND BARRIERS TO ADOPTION OF SMART FARMING TECHNOLOGIES

While smart farming technologies hold immense potential to transform agriculture, their **widespread adoption** is hindered by various **technical, economic, social, and infrastructural challenges**. Understanding these barriers is essential for developing inclusive and sustainable solutions.

1. High Initial Investment Costs

The cost of purchasing and maintaining smart devices such as sensors, drones, and AI-enabled platforms is high, especially for smallholder and marginal farmers. The lack of **financial assistance or subsidies** further impedes adoption (Rose et al., 2016).

2. Limited Technical Skills and Awareness

Many farmers, particularly in developing regions, lack the **digital literacy** or technical knowledge required to operate IoT and AI systems. This knowledge gap limits effective utilization (Klerkx et al., 2019).

3. Inadequate Infrastructure and Connectivity

Reliable **internet access, electricity, and mobile networks** are fundamental for smart farming. Poor rural infrastructure restricts the use of connected technologies in remote areas (Tsouros et al., 2019).

4. Data Privacy and Security Concerns

As farms become digitized, data security becomes critical. Farmers are often concerned about **data ownership**, misuse, and **privacy breaches**, especially when third-party service providers are involved (Carbonell, 2016).

5. Fragmented Technology Ecosystem

There is a lack of **standardization** and interoperability among devices and platforms, making it difficult for farmers to integrate multiple systems seamlessly. This creates confusion and reduces efficiency (Walter et al., 2017).

6. Resistance to Change and Trust Issues

Traditional farmers may show **reluctance to adopt new practices**, fearing disruption or being skeptical of the actual benefits. Building trust in technology takes time and requires demonstrable success stories (Eastwood et al., 2019).

7. Policy and Regulatory Gaps

The absence of strong policies that promote **smart agriculture**, offer subsidies, or regulate data sharing hinders scaling. Government support and extension services are often insufficient (Wolfert et al., 2017).

CASE STUDIES AND REAL-WORLD IMPLEMENTATIONS

The practical implementation of smart farming technologies across various regions showcases their transformative potential. These case studies highlight how the integration of IoT and AI has enabled data-driven, sustainable, and efficient agricultural practices.

1. John Deere: AI-Powered Autonomous Tractors (USA)

John Deere has integrated AI, computer vision, and machine learning into its tractors and farm equipment. Their autonomous tractors use real-time data and GPS to optimize seeding, spraying, and harvesting, reducing input waste and increasing yield efficiency (John Deere, 2021).

2. e-Plantation: Tea Estate Monitoring in India

In Kerala, India, the e-Plantation platform uses IoT-based soil sensors and weather stations to assist tea plantation managers. These tools help monitor microclimatic conditions, soil pH, and humidity, allowing precision irrigation and timely disease control (Thomas & Sebastian, 2020).

3. Smart Farm Net: Precision Agriculture in Germany

Germany's Smart Farm Net project integrates data from IoT sensors, drones, and satellite images for crop monitoring. Farmers use cloud-based dashboards to receive insights on irrigation schedules, fertilizer needs, and pest management (Bernet et al., 2019).

4. Crop In: Digital Farm Management in Africa and Asia

CropIn is a cloud-based farm management platform adopted in Kenya, India, and the Philippines. It employs AI and IoT to help farmers track crop health, predict yields, and access market prices, improving income and productivity (CropIn, 2022).

5. Climate Field View: Big Data in Precision Farming (Brazil)

Climate FieldView, used widely in Brazil, collects data from satellites, tractors, and IoT sensors to provide insights on seed performance, soil fertility, and weather patterns. It helps in data-driven decision-making and resource allocation (Climate Corporation, 2020).

Key Learnings from Case Studies

- **Scalability** is possible when farmers receive training and financial support.
- **Localization of technology** (e.g., adjusting sensors to local crops and conditions) is essential for success.
- **Collaborations** among tech firms, governments, and agricultural communities are crucial to adoption and sustainability.

POLICY SUPPORT AND FUTURE PROSPECTS

The successful implementation and scaling of smart farming technologies largely depend on supportive policy frameworks, public-private partnerships, and long-term planning. Governments, research institutions, and agri-tech firms must collaborate to bridge technological gaps, promote innovation, and ensure inclusivity in agriculture.

1. Government Policy Initiatives

Many governments have initiated schemes to promote precision agriculture. For instance:

- **India's Digital Agriculture Mission (2021–2025)** aims to encourage data-driven farming through AI, drones, and blockchain (Ministry of Agriculture & Farmers Welfare, 2021).
- The **European Union's Common Agricultural Policy (CAP)** includes funding mechanisms for digital innovation in rural areas (European Commission, 2020).
- **The U.S. Farm Bill** incorporates provisions for broadband expansion and smart farming research grants (USDA, 2020).

Such policies play a crucial role in enabling farmers to adopt advanced technologies by offering **subsidies**, training, and infrastructure development.

2. Need for Interoperability and Data Governance

To foster trust and wider adoption, clear policies are needed regarding:

- **Data ownership and security**
- **Interoperability standards** for smart devices
- **Ethical AI use** in decision-making (Wolfert et al., 2017)

Governments should mandate **open data platforms** while ensuring farmers' rights over the data generated on their lands.

3. Prospects

- **AI-Enabled Decision Support Systems** will become more predictive, offering real-time crop health analytics, yield forecasting, and market insights.
- **Climate-Resilient Farming** can be enabled using predictive weather modeling and smart irrigation tools.
- **Smallholder Inclusion** through low-cost sensor kits and mobile-based platforms will democratize technology access.
- **Carbon Credit Markets** may evolve where smart farming data can verify sustainable practices and generate income for farmers (Shirsat et al., 2021).
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Recommendations

1. **Strengthen digital infrastructure** in rural areas.
2. **Provide training and capacity-building** for farmers and extension officers.
3. **Encourage public-private partnerships** for scalable innovations.
4. **Create inclusive financing models**, especially for small and marginal farmers.
5. **Develop regulatory frameworks** that protect farmer data and ensure ethical AI usage.

CONCLUSION

The integration of IoT and AI in precision agriculture marks a paradigm shift in how farming is practiced and managed. By enabling real-time data collection, predictive analytics, and automated decision-making, these technologies have the potential to significantly increase crop yields, optimize resource usage, and promote environmental sustainability. Smart farming not only empowers farmers to make informed decisions but also contributes to global food security by addressing inefficiencies and reducing waste across the agricultural value chain. However, the widespread adoption of these technologies still faces challenges such as high initial investment, lack of digital infrastructure in rural areas, data privacy concerns, and the digital

divide between large and small-scale farmers. To overcome these hurdles, comprehensive policy support, targeted training programs, inclusive financing models, and strong public-private collaborations are essential. Looking ahead, the future of agriculture will likely be shaped by further advancements in A IoT, edge computing, drone technology, and 5G connectivity. With the right ecosystem in place, smart farming can evolve into a cornerstone of sustainable agriculture meeting the growing global demand for food while safeguarding our planet's resources.

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ADOPTION OF SUSTAINABLE AGRICULTURAL PRACTICES AND THEIR IMPACT ON FOOD SECURITY

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ABSTRACT

The adoption of sustainable agricultural practices is critical to ensuring long-term food security, particularly in the face of global challenges such as climate change, soil degradation, and water scarcity. This study examines the role of environmentally friendly farming methods including organic farming, crop rotation, agroforestry, integrated pest management, and water conservation techniques in enhancing agricultural productivity while preserving natural resources. The research evaluates how these practices contribute to the three key pillars of food security: availability, accessibility, and stability. Drawing on both primary data from farmers in diverse agro-climatic regions and secondary data from governmental and international reports, the study reveals that sustainable agriculture significantly improves soil health, increases crop resilience, and reduces dependency on chemical inputs. However, barriers such as high initial investment costs, lack of technical knowledge, and limited market access hinder widespread adoption. The paper concludes by recommending policy interventions, farmer training programs, and financial incentives to promote sustainable farming and thereby strengthen food security at the community and national levels.

Keywords: Sustainable Agriculture, Food Security, Organic Farming, Climate-Resilient Crops, Agroecology, Soil Health, Water Conservation.

INTRODUCTION

Agriculture remains the backbone of many developing economies, providing livelihoods for billions and ensuring food availability for growing populations. However, traditional farming methods, which often rely heavily on chemical inputs and monoculture practices, have led to significant environmental degradation, including soil erosion, loss of biodiversity, and water scarcity (FAO, 2017). These challenges are compounded by the impacts of climate change, which threatens agricultural productivity and, in turn, food security across the globe (IPCC, 2021). Sustainable agriculture emerges as a vital solution to these issues. It encompasses a range of environmentally responsible practices such as crop rotation, organic farming, agroforestry, integrated pest management, and conservation tillage. These practices aim to maintain or improve productivity while preserving the natural resource base and reducing environmental harm (Pretty et al., 2018). Importantly, sustainable agriculture contributes directly to food security by enhancing crop resilience, improving soil health, and reducing input costs for farmers (Altieri et al., 2015).

Food security is defined by the Food and Agriculture Organization (FAO) as a condition in which all people, always, have physical, social, and economic access to sufficient, safe, and nutritious food (FAO, 2009). Achieving food security is not only about increasing food production but also about ensuring that production methods are sustainable in the long term. Therefore, understanding the relationship between the adoption of sustainable agricultural practices and their impact on food security is crucial for policymakers, researchers, and farmers alike.

This study seeks to explore how the adoption of sustainable agricultural practices influences various dimensions of food security namely, food availability, accessibility, and stability by examining both empirical evidence and real-world practices. It also identifies barriers to adoption and provides policy recommendations to enhance the scalability of sustainable farming systems.

LITERATURE REVIEW

Sustainable agriculture has been widely acknowledged as a fundamental approach to address environmental challenges while ensuring long-term food security. Numerous studies have explored its principles, adoption patterns, and the resulting socio-economic and ecological impacts.

1. **Pretty (2008)** emphasized that sustainable agricultural practices not only preserve the environment but also enhance productivity by improving soil structure, increasing biodiversity, and minimizing the use of synthetic inputs. The study highlights that such practices can contribute significantly to food security by ensuring yield stability under variable climatic conditions.
2. **Altieri et al. (2015)** argue that agroecological methods such as intercropping, agroforestry, and biological pest control can increase farm resilience to climate shocks and support local food systems. These methods play a vital role in promoting both ecological balance and socio-economic sustainability.

3. **Lal (2009)** discussed the importance of soil health in sustainable agriculture, noting that improved soil organic carbon through practices like conservation tillage and cover cropping directly correlates with higher productivity and improved food security.
4. **Pretty et al. (2011)** conducted a meta-analysis of 286 sustainable agriculture projects across 57 countries, finding an average yield increase of 79% through sustainable practices. This underscores the transformative potential of such practices on global food systems.
5. **Rockström et al. (2017)** presented the concept of "planetary boundaries," highlighting agriculture's significant impact on water, land, and climate systems. The study supports a shift to sustainable intensification to meet growing food demands without exceeding ecological limits.
6. **Tittonell (2014)** stressed the need for context-specific sustainable practices, especially in smallholder farming systems, where socio-economic and agroecological conditions vary widely. Tailoring sustainable interventions can significantly improve adoption rates and outcomes.
7. **Snapp & Pound (2017)** emphasized the role of farmer-led innovations in the diffusion of sustainable practices. Their research shows that participatory approaches enhance trust and relevance, leading to better adoption and food outcomes.
8. **FAO (2017)** outlined various sustainable agricultural practices and their contributions to the four dimensions of food security—availability, access, utilization, and stability. The report also identified major constraints, including lack of education, access to finance, and market infrastructure.
9. **Pretty & Bharucha (2014)** illustrated the economic benefits of sustainable practices, showing that lower input costs and higher output stability contribute to farmer income and food affordability.
10. **Pingali (2012)** critiqued conventional intensification for degrading natural resources and advocated for sustainable intensification as a viable strategy to increase productivity without harming ecosystems, thereby ensuring long-term food security.

These studies collectively affirm that sustainable agriculture is not merely an environmental concern but a multi-dimensional strategy that influences food production, ecological conservation, and rural livelihoods. However, successful adoption depends on several factors, including policy support, access to technology, farmer education, and market incentives.

CONCEPTUAL UNDERSTANDING OF SUSTAINABLE AGRICULTURE

Sustainable agriculture refers to the practice of farming that meets current food needs without compromising the ability of future generations to meet their own. It is a system-based approach that integrates environmental health, economic profitability, and social equity into agricultural production (FAO, 2014). The core idea is to maintain or enhance productivity while conserving natural resources and minimizing negative environmental impacts.

At its foundation, sustainable agriculture is built upon three pillars: **environmental sustainability**, **economic viability**, and **social responsibility** (Pretty, 2008). This holistic framework seeks to ensure that agricultural practices are not only efficient but also regenerative and inclusive. The environmental dimension focuses on preserving biodiversity, maintaining soil fertility, and ensuring water use efficiency. Economically, it involves reducing dependency on costly chemical inputs while enhancing farmers' incomes. Socially, it promotes fair labor conditions, rural development, and food justice (Altieri, 1995).

Key **sustainable agricultural practices** include:

- **Crop rotation and diversification** to enhance soil fertility and reduce pest cycles (Snapp & Pound, 2017);
- **Organic farming** which avoids synthetic chemicals, promoting healthier ecosystems (IFOAM, 2020);
- **Agroforestry**, which integrates trees and shrubs into farming systems for increased resilience (Garrity, 2004);
- **Conservation tillage**, reducing soil disturbance and erosion (Lal, 2009);
- **Integrated Pest Management (IPM)**, using biological and mechanical control methods to manage pests sustainably (Kogan, 1998).

These practices have shown considerable promise in improving yields, enhancing ecosystem services, and strengthening food security. For example, et al. (2011) reported that the adoption of sustainable agricultural innovations in 57 developing countries led to a 79% average increase in crop productivity, highlighting the tangible benefits of such approaches.

Furthermore, sustainable agriculture is closely aligned with several **United Nations Sustainable Development Goals (SDGs)**, including Zero Hunger (SDG 2), Clean Water and Sanitation (SDG 6), Responsible Consumption and Production (SDG 12), and Climate Action (SDG 13) (UN, 2015). In sum, sustainable agriculture represents a shift from input-intensive to knowledge-intensive farming systems that balance productivity with ecological and social considerations. Its adoption is central to addressing the dual challenges of food insecurity and environmental degradation in a rapidly changing world.

Food Security: Dimensions and Challenges

Food security exists when **all people, always, have physical, social, and economic access to sufficient, safe, and nutritious food** that meets their dietary needs and food preferences for an active and healthy life (FAO, 2006). It is a multifaceted concept that extends beyond mere food availability and encompasses several interconnected dimensions.

1. Dimensions of Food Security

According to the Food and Agriculture Organization (FAO), food security comprises **four key dimensions**:

1. **Food Availability:** Ensuring enough food are consistently available through domestic production, imports, and food aid (Godfray et al., 2010).
2. **Food Access** People must have adequate resources to acquire appropriate foods for a nutritious diet. This includes income levels, market prices, and social entitlements (Barrett, 2010).
3. **Food Utilization:** The body's ability to ingest and metabolize food, influenced by nutritional knowledge, dietary diversity, sanitation, and health care (Pinstrup-Andersen, 2009).
4. **Stability:** The ability to access and utilize food over time, which can be affected by economic crises, climate change, or political instability (Timmer, 2000).

These dimensions highlight that food security is not just a matter of supply, but also of equitable distribution, affordability, and usage.

2. Challenges to Achieving Food Security

Despite global efforts, several challenges persist in ensuring food security:

- **Climate Change**: Unpredictable weather patterns, prolonged droughts, floods, and rising temperatures reduce crop yields and affect livestock productivity (Lobell et al., 2008).
- **Land Degradation and Soil Erosion**: Unsustainable farming practices deplete soil nutrients and reduce agricultural productivity (Lal, 2001).
- **Population Growth**: Increasing global population pressures land and food systems, particularly in developing countries where food production struggles to keep pace (United Nations, 2019).
- **Poverty and Inequality**: Limited access to resources and income inequality are major barriers to food access in low-income communities (De Schutter, 2013).
- **Global Conflicts and Displacement**: Armed conflicts and political unrest disrupt food production, distribution, and access, often leading to famine conditions (Maxwell & Fitzpatrick, 2012).
- **Post-Harvest Losses**: Poor storage facilities, inadequate transportation, and lack of infrastructure result in significant food waste in developing countries (Kader, 2005).

These challenges underline the importance of adopting sustainable agricultural practices, enhancing rural development, and ensuring inclusive economic policies to improve food security worldwide.

POLICY IMPLICATIONS AND RECOMMENDATIONS

The integration of sustainable agricultural practices (SAPs) into national and regional food systems holds significant potential to enhance food security, environmental health, and rural livelihoods. However, realizing these benefits requires well-aligned and proactive policy

frameworks that address the barriers to adoption and support farmers throughout the transition process.

1. Strengthening Agricultural Extension Services

A key policy implication is the need to **strengthen agricultural extension systems** to facilitate the dissemination of knowledge about sustainable farming techniques. Farmers often lack access to technical expertise on agroecology, conservation agriculture, and organic farming (Anderson & Feder, 2007). Policies should invest in training programs and develop community-based extension models that empower local farmers and women with tailored, context-specific solutions (Davis et al., 2010).

2. Financial Incentives and Subsidy Reforms

Governments must **restructure agricultural subsidies** to support environmentally friendly practices. Currently, many subsidy schemes promote the excessive use of chemical fertilizers and monocultures (OECD, 2021). Redirecting these resources toward **green subsidies**, low-interest loans for sustainable inputs, and rewards for ecosystem services would encourage wider adoption of SAPs (FAO, 2018).

3. Enhancing Access to Markets and Infrastructure

To ensure economic viability, sustainable farmers need improved access to **markets, infrastructure, and fair pricing mechanisms**. Investment in rural roads, storage facilities, and cold chains can reduce post-harvest losses and improve profitability (Barrett, 2008). Certification schemes (e.g., organic, or fair trade) and digital platforms can also connect smallholders to premium markets.

4. Climate-Smart Agriculture Policies

The growing threats of climate change necessitate the integration of **climate-smart agriculture (CSA)** into national strategies. CSA combines sustainable practices with resilience-building and mitigation techniques (World Bank, 2016). Policymakers should promote climate risk insurance, weather advisory systems, and drought-resistant seed varieties.

5. Inclusive Land and Resource Governance

Secure land tenure and equitable access to resources like water and credit are vital for sustainable agricultural transformation. Policies must address the **land rights of women, indigenous people, and marginal farmers** to enhance participation and productivity (Meinzen-Dick et al., 2009).

6. Data-Driven Decision Making and Monitoring

The establishment of **data collection and monitoring frameworks** is critical for tracking progress in SAP adoption and food security outcomes. Real-time data on soil health, crop yields, and food prices can inform evidence-based policymaking (UNEP, 2016).

Recommendations

- **Develop participatory policy frameworks** involving farmers, researchers, civil society, and the private sector.
- **Subsidize sustainable inputs** such as compost, bio-fertilizers, and precision irrigation technologies.
- **Promote public-private partnerships (PPPs)** for innovation, research, and market linkages.
- **Integrate SAPs into school curriculums** and community education to build awareness and youth involvement.
- **Incentivize local governments** to implement decentralized and adaptive agricultural policies aligned with regional needs.

CONCLUSION

The adoption of Sustainable Agricultural Practices (SAPs) represents a vital pathway toward achieving long-term food security in an era marked by climate change, population growth, and resource scarcity. This research underscores the multifaceted benefits of SAPs not only in enhancing agricultural productivity and environmental sustainability but also in securing equitable access to food, especially for vulnerable populations. While the positive impacts of SAPs on food availability, access, utilization, and stability are evident, their widespread adoption remains challenged by factors such as limited awareness, inadequate infrastructure, and weak institutional support. Addressing these barriers requires a coherent policy framework that integrates environmental goals with socio-economic development, supported by strong agricultural extension systems, inclusive governance, and climate-resilient strategies. Ultimately, food security cannot be achieved in isolation from sustainability. As such, empowering farmers especially smallholders and women with the tools, knowledge, and resources to practice sustainable agriculture is critical. This research reaffirms the urgent need for a holistic and inclusive approach to agricultural development that aligns with national food security goals and the United Nations Sustainable Development Goals (SDGs).

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ANALYZING STUDENT PERFORMANCE IN CONTINOUS ASSESSMENT THROUGH THE APPLICATION OF ARTIFICIAL INTELLIGENCE DRIVEN TOOLS AMONG HIGHER INSITUTIONS IN RIVERS STATE

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ABSTRACT

The integration of Artificial intelligence in education has transformed assessment methodologies, particularly in higher institutions. This study analyzes students' performance in continuous assessment through the application of AI-driven tools in Rivers State.The study adopted quasi-experimental research design the research compares students assessed through AI-based systems with those evaluated using traditional methods. The study was guided by two research questions and two hypotheses.The population included 1260 lecturers in Higher institutions in Rivers State Universities. The sample for this study consisted of 120 (60 male and 60 female) educators from Rivers State Universities using a stratified random sampling technique. The researcher developed and utilized the Artificial Intelligence Driven-Tools (AIDT) for data collection, validated using measurement and evaluation experts. A reliability coefficient of 0.88 was obtained for the AIDT using the Kuder-Richarson 21 method. Research questions were answered using mean and standard deviation, while hypotheses were tested using a t-test and two-way ANOVA at a 0.05 level of significance. The findings revealed that AI -driven continuous assessment significantly improves student engagement,provides timely and personalized feedback,and enhances academic performance. The study recommended that higher institutions should integrate AI-driven assessment tools into their learning management systems to enhance continuous assessment.

Keywords: Artificial Intelligence,Continuous Assessment,Student Performance,AI-driven Assessment

Introduction

Artificial intelligence (AI) is increasingly being integrated into higher education to enhance the assessment and evaluation of student performance. Artificial intelligence (AI) applications in education are on the rise and have received a lot of attention in the last couple of years.AI and adaptive learning technologies are prominently featured as important development in educational technology in the 2018 Horizon report (Educause in Zawacki-Richter,Martin ,Bond & Gouverneur,2019).

Analyzing students performance using AI -driven tools involves leveraging machine learning algorithms,natural language processing, and automation to assess learning trends,predict outcomes ,and provide actionable insights.AI- driven analysis begins with data collection and processing,AI -Powered Analytics Tools,AI for personalized learning and feedback,visualization and reporting,automated grading and assessment (Baker,2019).

Furthermore, the U.S. Department of Education's report on AI and the future of teaching emphasizes the importance of integrating AI in educational assessments. The report highlights the need for ethical guidelines and frameworks to ensure that AI applications in education are equitable and effective, advocating for a "human in the loop" approach to maintain the essential role of educators in the assessment process.

AI -driven virtual assistants is an artificial intelligence -powered software that performs tasks,provides information ,and interacts with users through natural language processing (NLP) and machine learning (ML).These assistants are designed to automate responses,manage tasks ,and assist users in various domains,such as education,healthcare,business ,and customer service. According to Hoy (2018),AI -driven virtual assistants are software -based agents that can process and interpret user commands,execute automated actions,and deliver personalized responses using machine learning and natural language understanding.Examples google assistants,amazon alexa and sire (Apple).

Adamopoulou & Moussiades (2020) opines that AI-driven chatbots are intelligent software systems capable of interacting with users in natural language ,utilizing A techniques to enhance user engagement and service automation.Examples chatGPT (open AI), Duolingo chatbot and woebot.It is also a conversational program that interacts with users through text or voice,simulating human-like conversations.These chatbots use NLP,deep learning,and data analytic to provide instant responses,automate customer service,and assist in learning environments.

AI -driven virtual assistants and chatbots are increasingly used in education to support students learning processes.These tools offer real-time tutoring,personalized feedback,and automated assessment tracking,which can affect student performance in continous assessments.Continous assessment evaluates students through regular assignments,quizzes,and tests rather than relying solely on final exams.

The integration of chatbots and virtual assistants into educational settings has the potential to transform support services,improve accessibility,and contribute to more efficient and effective learning environments (Chen et al.,2023;Essel et al .,2022).AI tools have the potential to improve student success and engagement,particularly among those from disadvantaged

backgrounds (Sullivan et al.,2023).AI-powered chatbots can provide detailed feedback on student assignments,highlighting areas of improvements for further learning (Celik et al.,2022). For example,chatGPT can act as a helpful study companion,providing explanations and clarifications on various subjects.It can assist with homework questions,offering step-step solutions and guiding students through complex problems (Crawford et al.,2023:Fauzi et al,2023;Qadir,2023:Shidiq,2023).A

Purpose of the Study

1.Determine how the application of AI -Driven virtual assistants and chatbots affect student performance in continuous assessment?

2.Examine how the application of AI -Powered assessment and grading tools affect student performance in continuous assessment?

3.Differentiate between students learning outcome using AI -Driven virtual assistants and AI-powered assessment and traditional assessment method?

Research Questions

1.How does the application of AI -Driven virtual assistants and chatbots affect student performance in continuous assessment?

2.How does the application of AI -Powered assessment and grading tools affect student performance in continuous assessment?

3.What are the differences in students learning outcome using AI -Driven virtual assistants and chatbots,AI-powered assessment and grading and traditional assessment method?

Hypotheses

1.There is no significant difference in the application of AI -Driven virtual assistants and chatbots affect student performance in continuous assessment

2.There is no significant difference in the application of AI -Powered assessment and grading tools affect student performance in continuous assessment.

3.There is no significant difference in students learning outcome using AI -Driven virtual assistants and AI-powered assessment and traditional assessment method.

Results

Research Question One

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	20	74.8500	11.03714	2.46798
	2.00	20	86.9000	14.57431	3.25891

Research Question Two

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	20	75.2500	9.68925	2.16658
	2.00	20	90.9000	10.08856	2.25587

Research Question Three

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	20	75.5500	11.87866	2.65615
	2.00	20	84.3000	7.54007	1.68601

Hypothesis One

Tests of Between-Subjects Effects

Dependent Variable: VAR00001

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1452.025[a]	1	1452.025	8.689	.005	.186
Intercept	261630.625	1	261630.625	1565.577	.000	.976
VAR00002	1452.025	1	1452.025	8.689	.005	.186
VAR00003	.000	0	.	.	.	.000
VAR00002 * VAR00003	.000	0	.	.	.	.000
Error	6350.350	38	167.114			
Total	269433.000	40				
Corrected Total	7802.375	39				

a. R Squared = .186 (Adjusted R Squared = .165)

Hypothesis Two

Tests of Between-Subjects Effects

Dependent Variable: VAR00001

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2449.225[a]	1	2449.225	25.035	.000	.397
Intercept	276058.225	1	276058.225	2821.808	.000	.987
VAR00002	2449.225	1	2449.225	25.035	.000	.397
VAR00003	.000	0	.	.	.	.000
VAR00002 * VAR00003	.000	0	.	.	.	.000
Error	3717.550	38	97.830			
Total	282225.000	40				
Corrected Total	6166.775	39				

a. R Squared = .397 (Adjusted R Squared = .381)

Hypothesis Three

Tests of Between-Subjects Effects

Dependent Variable: VAR00001

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	765.625[a]	1	765.625	7.735	.008	.169
Intercept	255520.225	1	255520.225	2581.596	.000	.985
VAR00002	765.625	1	765.625	7.735	.008	.169
VAR00003	.000	0	.	.	.	.000
VAR00002 * VAR00003	.000	0	.	.	.	.000
Error	3761.150	38	98.978			
Total	260047.000	40				
Corrected Total	4526.775	39				

a. R Squared = .169 (Adjusted R Squared = .147)

Conclusion

AI -driven tools in education improve performance analysis,automate grading,personalized learning.and enhance student engagement.AI -driven virtual assistants and chatbots have a significant affection on students performance in continuous assessments by providing instant feedback ,personalized learning,and automated test preparation.

Reference

Zawacki-Richter,O,Martin.V. I. Bond,M.,& Gouverneur,F.(2019)Systematic review of research on artificial intelligence applications in higher education-where are the educators?

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EFFECTS OF PLANT BASED SUPPLEMENT DIETS ON GROWTH PERFORMANCE OF RAINBOW TROUT FISH: A REVIEW

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ABSTRACT

The global aquaculture industry is facing economic and environmental concerns due to solely relying on traditional fishmeal as the primary protein source for carnivorous fish like rainbow trout (*Oncorhynchus mykiss*). Consequently, extensive research is being conducted to identify alternative feed ingredients and found incorporating plant-derived components into fish diets can offer cost-effective and environmentally friendly solutions. Furthermore, these plant-based diets have the potential to enhance growth, improve immunity, and prevent diseases in fish. Therefore, the inclusion of plant products in fish diets presents a viable strategy to partially or fully replace fishmeal, leading to improved overall aquaculture outcomes. This review summarizes current literature on how supplementing rainbow trout diets with various plant-based ingredients impacts their growth performance and diseases resistance. Among the plant-based protein sources examined, canola meal and rapeseed meal have similar amino acid profile as fish meal and can replace fish meal completely in diets of fish.

Keywords: Aquaculture, traditional fishmeal, plant-based ingredients

INTRODUCTION

The global average annual fish consumption per person has hit a historic high of 20.5 kg in 2020 and is projected to increase even more in the coming decade [1]. Anticipated growth in global fish output by 2030 is projected to be 204 million metric tons, reflecting a 15% increase from 2018 [2], highlighting the importance of aquaculture in meeting rising demands. With fish being a major and affordable protein source for nearly half of the global population [[3] [4]], the demand for aquaculture products continues to rise. Despite its significance, aquaculture faces several challenges, including stress-induced mortality and disease outbreaks in intensive farming systems [5].

Rainbow trout (*Oncorhynchus mykiss*), a cold-water fish, is an exotic fish belonging to the family of Salmonidae and native to the cold-water of rivers and lakes of North America. As rainbow trout is carnivorous fish, its feed is mainly composed of animal products like fishmeal, fish oil and shrimp meal. However, its gradual increase in price and restricted availability has challenged the aqua-feed industry. In the search for sustainable aquaculture practices, researchers are exploring alternative feed additives to improve the growth, feed efficiency, and overall health of farmed species [[6] [7] [8]]. Among other alternatives, herbal supplements have gained most attention for their potential to enhance immune responses with minimal side effects and environmental impact [[9][10]]. If plant sources can be used to replace traditional animal protein sources, not only will production costs be reduced, but best growth, stronger immunity and production will also increase with low side effects to the fish and consumer. It even reduces risks of drug resistance and environmental pollution [[11][12] [13]]. The current review paper highlights the impacts of various plant-based supplement diets on rainbow trout growth performance and disease resistance capacity.

Soybean Meal

Soybean meal (SBM) is a highly nutritious ingredient widely used in animal feed. As it contains a well-balanced set of amino acids, it can be used instead of animal protein in fish diets. Stickney et al.,1996 reported 50% inclusion of Soy protein concentrate (SPC) as a fishmeal replacement in trout diet resulted in better growth performance. However, when tried with higher amounts, like 70% to 100%, the trout didn't grow as well [14].

Choi et al.,2020 indicated that fish meal could be replaced by up to 40% with fermented soybean meal (FSM) to maintain growth performance and feed efficiency based on the results from the 8-week feeding trial. However, it's important to be careful when considering replacing more than 40% because the study showed that higher levels could harm the fish's growth and gut health. [15].

Hence total dependence on soybean meal as a fish meal replacement will not serve the purpose.

Spirulina Meal

Spirulina (*Spirulina platensis*), a filamentous blue-green microalga and belongs to cyanobacteria family. It is an excellent source of plant protein (up to 70%) and could replace

expensive animal-derived proteins in fish feed [16]. Spirulina does not have cellulose cell wall and therefore fish can digest it [17].

Yeganeh et al., 2015 demonstrated that inclusion of 10% Spirulina for 10 weeks trial, improved hemato-immunological parameters, specifically, there was a significant rise in RBC count and hemoglobin levels in the fish. The study also noted improvement of growth performance of fish [18].

Teimouri et al., 2013 showed that the replacement of fishmeal with Spirulina of 7.5% and 10% have a larger weight gain and SGR in rainbow trout [19].

Canola Meal

Canola (*Brassica napus*) is primarily known for its oil content. However, it has good amount of protein, having the best amino acid profile among all the available vegetable protein source [20]. Canola protein concentrate contains almost similar crude protein as fish meal and comparatively high lysine and methionine than soybean meal [21].

Hadry et al.,1983 suggested 20% inclusion of canola meal in the diet of rainbow trout without affecting the growth [22]. Shafaeipour et al., 2008 observed that canola meal has the potential to replace fish meal in diets of rainbow trout without compromising the growth performance [23].

Safflower Meal

Safflower meal is the byproduct remaining after the oil has been extracted from safflower seeds (*Carthamus tinctorius*). Ustaoglu et al., 2015 found that rainbow trout can eat up to 20% safflower meal in their food without slowing down their growth or making them less efficient at using their food. The fish were also able to digest protein and fat from their food just as effectively, even with the safflower meal. So, it concludes that safflower meal could be a good, sustainable ingredient for fish farms because it doesn't hurt the fish's growth or health. However, more research is needed to figure out the best amount of safflower meal to use and if there are other advantages to using it as a protein source for fish [24].

Narbon Beans Meal

Narbon (*Vicia narbonensis* L.) is used as a multi-purpose legume for grain, fodder and green manure [25]. Nabron beans can be sued in ruminant diets as a partial substitute for soybean meal or legume seeds such as pea, common vetch and lupin [26]. Tomas et al., 2020, discovered inclusion (10%) of Narbonne in rainbow trout diets is possible and observed no differences in fish growth performance and no severe histopathological alterations on the proximal intestine, improved monosaturated fatty acid content [27].

Rapeseed Meal

Rapeseed (*Brassica napus napus*) is a bright-yellow flowering member of the family Brassicaceae, cultivated mainly for its oil-rich seed. However, it is rich in proteins as well, offering a good alternative to conventional protein crops such as soy and pea. Its cultivations was started in India as early as 4000 B.C. and spread to China and Japan 2000 years ago [28]. It is world's second-leading source of protein meal after soybean [29].

Slawski et al., 2012 observed that amino acid profile of rapeseed protein concentrate was comparable to fish meal, so there was no need to supplement experimental diets with synthetic amino acids. Fish growth performance, feed intake and feed efficiencies were not compromised, when 100% of fish meal in the control diet was replaced with rapeseed protein concentrate. Blood parameters including hematocrit and hemoglobin as well as glucose, triglycerides and total protein in the plasma were not different between treatment groups. Thus, the rapeseed protein concentrate has great potential as an alternative to fish meal in rainbow trout diets [30].

Nagel et al., 2012 demonstrated that the used albumin concentrate can effectively replace 50% of dietary fish meal in rainbow trout diets, whereas the application of the globulin concentrate negatively influenced diet palatability, thereby reducing diet intake and subsequently fish growth. The study concludes that rapeseed protein fractions, specifically albumin and globulin, can effectively replace fish meal in the diets of rainbow trout without negatively impacting growth performance. [31].

Potato Protein Concentrate Meal

Potato Protein Concentrate (PPC) has a balanced amino acid profile and high digestibility. This together makes it an interesting plant-based substitute for animal proteins such as fishmeal and milk powder.

Tusche et al. (2013) showed that the amount of fish feed with the replacement of fish meal protein up to 60% PPC, did not adverse effects on feed intake, growth rate or overall health. However, when the replacement of FM protein with PPC exceeded 60%, the growth of the fish started to decline. This indicate that PPC can be a good substitute but cannon completely replace FM without affecting the fish's growth performance [32].

Pea Protein Concentrate Meal

Pea protein concentrate has a bit more carbohydrates and fats compared to pea protein isolate, giving it a wider range of nutrients. However Rolland et al. (2015) found that a diet for rainbow trout based on pea protein concentrate (PPC) was deficient in three essential amino acids (EAAs): lysine, methionine, and threonine. Hence the PPC diet, supplemented with crystalline amino acids (CAAs), helped to meet the nutritional needs of the fish more effectively. The findings suggest that even though plant-based diets can work as a replacement for fish meal, it's important to carefully plan them and add the correct amino acids to guarantee the fish get enough nutrition. [33].

Lapsi Fruit Meal

Lapsi (*Choerospondias axillaris*) is a large, deciduous fruit bearing tree, native to Nepal of the family Anacardiaceae. It is also found in India, China, Thailand, Vietnam and Japan. It can be

reliable alternative fish meal for sustainable aqua feed production as it is rich in vitamin C, antioxidants [34] and phytochemicals [35].

Shakya et al. (2019) observed cent per cent survival rate with higher final average weight, weight gain %, SGR, Vitamin C and Protein concentration in brain and liver and blood parameters when fed with 0.04% lapsi pulp supplemented diet [36]

Nettle Meal

Stinging nettle (*Urtica dioica* L.) is a perennial plant with spiny leaves belonging to the family Urticaceae . It is considered as both a medicine and food in many countries due to its easy availability and notable biological properties [37]. It shows as a promising fish meal alternative for sustainable aquafeed because it's rich in beneficial compounds like flavonoids, tannins, and vitamins, as well as essential minerals and fatty acids [38].

Adel et al. (2017) explored the impact of feeding rainbow trout a diet that included 3% stinging nettle for eight weeks had some really positive effects. The fish grew more, grew faster, and were better at turning their food into body mass. Their blood also showed improvements, with higher counts of red and white blood cells, more hematocrit and hemoglobin, and increased levels of important immune cells called lymphocytes and neutrophils. Additionally, their total protein and glucose in their blood went up, while their triglyceride levels went down. Even better, when these fish were exposed to a harmful bacteria called *Yersinia ruckeri*, they had the lowest death rate compared to other groups. [39]. Mehrabi et al. (2020) found that adding 0.5% nettle powder to the diet of juvenile rainbow trout (10.72 ± 0.55 g) for 8 weeks, helped them grow better, improved their blood health, boosted their immune system, and even made them more resistant to a fungal infection called *Saprolegnia parasitica*. [40]. Awad et al. (2010) found that adding 1% nettle to the diet of rainbow trout (15g) for 14 days led to better growth and significantly boosted their immune system. This included increased respiratory burst activity, lysozyme enzyme activity, and bactericidal activity. Additionally, these trout showed a high survival rate of 96% after being exposed to *Aeromonas hydrophila* for 10 days [41]. Zare et al. (2021) investigated nettle leaf powder as a medicinal plant additive in fish feed, found that after an 8-week period, fish (7g) fed a diet containing 3% nettle leaf powder showed a significant increase in weight gain (WG) and specific growth rate (SGR) when fed to apparent satiation, without any change in the feed conversion ratio (FCR) [42]. It indicates that including *Urtica dioica* in the diet enhances growth and boosts the immune system of rainbow trout, making them more resistant to bacterial infections

CONCLUSION

The future of fish feed shouldn't solely depend on traditional fish meal as a protein source. With the growing demand for protein-rich feed, the aquaculture industry definitely needs to explore alternative options. Plant based protein sources could be the possible solutions since it is easily available and rich in protein.

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COMPARATIVE ANALYSIS OF PROFITABILITY OF IRRIGATED RICE PRODUCTION IN KANO RIVER AND HADEJIA VALLEY IRRIGATION SCHEMES, NIGERIA

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ABSTRACT

The study compares the profitability of irrigated rice production in Kano River and Hadejia Valley Irrigation Schemes, Nigeria with special emphasis on farmers' plot hydrological location along the irrigation network of the sectors. In pursuance of this objective, multistage sampling approach was employed to draw the sample of 164 respondents from Kura and Garum Malam LGAs to represent Kano River Irrigation Scheme (KRIS) in Kano State, and 99 respondents from Auyo Local Government to represent Hadejia Valley Irrigation Scheme (HVIS) in Jigawa State. The data was analysed using descriptive statistics and profitability analysis. The results shows that the age of the respondents across KRIS and HVIS were averagely 38 and 40 years respectively with the enterprise been dominated by male. The result further reveals that at KRIS, upon incurring an average cost of ₦246,861.4 ₦250,347.8 and ₦271,433.4 at the respective head, middle and tail axes of the production sectors, a gross margin of ₦883,042.9, ₦856,539.2 and ₦699,739 is obtainable respectively per hectare. Similarly, at HVIS, upon incurring an average total cost of ₦219,874.4, ₦252,129 and ₦193,927 at the respective head, middle and tail axes, a gross margin of ₦1,077,426, ₦1,243,113 and ₦992,595.2 can be generated per hectare. It is concluded that irrigated rice production along both Hadejia Jama'are River Basin operational districts (KRIS and HVIS) was highly profitable and that the project site as well as hydrological locations of the farmer's plot plays an important role in determining the output and the profit margin of the enterprise. Therefore, it is recommended that increase in irrigated rice production can be achieved through capacity buildings sessions. Hence, trainings through extension services should be intensified to motivate farmers to embrace improved farming practices for optimal utilization of inputs and hence increase the yield of irrigated rice as well as the profit level.

Introduction

Despite the oil boom in years back, agriculture still remain the sole source of food for the globe teeming population, a significant source of raw materials utilized in processing industries as well as major source of foreign exchange earnings globally (Akanbi, Omotesho & Ayinde, 2011). The arena continues to remains quite important to several developing countries with potentials of reducing poverty, raising incomes and improving food security for about 80% of the world's poor, who board rural areas and work mainly in farming sector (Central Bank of Nigeria, 2020).

As global oil prices continue to fall sharply over years, for an economy that's now largely hooked in to oil, Nigerians needs not be told that tough times set in. Nigerians must therefore recognize the anarchical gravity and emergency of the matter (Adams, 2016). As a matter of fact, all efforts must be geared and directed towards the rejected stone, " which must now become the chief corner stone as a way to line the nation's economy on a path of rebirth and recovery (Adams, 2016). Setting the nation's economy on the trail of rebirth and recovery requires a whole shift of attention back to agricultural sector as the only way-out of this quandary. Hence, agriculture must continue to stay the bottom of Nigeria's economy, providing the most source of livelihood for many Nigerians (Akanbi *et al*., 2011).

Nigeria is a country that is fully blessed with all what is required to produce rice in large quantity. The country has abundant fertile arable land, favorable climate, available labour forces and water resources to embark on large scale irrigation schemes to confirm all year-round rice production. This shows that an intensive and consistent irrigation rice production scheme will set Nigeria on a pathway to rice self-sufficiency thereby bringing an end to the gross loss in exchange due importation and smuggling of the commodity.

In Nigeria, the concept of large-scale irrigation projects across HJRBDA as pointed by Muhammad (2011) came as a result of a study conducted within the mid-1960s by the US Bureau of Reclamation which was financed by United State Agency for International Development (USAID). One of the analyses included the chance of constructing several dams on rivers that drain the upper reaches of the Chad Basin through the Hadejia and Yobe Rivers into Lake Chad (Ministry of Agriculture and Natural Resources, 1975). The project aims at boosting national capacity towards achieving food security; for Nigeria to curb imports of food items with rice been the first-class target of the policy.

Kano River Irrigation Scheme (KRIS) and Hadejia Valley Irrigation Scheme (HVIS) are multi-purpose projects involving the land, water resources and irrigation facilities development to enhance agricultural production in the predominantly farming communities within the Schemes. The schemes were designed in such a way that water released from the upstream Challawa and Tiga dams into the river system could be used for irrigation. It is unique in its design in that the entire water distribution network operates on gravity.

The irrigation water is conveyed from the source dams to the Project site through an 18Km long Main Canal (MC), which splits into east and west branches. These are then further broken into Lateral Canals (LC), field channels (FC) and finally to the farm for irrigating crops. A

barrage/storage pond was constructed to store the water and from there the water is diverted through water control structures into the irrigation canals of the project (HJRBDA, 2012).

Therefore, in view of the above background, it's therefore crucial to assess the cost and return of irrigated rice production across the two distinct study areas with special emphasis on hydrological references along which farmer's plot was located across the various sectors of the schemes.

Methodology

The Study Area

The study was conducted across Hadejia Jama'are River Basin Development Authority (HJRBDA) production sites; Kano River Irrigation Scheme (KRIS) covering Garum Malam, Kura and Bunkure Local Government Areas of Kano state (though Bunkure was exempted from the study due to cessation of irrigation activities to allow for renovation of the irrigation facilities during the study year; 2021) and Hadejia Valley Irrigation Scheme (HVIS) situated in Auyo Local Government area of Jigawa State.

Sampling Procedure and Sample Size

The study employed a multi-stage sampling approach to select a total of 164 and 99 irrigated rice farmers across KRIS and HVIS respectively. Two production sectors were randomly selected in local government, making a total of six selected production sectors. Stratified random sampling approach was then employed to draw the sample across the three hydrological locations (head, middle and tail) within each of the selected production sector of the irrigation command areas. Purposive sampling was also employed to select one community each to represent farmers along the head, middle and tail axes of each stratum. Finally, Raosoft Sample Size Calculator was used to select a total of 263 respondents while the Bowley's proportion allocation formula was employed to establish the sample size at each stratum.

Data Analysis

Socioeconomic characteristics of the respondents was analysed using descriptive statistics such as means, percentages and frequencies. Profitability of irrigated rice enterprise was analyzed using cost and returns (farm budgeting) technique and the profit is thus defined as:

$$\pi_i = P_i y_i - \sum(X_j R_j + K_i) \quad \ldots\ldots(1)$$

Where,

π_i = profit from the i^{th} enterprise

Y_i = Quantity of rice output of the i^{th} enterprise (in Kg)

P_i = price per unit of i^{th} enterprise (in Naira)

X_j = Quantity of the i[th] input used by each enterprise (e.g seeds/seedlings, fertilizer, pre emergence, post emergence and selective herbicides, fungicides, pesticides, labour)

R_j = price per unit of the i[th] input

K_j = fixed cost per period associated with i[th] enterprise

Net Farm Income

The net farm income is mathematically expressed as;

$$NFI = GM - TFC \quad \text{.....(2)}$$

Where;

NFI = Net Farm Income,

GM = Gross Margin and

TFC = Total Fixed Cost

$$GM = TR - TVC \quad \text{.....(3)}$$

Where;

GM = Gross Margin,

TR = Total Revenue (gross value of output),

TVC = Total Variable Cost.

Gross Ratio

$$GR = \frac{TFE}{GI} \quad \text{.....(4)}$$

Where;

GR = Gross Ratio,

TFE = Total Farm Expenses and GI = Gross Income

Rate of return on Investment (RRI)

$$RRI = \frac{NFI}{TC} \quad \text{.....(5)}$$

RESULT AND DISCUSSION

Socio-Economic Characteristics of Irrigated Rice Farmers

The result of age distribution of the surveyed farmers from both Kano River Irrigation Scheme (KRIS) and Hadejia Valley Irrigation Scheme (HVIS) was recorded at averagely 39 years. This attest that farmers across both KRIS and HVIS are within the youthful age bracket indicating an active and productive labour force age and also signifying that the attention of youth was drawn back to agriculture as a means of livelihood contrary to the known inherent trend of youth abandoning the agricultural sector especially the irrigation scheme. This result conforms to the findings of Ahungwa, Suleiman and Abdulkarim (2018), who posited that youthful age is expected to increase the productivity and efficiency of the enterprise. Iheke and Nwaru (2014), also viewed that the risk bearing abilities and innovativeness of a farmer, his mental capacity to coup with daily challenges and demands of farm production activities and his ability to do manual work decrease with advancing age, hence, the younger, the better.

The result also shows that the mean years of farming experience for farmers along both KRIS and HVIS was 14 years each. This implies that irrigated rice production enterprise in the study areas was a long practicing venture as it is in place for more than a decade. Though years of farming experience plays a vital role in determining the production efficiency, managerial ability and decision-making process of an entrepreneur, Mwangi and Samuel, (2015) states that years of production experience may hinder adoption of innovation, but can influence production efficiency due to the knowledge of local production conditions. Historically, farmers rely on their own experience and that of their neighbors with regards to adopting ‘good farming practices’, advice and information rather than from either privately or publicly funded agencies.

The result contained in Table 1 also shows the distribution of the selected irrigated rice farmers across KRIS and HVIS on the basis of the household size. Household size plays an important role in determining the extent of labour availability at household level and the farming society in general. The result thus depicts that the mean household size of the irrigated rice farmers at both KRIS and HVIS were 10 and 9 persons respectively. This therefore might be translated to relative availability of family labour which will help in minimizing the running cost of irrigation enterprise. This result justifies the position of Ogundele and Okoruwa (2016) who alluded that the quest to satisfy labour requirements necessitates large household sizes among farmers in developing countries. The result also corroborates the findings of Mustapha, Yusuf and Ibrahim (2018), and Mohammed (2015) who indicated a similar range of household sizes among rice farmers. The result also further agreed with the result of Nchare (2011) that found that the average family size of rice farmers in Cameroun was 10 and that the large family size translates to higher use of family labour.

Table 1: Socio-economic Characteristics of Irrigated Rice Farmers (Quantitative)

	KRIS (n =164)					HVIS (n = 99)				
	Freq.	Percentage	Mean	Min.	Max.	Freq.	Percentage	Mean	Min.	Max.
Age of the Farmers (Years)										
18 – 28	33	20				7	8.9			
29 – 39	59	36	39	18	68	38	48.1	39	21	70
40 – 50	49	30				20	25.3			
51 – 61	18	11				11	14			
62 – 72	5	3				3	3.7			
Irrigation Farming Experience (Years)										
2 – 7	53	32.3				13	16.5			
8 – 13	42	25.6				25	31.6			
14 – 19	20	12.2	14	2	30	21	26.6	14	2	30
20 – 25	35	21.3				14	17.7			
26 – 31	14	8.6				6	7.6			
Household Size (Number)										
1 – 7	73	44.5				47	59.5			
8 – 14	61	37.2	10	1	33	17	21.5	9	1	33
15 – 21	22	13.4				6	7.6			
22 – 28	7	4.3				7	8.9			
29 – 35	1	0.6				2	2.5			

Source: Field Survey, 2021

Table 2 below further depicts that irrigated rice production enterprise is entirely dominated by male, given that majority (96.3 and 96.2 percent) were male leaving the female counterpart with just 3.7 and 3.8 percent for farmers across KRIS and HVIS respectively. The male dominance in agricultural sector may be attributed to culture and traditional behavior of most rural dwellers. This agrees with the findings of Oladeji (2010) who reported that culture of the society may favor full participation of one sex over the other in agribusiness generally.

The analysis of distribution of farmers based on their educational qualification at KRIS attest that 34.2 percent attended secondary school with 26.2 percent having Qur'anic education followed by 24.2 and 15.2 having tertiary education. It also reveals that 40.6 percent of the farmers at HVIS attained secondary education followed by those attended primary and tertiary schools with equal proportion of 20.2 percent each. Schooling or the level of education of a farmer helps the farmer in the use of production and marketing information leading to increased yield and profit. Pudasaini (1983) documented that education contributed to agricultural production in Nepal via the farmer's knowledge and allocated effects. Education is also an

important determinant of adoption of new innovation as well as a tool for a successful implementation of action and increase productivity. Chandan and Vijaya (2021), opined that the variation in educational background of farmers was usually responsible for the differences in their ability to evaluate and manage risk.

Table 2: Socio-economic Characteristics of Irrigated Rice Farmers (Qualitative)

Variable	Scheme			
	KRIS (n =164)		HVIS (n = 99)	
	Frequency	Percentage	Frequency	Percentage
Sex				
Male	158	96.3	76	96.2
Female	6	3.7	3	3.8
Level of Education				
Primary	40	24.4	16	20.2
Secondary	56	34.2	32	40.6
Tertiary	25	15.2	16	20.2
Qur'an	43	26.2	15	19
Association Membership				
Member	152	92.7	72	91.1
Non-Member	12	7.3	7	8.9
Access to Extension Service				
Have Access	148	90.2	73	92.4
No Access	16	9.8	6	7.6
Access to Credit for Production				
Have Access	108	66	67	84.8
No Access	56	34	12	15.2

Source: Field Survey, 2021

Furthermore, the result shows that, majority of the respondents (92.7 and 91.1 percent) in both the KRIS and HVIS were into water users association. Iheke (2010) noted that membership of farmers association 'serve as outstanding source of good quality inputs, labour, credit, information and organized marketing with economies of scale. By this assertion, irrigated rice producers across KRIS and HVIS may stand a greater chance of immensely benefiting from various government programs as it is the case with the federal government anchor borrower's program in Nigeria today.

The result from Table 2 also reveals that, majority of the irrigated rice farmers across KRIS and HVIS have access to extension services with a proportion of 90.2 and 92.4 percent respectively.

Agricultural extension represents a mechanism by which information on new technologies, better farming practices and management could be transmitted to farmers. Owen, Mundy, Will and Robert (2001) investigated the impact of farmers‘ contact with agricultural extension services on farm productivity and the results showed that access to agricultural extension services, defined as receiving one or two visits per agricultural year, raised the value of crop production by about 15 percent. This means that farmers at Hadejia Jama'are River Basin stand a high chance of having access to information related to improved agricultural technologies such as modern production practices, value addition, market related information and sources of credit, hence lead to increase in the per hectare output and returns.

In addition, the analysis of information regarding farmer's access to credit reveals that 66 percent of the irrigated rice farmers at Kano River Irrigation Scheme site has access to credit mostly from government through anchor borrower program and from friends and relatives. On the other hand, majority (84.8 percent) of the farmers across Hadejia Valley Irrigation Scheme also have access to credit for production from same source as the case with farmers at KRIS leaving only few (15.2 percent) having no access to credit. Access to credit can serve as an important indicator for determining the scale and the type of production a farmer is into (that is subsistent or commercial). This agrees with the findings of Ayodele (2016), who affirms that accessibility to credit increases farmer's liquidity, which in turn, enhances their ability to purchase inputs and pay for hired labour. Ajala and Gana (2015), also posits that accessibility of farmers to credit facilities would increase their access to agricultural inputs and newly introduced innovations which would increase food production.

Profitability Analysis

The result of comparative profitability analysis of irrigated rice production along KRIS and HVIS was presented in Table 3 as average of the 2021 irrigation season. The analysis was made with special emphasis on hydrological locations of the farmers' plot across the selected sectors of Kano River Irrigation Scheme (KRIS) and Hadejia Valley Irrigation Scheme (HVIS) sites. The variable cost components considered for the average cost and return analysis include cost of labor, seed, fertilizer, agrochemicals, land rental cost as well as drum and tarpaulin hired costs. The analysis also considered the depreciated cost of fixed inputs used in irrigated rice production.

The result shows that the average total cost for a hectare of irrigated rice plot along the head, middle and tail axes of KRIS were ₦246,861.4, ₦250,347.8 and ₦271,433.4 respectively. The variable cost components contributed the highest (97.4, 97.9 and 93.4 percent) to the average total cost of producing an average hectare of land at respective head, middle and tail axes of the production sectors. The result shows that cost components of labor, fertilizers and rental cost of land contribute the highest percentage to the average total cost of producing an average

hectare and thus proved to be the most the most significant drivers of irrigation rice production that requires much capital.

The result further shows that an average 5275, 5175.9 and 4465.8 kilograms of irrigated rice yield is obtainable along the head, middle and tail axes of the KRIS irrigation sectors with

average gross margin of ₦883,042.9, ₦856,539.2 and ₦699,739 respectively. Additionally, the rate of return on investment for farmers at the head, middle and tail ends was recorded at ₦3.7, ₦3.5 and ₦2.8 respectively. This shows that there is a strong relationship between the location of the farmer's plot along the irrigation network and their productivity as well as profit margins. The reason being that the gravity of water supply decreases along the irrigation network of the sectors from head down to the tail reaches. Subsequently, with water shortage at farmers' plot along the irrigation network of the sectors, the issue of invasive weed species and the need for water supplementation arises, hence lead to increased cost of production as well as decrease in per hectare output and gross margin. Nevertheless, The result also shows that despite the variation in the average per hectare yield, net return, gross margin and return to naira invested, it is with no doubt that irrigation rice production enterprise along the respective hydrological locations of Kano River Irrigation Scheme is a profitable venture and improving the schemes' main, lateral and field canals will go along in delineating the output variations among the hydrological locations.

It is evident from the result that farmers at the tail end of the various irrigation sectors of KRIS incur high cost of production, then followed by those at the middle and head in that order. This could be attributed to the extent of irrigation water availability at the various hydrological locations along the irrigation network of each sector. Accordingly, farmers located at heads of the irrigation sector easily have access to irrigation water, thus incur less production cost. The cost progressively increases downstream along the middle and tail of the sectors where the farmer along these axes, through the use of water pumps and excessive fertilizer application tries to meet up the production frontier of their head counterparts.

Table 3: Cost and Return Analysis of Irrigation Rice Production along KRIS and HVIS

Cost Components	KRIS (164)						HVIS (99)					
	Head		Middle		Tail		Head		Middle		Tail	
1. Variable Cost	Average Value (₦)	%	Average Value (₦)	%	Average Value (₦)	%	Average Value (₦)	%	Average Value (₦)	%	Average Value (₦)	%
Seed/Seedlings	7195.4	3.1	6438.14	2.6	7799.4	2.7	7954.01	3.6	8555.3	3.4	6707.4	3.5
Water charges (Ha/Cycle)	5000	2.2	5000	2	5000	1.7	5000	2.3	5000	2	5000	2.6
Fertilizer (Kg)	62280.2	27	66100.5	26.4	69137.6	24	69707.4	31.7	84330	33.4	59461	30.7
Herbicides (L)	8975.08	3.9	11179.5	4.5	15027.5	5.2	15741.9	7.1	19798	7.8	19307	10
Pesticides (L)	1523.7	0.7	2655.95	1.1	4737.5	1.6	3512.1	1.6	2948.4	1.2	3245.2	1.7
Land rental cost (Ha)	15355.3	6.7	16230	6.5	16125	5.6	14960.5	6.8	7	7	1250	0.6
Drum hiring	685.8	0.3	665.3	0.3	650.2	0.2	556.5	0.2	559.3	0.2	545.7	0.3
Tarpaulin hiring	658.6	0.3	608.4	0.2	623.3	0.2	523.1	0.2	538.8	0.2	528.5	0.3
Labour (Mandaya)												
Land Preparation	2284.2	1	2854.3	1.1	2380.85	0.8	2986.5	1.4	3357.2	1.3	3458.3	1.8
Watering of plots	18750.5	8.1	22647.2	9	35207.9	12.2	16483.5	7.5	15789	6.3	17024	8.8
Ploughing/Harrowing	9920.3	4.3	10258.6	4.1	12722.8	4.4	15058.8	6.8	15871	6.3	12267	6.3
Planting/transplanting	13536.3	5.9	15687.3	6.3	14386.1	5	12570.5	5.7	17394	7	11616	6
Fertilizer Application	1598.42	0.7	1893.2	0.7	1756.1	0.68	2130.5	1	2014.8	0.8	2438.1	1.3
Weeding	12878.6	5.6	14927	6	15448	5.4	12392	5.6	13469	5.3	13975	7.2
Spraying	2444.1	1.1	2747.8	1.1	3387.46	1.2	3462.6	1.6	4278.4	1.7	3323.8	1.7
Harvesting	61421.05	26.7	65071.9	26	64515.9	22.4	30657.9	14	34533	13.7	27667	14.3
Total Variable Cost	240965	97.4	244985	97.9	252448	93.4	213698	97.2	245953	97.6	187813	98.8
2. Fixed Cost (depreciated)												
Water Pump (₦)					13803.6	4.8						
Hose/Siphon	3514.25	1.5	3258.15	1.3	2897.89	1	3958.3	1.8	3848.3	1.5	3929	2
Hoe (₦)	338.5	0.1	278.5	0.11	378.2	0.1	328.7	0.1	348.7	0.1	369.1	0.2
Axe (₦)	289.1	0.1	259.1	0.1	199.6	0.2	278.5	0.1	213.8	0.1	209.5	0.1
Sickle (₦)	205.8	0.1	218.2	0.09	258.8	0.2	213.4	0.1	264.2	0.1	248.5	0.1
Sprayer (₦)	1548.8	0.7	1348.8	0.5	1447.1	0.5	1397.7	0.6	1501.7	0.5	1358.6	0.7
Total Fixed Cost	5896.45	2.5	5362.75	2.1	18985.2	6.6	6176.6	2.8	6176.7	2.4	6114.7	3.2
Average Total Cost	246861.4	100	250347.8	100	271433.4	100	219874.4	100	252129	100	193927	100
3. Returns												
Average Yield (Kg/ ha)	5275		5175.9		4465.8		6131.6		6906.4		5533.3	
Average Price (₦/Kg)	203.3		202.4		201.4		202.2		206.7		205	
Value of the Haulms (₦)	51600.4		53922		52774.9		51314.6		61513		46081.7	
Gross Revenue (₦/ha)	1,124,008		1,101,524		952,187		1,291,124		1,489,066		1,180,408	
Gross Margin	883,042.9		856,539.2		699,739		1,077,426		1,243,113		992,595.2	
Return to ₦ Invested	3.7		3.5		2.8		5		5		5.3	

Source: Field Survey, 2021

Similarly, famers along Hadejia Valley Irrigation Scheme site of Jigawa State upon incurring an average total cost of₦219,874.4, ₦252,129 and ₦193,927 at the head, middle and tail axes of the sectors respectively were found to record an average per hectare irrigated rice yield of 6176.6, 6906.4 ang 6114.7 kilograms at the respective hydrological locations. It is therefore seen from the result that farmers along the middle axis of the irrigation sectors of HVIS incur high per hectare production cost and has higher per hectare yield, followed by those at the head and tail axes. This difference in the cost could be attributed to the variations in cost of labour among the selected communities that represent the respective hydrological locations.

The result also shows that farmers at the head, middle and tail axes of HVIS obtain an average gross margin of ₦1,077,426, ₦1,243,113 and ₦992,595.2 respectively with an average return to naira invested of ₦5, ₦5 and ₦5.3 respectively. This implies that for each naira invested in this enterprise, a net return of 500, 500 and 530 percent of the total investment is obtainable at the respective hydrological locations. This similarly is therefore enough justification that irrigation rice production enterprise along HVIS operational districts of Jigawa state is a profitable venture and indeed an outstanding rare exception the entrepreneurs along the networks are enjoying in comparison with other enterprises and locations. In his findings, Ayodele (2016), affirms that the gross return per hectare and average rate of return on investment for irrigated rice enterprise was ₦391,017 and ₦1.73 respectively. Contrarily, in his study, Sa'ad (2019) founds that the average rate of return on investment in irrigation rice production in Bauchi state is 0.7 kobo. The findings of Ayodele (2016) and that of Sa'ad (2019) were far cry away from the finding of this research, hence the need for diversification of irrigation scheme of this kind will contribute greatly in breaking the farmer's vicious circle of poverty and in delineating the issue of food insecurity across the nation.

Additionally, the results of cost and returns analysis from irrigated rice production enterprise along KRIS and HVIS shows a clear variation in the profit margin of the irrigated rice entrepreneurs along the two studied schemes sites. These variations between the two schemes could be accrued to their respective hydrological locations along the irrigation network and the overall topography of the sites. The irrigation network of KRIS site was observed to have poor topography when compared to its HVIS counterpart. Hydrological location and sloppiness of the schemes is quite a vital determinant of water availability at the entire scheme site and subsequently at the individual farmer's plot.

Comparatively, it can be deduced from the result that at KRIS, the average total costs tended to increase ascendingly from the head to the middle and then the tail. This could be attributed to the level of weed invasion which could also be a product of water shortage along the hydrological locations. When there is availability of irrigation water at farmers plot, the growth of weeds is mostly suppressed and *vis-versa*. The cost was therefore recorded high for farmers at the tail then followed by those at the middle axis due to increased cost of weeding, intensive use of herbicides and chemical fertilizers to meet up with the production frontiers of their head counterparts. Furthermore, despite the fact that the cost of production increases in an ascending order along the head, middle and tail axes of the sectors, the average yield, gross margin and return to naira invested increases in a descending order of the farmer's plot hydrological locations. This therefore shows how deep the hydrological reference of the farmers' plot affects their output level and profit margin. However, farmers at the head earned the highest profit

followed by those at the middle and then those at the tail. Rice requires abundant supply of water to perform optimally. Water availability at the farmers' plots decreases from the head, through the middle to the tail. The decreasing profits observed could be attributed to lower yields obtained due to the farther away from the primary water source due to insufficient water at the plots (Yakubu, Baba & Mohammed, 2016).

On contrary, the above scenario differs in the case of HVIS, where farmers at the middle axis incur highest cost of production then followed by those at the head and tail axes in that order. Similarly, farmers at the middle axis recorded highest yield then followed by those along the head and tail axes. This could be attributed to the structural description of the farm plots along this site, where plots located at the head and tail axes were recorded to be relatively upstream when compared to middle axis. The high yield and gross margin recorded by the farmers at the middle axis of HVIS sectors could be due to washing away of nutrients from the relatively upstream head and tail axes to the relatively downstream middle axis.

Conclusion and Recommendations

From the findings of the study, it could be concluded that irrigated rice production along both KRIS and HVIS was highly a profitable venture. It is also clearly evident from the findings that the scheme as well as hydrological locations of the farmers' plot plays an important role in determining the per hectare yield as well as profitability of the enterprise. Improving the existing scheme's main and distributing canals especially the tail and middle axes of KRIS will greatly help in reducing the margin in output and profit levels and also increasing the schemes capacity and extending it to various suitable locations by government will go a long way in delineating the issue of food insecurity and vicious circle of poverty bedeviling farmers in Nigeria.

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AN ASSESSMENT OF THE EFFICACY OF NANOTECHNOLOGY AS A MODERN AGRICULTURAL APPLICATION

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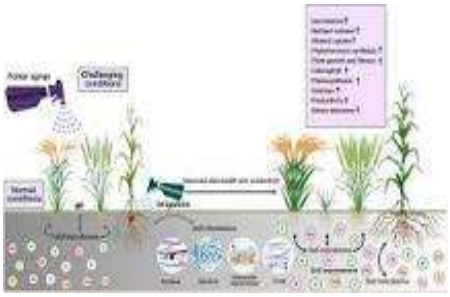
ABSTRACT

The incorporation of modern day technologies into agricultural practices has proven to have positive effects on crop production and food security. Nanotechnology uses novel delivery techniques and chemical agents to increase crop productivity and decrease bulk agrochemical application through innovative and sustainable approaches. The development and applications of nanomaterials on crop production and food security have demonstrated its potentials in improving seeds' germination and growth, protection of plants, and the detection of pathogens and herbicide/pesticide residues. This paper evaluates the efficacy of nanotechnology as a modern agricultural application. The paper summarizes the applications of nanomaterials and their importance in sustainable agricultural practices. In order to gather useful data for the paper discussion, questions were carefully drafted by the researcher and administered to respondents through online Google form questionnaire instrument. The responses were collated and subjected to reliability analysis. Conclusively, the paper inferred that the incorporation of nanotechnology into the field of agriculture has contributed towards addressing the increasing challenges in crop production and food security.

Keyword: Nanotechnology, Agricultural Application, Crop Production and Food Security.

INTRODUCTION



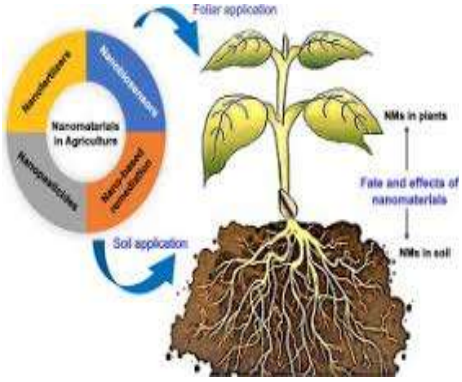
Nanotechnology is a modern agricultural technique that uses novel delivery techniques and chemical agents to increase crop productivity and decrease bulk agrochemicals' applications through innovative and sustainable approaches. The incorporation of nanotechnology into the fields of agriculture has proven to have positive improvement in crop production and food security. The application of nanomaterials in agriculture increases the efficacy and sustainability of agricultural practices. This technique has demonstrated its potentials to release agrochemicals needed for improved plant disease resistance, detect pathogens and herbicide/pesticide residues and enhanced plant growth. Nanotechnology offers innovative set of tools to manipulate genes using nanoparticles which have enhanced reactivity due to greater proportion of surface atoms relative to the interior of a structure, unique magnetic/optical properties, enhanced solubility, and catalytic reactivity that differ from equivalent bulk materials. The application of these nanoparticles for nutritional improvements, and disease suppression depends on the difference in particle size between the bulk and nanomaterials. The positive morphological effects of the utilization of nanomaterials such as enhanced germination rate; enhanced photosynthetic activity and nitrogen metabolism in many crop plants. However, the non-judicious usage of nanomaterials may lead to environmental hazards. It is therefore important to moderate the release of pesticides, herbicides, and plant growth regulators using nanocarriers.

RELATED LITERATURE

Several studies have shown that the incorporation of nanotechnology is extensively aimed to meet up with the high demands of food production and various other agricultural issues. Nair et al. (2010) noted that various nanomaterials based on carbon materials, metal and metal oxides, nanosized polymers, and biocomposites are being developed for different applications. The benefits of these materials are numerous in environmental remediation, water purification, wastewater treatment, food processing and smart sensor development (Chand et al, 2021; Demirer et al., 2021; Liu et al., 2021; Wang et al., 2021). The applications of nanomaterials have growingly gained attention due to its positive effects on crop production and food security (Sharon, et al., 2010). The study of Emamifar et al., (2010) reported that nanomaterials enhance plant germination and growth. Rajpur et al. (2021) revealed the positive effects of the application of nanomaterials for plant growth and development. For example, Zheng et al. (2021) analyzed that nano-TiO_2 supports water absorption and improve seed germination and growth. Yang et al. (2007) pointed that TiO_2 nanoparticles enhances nitrogen metabolism and photosynthetic rate thereby improving plant growth. Other studies have shown the progressive effects of MWCNTs on the seed germination and plant growth (Du et al., 2011). However, the use of chemical pesticides may leads to environmental hazards, if not judiciously

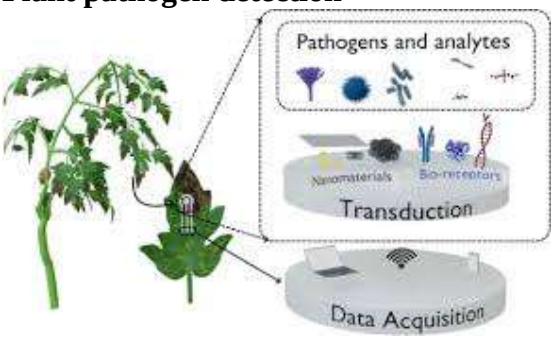
applied. Sharon et al. (2010) emphasized that the release of pesticides, herbicides, and plant growth regulators should be controlled using nanocarriers.

Plant production and protection



The application of nanomaterials to increase plant protection and production is growingly being achieved. Many studies have introduced the application of nanomaterials on farm lands, because of its positive effects on crop yield. The study of Iqbal et al. (2019) depicted that different types of nano-fertilizers have been developed for different crop systems. The research work of Kumar et al. (2021) signified that nano- nitrogen fertilizer (N2) have been found to improve rice productivity. The study of Verma et al. (2022) revealed that Ammonium- modified zeolites have been found to improve phosphorus availability and its uptake in plants. Employing the application of appropriate ingredients of nanomaterials is also imperative for mitigating crop losses and effective pest control. The study carried out by Vuong (2019) proved that the application of nano-formulations minimizes likelihood of increased resistance among target organisms. The research work of Kasote et al. (2021) inferred that the pesticides in nano-formulation indicate the availability of useful properties such as increased permeability, solubility, crystallinity, stiffness, thermal stability, and biodegradability needed for a sustainable agro-environmental system. However, Khan & Rizvi (2014) enumerated the importance of the controlled release of active ingredients of nano-formulation as the excessive release can be harmful to plant.

Plant pathogen detection



The use of advanced pathogen detection and prevention techniques is crucial to minimize diseases or harms related to crops during their growth, harvest, and postharvest processing stages. Zhao (2011) stated that nanoparticles can serve as rapid diagnostic tools or biomarkers for prompt detection of viral, bacterial, and fungal plant pathogens in agriculture. Nanoparticles can essentially be used to design pathogen detection devices with smart sensing capabilities for agricultural practices. According to Boonham (2008), Nanoparticles are suitable for making of sensing applications as they can be combined with other materials having intriguing optican and electronic characteristics. The record of Yao et al. (2009) signified that nanoparticles can be combined with biological elements like antibodies, primarily to detect bacterial spot disease causative agent such as 'Xanthomonas axonopod'. The record of Yao et al. (2009) also revealed the utilization of silica nanoparticles

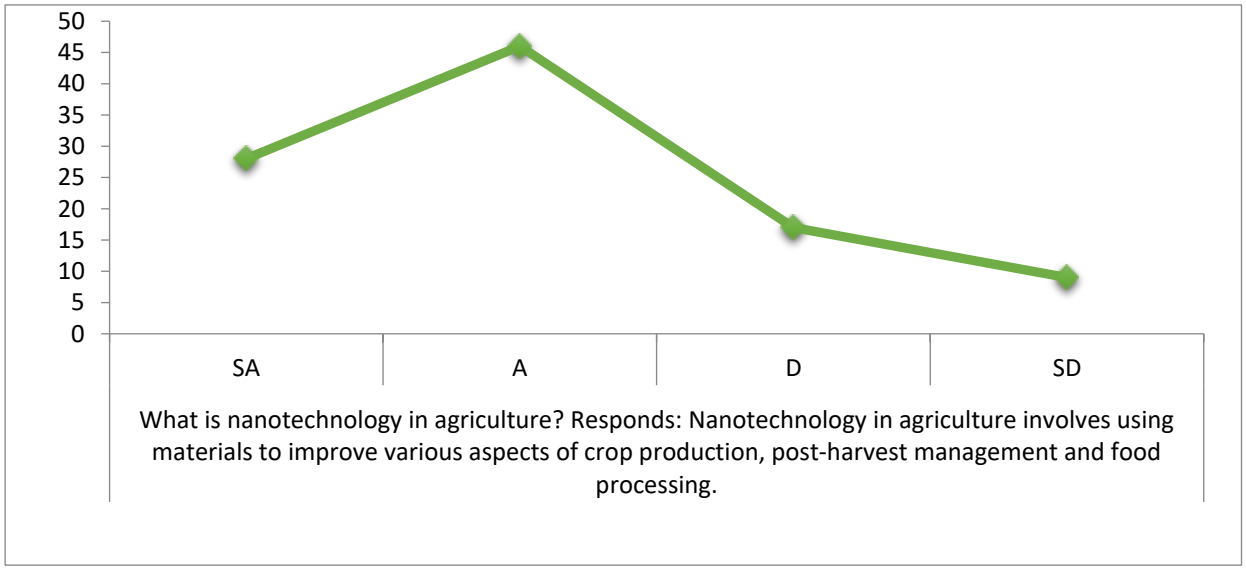
in conjunction with antibodies to effectively detected plant pathogens such as 'Xanthomonas axonopodis pv'. In the same way, the research work of Umasankar et al. (2013) outlined that nanomaterials was used to developed the electrochemical sensors for detecting plant diseases. The research study of Wang et al. (2010) also showed that a sensitive electrochemical sensor that used copper nanoparticles modified with gold electrode was used to detect fungi (*Sclerotinia sclerotiorum*) by monitoring the levels of salicylic acid in oil seeds. Thus, so many other studies have proven that similar sensors and censuring techniques combined with nanoparticles were used in the detection of plant pathogens.

MATERIALS AND METHODS

The researcher adopts mixed methodologies, including controlled experiments, field trials, and analytical techniques to assess the efficacy of nanotechnology modern agricultural application. These methods allow for evaluating the impact of nanotechnology on crop yield, plant health, disease resistance, and resource utilization efficiency. The researcher used controlled laboratory settings to isolate the effects of specific nanomaterials on plant growth, nutrient uptake, and disease susceptibility. The researcher also carried out field- monitoring to allow for the assessment of nanotechnology applications under realistic agricultural conditions, including soil type, climate, and pest pressures. For the analysis of the soil and plant, the researcher took some soil and plant samples to determine the fate and behavior of nanomaterials, including their uptake, translocation, and degradation in the environment. Over all, the researchers gain a comprehensive understanding of the efficacy and potential risks associated with nanotechnology applications in modern agriculture. For the purpose of gathering information needed for the research work, drafted questions were also administered to different people consisting of plant physiologist and plant pathologist using online Google form questionnaire instrument.

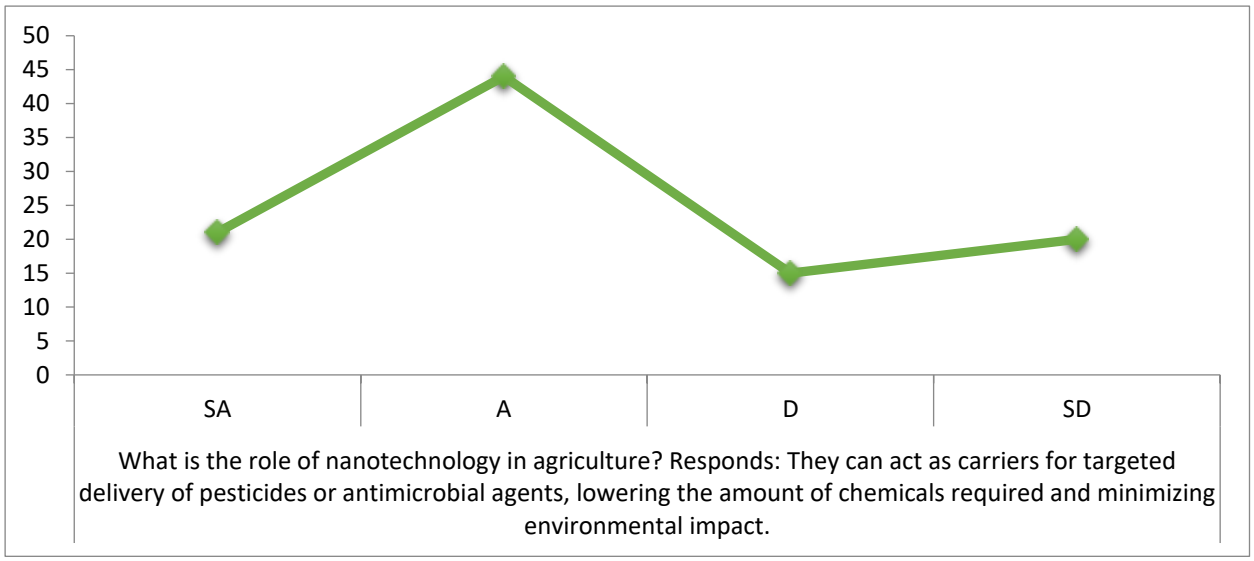
RESULTS AND DISCUSSION

Fig.1: Chat Analysis



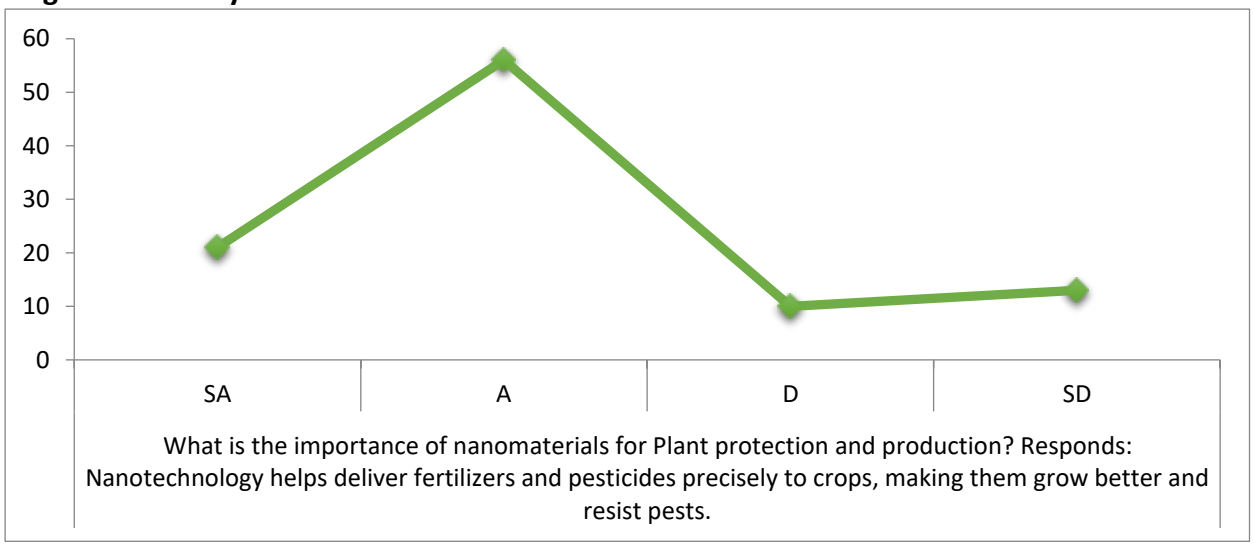
The graph plotted in figure 1 clearly shows that the respondents are fully aware of the trends of development in the fields of agriculture. Most of the respondents described nanotechnology as the incorporation of technology that uses materials at a nanoscale to improve various aspects of crop production, post-harvest management, and food processing. According to the respondents, it includes creating nano-fertilizers, pest control agents, nanosensors, and more. The respondents explained that nanosensors are devices designed to monitor soil health, optimize irrigation, detect pathogens, and assess the overall plant conditions.

Fig.2: Chat Analysis



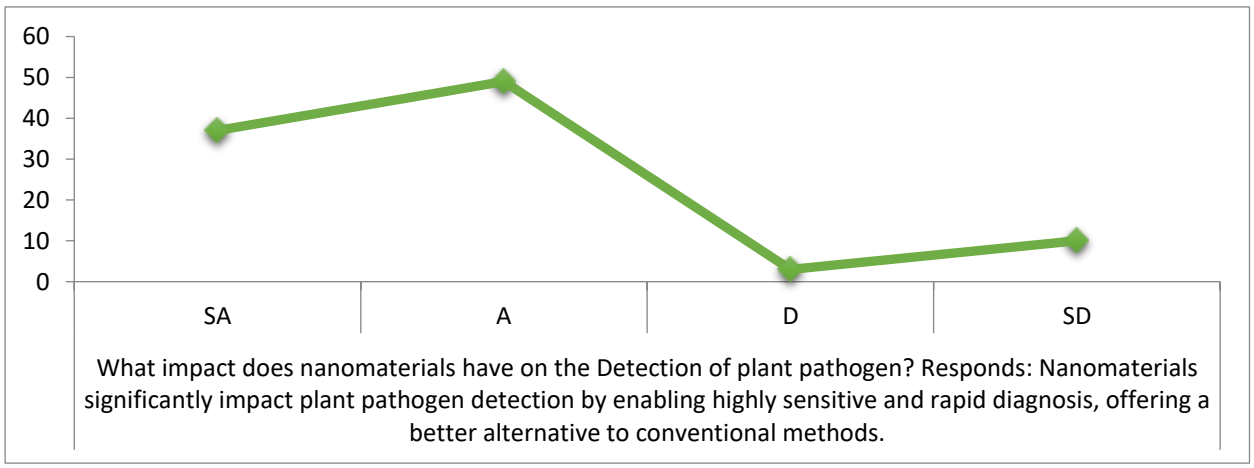
The graph plotted in figure 2 depicts that a higher number of the respondents agree that nanotechnology acts as carriers for targeted delivery of pesticides or antimicrobial agents, lowering the amount of chemicals required and minimizing environmental impact. In other words, the respondents emphasized that nanotechnology helps to improve agricultural production by increasing the efficiency of inputs and minimizing relevant losses. According to the respondents, nanotechnology utilizes nano based smart delivery system and nanosensors that used by farmers to reduce the input of resources such as nutrient and agrochemicals and productivity under adequate supervision.

Fig.3: Chat Analysis



The graph plotted in figure 3 illustrates that a greater amount of respondents affirmed that nanotechnology helps to deliver fertilizers and pesticides precisely to crops, making them grow better and resist pests. The respondents added that nanotechnology ensures that plants effectively absorb nutrients, helping crops grow healthier and reducing waste. According to the respondents, it should be noted that nanomaterials offer significant potential for both plant protection and production, minimizing environmental impact, enhancing efficiency, and improving crop quality. The respondents explained further that nanomaterials help plants to cope with environmental stresses like drought and salinity, and can be used to detect pesticide residues in smart sensors.

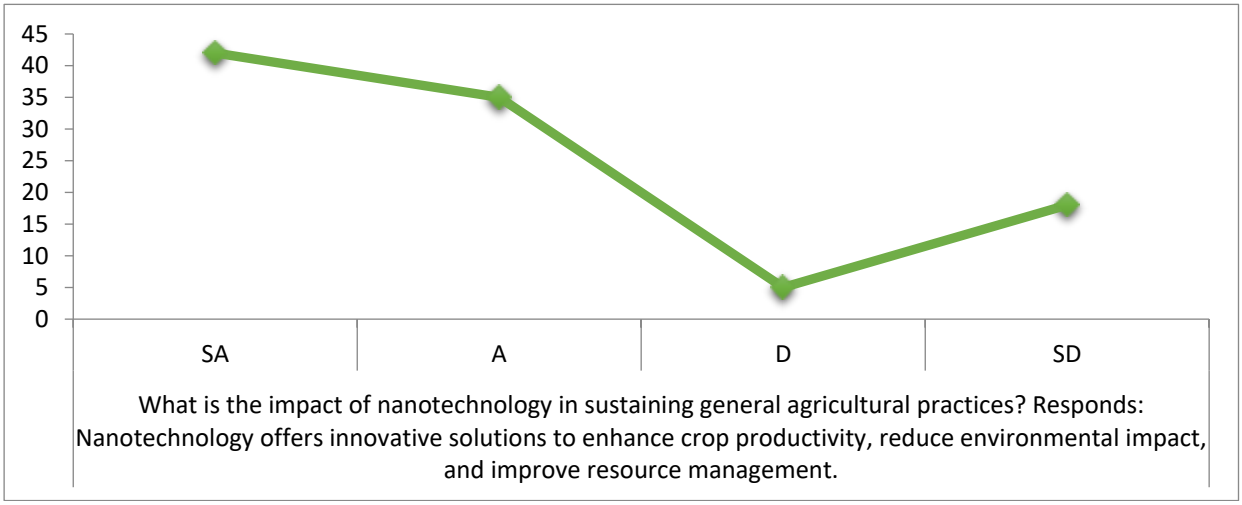
Fig.4: Chat Analysis



The graph plotted in figure 4 reveals that a higher amount of respondents agree with the statement that nanomaterials have significant impact on the detection of plant pathogen as it

enables highly sensitive and rapid diagnosis, offering a better alternative to conventional methods. The nanoscale and unique properties of nanomaterials make them to effectively interact with pathogenic agents, enhancing the selectivity of biosensors and other relevant detection tools.

Fig.5: Chat Analysis



The graph plotted in chart 5 indicates that a large number of respondents supported that nanotechnology have significant impact in the sustenance of agricultural practices, offering innovative solutions to enhance crop production and food safety. According to the respondents, nanotechnology enables the development of new materials and techniques that can be used to address huddles such as nutrient deficiency, soil contamination and pest control. More so, nanotechnology can act as carriers for targeted delivery of antimicrobial agents or of pesticides, minimizing environmental impact and lowering the amount of chemicals required.

CONCLUSION

The discussion on this paper is focused on the assessment on the efficacy of nanotechnology as a modern agricultural application, such as crop production and food security. The paper described the impact of nanotechnology on plant growth, plant production and protection, and plant pathogen detection. The paper affirmed that the application of nanomaterials can improve plant growth and better protection of plant compared to conventional agricultural practices. The paper also asserted that nanomaterial-based sensors have the potential for detecting residual pesticides and pathogens to ensure food safety. The paper added that various metal and metal oxide nanoparticles can positively improve seed germination and plant growth within specified concentration level. The paper concluded that the incorporation of nanotechnology into the field of agriculture has helped to improve nutrient delivery in fertilizers, create more effective and targeted pesticides, enhanced crop protection and food security. However, the injudicious use of chemical pesticides may leads to environmental hazards, and therefore crucial to address before adoption.

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EDGE COMPUTING DEVICES IN DIGITAL AGRICULTURE AND AGRICULTURAL IoT: CORE TECHNOLOGIES, APPLICATION AREAS, AND ENCOUNTERED CHALLENGES

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ABSTRACT

With the increasing digitalization of the agricultural sector, the need for collecting large amounts of data in the field, analyzing it, and making real-time decisions has become more prominent. At this point, edge computing technologies, which enable data to be processed on devices located close to where it is generated without sending it to centralized systems have gained importance, especially in conjunction with Agricultural Internet of Things (Agri-IoT) systems. Edge computing devices offer significant advantages in rural areas due to their low energy consumption, real-time data processing capabilities, and reduced dependency on internet connectivity, thus having the potential to enhance agricultural productivity.

This study aims to examine the use of edge computing-based devices in digital agriculture from an Agri-IoT perspective. It presents examples of how edge devices are utilized in key agricultural applications such as precision farming, irrigation management, environmental condition monitoring, and pest and disease detection. The study also discusses the hardware components used in these systems (such as microcontrollers, sensors, and communication protocols) as well as their architectural frameworks. In addition to highlighting the potential benefits of edge computing technologies in agriculture, the study evaluates major challenges such as data security, hardware costs, maintenance requirements, and infrastructural limitations.

The findings show that edge computing not only increases efficiency but also serves as a key component of the vision for sustainable and smart agriculture.

Keywords: Edge Computing, Digital Agriculture, Real-Time Data Processing, Smart Farming Systems, Agricultural Internet of Things - Agri-IoT

DİJİTAL TARIMDA UÇ BİLİŞİM CİHAZLARI VE TARIMSAL NESNELERİN İNTERNETİ: TEMEL TEKNOLOJİLER, UYGULAMA ALANLARI VE KARŞILAŞILAN ZORLUKLAR

ÖZET

Tarım sektöründe dijitalleşmenin artmasıyla birlikte, büyük miktarda verinin sahada toplanması, analiz edilmesi ve anlık kararlar alınması ihtiyacı doğmuştur. Bu noktada, verilerin merkezi sistemlere gönderilmeden, verinin üretildiği noktaya en yakın cihazlarda işlenmesini sağlayan uç bilişim (edge computing) teknolojileri, özellikle Tarımsal Nesnelerin İnterneti (Agri-IoT) sistemleriyle birlikte önem kazanmaktadır. Uç bilişim cihazları; düşük enerji tüketimi, gerçek zamanlı veri işleme, internet bağlantısına daha az bağımlılık gibi avantajlarıyla kırsal alanlarda tarımsal verimliliği artırma potansiyeline sahiptir.

Bu çalışma, dijital tarım uygulamalarında uç bilişim tabanlı cihazların kullanımını Agri-IoT perspektifinde incelemeyi amaçlamaktadır. Çalışmada; hassas tarım, sulama yönetimi, çevresel koşul izleme, zararlı ve hastalık tespiti gibi temel tarımsal uygulama alanlarında uç bilişim cihazların nasıl kullanıldığı örneklerle açıklanmakta; kullanılan donanımlar (mikrodenetleyiciler, sensörler, iletişim protokolleri) ve sistem mimarileri ele alınmaktadır. Ayrıca, uç bilişim teknolojilerinin tarımsal alandaki potansiyel faydalarının yanı sıra, karşılaşılan başlıca zorluklar olan veri güvenliği, donanım maliyeti, bakım gereksinimi ve altyapı eksiklikleri de değerlendirilmektedir. Elde edilen bulgular, uç bilişimin yalnızca verimliliği artırmakla kalmayıp aynı zamanda sürdürülebilir ve akıllı tarım vizyonunun temel bileşenlerinden biri olduğunu göstermektedir.

Anahtar Kelimeler: Uç Bilişim, Dijital Tarım, Gerçek Zamanlı Veri İşleme, Akıllı Tarım Sistemleri, Tarımsal Nesnelerin İnterneti

1. GİRİŞ

Nesnelerin İnterneti (IoT), bilgi işlem ve iletişimin geleceğini temsil eden devrim niteliğinde bir teknolojidir. Bu teknoloji yazılım, sensör ve diğer teknolojik bileşenlerle, internet üzerinden birbirine bağlı cihazlardan oluşan bir ağı belirtmektedir. Bu bileşenler, cihazların verileri birbirleriyle toplamasına, değiştirmesine ve internet üzerinden merkezi sistemlere dönüşmesine izin vermektedir. IoT'nin altında yatan temel ilke, sıradan nesneler arasında otonom iletişimi ve etkileşimi kolaylaştırmak; böylece fiziksel ve dijital ortamın uyumlu bir şekilde bir füzyonunu oluşturmaktır (Mekala ve Viswanathan, 2017; Saini ve ark., 2025). Son yıllarda dünya nüfusunun hızla artması ve artan gıda talebinin karşılanmasında yaşanan sorunlar üretim, sürdürülebilirlik ve verimin artırılması kapsamında modern tarımın gelişmesinde önemli zorlukları da beraberinde getirmiştir. Günümüzde 5G teknolojisinin kademeli olarak popülerleşmesiyle IoT ve yapay zekâ gibi gelişmiş bilgi teknolojileri, modern tarımın akıllı tarıma dönüşümünü teşvik etmiştir. 5G tabanlı IoT, akıllı tarımın geliştirilmesinde önemli bir rol oynayacaktır (Liu ve ark., 2023a). IoT'nin tarımda kullanılmasıyla ortaya çıkan Tarımsal Nesnelerin İnterneti (Agri-IoT) teknolojisi ile tarımsal üretimde önemli değişiklikler olmuştur. Farklı araştırmacılar tarafından farklı yorumlanan Agri-IoT kavramı Li ve ark. (2015) tarafından genellikle tesislerdeki çevresel faktörler, tarımsal üretim araçları vb. hakkındaki bilgileri algılamak için ilgili algılama cihazlarının ve tarımsal üretim süreçlerinin gerçek zamanlı olarak izlenmesi, veri iletimi için önceden tanımlanmış protokollere dayalı olarak tarımsal üretim nesnelerinin konumlandırılması ve yönetilmesi için bilgi birikimi olarak ifade edilebilmektedir. Bu teknolojinin kullanımı sadece tarımsal üretimi artırmakla kalmaz aynı zamanda ürün kalitesini, çiftçi gelirini ve tarımsal modernizasyonu da artırırken işçilik maliyetlerini azaltmaktadır (Zhang ve ark., 2020; Xu ve ark., 2022).

İnternete bağlı akıllı cihazların sayısının hızla artması büyük verilerle çalışma, geleneksel bulut bilişim modellerinde bant genişliği yükü, yavaş yanıt hızı, zayıf güvenlik ve gizlilik gibi sorunlara neden olabilmektedir. Geleneksel bulut bilişim, günümüzün akıllı toplumunun veri işleme konusundaki çeşitli ihtiyaçlarını desteklemek için artık yeterli olmadığından son yıllarda uç bilişim teknolojileri ortaya çıkmıştır. Elbette bu durum, uç bilişimin bulut bilişimin yerini alması anlamına gelmemektedir. Her ikisi de birlikte olmalı, birbirini tamamlamalı, koordineli bir şekilde gelişmeli ve sonuçta dijital dönüşüm sağlanmalıdır (Cao ve ark., 2020). Ağın ucunda hesaplamalar yapmak için yeni bir bilişim paradigması olan uç bilişim, işleme ve depolama işlemlerinin sistem gereksinimleri tarafından tanımlanan, uca yakın bir dizi ağa bağlı makinede gerçekleştiği dağıtılmış bir bilgi işlem biçimidir (Pérez ve ark., 2022). Kısaca uç bilişim, IoT cihazlarının uzaktaki bulutla iletişim kurarken ağın çevresinde gerçekleştirdiği hesaplama ve ağ işlemlerini ifade etmektedir (Sharma ve ark., 2024). Temel fikri, bilişimin veri kaynağına daha yakın olması olan uç bilişim, geleneksel bulut bilişimden farklıdır. Ancak uç düğümlerindeki tüm verileri derinlemesine analiz elde etmek ve daha anlamlı analiz sonuçları

elde etmek için bulutta özetlenmesi gerekmektedir. Bu nedenle bulut bilişim giderek daha akıllı hale gelen IoT cihazlarının geliştirilmesinde önemli bir rol oynamaktadır (Satyanarayanan, 2017; Cao ve ark., 2020).

Uç bilişim, bilişim görevinin uç cihazlara daha yakın düğümlere (onlardan bir sıçrama uzaklıkta) aktarılmasına olanak tanımaktadır. Bu nedenle, bu görevler veri kaynağına ve veri tüketicisine daha yakındır ve sunulan hizmetin kalitesini artırmaktadır. Farklı araştırmalar, altyapı maliyetini düşürmek veya gizlilik yönetimini iyileştirmek isteyenler için farklı alanlar, sıkı bir yanıt süresine sahip uygulamalar için uç bilişimin uygulanmasını önermektedir. Bu nedenle, şu anda uç bilişimin belirli kapsamı, hedeflenen alanlar ve faydaları konusunda bir fikir birliği eksikliği bulunmaktadır. Bu paradigmanın, bulut bilişim gibi diğer önerilere benzer şekilde sektör tarafından benimsenmesi için, tüm paydaşların ortak bir vizyona sahip olması, içinde yer alan farklı unsurları ve kavramları açıkça bilmesi, ele almalarına olanak tanıyan temel sorunların neler olduğunu, sağlanan temel faydaların neler olduğunu ve hangi alanlar için olduğunu bilmesi gerekmektedir (Pérez ve ark., 2022).

IoT bağlamında, bağlı cihazlar tarafından üretilen büyük miktardaki tüm veriler buluta iletilirse, bulut bilişim büyük bir yüke neden olur. Bu sırada, uç bilişimin bulutun baskısını paylaşması ve uç kapsamındaki görevleri üstlenmesi gerekir. Uç bilişimde bir sorun olduğunda, buluttaki veriler kaybolmaz. Bazı internet hizmetlerinde, veri madenciliği ve paylaşımının derinlemesine analizi gibi, uç bilişim tarafından işlendikten sonra bazı verilerin işlenmek üzere buluta geri döndürülmesi gerekir; bu da bulut bilişimin ve uç bilişimin iş birliğini gerektirir. Her iki gelişme de IoT ağındaki bağlı cihazlara istikrar getirmektedir. İkisinin çalışma yöntemi, bulut bilişimin büyük veri analizi ve çıktısına dayanması, uç tarafa iletilmesi ve ardından uç bilişim tarafından işlenip yürütülmesidir. Uç bilişim, bulut bilişim platformuna yükleme yapmadan verileri uç aygıtlarında depolar ve işler. Bu özellik nedeniyle uç bilişimin gerçek zamanlı, hızlı veri işleme ve analizi, güvenlik düşük maliyet, düşük enerji tüketimi ve düşük bant genişliği maliyeti gibi önemli avantajları bulunmaktadır. Bu önemli avantajları da göz önünde bulundurulduğunda uç bilişim, ağın ucunda veri depolama ve bilişim sağlamakta, yakınlarda internet akıllı hizmetleri sunarak çeşitli endüstrilerin dijital dönüşümüne destek olmakta ve farklı endüstrilerin veri çeşitlendirmesi gereksinimlerini karşılamaktadır (Cao ve ark., 2020).

Uç bilişimin önemli avantajları nedeniyle tarımsal uygulamalarda özellikle gerçek zamanlı veri işleme uygulanabilir hale gelmekte ve değişen tarımsal koşullara anında yanıt verilebilmektedir (Yang ve ark., 2024). Ayrıca tarımsal üretimin geniş alanlarda yapılması ve üretimdeki çeşitlilik gibi nedenlerle, tüm alandan toplanacak veriler bulut sunucusuna toplanması durumunda, sunucu ağ üzerinde daha fazla baskı uygulanmasına neden olacak ve bu da veri işleme hızının azalmasına neden olacaktır. Bu sorun, bulut sunucusunun yükünü paylaşabilen ve gecikmeyi azaltabilen uç bilişim teknolojisinin Agri-IoT ile kullanımı sayesinde mükemmel bir şekilde çözülebilecektir.

Bu çalışmada veri kaynaklarına daha yakın tasarlanmış bir sistem olan uç bilişim ve bu sisteme ait cihazların tarımsal uygulamalarda kullanımının araştırılması amaçlanmıştır. Çalışmada, tarımsal uygulamalarda kullanılan uç bilişim cihazlarının donanımı ve sistem mimarileri özellikle hassas tarım uygulamaları, çevresel koşul izleme, sulama sistemlerinin yönetimi hastalık ve zararlıların tespiti gibi uygulamalar kapsamında detaylı bir şekilde irdelenmiştir.

Ayrıca bu çalışma, tarımda uç bilişim uygulamalarının kazandırdığı potansiyel çözüm önerilerinin yanı sıra karşılaşılan temel zorlukların kapsamlı bir incelemesini de sunmaktadır.

2. TARIMDA UÇ BİLİŞİM VE NESNELERİN İNTERNETİ TEKNOLOJİLERİNİN TEMELLERİ

Uç bilişim, akıllı cihazlardan yollardaki otonom arabalara kadar verilerin hızlı, güvenli ve üretildiği yere yakın ortamlarda işlenmesini sağlamaktadır. Verileri işlemeyi, verilerin üretildiği yere yakınlaştırarak her şeyi merkezi bir sunucuya veya bulut veri merkezine gönderme ihtiyacını ortadan kaldırmaktadır (Andriulo ve ark., 2024). Tarım ve akıllı çiftçilik için uç bilişim, çiftçilerin sensör verilerini tamamen merkezi sunuculara göndermek yerine, IoT cihazları ve akıllı sensörler gibi kaynağına daha yakın bir noktada işlenmesini ve karar alınmasını sağlamaktadır (Shi ve ark., 2016). Yerel düzeyde uç bilişim, gerçek zamanlı işlem yapma becerisini ifade eder ve tarımsal sistemler için hızlı yanıtlar sağlamaktadır. Bu durum, sistemsel gecikmeleri en aza indirerek toprak koşullarının, zararlı kontrolünün ve ürün büyümesinin sürekli izlenmesi ve anında eyleme ihtiyaç duyulan hassas tarım uygulamalarında hızlı kararlar alınmasını desteklemektedir. Uç bilişim, sınırlı internet bağlantısına sahip kırsal alanlarda kablolu ve kablosuz sensör ağları tarafından üretilen büyük miktardaki veriyi doğrudan çiftlik ortamında işlemektedir (O'Grady ve ark., 2019). Hava durumu tahminlerini, toprak nem seviyelerini veya hava durumu modellerinin gerçek zamanlı olarak analiz edilmesini sağlayarak sulama sistemlerinin su kullanımını ve çiftçilik verimliliğini optimize etmek için otonom olarak ayarlanmasına olanak tanımaktadır. Derin öğrenme yetenekleri de dâhil olmak üzere öngörücü analiz ve makine öğrenimi teknikleri, zararlı istilalarının erken belirtilerini belirleyebilir veya mahsul sağlığındaki değişiklikleri tespit ederek etkili mahsul yönetimine imkân tanıyarak sürdürülebilirliği artırma potansiyeline sahiptir (Singh ve ark., 2018).

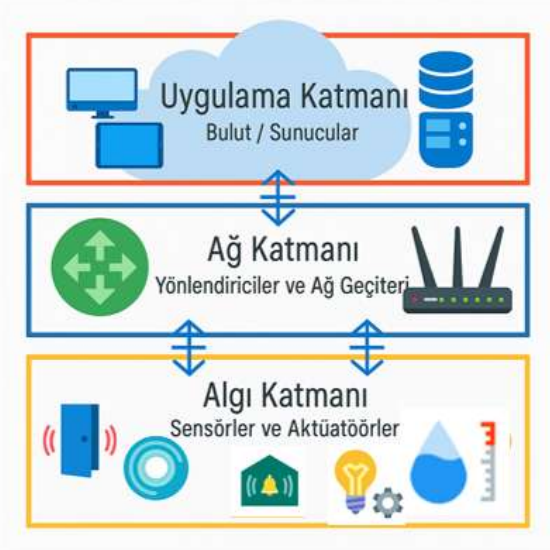
Tarımda uç bilişimin, gerçek zamanlı karar alma, gelişmiş kaynak verimliliği, azaltılmış gecikme, gelişmiş veri güvenliği, sürdürülebilirlik ve maliyet tasarrufu gibi temel avantajları bulunmaktadır (Sulieman ve ark., 2022). Günümüzde akıllı tarımda uç bilişim, hassas tarım, hayvancılık izleme, sera otomasyonu, mahsul sağlığının izlenmesi, tedarik zinciri optimizasyonu gibi uygulamalarda yoğun şekilde kullanılmaya başlamıştır (Abdo-Peralta ve ark., 2024).

Tarımda uç bilişimi yönlendiren temelde 5 ana teknoloji bulunmaktadır. Bunlar; IoT cihazları, yapay zeka entegrasyonu, düşük güç tüketen işlemciler, 5G ağları ve otonom sistemlerdir. Toprak ve bitkiye ait fiziksel, kimyasal ve biyolojik veriler, hava durumu ve hayvancılıkta hayvan takibi gibi gerçek zamanlı tarımsal verilerin yakalanmasında IoT sensör ve cihazları kritik rol oynamaktadır. Elde edilen tarımsal verilerin analiz edilmesinde uç bilişim destekli yapay zeka modelleri, öngörücü analiz ve otomasyon için karar alma süreçlerini iyileştirmektedirler. Düşük güç tüketen özelleştirilmiş işlemciler uzak noktalarda enerji açısından verimli ve yüksek hızlı işlem sağlayarak tarımsal operasyonları desteklemektedirler. Akıllı çiftçilik uygulamaları için daha hızlı ve ölçeklenebilir sistemler oluşturarak uç cihazlar arasındaki bağlantının hızlandırılması minimum beşinci nesil mobil teknoloji olarak da bilinen 5G hücresel ağını gerektirmektedir. Son olarak, insansız hava araçları, robotlar ve tüm otonom

sistemler, çiftçilik görevlerini anında gerçekleştirmek, verimliliği ve üretkenliği artırmak için uç bilişimden yararlanmaktadır.

2.1. IoT, Uç, Sis ve Bulut farkları

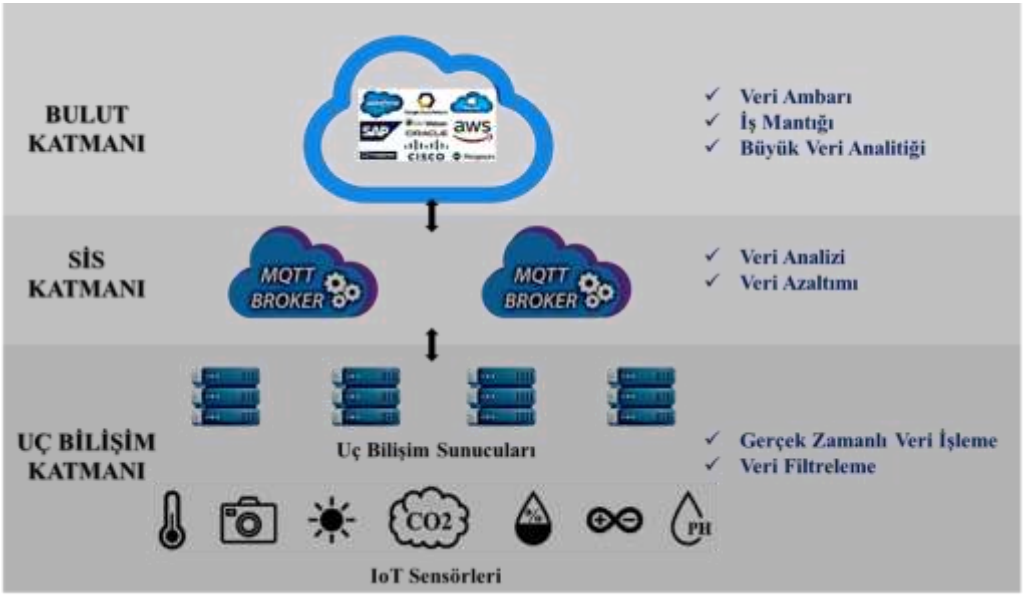
IoT, Şekil 1'de genel mimarisi verilen sensörler, yazılım ve ağ bağlantısı ile donatılmış fiziksel cihazlar, araçlar, gereçler ve diğer fiziksel nesnelerden oluşan bir ağı ifade eder ve bunların veri toplamasına ve paylaşmasına olanak tanımaktadır. IoT ve uç bilişim, sıklıkla birlikte kullanılsa da birbirini tamamlayan farklı teknolojileri işaret etmektedir. IoT, fiziksel cihazları veri alışverişi ve analizi için bağlamaya odaklanırken, uç bilişim, verilerin yerel olarak işlenmesine yani üretildiği yere yakın bir yerde vurgu yapmaktadır. Birlikte, gerçek zamanlı kararlar, otomasyon ve optimizasyon yapabilen güçlü sistemleri etkinleştirirler. IoT, birbirine bağlı cihazlara ve bunlar arasındaki kesintisiz veri akışına odaklanırken uç bilişim verilerin nerede ve nasıl işleneceğine odaklanarak yerelleştirilmiş hesaplamaya öncelik verir ve buluta bağımlılığı en aza indirir (Kalyani ve Collier, 2021). Pratik açıdan, IoT cihazları uç bilişim olmadan var olabilir, ancak uç bilişim, yerel veri işlemeyi etkinleştirerek IoT uygulamalarına yardımcı olmaktadır. Uç bilişim, sayısız IoT cihazından gelen bitmek bilmeyen trafiği yönetmek için tek bir bilgisayara güvenmek yerine, iş yüklerini birden fazla makineye atamayı sağlamaktadır. Bu anlamda uç bilişim, daha iyi performans, daha kısa yanıt süreleri, gerçek zamanlı içgörüler ve sınırsız ölçeklenebilirlik yanı sıra yalnızca gerçekten ihtiyaç duyulan ve kullanılan verilerin yakın noktalarda kaydedilmesine imkan vermesi nedeniyle daha az bulut depolama alanı kullanılmasını sağlamaktadır (Fernando ve ark., 2025).



Şekil 1. Genel IoT mimarisi

Cisco tarafından ortaya atılan fog (sis bilişim) ve uç bilişim terimleri, her ikisi de işleme ve analiz kaynaklarını verilerin üretildiği noktalara daha yakın bir yere tahsis etmeyi içerdiğinden, genellikle birbirinin yerine kullanılmaktadır. Sis bilişim veya sisleme, uç ve büyük sunucular

arasında bir yerde, yerel alan ağı (LAN) içinde gerçekleşmektedir. Uç bilişimde ise veriler sensörlere fiziksel olarak bağlı cihazlarda işlenmektedir. Uç ve sis bilişimine benzer şekilde, bulut bilişim dağıtılmış veri depolama ve işleme fikrini desteklemektedir. Bulut bilişim, geleneksel veri merkezlerinin yerini alır veya onları tamamlar. Aynı zamanda kaynakların birden fazla konuma ölçeklenebilir şekilde dağıtılmasını sağlar ve analiz için güçlü araçlar sunar. Yine de, bulut tesisleri verilerin üretildiği yerden yüzlerce hatta binlerce mil uzakta olabilmektedir. Uygulamada, uç, sis ve bulut bilişim, IoT verilerini işlemek için bir sistemin yalnızca farklı katmanlarıdır. Çoğu durumda, katmanlar bilgileri MQTT (Message Queuing Telemetry Transport- Mesaj Kuyruğu Telemetri İletimi) aracılığıyla değiştirmektedir (Chang ve ark., 2023). Şekil 2'de uç, sis ve bulut bilişimlerinin kullanımını gösteren yapı verilmiştir. Bulut, sis ve uç bilişim arasında veri işleme yeri, işlem gücü ve depolama kapasitesi, hedefler, internet bağlantısı gereksinimi, veri güvenliği ve kurulum ve yönetim gibi noktalarda temel farklılıklar bulunmaktadır.



Şekil 2. Uç, sis ve bulut bilişimlerinin kullanımını gösteren mimari

2.2. Tarımsal verilerde uç işlemeye duyulan ihtiyaç

Uç bilişim, merkezi bilişimin geleneksel modellerinin çözemediği zorlukları ele aldığı için günümüz dünyasında hayati öneme sahiptir. Tarımsal süreçlerde kararların genellikle gerçek zamanlı olarak alınması gerekmektedir (Cruz ve ark., 2022). Uç bilişim, IoT cihazlarının verileri yerel olarak işlemesine olanak tanıyarak kararların milisaniyeler içinde alınmasını sağlamaktadır. Örneğin, yabancı ot tespiti yapacak otonom bir mobil robot, hareketli halde yabancı otu sensörlerden gelen girdileri saniyenin onda biri kadar kısa sürede tespit ederek uç efektörün hızlı bir şekilde çalıştırılmasına imkan sağlayabilir. Akıllı çiftlik ortamında yüzlerce IoT cihazı muazzam miktarda veri üretmektedir. Tüm bu verileri işlemek için merkezi bir

sunucuya veya buluta göndermek ağ bant genişliğini zorlayarak maliyetlerin artmasına neden olmaktadır. Uç bilişim, verileri yerel olarak işleyerek bu sorunu çözer ve hem işletmeler hem de son kullanıcılar için daha sorunsuz performans sağlar. Uç bilişim verileri kaynağına yakın tutarak hassas bilgileri ağlar üzerinden iletmeyle ilişkili riskleri azaltma özelliğine sahiptir. Yapay zeka ve makine öğrenimi gibi teknolojiler gelişmeye devam ettikçe, uç bilişim bunların gelişimini desteklemede önemli bir rol oynamaktadır (Hoque ve ark., 2024). Tüm bu gelişmeler, uç bilişimin inovasyon ve verimliliği yönlendirmede ne kadar önemli olduğunu göstermektedir.

2.3. Uç bilişim mimarileri

Uç bilişim cihazları, genellikle veri kaynaklarına veya tüketicilere yakın olan ağın kenarına yakın bilgi işlem cihazlarıdır. Bunlar gerçek zamanlı uygulamalarda ve IoT dağıtımlarında önemli bir rol oynamaktadır. Bu cihazlar, verileri merkezi sunuculara veya diğer cihazlara göndermeden önce titizlikle toplar, filtreler ve analiz eder. Basit sensörlerden karmaşık endüstriyel sistemlere kadar her şeyi kapsarlar. Uç bilişim, veri işlemeyi kullanıcıya daha yakın bir yere taşımak için ağın kenarındaki yakın veri işleme yeteneklerinin kullanılması anlamına gelmektedir. Bu, verilerin hedefine daha hızlı ulaşmasını sağlayan "bağlantısı kesilmiş" bir anahtar veya yönlendirici gibidir. Uç bilişim ağ geçidi, geleneksel merkezi bilişim sürecini kullanıcılara daha yakın ve en geniş bant genişliğine sahip ağa taşıyan ve işletmelerin üretkenliğini ve yanıt hızını etkili bir şekilde iyileştiren bir ara düğüm olarak da anlaşılabilir. Uç bilişim ağ geçitleri, uç cihazlarının buluta bağlanması, veri ve uygulama hizmetlerini toplaması ve işlemesi için önemli bir ara yüzdür. Şekil 3'te sensör düğümleri, ağ geçidi, bulut ve son kullanıcı arasındaki veri mekanizması blok şema olarak gösterilmiştir.

Şekil 3. Sensör düğümleri, ağ geçidi, bulut ve son kullanıcı arasındaki veri mekanizması

Uç bilişimin üç temel bileşeni bulunmaktadır. Bunlar, uç cihazlar, uç sunucular veya ağ geçitleri ve bulut sunucularıdır. Veri üreten ve alan cihazlar (sensörler, kameralar, robotlar, vb.). uç cihazları oluşturmaktadır. Uç sunucular veya ağ geçitleri, verileri filtrelemek ve işleyen cihazlara yakın olan ve yalnızca önemli bilgileri buluta göndermek için kullanılmaktadır. Bulut sunucular, ilgili verilerin gelişmiş modeller kullanılarak daha derinlemesine analizlerinin yapıldığı sunuculardır. Şekil 4'te temel uç bilişim mimarileri verilmiştir.

Şekil 4. Temel uç bilişim mimarileri

3. TEMEL TEKNOLOJİLER

3.1. IoT sensörleri

Sensör teknolojileri, tarımsal uygulamalarda ekimden ürünün paketlenmesine kadar üretim sürecinin farklı aşamalarında aktif rol oynamaktadır (Alahmad ve ark., 2023). Toprak besin içeriği, çevresel koşullar ve iklim verileri gibi üretimi etkileyen değişkenlerin izlenmesinde kullanılan bu sensörler; konum belirleme, optik algılama, mekanik ölçüm, elektrokimyasal tespit ve hava akışı analizi gibi farklı teknik gruplarda sınıflandırılmaktadır (Li ve ark., 2010). Bu sensörler, IoT sistemleriyle entegre edildiğinde, tarla koşullarına ait veriler gerçek zamanlı olarak toplanıp analiz edilebilmekte, üretim süreçlerine dair kararlar yerinde ve hızlı biçimde alınabilmektedir. Uç bilişim mimarilerinin kullanımı, verilerin bulut ortamına aktarılmadan önce yerel olarak işlenmesini mümkün kılarak ağ üzerindeki veri yükünü azaltmakta ve sistemin yanıt süresini iyileştirmektedir. Böylece IoT tabanlı sensör sistemleri, yalnızca izleme aracı olmaktan çıkarak karar destek sistemlerinin temel bileşeni hâline gelmektedir.

Günümüzde toprak nemi, sıcaklık, pH, elektriksel iletkenlik, CO_2 seviyesi, ışık yoğunluğu, fotosentez kapasitesi, meyve gelişimi ve hava akımı gibi birçok parametre IoT destekli sensörler aracılığıyla sürekli olarak izlenebilmektedir. Bu veriler, sulama yönetimi, gelişim takibi, çevresel kontrol ve erken uyarı sistemleri gibi pek çok uygulamada etkin şekilde değerlendirilmektedir. Ayrıca, sensör ağlarının modüler yapısı sayesinde üretim alanına özgü özelleştirilebilir sistemler kurulabilmekte, bu da sistem esnekliğini artırmaktadır.

Agri-IoT sistemlerinde özellikle makine bileşenlerine entegre edilen sensörler, sistemin maruz kaldığı biyotik ve abiyotik stres faktörlerine dair sürekli bilgi akışı sağlayarak üreticiye operasyonel farkındalık kazandırmaktadır. Toprak, bitki ve hayvan üzerinde konumlandırılan sensörlerden elde edilen çoklu verilerin analizi; çevresel ve ekonomik sürdürülebilirliği gözeten teknik iyileştirmelere olanak tanımakta, hassas tarım uygulamalarının doğa dostu ve yüksek verimli bir yapıya kavuşmasını sağlamaktadır (Baillie ve ark., 2018). Bu noktada, kullanılacak sensörlerin doğru seçilmesi, sistemin verimliliği ve güvenilirliği açısından kritik önem taşımaktadır. Son yıllardaki teknolojik gelişmeler, sensör tabanlı IoT çözümlerinin hızlı

yayılımına olanak sağlamıştır. Ancak, sistem tasarımında sensör tercihi yapılırken; düşük güç tüketimi, sensör-bilgisayar iletişim uyumu, ölçüm doğruluğu, hassasiyet, tekrarlanabilirlik ve uzun ömür gibi teknik kriterler göz önünde bulundurulmalıdır (Chamara ve ark., 2022). Bu bağlamda, Tablo 1'de farklı tarımsal uygulama alanlarında kullanılan IoT tabanlı sensör sistemleri ve ilgili literatür çalışmaları özetlenmiştir.

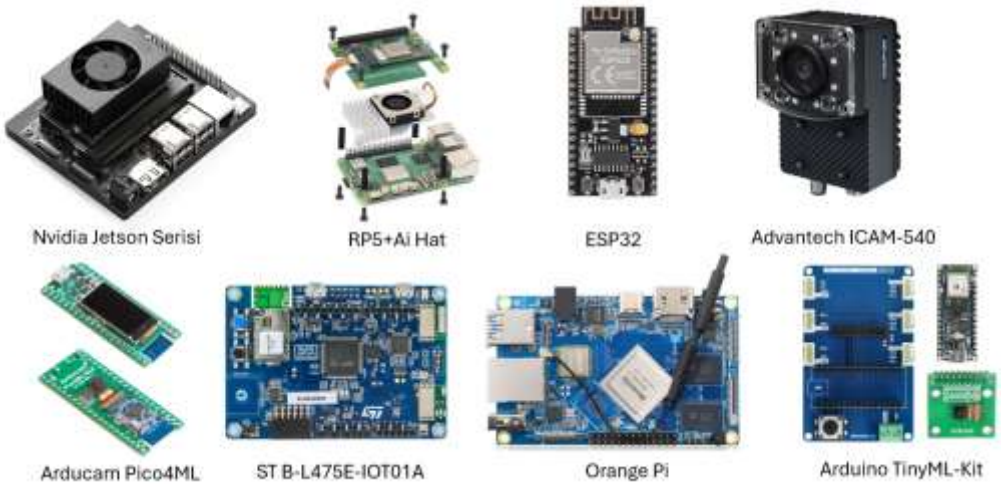
Tablo 1. Tarımsal uygulama alanlarında kullanılan bazı IoT tabanlı sensör sistemleri ve ilgili literatür çalışmaları

Sensör	Tarımsal Çalışma Alanı	Çalışma
pH sensörü, toprak nem sensörü, toprak sıcaklık sensörü	Toprak	Na ve ark. (2016)
Hava sıcaklığı ve nem sensörü, toprak sıcaklığı ve nem sensörü, rüzgar hızı/yönü sensörü, yağmur ölçer, güneş radyasyonu sensörü, yaprak ıslaklığı sensörü.	Hastalık	Khattab ve ark. (2019)
Hava kalitesi (CO_2) sensörü, ışık sensörü, toprak nem sensörü	Sera	Aafreen ve ark. (2019)
Toprak nemi, sıcaklık ve yağış sensörleri	Sulama	Tace ve ark. (2022)

3.2. IoT ve uç bilişim uygulamaları için yaygın olarak kullanılan bazı gömülü sistem donanımları

IoT ve uç bilişim uygulamalarının artan gereksinimleri doğrultusunda, düşük güç tüketimli ve yüksek işlem kapasiteli gömülü sistem donanımları yaygın şekilde kullanılmaktadır. Bu tür sistemler; veri toplama, analiz etme ve karar süreçlerine doğrudan etki eden mimarilerle donatılmıştır. Şekil 5'te yer alan Nvidia Jetson serisi, RP5+AI Hat, ESP32, Advantech ICAM-540, Arducam Pico4ML, ST B-L475E-IOT01A, Orange Pi ve Arduino TinyML-Kit gibi donanımlar, özellikle tarımda görüntü işleme, çevresel izleme, makine öğrenmesi, kablosuz veri aktarımı ve uç yapay zekâ uygulamalarında etkin biçimde kullanılmaktadır.

Yüksek işlem kapasitesine sahip Jetson serisi veya RP5+AI Hat gibi platformlar, kamera tabanlı analizlerde kullanılabilirken; ESP32 gibi mikrodenetleyiciler düşük güçle Bluetooth/Wi-Fi üzerinden haberleşme sunar. Kamera ve görüntü işleme odaklı sistemler (örneğin ICAM-540 ve Pico4ML) görsel verilerin uçta işlenmesini sağlarken, ST ve Orange Pi gibi geliştirme kartları ise çoklu sensör girişine uygun yapısıyla veri toplama ve aktarma görevlerini üstlenmektedir. Bu cihazların modülerliği, sahaya özgü çözümler üretilmesine olanak tanımakta ve IoT tabanlı uygulamalarda sistemlerin özelleştirilmesini kolaylaştırmaktadır.



Şekil 5. IoT ve uç bilişim uygulamaları için yaygın olarak kullanılan bazı gömülü sistem cihazları

Farklı tarımsal uygulama alanlarının gereksinimlerine bağlı olarak, çeşitli mikrodenetleyici ve gömülü sistem donanımları tercih edilmektedir. Tablo 2'de, hastalık tespiti, meyve izleme, üretim süreci takibi ve hayvansal verimliliğin değerlendirilmesi gibi alanlarda kullanılan bazı donanımlar ile bu sistemlerin kullanıldığı örnek çalışmalar özetlenmiştir.

Tablo 2. Uç bilişim ve IoT tabanlı tarımsal uygulamalarda kullanılan bazı gömülü sistem cihazları ve ilgili literatür çalışmaları

Donanım	Tarımsal Çalışma Alanı	Çalışma
Raspberry Pi 4B Arduino	Hastalık Tespiti	Cruz ve ark. (2022)
Raspberry Pi 4 Coral TPU	Meyve Tespiti	Assunção ve ark. (2022)
ESP8266 Node MCU Modül	Meyve Yetiştiriciliği	Abdo-Peralta ve ark. (2024)
Nvidia Jetson AGX Xavier	Süt İneklerinde Vücut Kondisyon Skoru Tespiti	Wang ve ark. (2024)

3.3. Bağlantı protokolleri

Son yıllarda kablosuz veri iletim teknolojileri hızlı bir şekilde gelişmiştir. Tarımda IoT uygulamaları için Wi-Fi, LoRaWAN, mobil iletişim (örneğin 2G, 3G, 4G ve 5G), ZigBee ve Bluetooth gibi çeşitli iletişim teknolojileri kullanılmaktadır. Bu iletişim altyapıları, tarımsal süreçlerin baştan sona otomatikleştirilmesine olanak tanıyarak, işlemlerin daha kolay yönetilmesini ve üretkenliğin önemli ölçüde artmasını sağlamaktadır. (Kim ve ark., 2020). Kablosuz ağ teknolojileri; frekans aralığı, enerji tüketimi, iletişim mesafesi ve veri aktarım

kapasitesi gibi farklı teknik özelliklere sahiptir. Özellikle veri iletim uzaklığı, kullanılacak teknolojinin seçiminde belirleyici olup, aynı zamanda sistemin maliyetini de etkileyen bir faktördür (Ray, 2017). Bu nedenle, üreticiler tarımsal ihtiyaçlara uygun iletim menziline sahip bir iletişim yöntemini tercih etmelidir. Tablo 3'te farklı IoT için kablosuz ağ protokollerinin özellikleri verilmiştir. Bu protokoller; veri iletim hızı, menzil, desteklediği cihaz sayısı ile ağ geçidi ve sensör bazında güç tüketimi gibi temel parametreler açısından farklılık göstermektedir. Örneğin, Zigbee protokolü düşük güç tüketimi (0.1 Watt) ve kısa menzil (20 m) ile sınırlı cihaz kapasitesine (240 cihaz) sahipken; buna karşın NB-IoT daha geniş menzil (15 km) ve çok daha yüksek cihaz kapasitesi (55.000 cihaz) sunmakta, ancak ağ geçidi güç tüketimi oldukça yüksektir (6877 Watt).

Özellikle geniş arazilerde yapılan uygulamalar için menzil ve cihaz sayısı gibi faktörler önem kazanmakta ve bu bağlamda LoRa, 10 km'ye varan menzili ve 10.000 cihaza kadar destek kapasitesi ile düşük güç tüketimi avantajı sayesinde dikkat çekmektedir. 5G ise 28 km'lik etkileyici menzili, 1 km² başına 1 milyon cihaza kadar destek sağlaması ve yüksek veri iletim hızı (20 Gbps) ile yoğun veri trafiği gerektiren uygulamalarda öne çıkmaktadır. Ancak bu avantajların yanında, ağ geçidi seviyesindeki güç tüketimi (11.500 Watt) oldukça yüksektir. Bu değerlendirmeler kapsamında, IoT tabanlı tarımsal uygulamalarda kullanılacak kablosuz iletişim protokolünün seçiminde; uygulamanın kapsama alanı, veri yoğunluğu, enerji verimliliği ve altyapı maliyeti gibi unsurlar birlikte ele alınmalıdır.

Tablo 3. IoT kablosuz ağ protokolleri (Alharbi ve Aldossary, 2021)

Bağlantı Protokolleri	**Veri Hızı**	**Menzil**	**Cihaz Sayısı**	**Güç Tüketimi (Ağ Geçidi / Baz İstasyonu)**	**Güç Tüketimi (Sensör)**
Zigbee	250 Kbps	20 m	240 cihaz	1 Watt	0.1 Watt
LoRa (Long Range)	50 Kbps	10 km	10.000 cihaz	30 Watt	0.44 Watt
NB-IoT (Near Band)	200 Kbps	15 km	55.000 cihaz	6877 Watt	0.55 Watt
5G	20 Gbps	28 km	1 km² başına 1 milyon cihaz	11.500 Watt	0.4 Watt

4. TARIMSAL UYGULAMA ALANLARI

4.1. Sulama Otomasyonu

Angelopoulos ve ark. (2020), çilek seralarında su kullanımını optimize etmek amacıyla uç bilişim temelli akıllı bir sulama sistemi geliştirmiştir. Başlangıçta, nane, lavanta ve sardunya gibi bitkilerle yapılan küçük ölçekli prototip denemelerinde toprak nem sensörleri ve otomatik vanalar kullanılarak sistemin işlevselliği test edilmiştir. Daha sonra, Yunanistan'daki bir çilek serasında geniş çaplı uygulama gerçekleştirilmiş ve bu sistemin geleneksel yöntemlere kıyasla %50 oranında daha az su tüketimi sağladığı, toprak nem seviyesini daha dengeli tuttuğu ve veri işleme süreçlerinde daha hızlı ve güvenli olduğu ortaya konmuştur. Bu bulgular, uç bilişim teknolojisinin tarımsal sulamada verimlilik ve su tasarrufu açısından etkili bir çözüm sunduğunu göstermektedir. Liu ve ark. (2023b), Nebraska'da tarımsal sulama sistemlerinde kullanılan su sayaçlarının uzaktan izlenmesi amacıyla, uç bilişim tabanlı ve derin öğrenme destekli bir algoritma geliştirmiştir. YOLOv3 modeli ile su sayacı görüntülerinden yalnızca gerekli verileri çıkaran bu sistem, Raspberry Pi tabanlı AI-FlowCAM cihazı üzerinde çalışmakta ve 3.248 gerçek dünya görüntüsüyle eğitilmiştir. Sistemin doğruluk oranı %95.35 olarak belirlenmiş, LoRaWAN ağı üzerinden yalnızca küçük boyutlu verilerin iletilmesi sayesinde düşük bant genişliği ile çalışabildiği gözlemlenmiştir. Saha testlerinde %73.8 başarı oranı elde edilen sistem, düşük maliyetli ve etkili bir su yönetimi çözümü sunarken, özellikle görüntü kalitesine duyarlılığıyla dikkat çekmiştir.

4.2. Hassas Tarım ve Konumsal İzleme

Abdo-Peralta ve ark. (2024), çilek seralarında verimliliği artırmak üzere geliştirilen AgroTec 4.0 isimli düşük maliyetli ve kullanıcı dostu bir akıllı tarım sisteminin performansını değerlendirmiştir. 500 m² büyüklüğündeki iki yarı-hidroponik serada yapılan karşılaştırmalı deneyde, bir seraya sistem entegre edilirken diğerinde geleneksel yöntemler uygulanmıştır. IoT sensörleriyle toplanan çevresel veriler, Node-RED platformunda çalışan uç bilişim tabanlı sistem ile analiz edilmiş; sonuçlar, sistemin %15 verim artışı, %20 su tasarrufu, %11.8 daha yüksek şeker oranı ve %103 yatırım getirisi sağladığını göstermiştir. Bu veriler, uç bilişim teknolojilerinin ekonomik ve çevresel sürdürülebilirliğe katkı sağladığını ortaya koymaktadır. Lloret ve ark. (2021), elektromanyetik indüksiyon prensibine dayalı, kablosuz bir toprak nem izleme sistemi geliştirmiştir. ESP32 modülü ile kablosuz veri iletimi sağlayan bu sistem, çok katmanlı toprak analizine imkân tanıyan dört bobinli sensörlerden oluşmaktadır. 93 kHz frekansında çalışan bir devreyle uyarılan bu sistem, doğrusal yanıt kapasitesiyle farklı toprak tiplerinde test edilmiş ve 1:2 sarım oranı ile 50 mm çaplı prototipin en iyi performansı sunduğu belirlenmiştir. Geliştirilen sistem, düşük maliyeti, geniş alanlara uygulanabilirliği ve Wi-Fi tabanlı mimarisi ile hassas tarım uygulamaları için uygun bir çözüm olarak değerlendirilmiştir. Bayih ve ark. (2022), küçük ölçekli tarımda IoT ve kablosuz sensör ağlarının sürdürülebilirliğe katkılarını incelemiştir. 53 çalışmanın analiz edildiği bu sistematik derleme; toprak, iklim, zararlı kontrolü ve hayvancılık parametrelerinin izlenmesinde kullanılan sensörler, veri iletim protokolleri ve bilgi işlem yaklaşımlarının etkinliğini değerlendirmiştir. Çalışma, küçük çiftçiler için düşük maliyetli, modüler ve kullanıcı dostu sistemlerin önemine dikkat çekmiş; veri kalitesi, sensör kalibrasyonu ve kırsal altyapı gibi zorluklara çözüm önerileri sunmuştur.

Amiri-Zarandi ve ark. (2022), akıllı tarım uygulamalarında veri işleme süreçlerini iyileştirmek için bir platform yaklaşımı önermiştir. Mevcut sistemlerin heterojen veri yönetimi, güvenlik açıkları ve uyumluluk sorunlarını ele alan bu yaklaşım; birlikte çalışabilirlik, ölçeklenebilirlik, güvenlik ve düzenleme uyumu gibi temel ihtiyaçlara odaklanmış; uç bilişim ve blokzincir teknolojilerinin entegrasyonunu vurgulamıştır.

4.3. Zararlı ve Hastalık Tespiti

Bhujel ve ark. (2022), domates yaprağı hastalıklarını sınıflandırmak için dikkat mekanizmalarıyla desteklenmiş hafif bir CNN modeli geliştirmiştir. PlantVillage veri seti kullanılarak eğitilen model, CBAM modülünün %99.69 doğrulukla en iyi performansı sergilediğini ve parametre/veri işleme açısından oldukça verimli olduğunu ortaya koymuştur. Cruz ve ark. (2022), çilek tarımında IoT, uç bilişim, bilgisayarla görü ve makine öğrenimi entegrasyonu ile akıllı bir tarım platformu geliştirmiştir. YOLOv5s mimarisi ile hastalık tespiti yapılmış, modelin %92.8 doğruluk oranıyla yedi yaygın çilek hastalığını tespit ettiği gösterilmiştir. Liu ve ark. (2022), Alternaria yaprak lekesi hastalığını tespit etmek için iki aşamalı CNN tabanlı bir sistem geliştirmiştir. PSPNet ile yaprak segmentasyonu ve UNet ile hastalık bölgesi tespiti gerçekleştirilmiş, %96.41 sınıflandırma doğruluğu elde edilmiştir. Yao ve ark. (2022), kivi yaprağı hastalıklarını tespit etmek için YOLOX ve DeepLabv3+ modellerini içeren iki aşamalı bir sistem önermiştir. %96.6 doğruluk oranına ulaşan sistem, görsel segmentasyon ve sınıflandırma açısından etkili sonuçlar sunmuştur. Wang ve ark. (2024), süt ineklerinin vücut kondisyon skorlaması için derin öğrenme destekli Edge-IoT tabanlı bir platform geliştirmiştir. YOLOv7, EfficientID ve EfficientBCS modellerinin kullanıldığı sistem, %98.6 nesne tespiti ve %87'ye varan skor tahmin doğruluğu ile başarılı sonuçlar vermiştir. Monowar ve ark. (2022), etiketli veri ihtiyacını ortadan kaldıran ve yaprak hastalıklarını sınıflandıran öz denetimli bir öğrenme yaklaşımı sunmuştur. Siamese mimarili bu sistem, AutoEmbedder temelli olup k-means algoritması ile yüksek doğrulukla sınıflandırma gerçekleştirmiştir.

4.4. Seralarda İklim Kontrolü

Rizwan ve ark. (2024), sera ortamının iklimsel parametrelerini optimize etmek ve ürün izlenebilirliğini sağlamak amacıyla yapay zekâ ve blokzincir destekli bir yönetim sistemi geliştirmiştir. OCF protokolü ile veri toplayan sistem, Firefly algoritmasıyla enerji verimliliği sağlamış; fuzzy logic kontrol modülüyle ısıtma, soğutma ve havalandırma sistemlerini yönetmiştir. Sistemin %38 enerji tasarrufu sağladığı ve ürün takibini şeffaf biçimde gerçekleştirdiği belirlenmiştir.

4.5. Ürün Verimi ve Takibi

Sharma ve Shivandu (2024), AI ve IoT teknolojilerinin entegre kullanımını değerlendirerek, görüntü işleme, uzaktan algılama, robotik sistemler ve veri analitiği temelli yaklaşımların tarımda ürün verimi ve yönetim üzerindeki etkilerini incelemiştir. Derleme çalışmasında 5G/6G gibi yeni nesil bağlantı teknolojilerinin rolü vurgulanmış; küçük ölçekli çiftliklerde ölçeklenebilirlik ve karar destek sistemlerine dair araştırma boşluklarına dikkat çekilmiştir.

5. KARŞILAŞILAN ZORLUKLAR

Tarımda IoT sistemlerinin benimsenmesi ve güvenle uygulanabilmesi için yalnızca teknolojik altyapının değil, aynı zamanda güvenlik, veri yönetimi ve sistem kararlılığının da titizlikle değerlendirilmesi gerekmektedir. Tarımsal uygulamalarda kullanılan IoT sistemleri, büyük miktarda veri üretmekte ve bu verilerin gerçek zamanlı işlenmesini gerektirmektedir. Ancak bu durum, veri türü, depolama süresi ve aktarım stratejileri gibi başlıklarda çeşitli zorlukları beraberinde getirir. Örneğin, uç bilişim cihazlarda yürütülen görüntü işleme işlemlerinde, sadece öznitelik verilerinin saklanıp orijinal verinin silinmesiyle sistemin hafiflemesi sağlanabilir. Aynı şekilde, toplanan verilerin tamamının başka bir platforma aktarılmasına gerek duyulmayabilir; yalnızca özetlenmiş veya işlenmiş verilerin aktarılması yeterlidir. Bu bağlamda hem kısa vadeli hem de uzun vadeli veri yönetim planlarının yapılması kritik öneme sahiptir.

IoT tabanlı sistemlerin dağıtık doğası, görev dağılımı ve kaynak yönetimi açısından da zorluklar yaratmaktadır. Tarımda kullanılan uç–terminal–bulut mimarisi, görevlerin uygun şekilde ayrıştırılmasını gerektirir. Bu, her bir uç bilişim cihazının işlem kapasitesi, enerji kullanımı ve yanıt süresi dikkate alınarak uygulama bileşenlerinin farklı noktalara dağıtılması anlamına gelir. Bu görev paylaşımı yapılırken uygulamanın bütünlüğü korunmalı, aynı zamanda sistem performansı ve yanıt hızı maksimize edilmelidir. Güncel çalışmalarda yapay zekâ algoritmalarının kenarda ve bulutta bölünerek çalıştırılmasına yönelik modeller geliştirilmekte; bu da sistemin esnekliğini ve verimliliğini artırmaktadır.

Öte yandan, güvenlik ve gizlilik konuları da IoT uygulamalarının başarısını doğrudan etkileyen bir diğer önemli alandır. Özellikle seralar dışındaki açık tarım alanlarında kullanılan cihazlar yağmur, yüksek sıcaklık, nem ve rüzgâr gibi çevresel koşullara doğrudan maruz kalmakta ve bu durum cihaz performansını düşürebilmektedir. Bu nedenle, dış ortam koşullarına dayanıklı fiziksel donanımlar kullanılmalı ve cihazların güvenliği sağlanmalıdır. Ayrıca, toplanan tarımsal verilerin, çiftlik bilgilerinin ve ağ iletişiminin siber saldırılara karşı korunması gereklidir. Dağıtık sensör mimarilerinde tekil bir güvenlik protokolü yetersiz kalabileceğinden çoklu erişim kontrolü ve güvenli haberleşme yöntemleri tercih edilmelidir. Bununla birlikte, sistemin ölçeklenebilirliği ve tüm cihazların yönetilebilirliği açısından ağ protokollerinin güvenilir ve sürdürülebilir olması şarttır.

Son olarak, geniş tarım alanlarında sinyal gücünün zayıf olması sistem kararlılığını tehdit etmektedir. Hizmetlerin kesintisiz sürdürülebilmesi için sistemin; ayırt edilebilirlik, esneklik, izolasyon ve hata bildirimi gibi temel özellikleri sağlaması gerekmektedir. Örneğin, kritik görevlerin önceliklendirilmesi, arızalı bir bileşenin kullanıcıya bildirilmesi ya da yeni cihazların mevcut sistemle uyumlu çalışması gibi konular, tarımda IoT uygulamalarının güvenilirliğini artıracaktır.

6. SONUÇ VE DEĞERLENDİRME

Bu çalışma, dijital tarımın temel yapı taşlarından biri hâline gelen uç bilişim teknolojileri ve IoT uygulamalarının, tarımsal üretim süreçlerinde nasıl bütünleştiğini kapsamlı biçimde incelemiştir. Hassas tarım, çevresel izleme, sulama optimizasyonu, hastalık-zararlı tespiti ve

hayvancılıkta izleme gibi farklı alanlarda kullanılan mikrodenetleyici tabanlı sistemlerin; veri toplama, ön işleme, karar destek ve otonom yönetim mekanizmalarında kritik bir rol üstlendiği görülmektedir.

Literatürdeki çalışmalar, IoT tabanlı uç bilişim sistemlerinin, geleneksel bulut tabanlı yapılara kıyasla; düşük gecikme süresi, azalan bant genişliği gereksinimi, enerji tasarrufu ve modüler yapıları sayesinde saha koşullarına daha uygun çözümler sunduğunu ortaya koymaktadır. İncelenen kaynaklar, özellikle Raspberry Pi, Arduino, Nvidia Jetson ve ESP32 gibi gömülü sistem donanımlarının tarımsal uygulamalarda yaygın şekilde kullanıldığını göstermektedir. Bu donanımların, çeşitli sensör teknolojileri ile entegre edilerek gerçek zamanlı veri işleme ve karar destek süreçlerini desteklediği vurgulanmaktadır. Bununla birlikte, veri güvenliği, fiziksel çevre koşullarına dayanıklılık, maliyet ve sistem kararlılığı gibi konular, bu teknolojilerin yaygınlaşmasının önündeki temel engeller arasında yer almaktadır. Özellikle büyük ölçekli üretim sahalarında sistemin güvenilirliği, ağ protokollerinin sürdürülebilirliği ve görevlerin uç-bulut mimarisi arasında doğru biçimde paylaştırılması kritik önemdedir.

Gelecekteki çalışmalar için, uç bilişim destekli yapay zekâ algoritmalarının entegrasyonu, düşük maliyetli sensör-işlemci çözümlerinin geliştirilmesi ve kırsal alanlarda dayanıklı haberleşme altyapılarının yaygınlaştırılması hem akademik hem de sektörel uygulamalara önemli katkılar sağlayacaktır. Sonuç olarak, uç bilişim ve IoT tabanlı yaklaşımlar, sadece tarımsal verimliliği artırmakla kalmamakta; aynı zamanda sürdürülebilir, ölçeklenebilir ve çevresel olarak duyarlı bir tarımsal üretim sistemine geçişin temelini oluşturmaktadır.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN THE TRANSFORMATION OF SMART AGRICULTURE: TECHNOLOGICAL APPROACHES AND APPLICATION AREAS

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ABSTRACT

The agricultural sector faces increasing challenges due to global issues such as population growth, diminishing natural resources, and climate change. As a response, Artificial Intelligence (AI) technologies have emerged as a significant tool to improve productivity, reduce environmental impacts, and promote sustainability in agricultural production. This study aims to explore the current and potential applications of AI in agriculture and assess its contributions to agricultural processes. AI is being utilized in various critical agricultural activities, including crop health monitoring, disease and pest detection, soil structure analysis, water and fertilizer management, weather forecasting, yield prediction, and planting schedule optimization. Through the real-time analysis of sensor data, AI-based systems are developed to provide decision support for farmers. These systems play a crucial role in identifying the necessary nutrients for soil quality improvement and determining the optimal seed types and planting times. Furthermore, smart agricultural equipment can accurately calculate the ideal spacing between seeds and the optimal planting depth. Additionally, advanced AI technologies, such as 3D laser scanning and hyperspectral imaging, contribute to enhanced crop health assessments, providing high-precision data that support increases in both yield and quality. AI-powered applications like “Plant Health Monitoring Systems” allow for rapid and effective intervention by identifying crop health status and the required nutrients.

This paper presents a review on the role of AI in agriculture. It discusses the technologies in use, the agricultural parameters monitored, and their impact on agricultural production. The study concludes that AI not only enhances production levels but also optimizes resource utilization, thus serving as a vital tool in the transition toward sustainable and environmentally friendly agricultural practices. In this context, AI holds a strategic position in shaping future agricultural policies and technological transformations.

Keywords: Artificial Intelligence, Smart Agriculture, Precision Agriculture

AKILLI TARIMIN DÖNÜŞÜMÜNDE YAPAY ZEKANIN ROLÜ: TEKNOLOJİK YAKLAŞIMLAR VE UYGULAMA ALANLARI

ÖZET

Tarım sektörü, artan nüfus, azalan doğal kaynaklar ve iklim değişikliği gibi küresel zorluklarla başa çıkmak için yeni ve yenilikçi teknolojilere ihtiyaç duymaktadır. Bu bağlamda, yapay zeka (YZ) teknolojileri, tarımsal üretim süreçlerinde verimliliği artırmak, çevresel etkileri azaltmak ve sürdürülebilirliği sağlamak amacıyla önemli bir çözüm aracı olarak öne çıkmaktadır. Bu çalışma, YZ'nin tarım sektöründeki güncel ve potansiyel uygulama alanlarını inceleyerek, teknolojinin tarımsal üretime olan katkılarını değerlendirmeyi amaçlamaktadır. YZ; bitki sağlığının izlenmesi, hastalık ve zararlı tespiti, toprak yapısının analizi, su ve gübre yönetimi, hava durumu tahmini, verim öngörüsü ve ekim zamanlaması gibi birçok kritik tarımsal faaliyette kullanılmaktadır. Özellikle sensör verilerinin gerçek zamanlı analiz edilmesiyle, çiftçilere karar destek mekanizmaları sağlayan sistemler geliştirilmektedir. Bu sistemler, toprak kalitesinin artırılması için gerekli besinlerin belirlenmesi, en uygun tohum türü ve ekim zamanının seçilmesi gibi uygulamalarda etkin rol oynamaktadır. Akıllı tarım ekipmanları sayesinde tohumlar arasındaki ideal mesafe ve ekim derinliği de hassas bir şekilde hesaplanabilmektedir. Ayrıca farklı görüntüleme teknikleri ve üç boyutlu lazer tarama gibi ileri düzey YZ tabanlı teknolojiler, ürün sağlığını değerlendirmede yüksek hassasiyetli veriler sağlayarak verim ve kalite artışına katkı sunmaktadır. “Bitki Sağlığı İzleme Sistemleri” gibi YZ destekli uygulamalar sayesinde, tarım ürünlerinin sağlık durumu ve ihtiyaç duyulan besin maddeleri tespit edilerek hızlı ve etkili müdahale imkânı sağlanmaktadır.

Bu bildiride, YZ’nin tarım alanındaki işlevsel rolü literatür temelli olarak analiz edilmiş; kullanılan YZ teknolojileri, bu teknolojilerin izlediği tarımsal parametreler ve üretim süreçlerine olan etkileri ele alınmıştır. Çalışma sonucunda, YZ' nin yalnızca üretim miktarını artırmakla kalmadığı, aynı zamanda kaynakların daha etkin kullanımını sağlayarak sürdürülebilir ve çevre dostu bir tarım anlayışına geçişte önemli bir araç olduğu sonucuna ulaşılmıştır. Bu yönüyle yapay zekâ, geleceğin tarım politikalarında ve teknolojik dönüşüm süreçlerinde stratejik bir konuma sahiptir.

Anahtar Kelimeler: Yapay Zeka, Akıllı Tarım, Hassas Tarım

1. GİRİŞ

Tarım endüstrisi, dünya nüfusunun hızla arttığı ve geleneksel yöntemlerin yetersiz kaldığı bir dönemde, yeni teknolojik yöntemlere ihtiyaç duymaktadır. İş gücü sıkıntısı, azalan çiftçi sayısı gibi zorluklarla karşılmakta ve bu durum teknolojik çözümler arayışını hızlandırmaktadır. Yapay Zeka, Nesnelerin İnterneti ve Makine Öğrenimi gibi yaklaşımlar, "akıllı tarım" uygulamaları ile tarım ürünlerinin kalite ve verimliliğini artırmak amacıyla kullanılmaktadır [1,2].

Makine öğrenmesi kullanılarak, tarımda pestisitlerin kullanımı optimize edilmektedir, bu yöntemle tarım kimyasalları, zaman, yer ve etkilenen bitkilere göre uygulanır [3]. Ayrıca tarımda su yönetimi konusunda makine öğrenimi kullanılmaktadır. Su yönetimi, tarımsal, iklimsel ve hidrolojik denge üzerinde büyük etkiye sahiptir. ML tabanlı uygulamalar, buharlaşma ve transpirasyonu günlük, haftalık veya aylık olarak tahmin edebilir, böylece sulama sistemlerinin daha verimli kullanılmasını sağlar [4]. Çiftçiler, tarımsal verimliliği artırmak ve çevresel etkiyi en aza indirmek için yapay zeka (YZ) ve makine öğrenimi (ML) modellerini her geçen gün daha fazla kullanmakta; bu gelişme, gıda teknolojisi sektöründe önemli faydalar sağlamaktadır. Örneğin doğru günlük çiğ noktası sıcaklık tahminleri, beklenen hava olaylarını tanımlama ve buharlaşma ile transpirasyon oranlarını tahmin etme konusunda önemli bir rol oynamaktadır [5].

Yapay zeka (YZ), son yıllarda hızla evrimleşmekte ve hesaplama gücündeki gelişmeler ile bulut bilişiminin yaygınlaşması, dünya ekonomisinin pek çok sektörünün YZ'nin avantajlarından faydalanmasına olanak tanımıştır. Tarım, bu faydaları erken benimseyen alanlardan biri olmuştur. YZ, mahsul hasat zamanlaması, toprak ve ürün sağlığının izlenmesi, yabancı ot kontrolü ve verim tahminleri gibi alanlarda önemli uygulamalara sahiptir. Son on yılda YZ ve makine öğrenimi (ML), farklı sektörlerde geliştirme araçları olarak test edilse de, tarımda bu teknolojilerin karar destek süreçlerine katkıları ancak son dönemlerde netleşmiştir. Çiftçiler, YZ teknolojisi kullanarak daha verimli kararlar alabilir, bu da tarımsal ve hayvansal üretimde verimliliği artırmaktadır. Tarım sektörünün, YZ'yi daha etkin bir şekilde kullanma isteği, özellikle artan veri miktarının kolay erişilebilir olmasıyla doğrudan ilişkilidir [6].

Ayrıca yapay zeka (YZ) ve makine öğrenimi (ML) tabanlı izleme sistemleri, tarımda mahsulleri izlemek, zararlıları tespit etmek ve toprak sorunlarını teşhis etmek için önemli bilgiler sunmaktadır, üreticilerin maksimum verim için optimal zamanda tohum ekmelerine de olanak sağlar [7]. Yabancı otlar, tarım faaliyetlerini olumsuz etkileyerek mahsul verimini düşürür, meraları istila eder, nadir durumlarda ise hayvanlar için tehdit oluşturur. YZ sensörleri, bu yabancı otları tespit etmek ve herbisid kullanımını yerinde optimize etmek için kullanılabilir. Ayrıca, YZ sistemleri, hava durumu tahminleri yapabilir, mahsul sağlığını analiz edebilir ve hastalıklar, zararlılar ya da besin eksiklikleri gibi bitki sorunlarını belirleyebilir. Çiftçiler, YZ destekli insansız hava araçları sayesinde mahsullerinin sağlığını izleyerek, uzmanlar tarafından analiz edilen görüntülerle çiftlik sağlık raporları alabilirler. Bu durum, çiftçilerin zararlılarla etkili bir şekilde mücadele etmelerine yardımcı olmaktadır. Ayrıca, tarım robotları, zaman alıcı ve fiziksel olarak zorlayıcı işleri yerine getirmek için giderek daha fazla kullanılmakta olup, bu robotlar manuel iş gücü maliyetlerini düşürerek işçi yükünü hafifletmektedir. Bu çalışmada, tarımda yapay zekanın farklı uygulamaları incelenmektedir.

2. YAPAY ZEKA

Yapay zeka (YZ), insan benzeri düşünme, öğrenme, problem çözme ve karar verme yeteneklerini taklit etmeyi amaçlayan bir disiplin olarak tanımlanmaktadır. YZ, bilgisayar bilimlerinin ve mühendisliğinin bir alt dalı olup, makinelerin ve yazılımların insan zekasına benzer işlevleri yerine getirmesini sağlamak için çeşitli algoritmalar, veri analizleri ve öğrenme teknikleri kullanır. Bu alan, makine öğrenimi (ML), derin öğrenme (DL), doğal dil işleme (NLP) ve robotik gibi teknolojileri kapsayarak, makinelerin çevresel verileri analiz etmesini ve o veriler doğrultusunda otonom kararlar almasını sağlar. Günümüzde YZ, tarımdan sağlığa, sanayiden eğitime kadar geniş bir yelpazede uygulama alanı bulmakta ve verimlilik, doğruluk ve hız açısından devrim yaratmaktadır.

Tarım özelinde ise belli konu başlıkları altında YZ çalışmaları toplanmaktadır ve bu başlıklar aşağıdaki gibi özetlenebilir [8].

1. Tarım Üretim Yönetimi: Tarım üretimi, karmaşık bir tedarik zinciri gerektiren bir süreçtir. Yapay zeka (YZ), bu süreçlerin her aşamasında, özellikle gıda üretimi, dağıtımı ve tüketimi üzerinde önemli etkiler yaratmaktadır. YZ teknolojileri, sulama, haşere kontrolü ve hastalık yönetimi gibi alanlarda verimliliği artırmayı amaçlayan uygulamalarla tarım üretimini daha verimli hale getirmektedir. Ayrıca, YZ, daha doğru tahminlerde bulunarak tarım yönetimini iyileştirmeye yardımcı olmaktadır.
2. Bitki İzleme: Geleneksel bitki sağlığı izleme yöntemleri genellikle zaman alıcı ve iş gücü yoğun olup, yapay zeka (YZ) bu süreçleri daha verimli hale getirmektedir. Derin öğrenme ve makine öğrenimi (ML) teknikleri sayesinde, bitki sağlığı, toprak besin seviyeleri ve zararlı tespiti daha hızlı bir şekilde gerçekleştirilebilmektedir. Bu teknolojiler, tarımda bitki hastalıkları ve zararlılarının erken tespiti konusunda önemli avantajlar sunmaktadır.
3. Veri Bilimi ve Tarım: Tarımda her gün büyük miktarda veri toplanmakta olup, yapay zeka (YZ) bu verilerin gerçek zamanlı olarak analiz edilmesini sağlayarak çiftçilerin daha bilinçli kararlar almasına yardımcı olmaktadır. Bu durum, doğal kaynakların daha verimli bir şekilde kullanılmasını ve sağlıklı ürünlerin yetiştirilmesini mümkün kılmaktadır. Veri analitiği, aynı zamanda bilimsel iş gücünün etkinliğini artırarak tarımsal üretimi iyileştirmektedir.
4. Hastalık Tespiti: Bitki hastalıkları, çevresel, ekonomik ve gıda güvenliği açısından ciddi tehditler yaratmaktadır. Yapay zeka tabanlı görüntü tanıma sistemleri, bu hastalıkları yüksek doğrulukla tespit edebilir ve mobil cihazlar aracılığıyla saha üzerinde hastalıkların tespiti gerçekleştirilebilir. Bu teknolojiler, tarımda zararlıların ve hastalıkların erken uyarılmasını sağlayarak sürdürülebilir tarım yöntemlerinin uygulanmasına katkı sunmaktadır.
5. Gıda Kalitesi ve Güvenliği: Yapay zeka ve makine görüsü, gıda güvenliği ve kalite kontrolünde kritik bir rol üstlenmektedir. Yapay zeka, gıda üretim süreçlerini optimize edebilir, verimliliği artırabilir ve insan gücüyle yapılan görevleri daha doğru bir şekilde yerine getirebilir. Bu, gıda kalitesini yükseltirken, hatalı ürünlerin piyasaya sürülmesini önler.

6. Tahminsel Analitik ve Uzaktan Algılama: Uzaktan algılama teknolojisi, tarımda ürün verimliliğini tahmin etmek amacıyla kullanılmaktadır. Yapay zeka, çiftçilere daha hassas verim tahminleri yapma imkânı sunarak, doğal kaynakların korunmasına ve çevresel etkilerin azaltılmasına katkı sağlar.

Makine ve derin öğrenme algoritmalarını kullanarak verilerden öğrenen ve bu verileri yorumlayarak insan zekasını taklit etmeyi amaçlayan yapay zeka (YZ), bilgisayar biliminin önemli bir dalıdır. Giriş ve çıkış değişkenleri arasında dinamik bağlantılar kurarak tahminlerde bulunan bu sistemler, hem basit hem de karmaşık problemlere yönelik çeşitli çözümler üretmede kullanılabilir. Günümüzde YZ destekli teknolojiler, mobil yüz tanıma uygulamalarından otonom araçlara kadar pek çok alanda hayatımızın bir parçası haline gelmiştir. YZ, en köklü sektörlerden biri olan tarımı da geleceğe taşımaktadır. YZ'nin tarımda oldukça geniş ve dikkat çekici uygulama alanları mevcuttur. Özellikle hassas tarımı mümkün kılan YZ, çiftçilere sulama, ekim, ürün seçimi, ürün rotasyonu, hasat ve zararlı kontrolü gibi alanlarda ML tabanlı verilerle rehberlik edebilmektedir [9].

3. UYGULAMA ALANLARI

Çiftçiler, tarımsal faaliyetleri gerçekleştirirken genellikle aşağıdaki adımları takip ederler:

Adım 1: Ürün Seçimi

Adım 2: Arazi Hazırlığı

Adım 3: Tohum Ekim

Adım 4: Sulama ve Gübreleme

Adım 5: Ürün Bakımı [pestisit kullanımı, budama vb.]

Adım 6: Hasat

Adım 7: Hasat Sonrası Faaliyetler

Yukarıdaki algoritmaya göre, tarıma ilişkin görevler üç ana alt alana ayrılmıştır. Bunlar; hasat öncesi, hasat sırasında ve hasat sonrasında dikkat edilmesi gereken parametreleri şu şekilde özetleyebiliriz. Hasat öncesi aşama; tohum, toprak, hastalık tespiti, ürün fenotiplemesi, pestisit ,yabani ot tespiti ve sulamadan oluşur. Hasat sırasında ise, meyve tespiti ve sınıflandırması, kabuk rengi, boyut, olgunluk yaşı, sertlik parametreleri ile ilgilenilir Hasat sonrası aşamada, sıcaklık, kalite, nem, meyve derecelendirme gibi durumlarla ilgilenilir.

Bu bölümde her aşamadaki parametrelerin alınması, değerlendirilmesi ve verilerin kaydedilmesi sırasında yapay zeka veya onun alt sınıfı olan makine öğrenmesi nasıl kullanılmakta olduğuna dair literatür araştırması yapılmıştır.

3.1 Tohum ve Toprak Değerlendirmesi

Tarımda toprak yönetiminin temel odak noktası, bitki verimliliğini artırmak amacıyla dinamik toprak parametrelerinin korunması ve iyileştirilmesidir. Toprakta verimlilik artışı etkili toprak kaynaklarının yönetimi ve mikro besin elementlerinin uygulanmasına yönelik düzeltici

önlemlerle sağlanabilir. İlk çalışmalarda toprak verimliliğini tahmin etmek amacıyla Yapay Sinir Ağları'nda (ANN) Levenberg-Marquardt tabanlı geri yayılım yöntemi kullanılmıştır [11]. Bir çalışmada, pH değerleri ve toprak verimlilik indekslerinin sınıflandırılması ve tahminine yönelik bir model sunmuştur. Bu modelde farklı aktivasyon fonksiyonları (sinüs, kare, gaussian radial basis, üçgen taban, hiperbolik tanjant ve sert limit) kullanılan aşırı öğrenme (ELM) adı verilen hızlı öğrenme sınıflandırma tekniği ile problem çözülmüştür. Böylece toprak parametrelerinin sınıflandırılması ve tahmini, gübre harcamalarını azaltmaya, kârlılığı artırmaya, kimyasal toprak analiz uzmanlarının zamanını tasarruf etmeye, toprak sağlığını ve çevre kalitesini iyileştirmeye yardımcı olmuştur. Çalışma sonucunda Gaussian radial basis fonksiyonu, dört problemden dördünde maksimum performans elde etmiş, her bir problemdeki doğruluk oranlarında genellikle %80'in üzerinde sonuçlar elde edilmiştir [12]. Ayrıca yer yüzeyindeki ve çeşitli derinliklerdeki ölçülen toprak sıcaklığı verileri, birçok konum için nadiren mevcuttur. Bu nedenle, meteorolojik parametreler gibi diğer mevcut verileri kullanarak farklı derinliklerdeki toprak sıcaklığını tahmin etmek için teorik yaklaşımlar geliştirmek, son derece önemli bir anlam taşımaktadır. Toprak sıcaklığı ve diğer iklim parametreleri arasında karmaşık bir ilişki bulunmaktadır. Bu tür karmaşık problemler, nöral ağlar (NN) ve doğa ilhamlı meta-sezgisel algoritmalar kullanılarak verimli bir şekilde çözülebilir; örneğin, monark kelebek optimizasyonu, solucan optimizasyonu algoritması, krill sürüsü algoritması, ve kukuma arama ile uyum arama algoritması gibi [13].

Geleneksel olarak, tohum kusurlarının sınıflandırılması genellikle renk, şekil ve doku özelliklerine dayanır. Bu yöntem ile büyük miktarda özellik bilgisinin tekrarlanan şekilde çıkarılmasını gerektirir, ancak bu bilgi tespitte verimli bir şekilde kullanılması zordur. Son yıllarda, yapay zeka öğrenme, görüntü tanıma alanında oldukça başarılı sonuçlar elde etmiştir ve tohum kalitesinin sınıflandırılmasına dair çalışmaları ilerletmiştir [14]. Tohumların fenotipik kusurları, kaliteyi belirlemek için kullanılan kriterlerden biridir. Tohum kusurlarını tespit etmenin geleneksel yöntemi, genellikle manuel muayeneye dayanır ve bu yöntem verimli ve objektif değildir. Bu nedenle, objektif ve otomatik bir tohum tarama yöntemi gereklidir. Araştırmacılar, tohum kalitesi testleri için yapay zeka teknolojisini uygulamışlardır [15,16]. Renk, doku, boyut ve şekil gibi özellikler, tohumların görüntülerinden çıkarılabilir ve bilgisayarla görme tabanlı çeşitli sınıflayıcılar kullanılarak tohum kusurları tespit edilebilir. Bu prosedür kolayca otomatikleştirilebilir ve insan emeğiyle yapılan denetimlere kıyasla çok daha verimli bir tohum ayırma yöntemi sağlar.

3.2 Bitki izleme ve Hastalık Tespiti

Bitki hastalıklarının erken teşhisi, tahmini ve izlenmesi; ürün kalitesi ve verimini doğrudan etkileyen kritik bir süreçtir. Bu alanda yapay zeka (YZ) ve derin öğrenme (DL) teknikleri son yıllarda yaygın bir şekilde kullanılmaktadır. Görüntü işleme, spektral analiz ve sensör verileri sayesinde bitki hastalıkları yüksek doğrulukla teşhis edilebilmektedir. Bitkilerde virüsler, mantarlar ve bakteriler gibi çeşitli patojenler nedeniyle oluşan hastalıklar, dünya genelinde tarım sektöründe önemli ekonomik kayıplara yol açmaktadır. Bitkilerin kalitesi ve verimi açısından hastalıkların izlenmesi, ürün güvenliği için oldukça önemlidir. Bu nedenle, bitki hastalıklarının tanınması hayati bir öneme sahiptir. Bitki hastalığı belirtileri genellikle yapraklarda belirginleşir. Bilgisayarla görme, derin öğrenme, few-shot learning ve yumuşak

hesaplama gibi teknikler, bitki hastalıklarını otomatik olarak tanımak için kullanılır. Bu teknikler, çiftçilere hızlı ve etkili önlemler alarak ürün kalitesinin korunmasına yardımcı olur. Bu yöntemler, hastalıkların özelliklerinin yanlış seçilmesinin veya manuel çıkarılmasının getirdiği dezavantajları ortadan kaldırır ve araştırma hızını artırır [17]. Bitki hastalıkları, genel olarak şu başlıklar altında toplanmaktadır; bakteriyel hastalık, viral hastalık, mantar hastalığı gibi. Son yıllarda derin öğrenme (DL) ve bilgisayarla görme alanındaki gelişmeler, cep telefonu üzerinden tanılama yapılmasını mümkün kılmakta ve bu da özellikle büyük çiftliklerde otomasyonun önemini artırmaktadır. Görsel belirtileri insan gözüyle algılamanın zor olduğu durumlarda, görüntü işleme tabanlı yazılımlar hastalık sınıflandırmasında büyük rol oynamaktadır. Öte yandan Makine öğrenmesi (ML) destekli yazılımlar, bitki sağlığının değerlendirilmesinde kullanılmakta, böylece pestisit uygulaması yalnızca kritik bölgelere yönlendirilebilmektedir. Büyük tarım işletmeleri, genellikle görsel ve termal veriler toplayan Nesnelerin İnterneti (IoT) cihazları ile entegre dijital platformlar kullanmaktadır [18]. Convolutional Neural Network (CNN) tabanlı yaklaşımlar, bitki yapraklarının görsel semptomlarına dayalı hastalık tespitinde oldukça başarılı sonuçlar vermektedir [19]. CNN modelleri, özellikle sınıflandırma ve nesne tanıma gibi görevlerde yüksek doğruluk oranları ile tercih edilmektedir. Bunun yanında, YZ algoritmalarının tarımsal uzaktan algılama ile entegre edilmesiyle geniş alanlarda hastalık izleme mümkün hale gelmiştir. Ayrıca, tahminleme süreçlerinde Recurrent Neural Network (RNN) ve zaman serisi analizleri ile iklimsel değişkenler göz önüne alınarak, hastalıkların gelişim süreci öngörülebilmektedir [20]. Bu tür yaklaşımlar sayesinde çiftçiler erken önlem alarak tarımsal kayıpların önüne geçebilmektedir. CNN, özellikle zaman serisi verisi nedeniyle sensör okumalarındaki hataları azaltmada faydalı olurken, geri beslemeli sinir ağı (RNN), sensörden kaynaklanan yanlılıkları azaltmak için zaman serisi yaklaşımı kullanan bir yöntem olarak ürün verimi tahmininde de kullanılmaktadır. Yani CNN algoritmaları, özellikle görsel veriler üzerinden bitki hastalıkları ve fenolojik aşamaların tanımlanmasında güçlüdür, çünkü zaman serisi verilerinden bağımsız olarak görsel özellikleri etkili bir şekilde çıkarır. Öte yandan, RNN algoritmaları, özellikle sensör verilerindeki zaman bağımlılıklarını ve yanlılıkları azaltarak tarımda verim tahminleri ve çevresel koşulların izlenmesi gibi görevlerde daha etkilidir.

3.3 Hassas Tarım Sistemleri

Hassas Tarım, tarla yönetimine yönelik bir yaklaşımdır ve bilgi teknolojilerini (BT) kullanarak bitkilerin ve toprağın tam olarak ihtiyaç duydukları unsurları almasını ve böylece optimum sağlık ve verimlilik düzeyine ulaşmasını sağlamayı hedefler. Hassas Tarım'ın amacı, kârlılığı, sürdürülebilirliği ve çevrenin korunmasını garanti altına almaktır.

Büyük ölçekli tarımda iş gücü maliyetleri, tarımın önemli harcama kalemlerinden biridir. Geleneksel tarımda hasat gibi işlemler büyük bir iş gücü gerektirir ve ürünlerin zamanında hasat edilmemesi, yatırımın geri dönüşünü olumsuz etkiler. Robotik hasat makineleri, ürünleri doğru zamanda ve doğru şekilde toplayarak bu sorunu çözer, böylece iş gücü maliyetlerini düşürür ve hasadın kalitesini koruyarak müşteriye zamanında teslim edilmesini sağlar. Toplanan verilerle hastalık ve zarar tespiti yapılır, böylece bitkilerin sağlığını ve meyve durumunu daha verimli bir şekilde izlenir. Drone'lar ise, önceden belirlenmiş rotalarla geniş alanlarda tarama yapar ve bilgisayarla görme teknolojisini kullanarak ürün analizi, bitki sağlığı izleme, yabani ot tespiti

ve hastalık analizi gibi işlemleri gerçekleştirir. Bu sistemler, çok spektral görüntüler oluşturarak bitki sağlığını, kuraklığın etkisini ve verimliliği değerlendirir. Sonuç olarak, bu teknoloji tarımsal verimliliği artırırken, üretim süreçlerinin daha hassas ve verimli olmasını sağlar. Ayrıca, robotlar yabani otları toplama ve kimyasal uygulamaları daha hassas bir şekilde yapma gibi işlevlerle de tarıma katkıda bulunur. Günümüzde tarım robotları, yorucu, zaman alıcı veya tehlikeli faaliyetlerde insan gücünün yerini almayı amaçlayacak şekilde geliştirilmektedir. Tarım robotik sistemleri; robotun türüne, sensörlerine, aktüatörlerine ve iletişim sistemlerine bağlı olarak farklılık gösteren pek çok avantaj sunmaktadır. Robotların karar verme yetenekleri, yapay zekâ (AI) algoritmalarına dayanmaktadır ve bu algoritmalar, çevreye ve duruma bağlı olarak belirli eylemleri gerçekleştirmesini sağlamaktadır [21].

Akıllı tarım uygulamaları, çevresel değişkenliğin yüksek olduğu bitki yetiştirme süreçlerinde, geleneksel yöntemlerin yetersiz kaldığı durumlarda etkin çözümler sunmaktadır. Özellikle sera tarımı gibi kontrollü ortamlarda, düşük bakım gereksinimi ve yönetilebilir ekosistem avantajları nedeniyle otomasyon sistemleri ve otonom araçlar önemli rol oynamaktadır. Bu kapsamda, belirli bitki türlerinin gereksinimlerine göre çevresel koşulların optimize edilmesi amacıyla IoT (Nesnelerin İnterneti) tabanlı sensör ve aktüatör sistemleri önerilmektedir [22]. Bu sistemlerde kullanılan yapay sinir ağları (ANN), sensör verilerini IoT bulutu aracılığıyla analiz ederek gerekli çevresel düzenlemeleri gerçekleştirmektedir. Kablosuz Sensör Ağları (WSN), tarımsal üretimde veri toplama, depolama ve paylaşım amacıyla yaygın şekilde kullanılmakta olup, gerçek zamanlı çevresel izleme sağlamak için etkin bir altyapı sunmaktadır. WSN teknolojisinin tarımsal uygulamalardaki önemini vurgulayarak, bu sistemlerin üretkenlik ve sürdürülebilirlik açısından sağladığı katkıları birçok çalışmada ele alınmıştır [23]. Tarımda otonom sistemlerin ve IoT entegrasyonunun yalnızca üretim verimliliğini artırmakla kalmayıp, aynı zamanda kaynak kullanımını optimize ederek çevresel sürdürülebilirliği de desteklediği görülmektedir.

IoT (Nesnelerin İnterneti) ve WSN (Kablosuz Sensör Ağları) tabanlı çözümler, tarımsal parametrelerin gerçek zamanlı olarak izlenmesini mümkün kıldığı için; akıllı tarım uygulamalarında toprak ve bitki sağlığının izlenmesi, verimliliğin artırılması ve kaynakların etkin kullanımı açısından önemlidir. Bir çalışmada çiftçilerin akıllı telefonları üzerinden sıcaklık, toprak nemi, pH ve hava nemi gibi çeşitli parametreleri anlık olarak görüntüleyebileceği bir toprak sağlığı izleme sistemi geliştirmiştir [24]. Goswami ve arkadaşları, azot (N), fosfor (P), potasyum (K) gibi makro besinler ile pH, toprak nemi ve toprak nemliliğini izleyebilen IoT tabanlı bir toprak sağlığı izleme sistemi geliştirmiştir [25].

Nesnelerin İnterneti (IoT), bu alanda yaygınlığını kanıtlamış teknolojilerden biridir. IoT; sensörler, aktüatörler ve ağ bağlantı modülleri gibi fiziksel cihazların akıllı ve zeki şekilde birbirine bağlanmasını sağlar. Bu sayede, cihazlar ile makineler ve insanlar arasında veri toplama, paylaşma ve alışverişi için sorunsuz iletişim kurularak, gerçek zamanlı senaryolarda iş birliğine dayalı bir ortam oluşturulur. Başka bir çalışmada, çeşitli veri kümelerinden gelen sensör verilerine dayalı heterojen verilerin yönetimini amaçlanmıştır. Çalışma, büyük ya da küçük ölçekli, kamu ya da özel üretici firmaların kârlılığı artırma yarışında olduğunu ve sürekli olarak kaydedilen ve erişilebilir hale gelen verileri en uygun şekilde kullanmanın, bu bağlamda öznel hedeflere ulaşmak için doğru bir tercih olabileceğini ortaya koymaktadır. Çalışmada,

karar verme ve veri işleme süreçlerinde Yapay Sinir Ağları, Doğrusal Regresyon ve Polinom Regresyon gibi Makine Öğrenmesi modellerinin kullanılmasını önermektedir [26].

Hassas tarım konusunda, Nesnelerin İnterneti (IoT) ve yapay zeka kullanımının ayrıntılı çalışmalarına ilgili referanstan ulaşılabilir [27].

3.4 Ürün ve Verim Yönetimi

Ürün verimi tahmini, özellikle ülkesel ve bölgesel (AB düzeyindeki) politika belirleyicileri için hızlı ve güvenilir karar desteği sunan kritik bir görevdir. Doğru bir verim tahmin modeli, çiftçilerin ekim planlaması (hangi ürünü ne zaman ekecekleri) ve kaynak dağılımı (gübre, sulama vb.) kararlarını optimize etmelerine olanak tanır. Ürün verimi tahminine yönelik yaklaşımlar, temelde bir makine öğrenmesi problemi olarak formüle edilir. Çevresel değişkenler (iklim, toprak nemi, sıcaklık gibi) ile tarımsal girdilerin (gübreleme, sulama miktarı vb.) verim üzerindeki etkileri, istatistiksel modeller veya gelişmiş ML teknikleri (ör. regresyon, ağaç tabanlı modeller, derin öğrenme) kullanılarak tahmin edilir. Elde edilen verim haritaları, Nesnelerin İnterneti (IoT) verileriyle entegre edilerek saha düzeyinde gerçek zamanlı verim izlemesi ve ayrıntılı arazi kullanım analizi yapılmasını mümkün kılar. Sensör ağları ve uydu görüntüleri gibi IoT kaynaklarından toplanan yerinde (in-situ) veriler, ML modellerine beslenerek tahmin doğruluğunu artırır ve hatta uyarı sistemleri aracılığıyla potansiyel verim düşüşlerine karşı önleyici tedbirlerin alınmasını sağlar. Literatürde, IoT tabanlı ML sistemlerinin doğrudan tarlaya entegre edilip gerçek zamanlı geri bildirim (ör. sulama kontrolü, pest yönetimi) sunduğu çalışmalar bulunmaktadır [28]. Bu sayede, tahmin modelleri yalnızca planlama aşamasında değil; operasyonel düzeyde de karar destek mekanizması olarak kullanılabilmektedir.

Ürün verimi tahmini, tarımsal karar destek sistemlerinin temel bileşenlerinden biri olup; bitki genotipi, çevresel koşullar, iklim verileri ve bu faktörler arasındaki etkileşimlerin karmaşıklığı gibi çok sayıda değişkene bağlıdır. Bu parametreler arasındaki işlevsel ilişkilerin doğru biçimde modellenmesi, hem büyük ölçekli veri kümeleri hem de bu verilerdeki gizli desenleri ortaya çıkarabilecek gelişmiş algoritmaların kullanımını gerektirir. Son yıllarda bu doğrultuda, ürün verimi tahmin problemleri derin öğrenme temelli yöntemlerle ele alınmaya başlanmıştır. Özellikle, yarı-parametrik derin sinir ağı mimarileri, bu alanda dikkat çekmektedir. Bu modeller, bir yandan verideki karmaşık doğrusal olmayan ilişkileri öğrenebilirken, diğer yandan da önceden bilinen parametrik yapılar ile gözlemlenemeyen kesitsel değişkenlikleri dikkate alarak tahmin performansını artırmaktadır. Bir çalışmada Brezilya'nın güneyindeki sezon içi soya verimini tahmin etmek için yapay zeka kullanılmış ve tatmin edici sonuçlar elde dilmiştir. Bu çalışmada LSTM ağları diğer algoritmalara göre daha yükske performans sergilemiştir [29]. Başka bir çalışmada ise, pirinç verimi tahmin için iki adet geri yayılımlı (BPNN) ile bağımsız tekrarlayan sinir ağı (lndRNN) mimarisini birleştiren bir mpdel kullanılmıştır [30].

4. TARIM ALANINDA YAYGIN YAPAY ZEKA YÖNTEMLERİ

4.1 Yapay Sinir Ağları (ANN)

Biyolojik sinir ağlarından esinlenerek geliştirilmiş, karmaşık ve çok boyutlu veriler arasındaki ilişkileri öğrenebilen hesaplama modelleridir. Akıllı tarımda ANN, toprak özellikleri, sıcaklık, nem, gübre miktarı gibi çoklu değişkenlere dayalı olarak ürün verimi tahmini, sulama yönetimi ve hastalık tespiti gibi görevlerde kullanılmaktadır.

Bu teknik kullanılarak yapılan çalışmalara bakıldığında; buğday tanelerindeki tane bitini tespit etmek amacıyla yapay sinir ağı modelleri geliştirilen bir çalışma literatürde mevcuttur ve girdi olarak kütle, eşdeğer çap, nem oranı ve sertlik kullanılmıştır. Toplam 100 model denenmiş ve radyal tabanlı fonksiyona sahip 4:10:1 yapısındaki ağ en iyi performansı göstermiştir. Bu modelin test verisi için RMSE değeri 0.25 olarak elde edilmiştir [31].

Başka bir çalışmada ise, hidroponik acı biber bitkilerindeki kök bölgesi sıcaklığı değişiminin bitki büyümesi üzerindeki dinamik yanıtlarını modellemek için NARX sinir ağı modeli kullanılmıştır. Modelin performansı, tahmin edilen ve gözlemlenen bitki büyümesi değerlerinin karşılaştırılmasıyla değerlendirilmiş ve sonuçlar oldukça yüksek doğruluk göstermiştir. Yazarlar, kullanılan sinir ağı türünün karmaşık süreçlerin tanımlanmasında etkili olduğunu belirtmişlerdir [32].

4.2 Konvolüsyon Sinir Ağları (CNN)

Konvolüsyon sinir ağları, görüntü işleme ve örüntü tanıma konularında oldukça başarılı olan derin öğrenme modelleridir. Akıllı tarımda özellikle bitki hastalıklarının yaprak görüntülerinden otomatik olarak tespitinde yaygın olarak kullanılır. CNN'ler elle özellik çıkarımı yapmaksızın görüntülerden doğrudan öğrenme sağlayarak sınıflandırma performansını artırır. Bir çalışmada, elma ağaçlarının yapraklarını sağlıklı, elma kabuk hastalığı, elma sediri pası ve birden fazla hastalık kategorilerinden birine sınıflandırmak amacıyla bir model geliştirilmiştir. Önerilen CNN model ile, doğrulama veri setinde %96,25 doğruluk elde etmiş ve birden fazla hastalığa sahip yaprakları %90 doğrulukla tespit edebilmiştir. Bu model, bitki sağlığını doğru ve zamanında tespit etme konusunda tarım sektöründe verimli bir çözüm sunmaktadır [33].

4.3 Tekrarlayan Sinir Ağları (RNN)

Tekrarlayan sinir ağları modelleri, sırayla işlenen veriler üzerinde çalışarak her adımda önceki durumdan gelen bilgiyi değerlendirir. Bu özellikleriyle, özellikle hava tahmini, bitki gelişimi ve otomatik sulama gibi zamana bağımlı tarımsal uygulamalarda kullanılır. Yapılan bir çalışmada önerilen RNN algoritması ile hava koşullarının daha doğru tahmin edilmesi sağlanmıştır. Geliştirilen yapı ile gizli katmanların sayısı artırılarak, zaman çizelgesine dayalı hava durumu güncellemeleri iyileştirilmiş olup, mevcut diğer makine öğrenmesi algoritması ile karşılaştırıldığında %98,76 doğruluğa ulaştığı tespit edilmiştir [34].

5. SONUÇLAR

Tarım sektörü, günümüzün en büyük küresel sorunları arasında yer alan nüfus artışı, iklim değişikliği ve doğal kaynakların tükenmesi gibi etkenlerle karşı karşıya kalmaktadır. Bu zorluklara karşı sürdürülebilir, verimli ve çevre dostu çözümler sunma potansiyeline sahip olan yapay zeka (YZ) teknolojileri, akıllı tarımın dönüşümünde stratejik bir rol üstlenmektedir. Yapılan literatür incelemeleri ve örnek uygulamalar göstermektedir ki; YZ destekli sistemler, toprak ve tohum analizinden ürün sağlığına, hasat optimizasyonundan verim tahminine kadar birçok tarımsal faaliyette hem karar destek mekanizması hem de otomasyon aracı olarak etkin şekilde kullanılmaktadır. Makine öğrenmesi, derin öğrenme ve görüntü işleme gibi YZ bileşenlerinin tarım süreçlerine entegrasyonu, sadece üretim miktarını değil, aynı zamanda kaliteyi de artırarak ekonomik verimliliği yükseltmektedir. Ayrıca, kaynakların (su, gübre, pestisit vb.) daha etkin ve bilinçli kullanılmasını mümkün kılarak, çevresel sürdürülebilirliğe önemli katkılar sağlamaktadır. IoT ve kablosuz sensör ağları ile bütünleşik çalışan bu sistemler, gerçek zamanlı veri analizi ile çiftçilerin doğru, zamanında ve isabetli kararlar almasına yardımcı olmaktadır. Gelecekte, YZ teknolojilerinin daha yaygın ve ölçeklenebilir hale gelmesiyle birlikte tarımsal üretimde dijital dönüşümün hız kazanması beklenmektedir. Bu bağlamda, yapay zekâ sadece bir teknoloji değil; aynı zamanda yeni nesil tarım politikalarının, eğitim programlarının ve kırsal kalkınma stratejilerinin merkezinde yer alması gereken bir paradigma olarak değerlendirilmelidir. Dolayısıyla, yapay zekâ temelli akıllı tarım uygulamaları, hem ekonomik hem çevresel hem de sosyal açılardan tarımın sürdürülebilirliğini güvence altına almak adına vazgeçilmez bir araç niteliğindedir. Bu çalışmada, yapay zekâ teknolojilerinin tarım sektöründeki dönüşümüne dair bir bakış açısı sunulmuş; mümkün olduğunca ana başlıklara yer verilerek güncel literatür özeti ortaya konmuştur. Böylece ileride akıllı tarım ile ilgili yapılacak olan deneysel çalışmaların yapısı hazırlanmıştır.

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HISTORICAL DEVELOPMENT OF LAND CONSOLIDATION INHERITANCE MANAGEMENT AND LAND BANKING PRACTICES IN TURKİYE

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ABSTRACT

The small-scale, fragmented, and multi-share structure of agricultural lands is among the fundamental structural problems in Turkey's agricultural sector. According to 2024 data, the country has approximately 24 million hectares of agricultural land and 3 million agricultural holdings. The average farm size is only 5.99 hectares (TurkStat, 2024). Most farms operate on lands that are divided into an average of 11 parcels with 13 co-owners, which reduces productivity, increases production costs, and hinders the effective implementation of agricultural policies.

Land consolidation is a critical tool for addressing these challenges. Between 1961 and 2005, limited-scale land consolidation projects were carried out mainly in irrigated areas by various public institutions. The enactment of the Soil Conservation and Land Use Law No. 5403 in 2005 provided a legal and institutional framework for land consolidation as an integral part of land management. In 2008, basin-based and multi-purpose consolidation practices were initiated, particularly in the Southeastern Anatolia Project (GAP) region. The same year, satellite-based analyses identified 14.3 million hectares suitable for consolidation (TRGM, 2008).

By 2012, consolidation had been completed on approximately 1 million hectares, effectively addressing issues such as land fragmentation and access to roads and irrigation canals. However, the problems of multiple ownership and insufficient farm scale remained unresolved (Türker, 2025). Legal reforms in 2014 amended inheritance laws to prevent the uncontrolled division of agricultural lands. Between 2015 and 2023, 7.7 million parcels were transferred without further fragmentation (TRGM, 2024).

In 2018, the responsibility for land consolidation was transferred to the General Directorate of State Hydraulic Works (DSI), accelerating irrigation investments. However, this shift negatively impacted land banking practices managed by the General Directorate of Agricultural Reform. Therefore, resolving structural problems in agriculture requires a strong institutional framework and comprehensive legal regulations that integrate land consolidation and land banking efforts.

Keywords: Land consolidation, land fragmentation, inheritance management, land banking

TÜRKİYE'DE ARAZİ TOPLULAŞTIRMASI, MİRAS YÖNETİMİ VE ARAZİ BANKACILIĞI UYGULAMALARININ TARİHSEL GELİŞİMİ

ÖZET

Türkiye'de tarım arazilerinin küçük ölçekli, parçalı ve çok hisseli yapısı, tarım sektörünün temel yapısal sorunları arasında yer almaktadır. 2024 yılı verilerine göre, ülkede yaklaşık 24 milyon hektar tarım arazisi ve 3 milyon tarım işletmesi bulunmaktadır. Ortalama işletme büyüklüğü 59,9 dekardır (TÜİK, 2024). İşletmelerin büyük bir kısmı ortalama 11 parçalı ve 13 hissedarlı arazilerde üretim yapmakta olup, bu yapı verimliliği azaltmakta, maliyetleri artırmakta ve etkin tarım politikalarının uygulanmasını zorlaştırmaktadır.

Arazi toplulaştırması, bu sorunların çözümünde önemli bir araçtır. Ülkemizde 1961 yılından 2005 yılına kadar farklı kamu kurumlarınca daha çok sulama alanlarında basit arazi toplulaştırması yapılmıştır. 2005 yılında yürürlüğe giren 5403 sayılı Toprak Koruma ve Arazi Kullanım Kanunu ile arazi toplulaştırması arazi yönetiminin bir parçası olarak yasal ve kurumsal bir yapıya oturtulmuştur. 2008 yılında GAP bölgesinde havza bazlı ve çok amaçlı toplulaştırma modeline geçilmiş, aynı yıl uydu verileriyle yapılan çalışmalarda toplulaştırmaya uygun 14,3 milyon hektar alan tespit edilmiştir (TRGM, 2008).

2012 yılına kadar yaklaşık 1 milyon hektarlık alanda tamamlanan toplulaştırma uygulamalarının parçalılık, yol ve sulama kanallarına erişim gibi sorunları büyük oranda çözdüğü; ancak hisselilik sorunu çözmediği ve işletme ölçeğini büyütmediği görülmüştür (Türker, 2025). 2014 yılında miras hukukunda yapılan değişikliklerle, arazilerin kontrolsüz bölünmesi engellenmiş; 2015–2023 yılları arasında 7,7 milyon parselin parçalanmadan devri sağlanmıştır (TRGM, 2024).

2018 yılında toplulaştırma yetkisinin DSİ'ye devredilmesiyle sulama yatırımları hız kazanmış, ancak Tarım Reformu Genel Müdürlüğü'nce yürütülen arazi bankacılığı uygulamaları olumsuz etkilenmiştir. Bu çerçevede, tarımdaki yapısal sorunların çözümü için arazi toplulaştırması ve arazi bankacılığının entegre biçimde ele alındığı, güçlü bir kurumsal yapı ve yasal düzenlemeye ihtiyaç duyulmaktadır.

Anahtar Kelimeler: Arazi toplulaştırması, arazi parçalılığı, miras yönetimi, arazi bankacılığı,

1. GİRİŞ

Türkiye'de tarım arazilerinin küçük, parçalı, dağınık ve bozuk şekilli olması; sulama ve arazi verimliliğini olumsuz etkileyen ve tarımın sürdürülebilirliğini tehdit eden yapısal sorunların başında gelmektedir. Bu sorunun çözümünde arazi toplulaştırması ve tarla içi geliştirme hizmetleri önemli bir rol oynamaktadır. Ülkemizde 1961 yılında başlatılan toplulaştırma çalışmaları, ilk aşamada köy bazlı küçük sulama projeleri kapsamında, basit arazi toplulaştırması şeklinde uygulanmıştır.

1980'li yıllarda, arazi toplulaştırması, tarım reformu uygulamaları kapsamında tarımsal yapıyı düzenleme aracı olarak uygulanmaya başlanmıştır. Bu dönemde, Devlet Su İşleri (DSİ) tarafından inşa edilen sulama proje alanlarında, Tarım Reformu Genel Müdürlüğü (TRGM) tarafından "Tarım Reformu Uygulama Alanı" ilan edilen bölgelerde, 3083 sayılı *Sulama Alanlarında Arazi Düzenlemesine Dair Tarım Reformu Kanunu* kapsamında toplulaştırma çalışmaları yürütülmüştür.

2000'li yıllarda Güneydoğu Anadolu Projesi (GAP), Konya Ovası Projesi (KOP) ve Doğu Anadolu Projesi (DAP) gibi bölgesel kalkınma projelerinde, toplulaştırma; yatırımların maliyetini düşürmek ve uygulama süreçlerini hızlandırmak amacıyla etkili bir araç olarak kullanılmaya başlanmıştır. Bu süreçte toplulaştırma, yalnızca sulama yatırımlarını hızlandıran teknik bir işlem olmaktan çıkarılarak, kırsal kalkınmayı destekleyen çok yönlü bir politika aracı hâline gelmiştir. 2008 yılından itibaren toplulaştırma faaliyetleri, havza bazlı ve çok amaçlı projeler çerçevesinde daha geniş kapsamlı ve entegre bir yaklaşımla yürütülmeye başlanmıştır.

Ülkemizde tarım arazilerinin miras ve satış yoluyla bölünmesi, bu arazilerin verimli kullanımını engelleyen başlıca tehditlerden biri olmuştur. Tarım arazilerinin korunması ve etkin kullanımı amacıyla, 2005 yılında yürürlüğe giren 5403 sayılı *Toprak Koruma ve Arazi Kullanım Kanunu* ile başlayan yasal düzenlemeler, 2014 yılında çıkarılan 6537 sayılı Kanun ile daha da güçlendirilmiştir. Bu düzenlemelerle, tarım arazilerinin belirli büyüklüklerin altına bölünmesi yasaklanmış; miras ve satış yoluyla oluşabilecek parçalanmaların önüne geçilmesi hedeflenmiştir. Söz konusu sınırlamalar kısmen başarı sağlanmıştır. Ancak, kanunun amaçlanan etkileri bakımından beklenen gelişmelerin tam olarak sağlanamaması, uygulamada hâlen bazı eksikliklerin bulunduğunu göstermektedir (Türker, 2025)

Gelişmiş ülkelerde olduğu gibi ülkemizde de bu yapısal sorunların çözülmesi ve atıl tarım arazilerinin üretime kazandırılması için arazi bankacılığı sistemine ihtiyaç duyulmuştur. Bu kapsamda arazi bankacılığı ile ilgili yasal ve kurumsal altyapının geliştirilmesi için çalışmalar yürütülmüş, online sistemler kurulmuş ve uluslararası işbirlikleri geliştirilmiştir. Ancak uygulamaların gönüllülük esasına dayanması, yaptırım ve teşviklerdeki eksiklikler nedeniyle beklenen gelişmeler sağlanamamıştır. Bu nedenle arazi toplulaştırması ile birlikte arazi bankacılığı uygulamalarının yürütüleceği daha güçlü bir yasal ve kurumsal yapıya ihtiyaç duyulmaktadır.

Bu çalışmada arazi toplulaştırmasının tarihsel gelişimi ile miras uygulamaları ve arazi bankacılığı hakkında yapılan çalışmalar hakkında bilgiler verilmektedir.

2. TÜRKİYE'DE TARIMSAL YAPI VE SORUNLAR

2.1. Arazi Varlığı ve Kullanım Durumu

Türkiye'nin toplam yüzölçümü 78,4 milyon hektar olup, bunun %30,6'sı işlenebilir tarım arazisidir (yaklaşık 23,9 milyon ha). Ayrıca 14,6 milyon ha mera ve 23,2 milyon ha orman arazisi mevcuttur (Çizelge 1). Ekonomik olarak sulanabilir tarım alanı 8,5 milyon ha olup, bugüne kadar bunun %83,5'lik kısmı yani 7,1 milyon hektarı sulamaya açılmıştır.

2. Çizelge 1. Ülkemizde arazi varlığı ve kullanım durumu (2023)

Kullanım Şekli	Miktar (ha)	(%)
Tarım Alanı	23.942.000	30,56
Mera	14.617.000	18,65
Orman	23.245.000	29,67
Su Yüzeyleri	1.571.000	2,00
Yerleşim Alanları ve Diğer Alanlar	14.981.200	19,12
Toplam	78.356.200	100,00

Kaynak: TÜİK, 2024

Tarım; artan nüfusun beslenmesi, sanayiye hammadde sağlanması, istihdam yaratması ve ihracat potansiyeli açısından stratejik öneme sahiptir. Pandemiler, savaşlar ve iklim değişikliği gibi küresel gelişmeler, birçok ülkede tarımı milli güvenlik meselesi hâline getirmiştir.

Üç kıtanın kesişiminde yer alan Türkiye, stratejik ürünlerin üretimi ve tedarikinde önemli bir konuma sahiptir. 14,6 milyon ha merası, özellikle küçükbaş hayvancılık için kritik öneme sahiptir. Ancak hızlı kentleşme ve sanayileşme gibi nedenlerle tarım arazileri üzerindeki baskılar giderek artmaktadır. Son 30 yılda 2,7 milyon hektar tarım alanı tarım dışına çıkarılmıştır (TRGM, 2023). İklim değişikliği de tarımsal üretim üzerinde giderek daha fazla etkili olmaktadır. Bu nedenle mevcut tarım arazilerinin korunması, ıslah edilmesi ve verimli kullanımı hayati önem taşımaktadır.

2.2. Toprak ve Su Kaynakları Potansiyeli

Türkiye, kurak ve yarı kurak iklim kuşağında yer almaktadır. Ülke genelinde ortalama yıllık yağış miktarı 576 mm olup, yağış rejimi büyük ölçüde düzensizdir. Örneğin, Konya Ovası yılda ortalama 300 mm yağış alırken, Karadeniz Bölgesi'nde bu miktar 2.600 mm'ye kadar çıkmaktadır. Bitkisel üretim ise büyük ölçüde suya ve sulama olanaklarına bağlı olarak gerçekleştirilmektedir. Bu nedenle sulama, gıda arz güvenliği açısından kritik bir öneme sahiptir.

Ülkemizde yıllık kullanılabilir su potansiyeli 112 milyar m³ olup, bunun yaklaşık %77'si (yaklaşık 45 milyar m³) tarımsal sulamada kullanılmaktadır. Sulamaya açılan alanlar 7,1 milyon hektara ulaşmıştır. Sulamaya açılan alanın %67,7'si DSİ, %18,3'ü mülga KHGM ve %14'ü halk sulamaları oluşturmaktadır (Çizelge 2).

Çizelge 2. Sulamaya açılan alanlar (2023)

Sulama Alanları	**Milyon (ha)**	**Oran (%)**
DSİ	4,8	67,7
Mülga KHGM	1,3	18,3
Halk Sulamaları	1,0	14,0
Toplam	7,1	100,0

Kaynak: DSİ, 2024a

Sulamaya açılan alanların % 62'si açık kanal ve %38'i de basınçlı-borulu modern sulama sistemleri ile sulanmaktadır. Sulama oranı % 68 ve randımanı %50 seviyesindedir (DSİ 2024b). Görüldüğü gibi sulama oran ve randımanları düşüktür. Bunda; sulama şebekelerinin büyük bir kısmının eski olması, arazilerin küçük ve parçalı yapısı, sulama örgütlerinin kurumsal zayıflığı ve yaşlanan çiftçi nüfusu gibi nedenlerden kaynaklanmaktadır.

Ayrıca, kişi başına düşen yıllık kullanılabilir su miktarı 1.312 m³ ile ülkemiz, su kısıtı yaşayan ülkeler arasında yer almaktadır (DSİ, 2024b). Bu nedenle, sulama projelerinin kapalı sistem ve arazi toplulaştırması ile birlikte planlanması ve uygulanması önem taşımaktadır.

2.3. Tarımda Yapısal Sorunlar

İşletme ölçeği sorunu, Türkiye tarımının temel yapısal sorunlarından biridir. 2001 yılında yapılan son tarım sayımına göre ortalama işletme büyüklüğü 59,9 dekar olup işletmelerin %64,8'i, 50 dekarın altındadır. Bu küçük ölçekli yapı, tarımsal verimliliği sınırlamakta ve modern üretim tekniklerinin uygulanmasını zorlaştırmaktadır.

Parçalılık sorunu, 2013 yılında Tapu ve Kadastro Genel Müdürlüğü ile iş birliği yaparak 23,2 tapu ve 32,5 milyon tarım parseli sayısallaştırılarak Çiftçi Kayıt Sistemi (ÇKS) ile entegre edilmiştir. Buna göre bir tarım işletmesi ortalama 11 ayrı parselde tarım yapmaktadır. Bu durum ulaşım, işleme ve hasat maliyetlerini artırmakta, üretim süreçlerini zorlaştırmaktadır.

Hisselilik sorunu, çok sayıda ortak mülkiyet yapısı nedeniyle çözüm bekleyen önemli bir konudur. Türkiye'de 40 milyonun üzerinde hissedar bulunmakta, ancak sadece 3 milyon kişi araziyi fiilen işlemektedir. Hisseli yapı, üretim dışına itilen küçük parsellerle birlikte yatırımı ve etkin kullanımı engellemektedir. Örneğin, 1980'li yıllarda bir çiftçimize ait 10.000 m²'lik

bir parselin üç kuşak sonra 45 m²'ye kadar bölündüğü görülmüştür (Türker 2025). Bu durum çok küçülen parsellerde üretimi imkânsız hâle getirmektedir.

Parsele ulaşım sorunu, tarım parsellerinin yaklaşık %50'sinin yasal yolu bulunmamaktadır. Çiftçiler ulaşımı genellikle komşu araziler üzerinden veya sınırlardan sağlamakta, bu da hem sosyal sorunlara hem de üretim kayıplarına yol açmaktadır.

Sulama kanalına erişim sorunu, birçok parselin sulama kanalına doğrudan erişimi bulunmamaktadır. Su ihtiyacı komşu arazilerden karşılanmakta, bu da kayıpları ve komşuluk sorunlarını artırmaktadır. Bu sorunun çözümünde arazi toplulaştırması kritik bir araçtır.

Kayıtdışılık sorunu, tarımsal desteklerin ve üretimin izlenmesini güçleştirmektedir. 2023 itibarıyla ÇKS'ye kayıtlı 15,6 milyon hektar alan, toplam tarım arazilerinin yalnızca %65'ini kapsamaktadır. Sayısallaştırma ve entegrasyon çalışmalarına rağmen, mülkiyet sorunları nedeniyle kayıtlılık istenen seviyeye ulaşamamıştır (Türker, 2025).

3. ARAZİ TOPLULAŞTIRMASININ TANIMI VE ÖNEMİ

3.1. Arazi Toplulaştırmasının Tanımı

Arazi toplulaştırması; aynı kişiye veya çiftçi ailesine ait, çeşitli nedenlerle aşırı derecede parçalanmış, şekli bozulmuş ve dağınık hâlde bulunan küçük arazi parçalarının; ulaşım, sulama ve tarla içi geliştirme hizmetleriyle birlikte, verimli parseller hâline getirilerek yeniden düzenlenmesi işlemidir (Takka, 1993).

3.2. Arazi Toplulaştırmasının Faydaları

Arazi toplulaştırması hem üreticiler hem de kamu yatırımları için büyük önem taşımaktadır.

3.2.1. Çiftçiler açısından faydaları

- Parseller büyür, düzgünleşir; işlenen alan ve parsel verimliliği artar.
- Makine kullanımı kolaylaşır, modern tarım teknikleri uygulanabilir hale gelir.
- İşçilik, tohum, gübre, ilaç gibi girdilerde tasarruf sağlanır.
- Tarlaya ulaşım kısalır; zaman ve yakıt tasarrufu (50 L/ha) sağlanır.
- Sulama düzeni iyileşir, sulama verimliliği artar.
- Her parsel yola ve sulama kanalına kavuşur.
- Komşu anlaşmazlıkları azalır, sosyal huzur artar.
- Gelir artar, yaşam standardı yükselir.
-

3.2.2. Kamu yatırımları açısından faydaları (TRGM 2005)

Sulama projeleri ve karayolları gibi kamu yatırımlarının arazi toplulaştırması ile eş zamanlı yürütülmesi, kamu yatırımları açısından önemli avantajlar sağlamaktadır. Öncelikle, yol ve kanal gibi kamu inşaatları ile tarım arazilerinin parçalanması önlenmekte ve fiziki altyapı

yatırımlarındaki (örneğin sulama kanalları, yollar, şutlar, dirsekler vb.) azalmalar ile yatırım maliyetleri önemli ölçüde düşmektedir.

Özellikle yol ve sulama kanalı gibi ortak kullanım alanları için ihtiyaç duyulan araziler, kamulaştırma yerine, arazi toplulaştırması kapsamında %10'a kadar olan Düzenleme Ortaklık Payı (DOP) kesintisinden karşılanabilmektedir. Böylece yatırım maliyetlerinde %30 ila %45 arasında tasarruf sağlanabilmektedir (Çizelge 3)

Çizelge 3. Bazı sulama projelerinde toplulaştırma ile sağlanan tasarruflar

	Toplulaştırmasız Yatırım Maliyeti (TL/ha)	Toplulaştırmalı Yatırım Maliyeti (TL/ha)	Tasarruf Oranı (%)
Tokat İli Niksar, Zile ve Erbaa Ovalarında AT ve TİGH Projesi (9 köy)*	8.037	4.408	45
Karaman Merkez Kisecik sulama yenileme projesi**	7.270	4.910	32

(*)Mülga KHGM, Sulama Dairesi Başkanlığı dokümanları (1999, 2010)

(**) Mülga TRGM, Toplulaştırma ve TİGH Dairesi Başkanlığı dokümanları (2010)

Yine zarar-ziyan ve gelir kaybı ödemeleri ile inşaat süreçleri kesintiye uğramadan sürdürülebilmektedir.

Ayrıca Karaman Kisecik Sulama ve Toplulaştırma projesinde olduğu gibi toplulaştırmanın borulu sulama sistemleri ile birlikte yapılması ile % 64'lere varan oranlarda su tasarrufu sağlanabilmektedir (Türker ve Gencel 2010).

Arazi toplulaştırma çalışmaları çevresel açıdan ekolojik koridorlar, ağaçlandırma alanları ve koruma zonları oluşturarak habitatların korunmasını, erozyonun önlenmesini ve çevre dostu rekreasyon alanlarının planlanmasını sağlamaktadır. Sosyal açıdan ise komşu parseller arasındaki anlaşmazlıkları azaltarak yargı yükünü hafifletmekte ve toplumsal huzura katkı sunmaktadır.

4. TÜRKİYEDE ARAZİ TOPLULAŞTIRMASININ TARİHSEL GELİŞİMİ

Ülkemizde ilk arazi toplulaştırması 1961 yılında Konya Çumra Kargın köyünde yapılmıştır. Bu tarihten, toplulaştırma yetkisinin Devlet Su İşleri Genel Müdürlüğü'ne (DSİ) devredildiği 2018 yılına kadar, çeşitli kurumlar tarafından farklı mevzuatlara göre farklı nitelikte arazi toplulaştırma projeleri yürütülmüştür (Çizelge 4)

Çizelge 4. Ülkemizde arazi toplulaştırmasının tarihsel gelişimi (1961-2023)

No	Tarih	Sorumlu Kurum	Mevzuat	Alan (hektar)	Toplulaştırma Niteliği
1	1961-1984 1984-2005 1990-2008	Toprak-Su GM Köy Hizmetleri GM Tarım Reformu GM Toplam	AT Tüzüğü AT Tüzüğü 3083 SK	72.000 303.344 232.156 **607.500**	Basit arazi toplulaştırması
2	2009-2015	Tarım Reformu GM(*)	3083 SK	1.091.52	Havza bazlı ve çok amaçlı toplulaştırma
3	2009-2016	DSİ	5403	70.000	Özel arazi toplulaştırması (423.000 ha izin verilen)
4	2016-2017	Tarım Reformu GM	3083 K 5403 SK	1.404.999 (1.511.305 ha ihale edilen alan)	Arazi edinimli toplulaştırma projeleri (35 Toplulaştırma ihalesi)
5	2018 - …	DSİ (Toplulaştırma Yetki Devri 28 Nisan 2018)	6200 SK		Kamulaştırma amaçlı toplulaştırma
	1961-2018	GENEL TOPLAM		3.149.636	

(*) Bağlı kuruluş olan TRGM, 2011 yılında Merkez Genel Müdürlük olarak yeniden yapılandırılmıştır.

Çizelgede görüldüğü gibi 1961-2018 yılları arasında arazi toplulaştırma çalışmaları farklı kurumlarca yürütülmüştür ve ihtiyaçlara göre şekillenmiştir. 1961–1984 arasında Toprak-Su Genel Müdürlüğü 72.000 hektarda, 1984–2005 arasında Köy Hizmetleri Genel Müdürlüğü 303.344 hektarda, 1990–2008 arasında ise Tarım Reformu Genel Müdürlüğü 232.156 hektarda, sulama alanlarında basit toplulaştırma yapmıştır. Bu dönemde toplam 607.500 hektar alanda arazi toplulaştırması gerçekleştirilmiştir.

2009 sonrası dönemde, Tarım Reformu Genel Müdürlüğü tarafından 3083 sayılı Kanun kapsamında havza bazlı ve çok amaçlı projeler uygulanmaya başlanmıştır. Arazi toplulaştırmasıyla birlikte tarlaiçi geliştirme hizmetleri, mera düzenlemeleri, ekolojik koridorlar ile köy içme suyu temini ve arıtma tesisleri gibi sosyal altyapı hizmetleri de gerçekleştirilmiştir. Katılımcı yaklaşımla hazırlanan sosyal etüt raporları, sorunların tespiti ve toplulaştırma yoluyla çözümünde önemli bir açılım sağlamıştır. Bu dönemde toplam 1.091.520 hektar alanda toplulaştırma yapılmıştır.

İlk çok amaçlı ve büyük ölçekli toplulaştırma çalışmalarına GAP bölgesinde GAP Eylem planı (2008-2012) ile başlanmıştır. 7 ildeki 13 büyük sulama projesiyle 2,5 milyon hektarlık alan toplulaştırma kapsamına alınmıştır. Toplulaştırmanın DSİ'ye devredildiği 2018 yılına kadar 57.318 dekarlık arazi toplulaştırma ile ana kanal güzergâhı için ayrılmış, 22.500 km tarla yolu yapılmış, içmesuyu, foseptik ve yerleşim altyapıları tamamlanmış ve Harran Ovası'nda 120.000 hektarda drenaj çalışmalarıyla taban suyu ve tuzluluk sorunları giderilmiştir (TRGM 2018).

2008 yılında TRGM'nin kapasite yetersizliği nedeniyle kurumlara özel arazi toplulaştırma yetkisi verilmiş, ilk olarak DSİ bu yetkiyi kullanarak 423.000 hektarda toplulaştırma izni almış ve 2018 yılına kadar 70.000 hektar alanın toplulaştırmasını tamamlanmıştır (TRGM 2018). Karayolları Genel Müdürlüğü ise, kamulaştırma yerine toplulaştırma ile 38.749 dekar arazi temin ederek 16 milyar TL tasarruf sağlamıştır (KGM 2016).

2016-2017 yıllarında Tarım Reformu Genel Müdürlüğü, 35 projeyle 1.511.305 hektar alanda arazi edinimli toplulaştırma başlatmış ve altyapı geliştirme çalışmaları yapılmıştır. 2018'de arazi toplulaştırma yetkisi DSİ'ye devredilmiştir. Bu durum sulama yatırımlarını hızlandırırken TRGM'nin arazi bankacılığı çalışmalarını olumsuz etkilemiştir. 1961-2018 arasında toplam 7 milyon hektar alanda toplulaştırma çalışmalarına başlanmış ve 3.149.636 hektar alan tescil edilmiştir (Türker 2025).

5. TARIM ARAZİLERİNİN MİRAS VE SATIŞLA BÖLÜNMESİNİ ÖNLEYEN YASAL DÜZENLEME VE ARAZİ BANKACILIĞI UYGULAMALARI

Ülkemizde tarım arazilerinin miras ve satış yoluyla kontrolsüz biçimde parçalanması, tarımda verimlilik ve sürdürülebilirliğin önündeki başlıca engellerdendir. Yeter gelirli ölçeğin altına düşen, parçalı, çok hisseli ve mülkiyet sorunlu araziler; verimliliği artıracak önlemler ile yatırımları zorlaştırmakta, kırsalın cazibesini azaltarak kente göçü teşvik etmektedir.

Oysa gelişmiş ülkelerde tarım arazileri miras ile parçalanmamakta işletme bütünlüğü korunmaktadır (Çizelge 5).

Çizelge 5. Bazı gelişmiş ülkelerde işletme büyüklüğü ve miras uygulamaları

Ülke	İşletme Sayısı	Ort. İşletme Büyük. (ha)	Miras ile İlgili Uygulama
İngiltere	300.000	53,8	En büyük kardeşe devir.
Fransa	527.000	52,1	Kardeşlerden biri diğerlerine piyasa değerinden bedelini öder.
Almanya	371.000	45,7	Kardeşlerden biri diğerlerine tazminat öder.
İspanya	1.044.000	23,8	Ehil olan mirasçıya devir.
İtalya	1.679.000	7,6	Ehil olan mirasçıya devir.
AB (27 ülke ort)	13.700.000	12,6	
ABD	2.076.000	181,8	Bedeli karşılığı satılmakta.
Türkiye	3.022.000	5,9	Mirasçılara payları oranında intikal etmektedir.

Kaynak: http://ec.europa.eu/agriculture/agrista/2009/table_en/2009enfinal.pdf

Çizelgede görüldüğü gibi gelişmiş birçok Avrupa Birliği ülkesinde, tarım arazilerinin **miras yoluyla parçalanması yasal olarak sınırlandırılmış**, araziler genellikle **en büyük kardeşe veya ehil bir mirasçıya** devredilerek tarım işletmelerinin bütünlüğü korunmuştur. Ayrıca bu ülkelerde **genç çiftçilere yönelik özel devlet destekleri** sağlanmaktadır.

İngiltere, Fransa ve Almanya gibi ülkelerde ortalama işletme büyüklükleri 45–54 hektar arasında değişmekte ve araziler mirasla bölünmeden bir kişiye devredilmektedir. **İtalya ve İspanya** gibi ülkelerde de benzer uygulamalar görülmekte, araziler ehil mirasçıya bırakılmaktadır.

Buna karşın **Türkiye'de 3 milyondan fazla tarım işletmesi** bulunmakta olup ortalama işletme büyüklüğü sadece **5,9 hektardır**. Araziler mirasla **eşit şekilde tüm kardeşler arasında bölünmektedir**, bu da işletme ölçeğini küçülterek tarımsal verimliliği düşürmektedir.

Ülkemizde bu sorunu çözmek amacıyla, 2014 yılında 5403 Sayılı Toprak Koruma ve Arazi Kullanımı Kanunu'nda reform niteliğinde bir yasal düzenleme yapılmıştır. Yapılan değişiklikle, tarım arazilerinin miras ve satış yoluyla parçalanması sınırlandırılmış ve tarımsal bütünlüğün korunması hedeflenmiştir. Bu düzenlemenin temel amacı; tarım arazilerinin yeter gelirli arazi büyüklüklerinin altına düşmesini önlemek, üretim sürekliliğini sağlamak ve tarımsal verimliliği artırmaktır.

Bu kapsamda, Türkiye genelinde 81 il ve 920 ilçe için 'Yeter Gelirli Asgari Arazi Büyüklükleri; sulanan araziler (45–80 da), kuru tarım arazileri (120–240 da), örtüaltı (5 da) ve dikili (10 da) araziler olarak tespit edilmiş ve kanun ekinde yayınlanmıştır. Böylece belirlenen büyüklükler 'bölünemez arazi büyüklüğü' olarak kabul edilmiş ve altına düşecek bölünmeler yasaklanmıştır.

15 Mayıs 2014 tarihinde yürürlüğe giren bu kanun değişikliği, üç temel konuda düzenleme getirmiştir(Türker 2025):

1. Miras yoluyla mülkiyet devri,
2. Tarım arazilerinin alım-satım işlemleri,
3. Arazi edindirme (Bankacılığı) iş ve işlemleri.
4.

5.1. Miras Yoluyla Mülkiyet Devirleri

15 Mayıs 2014 tarihinden önce vefat eden kişilerin tarım arazileri, mirasçılar arasında elbirliği ya da paylı mülkiyet şeklinde intikal edilebilmektedir. Bu durumda, mirasçılar daha sonra aralarında anlaşarak devir, taksim veya üçüncü kişilere satış yapabilmektedirler. Ancak bu tarihten sonraki ölümler için, tarım arazilerinin daha fazla parçalanmasını önlemek amacıyla bazı yasal sınırlamalar getirilmiştir (Türker 2025).

Takbis (2023) verilerine göre ülkemizdeki tarım arazilerinin mülkiyet durumu çizelge 6'da verilmiştir. Görüldüğü gibi vasfı tarım olan 34,998.606 parsel olup 26.598.522 ha alana karşılık gelmektedir. Ayrıca 23.083.992 parsel tam mülkiyetli, 12.389.438 parsel paylı mülkiyet, 7.115.998 parsel elbirliği mülkiyet ve 7.111.062 parselde hem paylı hem de elbirliği mülkiyeti olan parsellerden oluşmaktadır. 2014 yılında miras ile ilgili düzenlemeden sonra normun altına olan parsellerde anlaşma olmaması durumunda elbirliği parsel olarak anlaşmayı beklemektedir. Ya da hak sahipleri rızai taksim ile kendine düşen bölümü işlemeye devam etmektedir.

Her geçen gün kronikleşen bu sorunların çözümü için arazi bankacılığının hayata geçirilmesi tüm taraflar açısından zorunluluk arz etmektedir.

Çizelge 6. Tarım arazilerinin mülkiyet durumu (2024)

Arazisi Niteliği	2023			
	Parsel Sayısı (Adet)	Oran (%)	Alan (Ha)	Oran (%)
Toplam Tarım Arazisi	34.998.606	100,00	26.598.522	100,00
Tam Hisseli	23.083.992	65,96	15.096.432	56,76
Paylı Mülkiyet	12.389.438		11.751.376	
Elbirliği Mülkiyet	7.115.998	34,04	6.009.386	43,24
Hem Paylı Hem Elbirliği Mülkiyet	7.111.062		6.007.249	

Kaynak: TAKBİS, 2024

2014 yılında miras hukukunda yapılan değişikliğe göre miras ile ilgili iş ve işlemler Şekil 3'te verilmiştir. Buna göre; **Miras yönetimi sürecine göre**, tarım arazilerinin devri için mirasın açılmasından itibaren **mirasçılara bir yıl süre** tanınmaktadır. Bu süre içinde taraflar, şu dört yöntemden birinde anlaşabilir:

1. Arazinin bir mirasçıya devri,
2. Aile malları ortaklığı kurulması,
3. Aile şirketi kurulması,
4. Arazinin satılması (tasfiye).

Eğer mirasın açılmasından sonra bir yıllık sürede anlaşma sağlanamazsa, Bakanlık mirasçılara tebligat göndererek 3 ay içinde anlaşma için ek süre tanımaktadır. Bu sürenin sonunda da devir yapılmazsa, Kardeşler dava açabildiği gibi Bakanlık da sulh hukuk mahkemesinde dava açma yetkisine sahip bulunmaktadır.

2016–2017 yılları miras ile mülkiyet devirlerinin en yoğun yapıldığı yıllardır. Mirasın açılmasından sonra kanunun verdiği 1 yıl süre dolmasına rağmen anlaşmayan 586.380 kişiye tebligat gönderilmiş ve varislerin 3 ay içinde anlaşmaları istenmiştir. Ancak sonraki yıllarda Bakanlık dava açma konusunda karar verememiş, tebligatlar durdurulmuş ve intikaller yeniden mirasçıların isteğine bırakılmıştır. Buna rağmen 2015-2023 yılları arasında toplam 471.111 kişi yaklaşık 10.916.748 dekar tarım arazisinin varisler arasında paylaşımı için başvuru yapmıştır. Yıllık ortalama 52.385 kişi miras paylaşımına başvururken 47.385 kişinin başvurusu (958.662 da) kabul edilirken, 12.203 kişinin başvurusu (285.686 da) kanun kapsamında reddedilmiştir.

5.2. Tarım Arazilerinin Satış İşlemleri

2014 yılında 5403 Sayılı Toprak Koruma ve Arazi Kullanım Kanununda yapılan değişikliklerle, tarım arazilerinin satış yoluyla devirlerinde önemli kısıtlamalar getirilmiştir. Arazilerin bölünemez büyüklükleri korunurken, satış işlemleri Tapu Müdürlükleri ve Tarım ve Orman Bakanlığı denetiminde yürütülmektedir.

31.12.2014 tarihli Resmî Gazete'de yayımlanan "Tarımsal Arazilerin Mülkiyetinin Devrine İlişkin Yönetmelik" ile satış işlemlerinde arazi sınıfı, ekonomik bütünlük, asgari büyüklük, yeter gelirli büyüklük, sınırdaşlık, ifraz ve hisselendirme gibi kriterler dikkate alınmaktadır. Ayrıca, hisselendirme, taksim, vasıf değişikliği gibi işlemler il/ilçe tarım müdürlüklerinin görüşüyle yapılmaktadır.

Paylı mülkiyetli taşınmazlarda, payların tamamı hisselendirilerek birleştirilebiliyorsa tapu müdürlüklerince işlem yapılabilmektedir. Asgari büyüklük altına düşmemek koşuluyla payların diğer paydaşlara devrine izin verilmektedir.

28.10.2020 tarihine kadar kadarki satışlarda yeter gelirli arazi büyüklükleri esas alınırken, bu tarihten sonra parsel bazlı düzenlemelere geçilmiş, hisse sayısı artırılmamak şartıyla parsel bazlı satışlara izin verilmiştir. Ayrıca ekonomik bütünlük arz etmeyen parsellerin (kuru ve sulu tarımda 10 dekar, dikili arazide 5 dekar, örtü altı tarımda 1 dekardan küçük) satışına izin verilmiştir.

2015-2023 yılları arasında toplam 4.046.104 tarım arazisi satış başvurusu (67.914.307 da) yapılmıştır. Bunların 260.730'u reddedilerek 10.966.924 dekar arazinin satışına izin verilmemiştir.

5.3. Arazi Edindirme (Bankacılığı) İş ve İşlemleri

5403 sayılı Kanunun 8K maddesi, Türkiye'de arazi edindirme (arazi bankacılığı) faaliyetlerinin yasal temelini oluşturmaktadır. Bu kapsamda Tarım ve Orman Bakanlığı; yeter gelirli tarımsal arazi büyüklüğünü artırmak, arazi değerlerini belirlemek, kredi temin etmek, ortakçılık ve kiracılığı düzenlemek, alım-satım ve kiralamalara aracılık yapmak gibi görevler üstlenmiştir. Amaç, tarımsal işletmelerin mülkiyet sorunlarını çözmek ve ölçeklerini büyütmektir. Uygulama, arazilerin alım-satımına aracılık edilmesi ve kiralama ya da ortakçılık gibi işlemler yoluyla yürütülmektedir.

Türkiye'de yaklaşık 3 milyon işletme, 40 milyondan fazla hissedara ait arazilerde faaliyet göstermektedir. Hissedarların çoğu arazilerinin yerini bilmezken, fiili kullanıcılar finansman eksikliği ve satış ortamının yetersizliği nedeniyle arazileri satın alamamaktadır. Bu nedenle satış süreçlerinin kolaylaştırılması ve uygun finansman mekanizmalarının sağlanması gerekmektedir. Tarım arazilerinin satış ve miras işlemleri, TAKBİS ile entegre çalışan TAY Portal üzerinden online yürütülmektedir. Tarımsal vasıflı araziler için Tarım il/ilçe Müdürlüklerinden uygunluk onayı alınmaktadır. Satışlarda tarafların anlaşamaması durumunda Tarımsal Gelir Değeri yöntemi uygulanmaktadır. Ayrıca, mirasçılar tapuya 20 yıl süreli değer artışı şerhi koydurabilmektedir.

Tarım arazileri ile ilgili önemli bir sorun da intikal işlemlerinin yapılmamasıdır. Mülkiyetin varislere devredilmemesi hem hukuki hem ekonomik sorunlara yol açmaktadır. Kanun, mülkiyet sorunlarını giderilmesi için kamulaştırma söz konusu ise bu görevi Tarım ve Orman Bakanlığının talebi ile Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'na vermiştir. Ancak bu konuda bugüne kadar hiçbir uygulama yapılmamıştır.

2016 yılı sonrası arazi edindirme altyapısını güçlendirmek amacıyla çeşitli adımlar atılmış, özellikle sulama alanlarında toplulaştırma projeleriyle entegrasyon hedeflenmiştir. Mirasçılar için "miras kredisi" üzerinde çalışılmış, başarı sağlanamamıştır. Bunun yerine %25 faiz indirimli sübvansiyonlu kredi uygulamaya alınmıştır. 2017 yılında 15 ilde pilot projeler yürütülmüş, Miras, satış ve kiralama işlemlerinin online yapılması için TAY ve TED portalları hazırlanmıştır. 2019 yılında FAO iş birliğiyle Azerbaycan ve Özbekistan'ı da kapsayan arazi toplulaştırma kapasitesinin artırılması ve atıl arazilerin kiralanması ile ilgili proje başlatılmıştır.

Toplulaştırma yetkisinin DSİ'ye devredilmesiyle birlikte arazi bankacılığına yönelik çabalar hız kazanmıştır. Bu kapsamda atıl araziler tespit edilmiş; atıl bırakma nedenleri ve çözüm önerileri, 2018-2019 yıllarında yedi bölgede tüm paydaşların katılımıyla düzenlenen çalıştaylarda ele alınmıştır. Atıl arazilerin yeniden üretime kazandırılması için mevcut yasal ve idari yapının yetersiz olduğu; bu nedenle güçlü bir sistem kurulabilmesi için yasal ve idari düzenlemelere ihtiyaç duyulduğu değerlendirilmiştir.

Bu soruna çözüm olarak, 23 Mart 2023 tarihinde yürürlüğe giren 7442 Sayılı Kanun ile iki yıl üst üste işlenmeyen özel mülkiyete ait tarım arazilerinin, kira geliri arazi sahibine ait olmak üzere kiralanması yasal hale getirilmiştir. Bu kapsamda, kiralama işlemlerinin yerel veya dijital ortamda yürütülmesi amacıyla Arazi Tespit ve Kiralama Komisyonları kurulmuş; uygun arazilerin belirlenmesi ve ilan süreci başlatılmıştır. Kiracılar, belirlenen ürünleri üretmek ve toprağı korumakla yükümlü olacaktır. 2024-2025 yılları, izleme ve veri toplama süreci olarak

belirlenmiş olup, kiralama işlemlerine 2025 hasat döneminden sonra geçilmesi planlanmaktadır.

Tarım arazilerinin miras ve satış yoluyla bölünmesini önleyen yasal düzenleme başarıyla uygulanmaktadır. Kanunun yürürlüğe girdiği tarihten 2024 yılına kadar miras yoluyla bölünmeden mülkiyet devri yapılan parsel sayısı ile miras ve satış yoluyla parçalanması önlenen arazi miktarı Çizelge 7'de verilmiştir.

Çizelge 7.Tarım arazilerinin miras ve satış ile bölünmesinin önlenmesi istatistikleri (2015-2023)

İşlem	Miktar
Bölünmeden mirasçılara intikali sağlanan parsel adedi	7,7 milyon
Miras ve satış yolu ile bölünme ve hisselendirilmesi önlenen alan	1,9 Milyon ha.

Kaynak: TRGM 2024

Görüldüğü gibi 7,7 milyon parselin bölünmeden devri gerçekleşmiş, yaklaşık 1,9 milyon hektar alanın hisselendirilmesi önlenmiştir.

6. ARAZİ TOPLULAŞTIRMASI VE ARAZİ BANKACILIĞININ GELECEĞİ

Ülkemizde ilk arazi toplulaştırmasının yapıldığı 1961 yılından 2002 yılına kadar Mülga Toprak-su, Mülga Köy Hizmetleri ve Mülga Tarım Reformu Genel Müdürlükleri gibi farklı kurumlar tarafından yaklaşık 450.000 hektar alanda basit arazi toplulaştırması yapılmıştır. 2002-2008 döneminde Köy Hizmetleri'nin kapatılması ve sulama yatırımlarının hızlandırılmasıyla toplulaştırma daha kapsamlı ve havza bazlı olarak ele alınmaya başlanmıştır.

2008 sonrası özellikle GAP gibi büyük sulama bölgelerinde DSİ'nin yatırımlarına paralel olarak çok amaçlı toplulaştırma projelerine hız verilmiştir. Ancak 2012 yılına gelindiğinde mevcut toplulaştırma uygulamalarının yatırımların hızlandırılması ile birlikte küçük ve parçalı arazilerin birleştirilmesi, sulama kanalı ve yola kavuşturulmasında başarılı olduğu ancak mülkiyet sorunlarının çözülmesi ve işletme ölçeğinin büyütülmesinde yeterli olmadığı fark edilmiştir (Türker 2025).

Tarım arazilerinin miras ve satış yoluyla sürekli bölünmesi, toplulaştırmanın etkisini azaltmış, tarımın sürdürülebilirliğini tehdit etmiştir. Bunun üzerine 2014 yılında Cumhuriyet tarihinin en önemli reformu gerçekleştirilmiştir. Miras ile ilgili yasal düzenleme yapılmış ve tarım arazilerinin miras ve satışlarla belirli normların altına parçalanması yasaklanmıştır. Ayrıca arazi toplulaştırması ile birlikte arazi bankacılığının geliştirilmesi ile ilgili bir dizi çalışma yapılmıştır. Bu kapsamda arazi değerlemesi ve edindirme yönetmeliği için pilot proje, arazi edindirmeli toplulaştırma projeleri, arazi edindirme pilot projesi, uluslararası projeler, hizmetlerin online yapılacağı Tarım Arazileri Edindirme ve Değerleme Portalı (Ted Portal) gibi çalışmalar yürütülmüştür.

Toplulaştırma genellikle sulama projeleriyle birlikte yürütülmüş, özellikle DSİ'nin büyük sulama sahalarında TRGM tarafından uygulanmıştır. Ancak kurumlar arası koordinasyon sorunları nedeniyle 2018'de bu yetki DSİ'ye devredilmiş, böylece toplulaştırma ve sulama yatırımları aynı kurum tarafından yürütülmeye başlanmıştır.

Arazi toplulaştırmasının yıllar itibariyle gelişimi Çizelge 8'de verilmiştir. Görüldüğü gibi 2024 yılına kadar 7.360.577 ha alanda toplulaştırma tamamlanmıştır.

Çizelge 8. Arazi Toplulaştırmasının Tarihsel Gelişim (1961-2024)

Yıllar	Hektar(Tescil)
1961-2002	449.713
2003-2007	132.287
2008	25.500
2009	39.965
2010	47.668
2011	57.970
2012	14.341
2013	306.120
2014	171.091
2015	454.367
2016	453.895
2017	951.104
2018	496.000
2019	619.000
2020	544.832
2021	1.258.117
2022	759.365
2023	492.252
TOPLAM	**7.360.577**

Kaynak: DSİ 2024

2018 yılında arazi toplulaştırma yetkisinin Devlet Su İşleri (DSİ) Genel Müdürlüğü'ne devredilmesiyle birlikte, sulama yatırımları hız kazanmış; ancak Tarım Reformu Genel Müdürlüğü (TRGM) tarafından yürütülen arazi bankacılığı faaliyetlerinde beklenen ilerleme sağlanamamıştır. Bu durumun temel nedenleri arasında uygulamaların gönüllülük esasına dayanması ile yeterli teşvik ve yaptırım mekanizmalarının bulunmaması yer almaktadır.

Arazi toplulaştırması, günümüzde olduğu gibi gelecekte de tarımsal yapının iyileştirilmesi, kaynakların etkin kullanımı ve üretimin sürdürülebilirliği açısından stratejik bir araç olmaya devam edecektir. Bu kapsamda, öncelikle sulamaya açılmış alanlarda "birinci kuşak" toplulaştırma çalışmalarının tamamlanması büyük önem taşımaktadır. Devamında ise mülkiyet sorunlarını çözen, hisseliliği azaltan ve işletme ölçeğini büyütmeyi amaçlayan "ikinci kuşak" toplulaştırma projelerinin, Avrupa Birliği ülkelerinde olduğu gibi Türkiye'de de geliştirilerek uygulamaya geçirilmesi gerekmektedir.

8. SONUÇ VE ÖNERİLER

Küresel ölçekte artan krizler, salgınlar, savaşlar, kuraklık ve deprem gibi afetler tarımın ve gıda güvenliğinin stratejik önemini bir kez daha ortaya koymuştur. Bu çerçevede, güçlü bir tarım sektörü için sürdürülebilir arazi yönetimine ihtiyaç vardır. Bu yönetim; sağlam yasal düzenlemeler, etkin kurumsal yapı ve dijital bilgi sistemleriyle desteklenmelidir.

2005 yılında yürürlüğe giren 5403 sayılı Toprak Koruma ve Arazi Kullanım Kanunu ile tarım arazilerinin korunması, sınıflandırılması ve planlı kullanımı merkezi bir yapı altında toplanmıştır. Bu sayede tarım dışına çıkarılan arazi miktarında ciddi azalmalar sağlanmış, ayrıca büyük tarım ovaları koruma altına alınmıştır. Arazi toplulaştırması ve sulama yatırımları hızlandırılmıştır.

Avrupa Birliği ülkelerinde arazi bankacılığı, toplulaştırmayı destekleyen bir araç olarak kullanılırken; Türkiye'de de benzer bir sistemin kurulması ve atıl tarım arazilerinin üretime kazandırılması için çalışmalar başlatılmıştır.

Türkiye'de arazi toplulaştırması 1961 yılından bu yana uygulanmakta olup, 2005 sonrası süreçte GAP, KOP ve DAP gibi bölgesel kalkınma projeleriyle birlikte havza bazlı ve çok amaçlı projelere geçilmiştir. Sulama yatırımlarıyla entegre biçimde yürütülen toplulaştırma çalışmalarında önemli gelişmeler kaydedilmiştir. Ancak küçük, parçalı ve dağınık parsellerin birleştirilmesi, yol ve kanala erişim sorununun çözülmesine rağmen hisselilik sorunu çözülememiş ve işletme ölçeği büyütülememiştir. Bu nedenle, miras ve satış yoluyla arazilerin yeniden bölünmesini engelleyen 6537 sayılı Kanun 2014 yılında yürürlüğe girmiş ve yeter gelirli tarımsal arazi büyüklüğü tanımı getirilmiştir. Bu düzenleme, sektörde son 30 yılın en önemli yasal reformlarından biri olarak değerlendirilmiştir.

Ayrıca, dijital altyapı güçlendirilmiş; Ulusal Toprak Bilgi Sistemi (TAD Portal) ve Çiftçi Kayıt Sistemi (ÇKS) dijital ortama aktarılmıştır. Ancak, küçük ve hisseli parseller nedeniyle ÇKS kayıt oranı %65'te kalmıştır (ÇKS 2023a). 2015-2023 arasında yaklaşık 7,7 milyon parselin mirasçılara bölünmeden intikali sağlanmış, 1,9 milyon hektar alanın parçalanması önlenmiştir (TRGM 2023b). Mirasla ilgili düzenlemeler olumlu sonuçlar üretse de, aynı başarı arazi bankacılığı alanında elde edilememiştir.

2018 yılında arazi toplulaştırma yetkisinin DSİ'ye devredilmesiyle sulama yatırımları hızlanmış ve kamu kaynaklarında tasarruf sağlanmıştır. Ancak bu durum, Bakanlığın mülkiyet yönetimi ve arazi edindirme konularındaki etkisini sınırlamıştır. Bu nedenle atıl arazilerin üretime kazandırılması ve etkin bir arazi bankacılığı yapısının kurulması yönünde yeni çalışmalara ihtiyaç duyulmaktadır.

Sonuç olarak, Türkiye'de güçlü ve sürdürülebilir bir tarım sektörü için arazi toplulaştırması ile arazi bankacılığı uygulamalarının eşgüdüm içinde yürütülmesi büyük önem taşımaktadır. Mülkiyet sorunlarının çözülmesi, işletme ölçeklerinin büyütülmesi ve tarım dışı kalan arazilerin üretime kazandırılması için yasal, kurumsal ve dijital altyapının daha da güçlendirilmesi gerekmektedir.

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THE IMPACT OF CLIMATE CHANGE ON WATER AND FOOD CRISES AND THE MEASURES THAT NEED TO BE TAKEN IN TÜRKİYE

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ABSTRACT

Climate change is becoming increasingly evident in the regions of the Mediterranean Basin, including Turkey. IPCC reports predict that Turkey's temperature increase will be 40-50% faster than the global average (IPCC, 2021). Especially in 2020-2021, Turkey has experienced 11 dry years, 13 wet years and 17 normal years in the 1981-2021 period, and the risk of drought has gradually increased (MGM, 2021). This situation threatens water and food security by creating great pressures on agricultural production and water resources.

The average annual rainfall in Turkey is 573.4 mm, which corresponds to 450 billion m³ of rainfall per year. According to DSİ (2024) data, the safe groundwater and surface water potential is calculated as 112 billion m³/year. With 1312 m³/year of renewable water per capita, Turkey is not a water-rich country but a water-constrained country. By 2030, it is a country that may experience water scarcity with the risk of falling below 1,000 m³. The economic irrigable area in Turkey is 8.5 million ha, of which 7.2 million ha (84.7%) has been opened to irrigation to date. Of the water used, 76% is used for irrigation in agriculture. With climate change, the decline in water resources in many basins and excessive groundwater withdrawals are triggering a water crisis.

Drought also poses great risks in dry agricultural areas. Approximately 18.5 million hectares of Turkey's 24 million hectares of agricultural land are dry farmed (TKMSEP, 2023). In these areas, failure to meet water demand due to drought leads to significant yield losses in strategic crops such as wheat. For example, 2008 was recorded as the driest year on record with 445 mm of rainfall across the country, leading to serious reductions in agricultural production (MGM, 2021). In addition, during severe drought periods, water and food crises increase.

In Turkey, various strategies and action plans have been developed and implemented within the scope of combating and adapting to climate change. Among these, in addition to measures such as Climate Change Mitigation and Adaptation Strategy and Action Plan covering the years 2024-2030, Strategy and Action Plan for Combating Agricultural Drought (2023-2027), many projects and activities are being carried out such as dissemination of modern irrigation systems that save water, increasing sink areas through pasture improvement works and afforestation

projects, development of drought resistant plant varieties and risk management practices such as drought insurance.

As a result, Turkey's efforts to combat climate change and agricultural drought are coordinated at national and local levels. Aiming to reduce greenhouse gas emissions by 21% by 2030, the country is trying to manage this process through both strategic plans and practical projects to mitigate the potential impacts of drought and water crises (TUIK, 2024). The measures taken aim to ensure the sustainability of agricultural production while minimizing risks to water and food security.

Keywords: Climate Change, Drought, Water Crisis, Food Crisis, Irrigation

TÜRKİYE'DE İKLİM DEĞİŞİKLİĞİNİN SU VE GIDA KRİZİNE ETKİLERİ VE ALINMASI GEREKEN ÖNLEMLER

ÖZET

İklim değişikliği, Türkiye'nin de içinde bulunduğu Akdeniz Havzası'ndaki bölgelerde giderek daha belirgin hale gelmektedir. IPCC raporları, Türkiye'nin sıcaklık artışının küresel ortalamadan %40-50 daha hızlı olacağını öngörmektedir (IPCC, 2021). Özellikle 2020-2021 yıllarında, 1981-2021 dönemi itibariyle Türkiye'de 11 yıl kurak, 13 yıl nemli ve 17 yıl normal geçmiş olup, kuraklık riskinin giderek arttığı görülmüştür (MGM, 2021). Bu durum, tarımsal üretim ve su kaynakları üzerinde büyük baskılar oluşturarak su ve gıda güvenliğini tehdit etmektedir.

Türkiye'de yıllık ortalama yağış miktarı 573,4 mm olup, bu değer yıllık 450 milyar m^3 yağışa karşılık gelmektedir. DSİ (2024) verilerine göre, emniyetli yeraltı ve yerüstü su potansiyeli 112 milyar m^3/yıl olarak hesaplanmıştır. Türkiye, kişi başına düşen 1312 m^3/yıl yenilenebilir su miktarı ile su zengini bir ülke olmayıp, su kısıtı çeken bir ülkedir. 2030 yılı itibariyle, 1.000 m^3'ün altına düşme riski ile su kıtlığı yaşayabilecek bir ülke konumundadır. Türkiye'de ekonomik sulanabilir alan 8,5 milyon ha olup, bugüne kadar bunun 7,2 milyon hektarı (%84,7) sulamaya açılmıştır. Kullanılan suyun %76'sı tarımda sulamada kullanılmaktadır. İklim değişikliği ile birçok havzada su kaynaklarındaki azalma ve aşırı yeraltı suyu çekimleri su krizini tetiklemektedir.

Kuraklık, kuru tarım alanlarında da büyük riskler taşımaktadır. Türkiye'deki 24 milyon hektar tarım alanının yaklaşık 18,5 milyon hektarında kuru tarım yapılmaktadır (TKMSEP, 2023). Bu alanlarda, kuraklık nedeniyle su talebinin karşılanamaması, buğday gibi stratejik ürünlerde önemli verim kayıplarına yol açmaktadır. Örneğin, 2008 yılı, ülke genelinde 445 mm yağışla en kurak yıl olarak kayıtlara geçmiş olup, bu durum tarımsal üretimde ciddi azalmalara yol açmıştır (MGM, 2021). Ayrıca şiddetli kurak dönemlerde su krizi ve gıda krizleri artmaktadır.

Ülkemizde, iklim değişikliği ile mücadele ve uyum kapsamında çeşitli strateji ve eylem planları geliştirilmiş ve uygulamaya alınmıştır. Bunlar arasında 2024-2030 yıllarını kapsayan İklim Değişikliği Azaltım ve Uyum Strateji ve Eylem Planı, Tarımsal Kuraklıkla Mücadele Stratejisi ve Eylem Planı (2023-2027) gibi tedbirlerin yanı sıra su tasarrufu sağlayan modern sulama sistemlerinin yaygınlaştırılması, mera ıslah çalışmaları ve ağaçlandırma projeleri ile yutak alanlarının artırılması, kuraklığa dayanıklı bitki çeşitlerinin geliştirilmesi ve kuraklık sigortası gibi risk yönetimi uygulamaları gibi birçok proje ve faaliyet yürütülmektedir.

Sonuç olarak, Türkiye'nin iklim değişikliği ve tarımsal kuraklıkla mücadele çabaları, ulusal ve yerel düzeyde koordineli bir şekilde yürütülmektedir. 2030 yılına kadar sera gazı emisyonlarını %21 oranında azaltmayı hedefleyen ülke, kuraklık ve su krizlerinin olası etkilerini azaltmak için hem stratejik planlar hem de uygulamalı projelerle bu süreci yönetmeye çalışmaktadır (TÜİK, 2024). Alınan önlemlerle, tarımsal üretimin sürdürülebilirliği sağlanırken, aynı zamanda su ve gıda güvenliğine yönelik risklerin de minimize edilmesi hedeflenmektedir.

Anahtar Kelimeler: İklim Değişikliği, Kuraklık, Su Krizi, Gıda Krizi, Sulama

1. GİRİŞ

Küresel ısınma ve iklim değişikliği, günümüzde en çok konuşulan konuların başında gelmektedir. Son yıllarda iklim değişikliği ve olumsuz etkileri daha fazla hissedilmeye başlanmıştır. İklim değişikliği sadece çevrede değil, tüm ekosistemlerde ve ekonomide doğal dengenin bozulmasına yol açmakta ve krizleri tetiklemektedir. Ayrıca son yıllarda sıkça gündeme gelen "iklim krizi" ise, küresel ısınmanın bir sonucu olarak ortaya çıkan ve çoğunlukla insan etkinlikleri sonucunda tetiklenen hızlı iklim değişiklikleri olarak ifade edilebilir. Aslında iklim krizi, durumun önemini ve tedbirlerin acilliğini vurgulamaktadır. İklim değişikliğinin zararlarını vurgulamak amacıyla kullanılan bu tanım, artık hayatımızın bir parçası olmuştur.

İklim krizinin en önemli nedeninin fosil yakıtlar olduğu, bilim insanları tarafından kanıtlanmıştır. Özellikle sanayileşme ve kalkınma hamleleri, fabrikasyon ve mekanizasyondaki hızlı gelişmeler, fosil yakıtların kullanımını hızla artırmıştır. İklim odaklı riskler ve krizler devam etmekte olup, bunun farkında olan ülkeler, sürdürülebilir bir gelecek için çözümler aramaktadır.

Bugün dünya nüfusu yaklaşık 8 milyar olup, 2050 yılında bu nüfusun 9,8 milyar olması beklenmektedir. Bu nüfusun beslenebilmesi için gıda üretiminin en az %60 oranında artırılması gerekmektedir. FAO (2022) verilerine göre, yerküre üzerinde 39 ülkede gıda, 80 ülkede ise su sıkıntısı yaşanmaktadır. Birçok iklim uzmanına göre, iklim değişikliği ve kuraklık; dünyanın birçok bölgesinde verimli tarım arazilerinin azalmasına, toprak ve su kaynaklarının kirlenmesine ve üretimde verim kayıplarına neden olarak krizlerine yol açacaktır

Dünyada küresel ısınma ve iklim değişikliği, sanayileşmenin başladığı 1800'lü yıllardan itibaren kayıt altına alınan sıcaklık verileri ile incelenmektedir. Bu verilere göre sıcaklıklar 1800'lü yıllardan günümüze yaklaşık 1^{o}C artmıştır. Sıcaklık artışlarının gelecek 100 yılda da artarak devam edeceği öngörülmektedir. Yine en fazla sıcaklık artışı 2000'li yıllarda olmuştur. Bu artışlara bağlı olarak mevsimlerde kaymalar, yağış rejimlerinde değişmeler, kuraklık, sel, kasırga gibi doğal afetlerde artışlar gözlendiği ve bunların gelecek yüzyılda da devam edeceği tahmin edilmektedir. Küresel yüzey sıcaklığı dikkate alınarak yapılan tüm emisyon senaryolarında, sıcaklığın en azından yüzyılın ortalarına kadar artmaya devam edeceği öngörülmektedir. Yine önümüzdeki yıllarda CO2 ve diğer sera gazı emisyonlarında ciddi azalmalar olmazsa, 21. yüzyılda 1,5°C ve 2°C'lik küresel ısınma değerine ulaşılacaktır (IPCC 2013 ve 2022).

Hidrolojik döngüdeki dengenin bozulması, buzulların erimesi, deniz seviyesinin yükselmesi, sıcak hava dalgalarının şiddet ve sıklığının artması, bazı bölgelerde ekstrem yüksek yağışların ve ani yağışlara bağlı taşkınların artması, bazı bölgelerde ise kuraklıkların daha sık görülmesi ve şiddetinin artması gibi ekolojik sistemleri, sektörleri ve insan yaşamını etkileyecek önemli değişikliklerin oluşması beklenmektedir (Türkeş 2008).

İklim değişikliğine neden olan sera gazı emisyonunun azaltılması ve olası değişimlere uyum sağlanması, tüm dünyada ortak çözülmesi gereken konular olarak ele alınmaya başlanmıştır. Günümüzde iklim değişikliği, gelişmiş ve gelişmekte olan tüm ülkelerin öncelikli konuları arasına girmiştir. Bu kapsamda, iklim değişikliğine önem veren ülkeler, iklim değişikliğinin etkilerinin belirlenmesi, niteliğinin tahmin edilmesi ve etkilerinin azaltılması amacıyla gereken tedbirlerin alınması konusunda idari, hukuki, mali ve teknik nitelikli önemli çalışmalar yürütmektedirler.

Türkiye'de 2021 yılında, Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'na bağlı İklim Değişikliği Başkanlığı kurulmuştur. 2011-2023 İklim Değişikliği Stratejisi ve Eylem Planı, Kalkınma Planları, 2053 Net Sıfır Emisyon Hedefi ve İklim Şurası Kararları dikkate alınarak, 2024-2030 yılları için revize edilip uygulanmaya başlanmıştır.

2. TÜRKİYE'DE ARAZİ VARLIĞI, KULLANIM DURUMU

Türkiye, kurak ve yarı kurak bölgede yer almakta olup, iklim değişikliğinden en fazla etkilenecek ülkeler arasında bulunmaktadır. 78,3 milyon hektar yüzölçümüne sahip olan ülkemizin, 23,9 milyon hektar tarım alanı, 14,6 milyon hektar mera alanı ve 23,2 milyon hektar orman alanı bulunmaktadır (TÜİK 2024). İklim değişikliğinden farklı bölgelerinin farklı şekilde etkilenmesi beklenmektedir (Çizelge 1).

Çizelge 1. Ülkemizde arazi varlığı ve kullanım durumu (2023)

Kullanım Şekli	Miktar (ha)	(%)
Tarım Alanı	23.942.000	30,56
Mera	14.617.000	18,65
Orman	23.245.000	29,67
Su Yüzeyleri	1.571.000	2,00
Yerleşim Alanları ve Diğer Alanlar	14.981.200	19,12
Toplam	78.356.200	100,00

Kaynak: TÜİK, 2024

Türkiye'de sulamaya açılan alanların artırılması, ülkenin ihtiyacı olan ürün çeşitliliğinin artırılması ile ülke ekonomisi açısından büyük önem taşımaktadır. TÜİK (2023) verilerine göre, tarım sektörü, 85 milyon ülke nüfusu ve 50 milyon turisti beslerken, 68,5 milyar dolar tarımsal hasıla ve 31 milyar dolar tarımsal ihracat geliri elde edilmesini sağlamıştır. Böylece Türkiye, AB'de 1'nci dünyada ise 10'uncu tarım ekonomisine sahip ülke olmuştur.

Dünyada ve ülkemizde tarım alanları, bir taraftan sanayileşme ve kentleşmenin baskısı altında azalmaya devam ederken, diğer taraftan iklim değişikliği sonucu yağış azalmaları, kuraklıkların şiddeti ve süresine bağlı olarak arazi bozunumları artmakta ve verimlilik düşmektedir. Tarım arazileri ile ilgili diğer önemli bir tehdit ise kirlenmedir. Yine, tarım alanlarında artan sanayi kaynaklı, evsel kaynaklı kirlilik ve tarımsal faaliyet kaynaklı kirlilik (ilaç ve gübre kullanımı), tarımı ve sürdürülebilir gıda sistemlerini tehdit etmektedir.

3. TÜRKİYE'DE SU KAYNAKLARI POTANSİYELİ VE KULLANIM DURUMU

Su, tüm canlılar için vazgeçilmez bir hayat kaynağıdır. Su, kalkınmanın itici gücü ve gıda arz güvenliğinin teminatıdır. Ülkemiz, kurak ve yarı kurak bir bölgede yer almaktadır. Uzun yıllar itibariyle yağış ortalaması yıllık 574 mm olup, en fazla yağış doğu Karadeniz Bölgesi'nde 2.500 mm/yıl, en az ise İç Anadolu Bölgesi'nde (Tuz Gölü çevresi) 250-300 mm/yıldır (DSİ 2024a).

Türkiye 25 nehir havzasından oluşmaktadır (Şekil 1). Yağışlar ve su potansiyeli havzalara göre değişmektedir.

Şekil 1. Türkiye Su Havzaları (DSİ 2024a)

Ülkemizde, DSİ (2024a) verilerine göre, kullanılabilir su potansiyeli 94 milyar m³/yıl yerüstü suyu ve 14 milyar m³/yıl yeraltı suyu olmak üzere toplam 112 milyar m³/yıldır. Bugün itibarıyla yaklaşık 57 milyar m³'ü kullanılmaktadır.
Türkiye'de, ekonomik sulanabilir 8,5 milyon hektar alanın 7,1 milyon hektarı (%83,5) sulamaya açılmıştır (Çizelge 3). Sulamaya açılan alanların %67,6'sı (4,8 milyon hektar) DSİ tarafından açılmıştır. Yine, tüm dünyada olduğu gibi, ülkemizde de fiilen kullanılan suyun en fazlası tarımda kullanılmaktadır. Toplam kullanılan suyun %77'si tarımda kullanılmaktadır.

Çizelge 3. Türkiye'de Sulamaya Açılan Alanlar (2023)

1. Sulama Alanları	2. Milyon 3. Ha	4. Oran 5. %
6. DSİ	7. 4,8	8. 67,1
9. Mülga KHGM	10. 1,3	11. 18,6
12. Halk Sulamaları	13. 1,0	14. 14,3
15. Toplam	16. 7.1	17. 100,0

Kaynak: DSİ 2024a

Ayrıca 7,3 milyon ha alanda toplulaştırma yapılmış olup, sulama yatırımları arazi toplulaştırma ile birlikte yapılmaktadır (DSİ 2024a). Böylece hem sulama yatırımlarını hızlandırılmakta hem de toplulaştırma ile parseller yol ve sulama kanalına erişim odaklı yeniden düzenlenerek modern tarıma uygun hale getirilmektedir. Böylece su ve girdilerin etkin kullanımı sağlanarak gıda arz güvenliğinin sürdürülebilirliği sağlanmaktadır.

1950-2023 arasında DSİ ve Mülga Köy Hizmetleri Genel Müdürlüğü tarafından değişik ölçeklerde 9000'in üzerinde sulama projesi tamamlanmıştır. 180 Sulama Birliği, 2500 Sulama kooperatifi, 605 Belediye başkanlığı ve 6000'den fazla Köy Muhtarlığı sulama tesislerini işletmektedir.

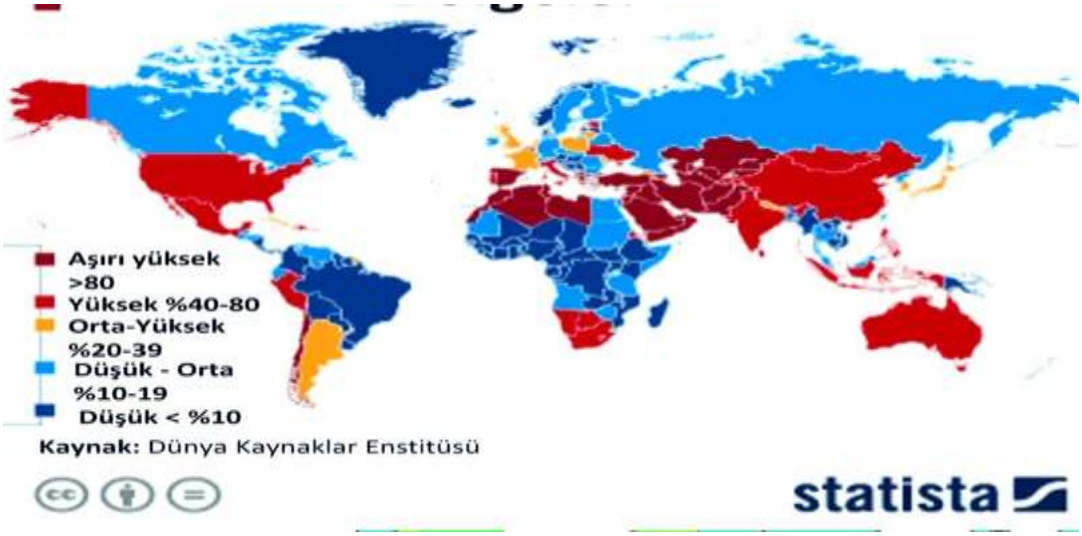
DSİ (2024b) verilerine göre sulama şebekelerinin %65'i açık kanal ve %35'i borulu sistemdir. Tesisler birçoğu eski ve bakım-onarım yenileme boyutundadır. Bu nedenler tarımda su verimli kullanılamamaktadır. Sulama oranı %70 ve sulama randımanı %50'ler düzeyindedir. Sulama şebekelerinin hızlı bir şekilde borulu ve akıllı sistemlere dönüştürülmesi gerekmektedir.

4. İKLİM DEĞİŞİKLİĞİNİN SU KAYNAKLARI ÜZERİNE ETKİSİ VE SU KRİZLERİ

Küresel ısınma sonucu ortaya çıkan iklim değişikliği, yağış rejiminde değişikliklere, ekstrem olaylarda artışa, kurak sezonların sayısı ve şiddetinin artmasına, yerüstü ve yeraltı su potansiyellerinde ise değişimlere, genelde de azalmalara yol açmaktadır

Dünya ekonomik forumu tarafından 2014 yılında hazırlanan Küresel Risk Raporuna göre olası bir "Su Krizi" dünya ekonomisinde en çok endişeye yol açan 3. Risk olarak belirlenmiştir. Bu nedenle, "su güvenliği" artık sadece yerel değil, küresel ölçekte ele alınması gereken bir sorun haline gelmiştir. Su krizi, belirli bir bölgede su kaynaklarının miktar ya da kalite açısından yetersiz ve riskli olması durumudur.

Birleşmiş Milletler'in su ve sanitasyon konularındaki çalışmalarını yürüten UN-Water'ın verilerine göre, bugün dünyada 2,2 milyar insan güvenli suya erişim sorunu yaşamaktadır. Bu sayının 2050 yılına kadar 3 milyara ulaşması beklenmektedir (UN-Water, 2020). Dünya genelinde 2040 sonrası su kıtlığı yaşanabilecek bölgeler arasında Türkiye de yer almakta (Şekil 2) ve "yüksek riskli" ülkeler arasında gösterilmektedir (WRI, 2020).

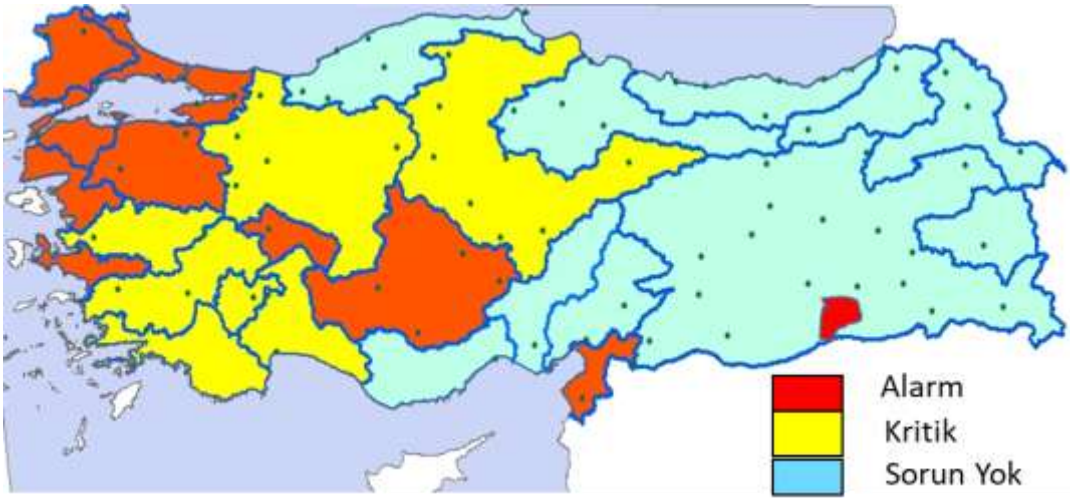


Şekil 2. 2040 sonrası su kıtlığı yaşanabilecek bölgeler (WRI 2020)

Ülkeler kullanılabilir su varlığına göre sınıflandırıldığında, kişi başına düşen kullanılabilir su miktarı **8.000 m³**'ün üzerindeki ülkeler **"su zengini"** olan ülkeler olarak kabul edilirken **2.000 m³'**den az olan ülkeler "**su azlığı (su kısıtı)**" **1000 m³**'den az ülkeler de **"su fakiri"** ülke kabul edilmektedir (DSİ 2016).

Türkiye'de kişi başına düşen yıllık su miktarı günümüzde yaklaşık 1.312 m³'tür. Bu değer, Türkiye'nin su zengini bir ülke değil, su stresi yaşayan bir ülke olduğunu ortaya koymaktadır. 2050 yılı projeksiyonlarına göre ise bu miktarın 1.000 m³'ün altına düşmesi beklenmektedir.

Yerüstü su kaynaklarının yetersiz olduğu bölgelerde, yeraltı suları hayati bir öneme sahiptir. Ancak, özellikle son yıllarda artan izinsiz kuyu açımları ve aşırı su çekimi, yeraltı su seviyelerinin ciddi şekilde düşmesine neden olmuştur. Yetersiz yağışlar, yeraltı sularının doğal beslenim-boşalım dengesini bozmakta ve bu da bazı bölgelerde obruk oluşumlarını hızlandırmaktadır. Entansif tarımın yaygın olduğu bölgelerde yeraltı suyu kullanımı kritik bir noktaya ulaşmıştır (Şekil 3.)



Şekil 3. Türkiye'de Havza Bazında Yeraltı sularının Durumu (DSİ 2016)

Su kıtlığı yaşanan bölgelerde; içme, kullanma, sanayi ve tarım gibi sektörlerin artan su taleplerini karşılamak giderek zorlaşmaktadır. Bu durum, sektörler arasında beklenmedik su tahsisi sorunlarına neden olabilmektedir. Bu bölgelerde su tahsisleri kapatılmakta, çok su tüketen ürünlere Bakanlık destekleri verilmemekte, su tasarrufu sağlayan yağmurlama ve damla sulama sistemleri %50 hibe ile desteklenmektedir. Bu nedenle, bu bölgelerde özellikle kar ve yağmur sularının toplanması, su hasadı, yeraltı barajları inşası, akiferlerin suni beslenmesi ve etkin su yönetimi büyük önem taşımaktadır

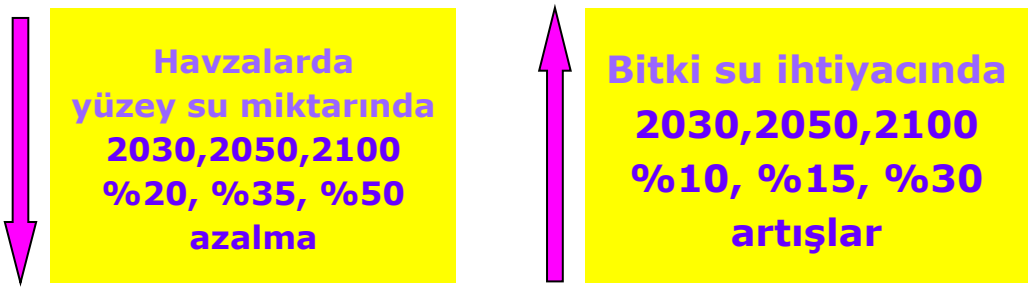
Küresel ölçekte yeryüzü sıcaklığı son yüzyılda ortalama 0,6°C artmış, 1970–2020 döneminde bu artış yaklaşık 1,5°C'yi bulmuştur. 2085 yılına kadar ise ortalama sıcaklık artışının 3,1°C seviyelerine ulaşacağı öngörülmektedir (IPCC, 2021). En sıcak 10 yılın büyük bir kısmı 2000 sonrası dönemde yaşanmıştır. Bu ısınma, yağış rejimlerini değiştirerek sel, kuraklık, dolu, fırtına, orman yangını gibi ekstrem doğa olaylarının sıklığını artırmakta, özellikle tarım sektörünü derinden etkilemektedir.

Türkiye, iklim değişikliğinden en fazla etkilenecek ülkeler arasında yer almaktadır. Dünya Kaynakları Enstitüsü tarafından 2020 yılında "Türkiye'nin Su Stresi Haritası" çıkarılmış (Şekil 4) ve bir su raporu hazırlanmıştır. Raporuna göre, Türkiye 2050 yılına gelindiğinde, su kaynaklarının %80'inden fazlasını tüketen ülkeler arasında olacak ve ciddi su stresi yaşayacaktır (WRI, 2020). İç Anadolu, Göller Yöresi, Doğu Akdeniz, Ege ve Çanakkale gibi bölgelerde su sorunları son yıllarda belirgin biçimde artmıştır.

Şekil 4. *Türkiye'nin su stresi haritası (WRI 2020)*

Su kaynaklarına olan taleplerin her geçen gün arttığı, sektörler ve su kullanıcılar arasında rekabetin krizlere yol açtığı bir dönemde mevcut su kaynaklarının verimli ve sürdürülebilir şekilde kullanımı hayati önem taşımaktadır. Tarım sektörü, mevcut su kaynaklarının büyük kısmını kullanmakta; içme, kullanma ve sanayi sektörlerinin ihtiyaçlarının da büyük oranda tarımdan karşılanması beklenmektedir. Kurak ve yarı kurak bölgelerde su varlığının azalması ve artan su açığı, bu kaynakların daha etkin yönetilmesini zorunlu kılmaktadır. İklim değişikliğini durdurmak mümkün olmasa da etkilerini azaltmak için önlemler alınması gerekmektedir (UNDP, 2007; IPCC, 2021).

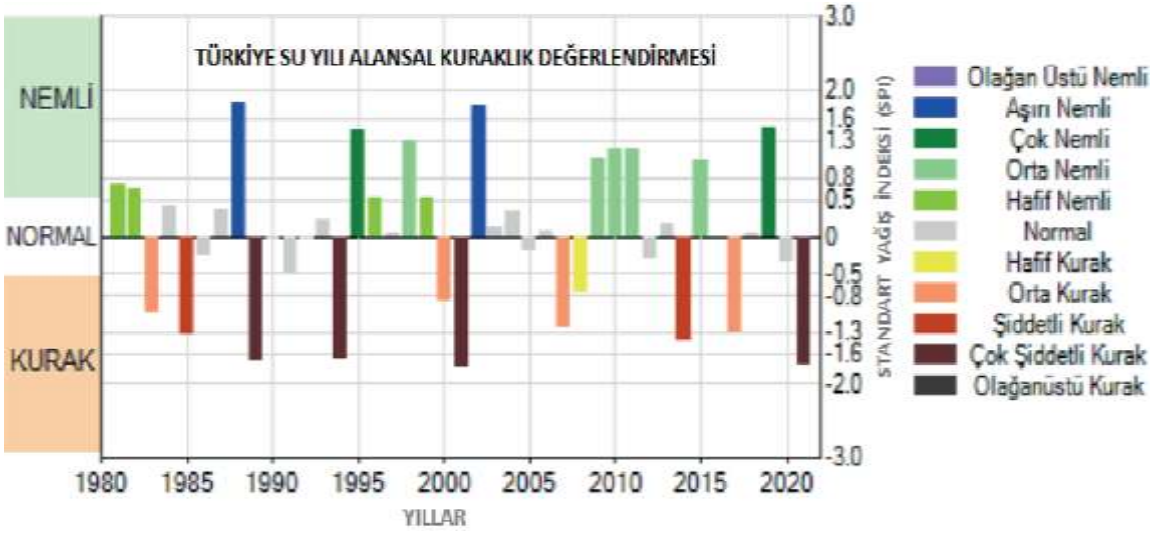
UNDP'nin 2007 yılında hazırladığı bir raporda, Gediz ve Büyük Menderes havzaları özelinde önemli tahminlere yer verilmiştir. Bu çalışmaya göre, 2030 yılına kadar bu havzalarda sıcaklıkların 1,2°C artması ve yağış miktarının %5 azalması beklenirken, 2050 yılına kadar ise sıcaklık artışının 2°C'ye, yağış azalmasının ise %10'a ulaşacağı öngörülmektedir. Aynı zamanda 2030, 2050 ve 2100 yılları olası yüzey su miktarlarındaki azalmalar ile bitki su ihtiyaçlarındaki olası artışlar da tahmin edilmiştir (Şekil 5).



Şekil 5. Gediz ve Büyük Menderes Havzaları İklim Projeksiyonları (UNDP 2007)

Son yıllarda yaşanan kuraklıklar bu tahminleri doğrular niteliktedir. Gediz ve Büyük Menderes havzalarında yerüstü su kaynaklarının azalması, kontrolsüz yeraltı suyu kullanımını artırmış, bu da su seviyelerinin ciddi şekilde düşmesine neden olmuştur. Aynı zamanda havzalarda barajlarda planlanan suyun birikmemesi İl Tarımsal Kuraklık Kriz Merkezlerinin su yönetimine müdahale etmesi ve kısıtlamalara gitmelerine yol açmıştır. Ayrıca Türkiye'nin yeraltı su potansiyelinin üçte birini oluşturan Konya Havzası'nda da durum farklı değildir. Bölgede açılan izinsiz kuyular ve aşırı yeraltı suyu çekimleri, su seviyelerinin yer yer 200 metrelerin altına düşmesine ve 2.500'ü aşkın obruk oluşumuna yol açmıştır.

Meteoroloji Genel Müdürlüğü'nün (2021) 1980–2020 yıllarını kapsayan kuraklık analizine göre, bu 41 yıllık dönemde 11 yıl kurak, 13 yıl nemli ve 17 yıl normal geçmiştir. Ancak özellikle 2010'lu yıllardan itibaren, rekor sıcaklıklarla birlikte kuraklık olaylarında belirgin bir artış gözlemlenmiştir (Şekil 6).



Şekil 6. Türkiye Kuraklık Değerlendirmesi 1980-2020 (MGM 2021)

İklim değişikliğinin su kaynakları üzerindeki etkileri, yalnızca çevresel sürdürülebilirliği değil, aynı zamanda tarımsal üretim kapasitesini ve dolayısıyla gıda güvenliğini de derinden etkilemektedir. Artan sıcaklıklar, azalan yağış miktarları ve sıklaşan kuraklık dönemleri,

özellikle sulamaya bağımlı tarımsal alanlarda ciddi ölçüde üretim ve verim kayıplarına yol açmaktadır (IPCC, 2021; UNDP, 2007).

Su kaynaklarının azalması, tarımsal üretim maliyetlerini artırmakta, bu durum gıda arzının düşmesine ve piyasalarda fiyatların yükselmesine neden olmaktadır. Küresel ölçekte yaşanan bu gelişmeler, düşük gelirli ve iklim kırılganlığı yüksek bölgelerde yaşayan nüfusların gıdaya erişimini zorlaştırmakta; böylece iklim değişikliğine bağlı su krizleri, doğrudan gıda krizlerini tetikleyen bir unsur haline gelmektedir (FAO, 2018; WRI, 2020). Bu çerçevede, iklim değişikliğinin su kaynakları üzerindeki etkileri ile gıda güvenliği arasındaki ilişki çok boyutlu ve stratejik öneme sahip bir konu olarak değerlendirilmektedir.

5. SUYUN GIDA ARZ GÜVENLİĞİ İÇİN ÖNEMİ

Her insanın yaşamını sağlıklı bir şekilde sürdürebilmesi için yeterli ve sağlıklı gıdaya ihtiyaç duymaktadır. Bunun için, gıda ürünlerinin sağlıklı bir şekilde üretilmesi, korunması ve tüketici sağlığına zarar vermeyeceğinin garanti altına alınması gerekmektedir. Bu bağlamda, gıda güvenliği ve gıda güvenilirliği kavramları önem kazanmaktadır. Gıda güvenliği genellikle miktar ile ilgili iken, gıda güvenilirliği kaliteyi temsil etmektedir.

Türkiye'de gıda üretiminin 2/3 ü sulu tarım alanlarında yapılan üretime dayanmaktadır (TOB 2021). Gıda arz güvenliği için su güvenliği şarttır Su, tarımsal üretimde bitki çeşitliliğini ve verimleri artıran en önemli kaynaktır. Tarımsal faaliyette toprağın tava gelmesinden, tohumun çimlenmesine ve hasata kadar ki tüm evrelerde suya ihtiyaç duyar. Bazı ürünlerin üretilmesi için gerekli olan su miktarları çizelge 4'te verilmiştir.

Çizelge 4. Bazı ürünlerin üretimi için gerekli olan su miktarları

18.	Ürün	19.	Su İhtiyacı
20.	1 kg buğday	21.	1 m^3 su
22.	1 kg pirinç	23.	3 m^3 su
24.	1 kg süt	25.	2,6 m^3 su
26.	1 kg peynir	27.	5 m^3 su
28.	1 kg biftek	29.	15 m^3 su

Kaynak: Hoekstra ve Chapagain, 2008

Sulama ile tarımsal verimi 3 ila 6 kat artırmak mümkündür. Hayvancılıkta yem temini, yem bitkileri üretimi açısından su en önemli girdilerden biridir. Ayrıca, hayvan başına günlük su tüketimi de hayvancılığın verimliliği açısından büyük önem taşır. Örneğin, günlük süt verimi 35–40 kg olan bir ineğin günlük su ihtiyacı 120–140 litre arasında değişmektedir. Normal bir sığır, her kilogram kuru madde tüketimi için 4,1 litre, her kilogram süt verimi için ise 2,6 litre suya ihtiyaç duymaktadır (Osborne, 2006).

Bu nedenle, büyük hayvancılık işletmeleri toplam hayvan sayısına bağlı olarak çok büyük miktarlarda suya ihtiyaç duyar. Yem bitkisi üretimi ve diğer hizmetler için gerekli olan su miktarları da eklendiğinde, su kaynaklarının kısıtlı olduğu, özellikle yeraltı suyunun kullanıldığı bölgelerde su kullanımı ciddi bir krize dönüşebilmektedir. Bu nedenle, yerüstü su

kaynaklarının bulunmadığı ve yeraltı su kaynaklarının da son derece sınırlı olduğu Konya ve Karaman gibi bölgelerde büyük ölçekli hayvancılık işletmelerine izin verilmemektedir.

Türkiye, iklim değişikliğinden en fazla etkilenecek riskli ülkeler arasında yer almaktadır. 2050 ve 2080 yılı projeksiyonları, ülkemizdeki yerüstü su miktarının %35 azalırken, bitki su ihtiyaçlarının %15 artacağını göstermektedir. Türkiye'de 7 coğrafi bölgede ve 5 temel üründe, Hadley iklim modeli kullanılarak yapılan 2050 yılı iklim projeksiyonlarına göre; buğday ve arpa veriminde %7,58, mısır veriminde %10,14, ayçiçeği veriminde %6,35 ve pamuk veriminde %2,19 azalma olacağı tahmin edilmektedir. Türkiye genelinde verimlilikte %2 ile %13 arasında bir azalma olabileceği, bunun ekim alanı ve üretim desenini değiştireceği, verimlilikteki düşüşün üretim miktarını gerileteceği ve bunun da fiyatlarda artışa yol açarak üretici refahını artıracağı, ancak tüketici refahını azaltacağı belirlenmiştir (Dellal ve Mc Carl, 2004)

Su krizi tüm dünyayı giderek daha fazla etkisi altına almaktadır. Uzmanlara göre 25 yıl içinde Dünyada gıda üretiminin yarısından fazlası kuraklıklardan dolayı tehlikeye gireceği uyarısı bulunmaktadır. Bugün dünya nüfusunun yarısından fazlası **su kıtlığıyla** karşı karşıyadır. 2022 yılında Hollanda'da kurulan **Global Su Ekonomisi Komisyonu'**nun yayımladığı raporda, dünyadaki su kaynaklarının bugüne kadar görülmemiş bir baskı altında olduğu ve taze su talebinin 10 yılda %40 oranında artacağı belirtilmiştir.

6. İKLİM DEĞİŞİKLİĞİNE KARŞI UYUM VE AZALTIM ÇALIŞMALARI

Küresel ısınma ve iklim değişikliğinin olumsuz etkileri, 1992 Rio Çevre ve Kalkınma Konferansı'nda imzaya açılan İklim Değişikliği Çerçeve Sözleşmesi (İDÇS) ile ele alınmıştır. 1994 yılında yürürlüğe giren bu sözleşmeye 184 ülke taraf olmuştur. Sözleşmenin amacı, sera gazlarının atmosferdeki konsantrasyonunu tehlikeli seviyelere ulaşmadan sabit tutmaktır. Ayrıca, sözleşme ile sera gazlarının insan kaynaklı etkilerini önlemek, ekosistemlerin iklim değişikliğine uyumunu desteklemek ve gıda üretiminin sürdürülebilirliğini sağlanması hedeflenmiştir.

İklim Değişikliği Çerçeve Sözleşmesi'ne (İDÇS) göre, Ek-1 ve Ek-2 listelerinde yer alan ülkelerin, sera gazı emisyonlarının sınırlandırılması ve azaltılması amacıyla belirli yükümlülükleri bulunmaktadır. Sözleşme, çevre koruma hedeflerinin ötesine geçerek küresel düzeyde kolektif eylemi teşvik eden bir yapı haline gelmiştir. Söz konusu gelişmeler, Taraflar Konferansı (COP) toplantılarında düzenli olarak izlenmektedir.

Paris Anlaşması (2015), 2020 sonrası dönemde iklim değişikliği tehdidine karşı küresel sosyo-ekonomik dayanıklılığın artırılmasını hedeflemektedir. Anlaşmanın uzun vadeli amacı, sanayi öncesi döneme kıyasla küresel sıcaklık artışını 2°C'nin olabildiğince altında, tercihen 1,5°C düzeyinde sınırlamaktır. Bu hedef doğrultusunda, taraf ülkeler sera gazı emisyonlarına ilişkin ulusal katkı beyanlarını sunmakta ve bu beyanlar doğrultusunda ulusal strateji ve eylem planlarını güncellemektedirler (UNFCCC, 2015; T.C. ÇŞİDB, 2023).

Türkiye, referans senaryoya göre 2030 yılına kadar sera gazı emisyonlarını azaltmayı taahhüt etmiş olup, bu kapsamda 2030 yılında emisyon miktarını 695 Mt CO_2 eşdeğeri düzeyine çekmeyi hedeflemektedir. Ayrıca, 2050 yılına kadar karbon nötr olmayı içeren uzun vadeli plan

çerçevesinde, orta vadede emisyon azaltım hedeflerine ulaşılması amaçlanmaktadır (ÇŞİDB, 2023).

İklim değişikliğinin etkilerinin farkında olan ülkeler, bu etkilerle mücadeleye yönelik stratejiler geliştirerek hem azaltım hem de uyum odaklı önlemler almakta ve uygulamaktadır. Türkiye'de, tarım sektöründe iklim değişikliği ile mücadele konusunda sorumlu kurum Tarım ve Orman Bakanlığı'dır. Bakanlığın çalışmaları, uyum ve azaltım hedefleri doğrultusunda iki temel grupta sınıflandırılmaktadır (TOB, 2023).

Sera gazı emisyonlarının azaltılması amacıyla Türkiye'de yutak alanların artırılmasına yönelik ağaçlandırma ve mera ıslahı faaliyetleri sürdürülmektedir. Bunun yanı sıra, iyi tarım uygulamaları ve organik tarım desteklenmekte; Avrupa Birliği Yeşil Mutabakat Eylem Planı kapsamında 2030 yılına kadar pestisit kullanımının %50, gübre kullanımının ise %20 oranında azaltılmasına yönelik çalışmalar başlatılmıştır. Ayrıca, arazi toplulaştırma faaliyetleri hızlandırılmış ve bugüne kadar yaklaşık 7,3 milyon hektarlık alan toplulaştırılmıştır. Bu çalışmalar sonucunda yıllık 365.000 tonluk mazot tasarrufu sağlandığı belirtilmektedir (TOB, 2023).

Yine Türkiye'de uyum kapsamında; Tarımsal Kuraklıkla Mücadele Strateji ve Eylem Planı (2023-2027), yağmurlama ve damla sulama sistemlerinin % 50 hibe ile desteklenmesi, Tarım Sigortalarının kapsamının genişletilmesi (Kuraklık Sigortası), yenilenebilir enerji (GES, RES, JES) yatırımlarının desteklenmesi, Konya'da Kuraklık Test Merkezi, Erzurum'da Soğukluk Test Merkezi, Kuraklığa dayanıklı bitkilerin geliştirilmesi ve ıslahı, kurak dönemlerde kısıntılı sulama programları (TAGEM SuET), iklim dostu akıllı tarım teknolojileri ve sulama ile ilgili eğitim ve yayım çalışmaları gibi çok önemli çalışmalar yürütülmektedir.

Ayrıca, Türkiye'de su kaynaklarının verimli kullanılması amacıyla DSİ tarafından inşa edilen sulama yatırımları, 2004 yılından sonra kapalı sistem olarak inşa edilmeye başlanmıştır. DSİ tarafından işletmeye açılan sulama alanlarının %21,5'i yağmurlama, %16,9'u damla sulama olmak üzere toplam %38,4'ü basınçlı sulama sistemleriyle sulanmaktadır. Oysa ICID (Uluslararası Sulama ve Drenaj Komisyonu) verilerine göre, İsrail ve Birleşik Krallık sulu tarım alanlarının tamamına yakınını, Brezilya %77'sini, İspanya %74'ünü ve ABD %57'sini basınçlı sulama yöntemleri ile gerçekleştirmektedir (ICID, 2018)

Sulama etkinliği açısından önemli bir yatırım da sulama alanlarında arazi toplulaştırması yapılmasıdır. Arazi toplulaştırması ile birlikte kapalı sulama şebekelerinin inşa edilmesiyle parseller büyümekte, her parsel yola ve sulama kanalına irtibatlandırılmaktadır. Böylece, verim artışları ile birlikte %30-60 su tasarrufu sağlanmaktadır. Ayrıca, ulaşım ve parsel içi makine verimliliği artmakta ve 50 Lt/ha tasarruf sağlanmaktadır (Türker ve Gencel, 2010).

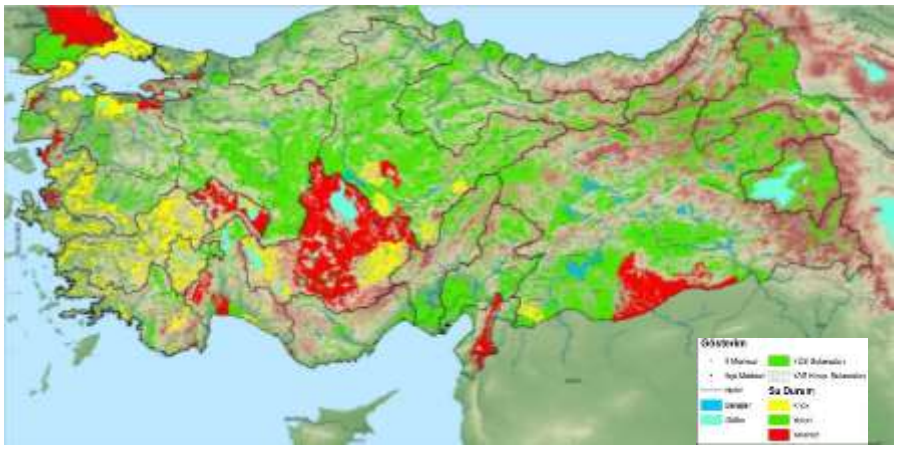
Türkiye'de arazi toplulaştırması çalışmalarına 2008 yılından sonra hız verilmiştir. Bugün itibariyle 7,4 milyon ha alanda toplulaştırma tamamlanmış, 2,3 milyon ha alanda da çalışmalar devam etmektedir.

Su kullanım etkinliği kapsamında yürütülen çalışmalardan biri de su tasarrufu sağlayan tarla içi modern sulama sistemlerinin (yağmurlama ve damla sulama sistemleri) Bakanlık tarafından %50 hibe ile desteklenmesi ve Ziraat Bankası ile Tarım Kredi Kooperatifleri aracılığıyla sübvansiyonlu kredilerle desteklenmesidir. Bu kapsamda, 2006 yılından günümüze kadar hibe

ve kredi desteği sağlanarak yaklaşık 350 bin üretici desteklenmiş ve yaklaşık 1,3 milyon hektar alan basınçlı sulama sistemine kavuşturulmuştur.

Türkiye'de havza bazlı destekleme modeli ile ürünlerin en uygun havzada üretilmesi amaçlanmaktadır. Havzada desteklenecek ürünlerin tespitinde esas alınan kriterlerden birisi de havzada su kısıtının olup olmadığıdır. Bu kapsamda, 2016 yılından beri azalan su kaynaklarımızın korunması ve suyun daha etkin kullanımı için DSİ, Tarım Reformu Genel Müdürlüğü (TRGM) ve Bitkisel Üretim Genel Müdürlüğü (BÜGEM) koordinasyonunda belirlenen su kısıtı olan bölgelerde, suyu az tüketen ürünlere ilave destekler verilmektedir.

Özellikle aşırı yeraltı suyu çekimlerinin olduğu ve su kısıtının bulunduğu bölgeler (11 il 52 İlçe) DSİ tarafından haritalanmış ve su kısıtına göre desteklemelerin yürütülmesi istenmiştir. Haritada işaretlenen su kısıtının bulunduğu ilçelerde yonca (1000 mm), pamuk (820 mm), şeker pancarı (780 mm), ayçiçeği (670 mm), dane mısır (650 mm), patates (645 mm) gibi çok su tüketen ürünlerin salma sulama ile sulanması yasaklanmış ve çok su tüketen bu ürünler yerine Kanola (440 mm) nohut veya mercimek (450 mm), K.Fasulye (545 mm), Buğday (550) ve soya (630 mm) gibi stratejik ürünlerin ekilmesi durumunda **%50 ilave destek** verilmektedir.



Şekil 7. DSİ Genel Müdürlüğü Su Kısıtı Haritası (DSİ 2016)

Sürdürülebilir üretim ve gıda arz güvenliği için önem taşıyan politikalardan birisi tarımda risk yönetimidir. Bu amaçla ülkemizde 2006 yılından beri uygulanan tarım sigortası (TARSİM) faaliyetlerin doğal afet risklerinin güvence altına alınmasında önemli tedbirlerinden biridir. Sigorta primlerinin **%50'si** devlet tarafından destek olarak ödenmektedir.

7. SONUÇ VE ÖNERİLER

Küresel ısınma ve iklim değişikliğine bağlı sorunlar, küresel olmakla birlikte, çözümler bölgesel ve yereldir. İklim krizi, su kaynaklarını ve gıda arz güvenliğini tehdit etmektedir. Su krizi, tüm dünyayı giderek daha fazla etkisi altına almaya başlamış olup bu etkinin gelecek yıllarda iklim krizine bağlı olarak artması beklenmektedir.

Ülke olarak, uluslararası gelişmeler yakından takip edilmekte ve uyum ile azaltım çalışmalarına devam edilmektedir. İklim Değişikliği ve Kuraklıkla Mücadele Stratejisi ve Eylem Planları hazırlanmış, ilgili kurumlar nezdinde tedbirler belirlenmiş ve uygulamalara devam edilmektedir. Bu kapsamda, DSİ tarafından sulamaya açılan alanlarda modern sulama sistemlerinin oranı %38,4'e ulaşmıştır. Ayrıca, 2006-2024 arasında 350 binden fazla çiftçiye yağmurlama ve damla sulama sistemleri için %50 hibe desteği ve faizsiz kredi kullandırılarak yaklaşık 1,3 milyon hektar alanın modern sulama sistemleri ile sulanması sağlanmıştır.

Türkiye'de iklim değişikliğine bağlı krizlerden en az etkilenmek ve sürdürülebilir gıda arz güvenliğine sağlamak amacıyla;

- İklim Yasası ve Su Yasası çıkarılmalı, su yönetiminde risk esaslı bir yaklaşım benimsenmeli,
- Su ile ilgili kurumlar yeniden yapılandırılmalı; su kaynakları yönetimi ile ilgili stratejiler, politikalar ve tedbirler kurumsal yapıda yeniden ele alınmalı,
- Sulama altyapısı modernize edilmeli ve açık kanal sistemleri kapalı sisteme dönüştürülmeli,
- Modern sulama sistemleri ve akıllı tarım uygulamaları yaygınlaştırılmalıdır.
- Tarım arazilerinde mülkiyet sorunlarının çözümü için arazi toplulaştırması ve arazi bankacılığı uygulamaları entegre şekilde uygulanmalı,
- Enerji verimliliği artırılmalı ve maliyetler düşürülmelidir.
- Sulama şebekeleri sayısallaştırılmalı, sağlıklı izleme ve değerlendirme sistemleri kurulmalı ve sulama verimliliği sürekli izlenmelidir.
- Su kullanıcı örgütleri yeniden yapılandırılmalı ve güçlendirilmelidir.
- Sulama ve Tarım Bilgi Sistemleri entegre edilmelidir.
- Erken uyarı sistemleri kurulmalı ve iklim değişikliğinin etkileri önceden tespit edilmelidir.

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FFECTS OF CLIMATE CHANGE ON VEGETATION OF GRASSLANDS

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ABSTRACT

Climate change includes the increase in greenhouse gases and all values deviating from the average situation in the climate, together with the effect of global warming. An increase of over 30% has been observed in atmospheric carbon dioxide (CO_2) concentration in the last 50 years. It is predicted that this increase will continue. Climate change causes differences in temperature and precipitation during the year. These differences, which are also seen between years, are one of the other effects of climate change. Along with climate change, structural and species composition changes occur in the vegetation. There have been decreases in the number of plant species in some regions experiencing climate change. It is estimated that the number of cool season species will decrease even more, especially because they are more sensitive to rising temperatures. Global climate change significantly affects the yields of grasslands. The yield increases in the Western Hemisphere have been higher compared to the Eastern Hemisphere. In regions where the climate is cool, the effects of global warming are less felt. Efforts are being made to investigate the effects of climate change on the grassland ecosystem and to predict possible scenarios. Detailed studies are needed to be able to make reliable and guiding predictions about climate change for the future. According to current climate scenarios, it is predicted that global warming will have a significant impact on our country. Therefore, there is a need to develop drought stress tolerant plant varieties of forage crops, to select C_4 plant species that can adapt to various ecological regions, and to develop proper cultivation techniques for these species.

Keywords: Grassland, Climate, Greenhouse gas, Global warming, C_4 plant

İKLİM DEĞİŞİKLİĞİNİN ÇAYIR-MERA VEJETASYONLARI ÜZERİNDEKİ ETKİSİ

ÖZET

İklim değişikliği, küresel ısınmanın da etkisiyle beraber sera gazlarının artışını ve iklimde meydana gelen ortalama durumdan sapmış tüm değerleri içerir. Atmosferik karbondioksit (CO_2) konsantrasyonunda son 50 yılda %30'un üzerinde bir artış görülmüştür. Bu artışın devam edeceği öngörülmektedir. İklim değişikliği, yıl içinde yaşanan sıcaklık ve yağış miktarlarında ortaya çıkan farklara sebep olmaktadır. Aynı zamanda yıllar arasında da görülen bu farklar iklim değişikliğinin diğer etkilerinden birisidir. İklim değişikliğiyle beraber bitki örtüsünde de yapısal ve tür kompozisyonu bakımından değişimler ortaya çıkmaktadır. İklim değişikliği yaşanan bazı bölgelerde bitki tür sayısında azalmalar yaşanmıştır. Serin iklim bitkilerinin yükselen sıcaklıklara karşı daha duyarlı olmaları nedeniyle özellikle bu bitkilerin sayılarının daha da azalacağı tahmin edilmektedir. Küresel iklim değişikliği beraberinde meralardan alınan verimi önemli düzeyde etkilemektedir. Batı yarım küredeki verim artışları, Doğu yarım küreye bakılarak daha yüksek seviyelerde gerçekleşmiştir. İklim değişikliğinin çayır mera vejetasyonları üzerindeki etkilerini araştırmak ve olası senaryoları tahmin edebilmek için çaba harcanmaktadır. İklim değişikliği ile ilgili geleceğe yönelik güvenilir ve yol gösterici tahminlerde bulunabilmek için detaylı çalışmalara gerek duyulmaktadır. Mevcut iklim senaryolarına göre ülkemizde küresel ısınmanın önemli düzeyde etkili olacağı öngörülmektedir. Bu nedenle çayır mera yem bitkilerinde kuraklık stresine toleranslı bitki çeşitlerinin geliştirilmesi, çeşitli ekolojik bölgelere uyum sağlayabilecek C_4 bitki türlerinin seçilmesi ve bu türler için uyumlu yetiştirme tekniklerine ihtiyaç vardır.

Anahtar Kelimler: Çayır-Mera, İklim, Sera Gazı, Küresel Isınma, C4 bitkisi

1.GİRİŞ

İklim, bir yerde uzun dönemdeki atmosfer hareketlerini (sıcaklık, nem, hava basıncı, rüzgar, yağış, yağış şekli) ifade eder (NASA, 2019). Bir bölgenin iklimini anlamak ve tam olarak belirlemek için birçok unsura dikkat etmek gerekir. Geçmişten günümüze değişen dünyada iklim de aynı kalmamış ve birçok değişikliğe uğramıştır. Zaman içinde doğal oluşumlarla günümüze kadar gelen iklim son birkaç yüzyıl içinde insanoğlunun da etkisiyle gözle görülür ölçüde değişerek normal seyrinin dışına çıkmaya başlamıştır. İklim değişikliği ise kısaca, uzun bir zaman diliminde kendini gösteren iklim özelliklerinin ortalama durumdan sapması olarak tanımlanır (Türkeş, 2008).

Yeryüzünde yaşamsal faaliyetlerin gerçekleşmesi için ortam sağlayan atmosfer, birden fazla gazın bir araya gelmesiyle oluşur. Atmosferi oluşturan CO_2, CH_4, N_2O, O_3, CFC (kloroflorokarbon) gibi gazlar güneşten yeryüzüne gelen ısının bir kısmını tutarak yeryüzünün belirli bir ısıda kalmasını sağlarlar. Bunlarla beraber daha birçok gaz dünyanın sıcaklık dengesini korur ve yaşam koşullarını elverişli hale getirir (Akın, 2006).

İklim değişikliği denildiğinde akla gelen bir diğer konu da küresel ısınmadır. Küresel ısınma, insan faaliyetleri sonucu atmosferde bulunan sera gazlarının artması ve bununla beraber iklimde görülen değişikliklerdir (Bayraç ve Doğan, 2016). Atmosferde bulunan gazlardan en fazla sera etkisine sebep olan gazlar sırasıyla Karbondioksit (CO_2), Metan (CH_4), Diazotoksit (N_2O), Ozon (O_3), Karbon monoksit (CO) ve Halokarbonlar (CFC gibi)'dır. Bunun yanı sıra su buharı da bu gazlar arasında sayılmaktadır (Akın, 2006). Bu gazların artışı ilk olarak sanayi devriminde kendini göstermiş, fosil yakıtların da fazlaca kullanımıyla etkisini artırmıştır. Sera gazlarından etkinliği düşük ancak önemli bir yere sahip olan karbondioksit, 1950 yıllarına kadar 300 ppm civarında seyrederken, 1980-2014 yılları içerisinde 338ppm'den 398ppm'e yükselmiştir (Hatipoğlu ve ark., 2019). Günümüzde ise bu değer rekor miktara yükselerek 2021 yılının mayıs ayında 419,13 ppm olarak kaydedilmiştir.

2.İKLİM DEĞİŞİKLİĞİNİN GÖSTERGELERİ

Tüm iklim bilimcilerin hem fikir olduğu günümüzde de sıkça bahsedilen küresel ısınma belirtilerini gün geçtikçe iklim üzerinde göstermeye devam etmektedir. En başta sıcaklık artışı olarak karşımıza çıkan bu belirtiler kuraklık, çölleşme, yağışlarda görülen düzensizlikler ve dengesiz hava olayları olarak sıralanabilmektedir.

Küresel ısınma yeryüzündeki varlığını 1880 yılından bu yana devam ettirmektedir (Hatipoğlu ve ark., 2019). Hükümetlerarası İklim Değişikliği Paneli (IPCC)'nin 6.Değerlendirme Raporu'nda yer alan bilgilere göre; 2010-2019 yılları arasında görülen küresel ısınmanın 1850-1900 yıllarına göre 1,1 ºC arttığını, 2030 yıllarında ise tahmin edilen küresel sıcaklığın 1,5 ºC artacağı ve bu artışların devam edeceği öngörülmektedir (Kara ve Yereli, 2022).

Türkiye iklim yapısının değişkenli olması, üç tarafının denizlerle çevrili oluşu ve parçalı topoğrafik yapısıyla iklim değişikliğinden en fazla etkilenecek ülkelerden biri olacağı gibi etkilerinin bölgesel olarak da değişeceği bilinmektedir. Güneydoğu Anadolu ve İç Anadolu bölgesi gibi daha çok çölleşme tehdidiyle beraber kuraklığın hakim olduğu bölgelerle, yetersiz

su miktarına sahip olan yarı nemli Ege ve Akdeniz bölgeleri olası sıcaklık artışından etkileneceklerdir (Öztürk, 2002).

İklim değişikliğine bağlı yüzey sıcaklığında bölgesel olarak farklar Türkiye'nin doğu ve iç kısımlarında kış sıcaklıklarında daha çok artış, güney ve güneydoğu bölgelerinde ise yaz sıcaklıklarında daha fazla artış olarak beklenmektedir. Son dönemde yüzey sıcaklığı artışları, Türkiye'nin güneydoğu ile güneybatı bölgelerinde yaklaşık 6 ºC'ye ulaşırken, Karadeniz ve Marmara bölgelerinde sadece 3 ºC dolayında kalacağı tahmin edilmektedir (Hatipoğlu ve ark., 2019).

Küresel ısınma sonucunda Türkiye'nin yaşayacağı en ciddi problem kuraklıktır. Ülkenin büyük bir kısmı yarı-kurak iklim etkisindedir ve küresel ısınmadan oldukça fazla etkilenecek ülkelerin başında gelir. Bunun öncelikli nedeni Türkiye'nin yakın güneyinde çöl kuşağının bulunması ve ısınmayla beraber bu kuşağın kuzeye doğru hareket etmesidir. Sıcaklıkta görülecek 1-3.5 ºC arası artış, orta enlemlerin 150-500 km kutuplara doğru ilerlemesine neden olacaktır (Kanat ve Keskin., 2018).

IPCC, önümüzdeki birkaç on yıl içinde 1,5 ºC sıcaklık artışını aşma konusunda yüzde elli ihtimalin olduğuna dikkat çekmektedir. Örnek olarak yaz aylarındaki sıcaklık ortalamaları yükselirken kış ayları için sıcaklık ortlamalarının azalacağı değerlendirilmekte, dolayısıyla daha sıcak daha az yağış alan ve daha fazla buharlaşmanın olduğu iklim koşullarına maruz kalınacağı öngörülmektedir (Kara ve Yereli, 2022).

Güler ve Erlat.(2023) Türkiye'de yaşanan ortalama hava sıcaklıklarındaki en belirgin artışın yaz mevsiminde gerçekleştiğini bildirmişlerdir. 1950-2022 döneminde görülen ortalama sıcaklıklar istatistiksel olarak 0.01 düzeyinde anlamlı olmak üzere her on yıl için 0.22 ºC yükselme eğilimi göstermiştir. Bu artış eğilimi, son 73 yılda Türkiye'de yaz mevsiminde ortalama hava sıcaklıklarının 1.61 ºC yükseldiğini ortaya çıkarmaktadır. Yaz mevsiminden sonra artışlar kuvvetli olarak ilkbahar mevsiminde de devam etmektedir. 2021 Mayıs ayı son 73 yılın en sıcak Mayıs ayı olmuştur. Sonbahar mevsiminde ise 2010 yılından itibaren sıcaklık ortalamalarında belirgin olarak bir atış gözlemlenmiş ve 2015, 2017 ve 2020 yıllarında bu değer 21 ºC üzerine çıkmıştır (Güler ve Erlat, 2023).

İklim değişikliğinin bir diğer etkisi de iklimin yıl boyunca ve yıllar arasında büyük değişim ortaya çıkarmasıdır ve bu değişim ekolojik olarak fazlaca öneme sahiptir. 2100 yılında atmosferdeki CO_2 konsantrasyonun 538 ppm kabul edildiği teorilere göre Kuzey Avrupa ülkelerinde hem yaz hem de kış döneminde olmak üzere yağışların %10-20 artacağı öngörülmektedir. Bunun yanında Akdeniz bölgesinde kış dönemindeki yağışın %10, yaz dönemindeki yağışın ise %10-20 azalacağı tahmin edilmektedir (Hatipoğlu ve ark., 2019).

Türkiye'de yıllar boyunca yağış ortalaması 631 mm olmasına rağmen, 1999 yılında %15 oranında, 2000 yılında ise %7 oranında azalmıştır (Öztürk, 2002). Genellikle, yağış Türkiye'nin Ege ve Akdeniz kıyılarında azalmakta, Karadeniz kıyılarında ise artmaktadır. İç Anadolu bölgesinde yağış bakımından çok az veya hiçbir değişiklik görülmemektedir (Kanat ve Keskin, 2018).

Meteoroloji Genel Müdürlüğü (MGM) istatistiklerine göre Türkiye 2024 yılı kış mevsimi (2023 Aralık, 2024 Ocak, Şubat) yağışları normalin altında, önceki yıl kış mevsimi ise yağışlarının

üzerinde olmuştur. Kış mevsimi normali (1991-2020) 205.3 mm, geçen yıl kış mevsimi yağışı 114.8, 2024 yılı kış mevsimi yağışı ise 190.5 mm olarak gerçekleşmiştir. Mevsim yağışlarında normaline göre %7 azalma görülürken, geçen yıl kış mevsimi yağışlarına göre %66 artma gözlenmiştir. Bölgesel olarak değerlendirme yapıldığında ise Doğu ve Güneydoğu Anadolu bölgeleri normalleri üzerinde, diğer bölgeler altında yağış almıştır. En çok azalma gözlenen bölge %29 ile Ege Bölgesi olmuştur.

Küresel ısınmanın bir diğer etkisi de buzulların erimesidir. Geçmiş yirmi yıllık dönemde Grönland ve Antertika buz kalkanları ve adaları kütle kaybetmiş, buzullar küresel ölçekte erimesini sürdürmüş, Antik deniz buzunu ve Kuzey Yarım Küre ilkbahar kar örtüsü alansal olarak azalmasını devam ettirmiştir (Edemen ve ark., 2023).

3.İKLİM DEĞİŞİKLİĞİNİN ÇAYIR-MERALAR ÜZERİNDEKİ ETKİLERİ

Dünya tarihi boyunca yeryüzünde bulunan vejetasyonda çok önemli boyutta değişim gerçekleşmiştir. Bu değişimin en belirgin sebebi iklimde yaşanan farklılıklar olmuştur (Hatipoğlu ve ark., 2019).

Bütün canlılar için vazgeçilmez bir yere sahip olan bitkiler, iklim değişikliğinden fazlaca etkilenmektedir. Özellikle değişken olan iklim olaylarıyla birlikte bitki türlerinin tehdit altında olduğu ve türlerin %10 azalma riski ile karşı karşıya kaldığı bilinmektedir. Yağış ve sıcaklıklarda gerçekleşecek değişiklikler bu zamana kadar coğrafyalarındaki iklim tiplerine adapte olmuş bitkilerin, yeni iklim olaylarıyla karşı karşıya kalmalarına ve stres altında olmalarına sebep olacaktır (Aydın ve Sarptaş, 2018).

Günümüzden yaklaşık 66-144 milyon yıl önce yani dinazorların dünyada dominant olduğu dönemde buğdaygiller ve çift çenekli bitkiler ortaya çıkmıştır. 144-206 milyon yıl önceki dönemde ise iklim, günümüzde olan durumuna göre çok daha üniform bir şekilde sıcak ve nemli olduğu gibi tropikal ormanlar da yaygındı. Zaman geçtikçe iklimde faklılaşmalar görülmüş, nemli havalar yerini giderek kuru havalara bırakmış ve tropik ormanlar daralarak buğdaygil meraları genişlemiştir. Şimdiki zamandan 1,8-65 milyon önceki dönemde yeryüzü daha serin ve kurak hale gelmiş ve buğdaygil meraları daha da yaygınlaşmaya devam etmiştir. 2,5 milyon yıl önce yeryüzündeki soğuma artış göstermiş ve Avrupa kıtasındaki subtropik vejetasyon değişerek yerini ılıman iklim türleri kaplamıştır. Günümüzden 18000 yıl öncesine baktığımızda Kuzey-Batı Avrupa kısmen buzullarla kaplanmıştır. Kutup ikliminin etkili olduğu Batı Avrupa tundra vejetasyonuyla, Akdeniz bölgesi ise steplerle kaplı hale gelmiştir. Sadece Balkanlar'da iğne yapraklı ve geniş yapraklı ağaçların hayatlarını devam ettirebileceği bir habitat oluşmuştur. Kuzey Amerika'da halen 400-600 mm yağış görülen büyük ovaların günümüzden 12000-14000 yıl önce ladin ve yaprağını döken ağaçlarla örtülü olduğu bildirilmektedir. Grönland'da 1990-1992 yılları arasında yerin 3000 metre derinliğinden alınan buzul örnekleri Kuzey yarımküredeki sıcaklık değişimlerini net olarak ortaya koymuştur (Hatipoğlu ve ark., 2019). Mevcut zamanda olduğu gibi 9000 yıl öncesinde de kitleler halinde buzul erimesi görülmüştür. Bu ısınma dönemi 20 yıldan fazla sürmemesine rağmen buzulların erimesi aşırı yağışlara, deniz sularında ve akarsularda yükselmeye sebep olmuştur. Dünyanın kuzey bölgelerinin buzlarla kaplı olduğu zamanda Amazon bölgesinde iklimin oldukça kurak olduğu ve bu yerlerin seyrek bir şekilde ağaçların bulunduğu geniş savan bölgeleri olduğu anlaşılmıştır. Amazon bölgesinin kapalı ormanlarla kaplı hale gelmesi günümüzden 10000 yıl önce gerçekleşmiştir. Şu anda

ekstrem kurak bölge olarak bilinen Sahra bölgesinin oluşumu günümüzden 5000 yıl önce başlamış ve daha sonra çöl hızlaSahel bölgesine uzamıştır. 5000 yıl öncesinde Sahra bölgesinin bozkırla kaplı olduğu anlaşılmıştır. 900-1000 ile 1200-1300'lü yıllar arasında dünyada ortalama sıcaklık ortalamanın üzerinde görülmüştür. 1000-1300 yılları arasında ise İngiltere'nin güney bölgesinde üzüm bağlarının oldukça yaygın olduğu bildirilmektedir (Hatipoğlu ve ark., 2019).

Bu üzüm bağı sınırı günümüzde Fransa ve Almanya'daki üzüm bağı yetiştiriciliği sınırının 500 km kuzey enlemlerine uzaması olarak anlaşılır. Buzulların kuzeye doğru yayılmasıyla birlikte Arktik okyanus buz miktarında artışlar gözlenmiştir. İzlanda'da bulunan tarım arazileri buzullarla kaplanmıştır. İzlandalılar ciddi bir iklim değişikliği yaşayarak ülkelerini terk etmek zorunda kalmışlardır. Grönland' da bitki hasatları başarısız olmuş ve çiftlikler bırakılmıştır. Küçük buzul çağında küresel sıcaklık ortalama 1-2 derece düşmüş ve birkaç yüzyıl boyunca bu düşüş devam etmiştir. Baltık denizi ve Thames nehri donmuştur. Avrupa'da kıtlık ve hastalıklar yaygınlaşmış ekimler başarısız olmuştur.

Yukarıda yeryüzünde tarih içinde iklim değişikliğiyle ilgili olarak bahsedilenlerin aksine, Mann ve ark., (1998) son 1000 yılın iklim olaylarını incelediklerinde yıllık ağaç halkaları, buz çekirdeği, mercan ve silt örneklerine göre, kuzey kutbunda yaklaşık son 900 yılda sıcaklığın nispeten stabil olduğu, 1900'den sonra sıcaklığın aniden yükselmeye başladığı sonucuna ulaşmışlardır. McIntryre ve McKitrick (2005), Mann ve ark., (1998)' nın yönteminde hatalar olduğunu Mann ve ark., (1998)'ın iddia ettiği gibi yeryüzünde sıcaklık artışının 20. yüzyılda değil 15. yüzyılda olduğunu açıklamışlardır.

Günümüzde dünyanın tüm bölgelerinde ortalama sıcaklığın arttığı kabul edilmektedir. İklim değişikliğiyle beraber flora da değişmektedir. Son 30 yılda Avrupa'nın bazı bölgelerinde tür sayısı azalmıştır ve buna habitat kaybı ve iklim değişikliğinin sebep olduğuna inanılmaktadır. Buna karşılık Hollanda'yı da içeren batı Avrupa'nın belirli bölgelerinde artan sıcak iklim sebebiyle tür sayısı artmıştır. Bunun yanında serin iklim türlerinin sayısında azalma görülmüştür (Hatipoğlu ve ark., 2019). Serin iklim türlerinin yüksek sıcaklıklara uyum sağlayamaması nedeniyle 21. yüzyılda Avrupa'da tür sayısının fazlaca azalacağı tahmin edilmektedir. Sonuç olarak ise Hollanda'da bitkilerin büyüme zamanı son 30 yılda 10-14 gün uzamıştır.

3.1. KARBONDİOKSİT KONSANTRASYONU ARTIŞININ ÇAYIR-MERALAR ÜZERİNDEKİ ETKİLERİ

Fotosentez için mutlak gerekli unsurlardan biri karbondioksittir. CO_2 miktarında artışla beraber bitki büyüme hızı da artmaktadır. $C0_2$ seviyesinde görülen iki katı artış sıcaklık ve nem gibi diğer faktörlere bağlı olarak fotosentez oranını %30 ile %100 dolaylarında artırmaktadır. Fakat bitki türlerinin fotosentez sistemlerindeki farklılıklarından dolayı CO_2 artışına tepkileri de değişmektedir (Özer ve Özer, 2003). İsviçre ve Yeni Zelanda'da yürütülen çalışmalarda baklagiller ve diğer çift çenekli bitkilerin buğdaygillere göre yüksek CO_2 konsantrasyonuna daha çok tepki gösterdiği ileri sürülmüştür (Hatipoğlu ve ark., 2019).

C_3 bitkileri yeryüzünde sayıca fazla bulunan ve en fazla yayılım gösteren bitki grubudur. Bu bitkiler yeterli ışıklanma şartlarında 800-1000 µmol /mol CO2'ye ihtiyaç duyarlar. Bu yüzden

bu bitkiler mevcut atmosferik karbondioksit konsantrasyonu koşullarında doymamış fotosentez metabolizmasına sahip bitkilerdir. Bunun yanında fotosentez işlevi bakımından ikinci büyük bitki grubu olan C_4 bitkileri ise 370 ppm'lik mevcut atmosferik CO_2 konsantrasyonu koşullarında doymuş fotosentez metabolizmasına sahip bitkilerdir.

Mevcut atmosferde bulunan CO_2 miktarı C_3 bitkilerinin fotosentez etkinliğini sınırlamaktadır. Küresel iklim değişikliğiyle beraber olası CO_2 miktarının artması bu bitkilerin fotosentez etkinliğini olumlu yönde değiştirebilir. C_4 bitkileri ise C_3 bitkilerine göre CO_2 miktarı artışına daha az tepki göstermektedir (Yavaş ve Ünay, 2018). CO_2 konsantrasyonu 377 ppm'den 550 ppm'e artırıldığında kuru madde verimi artışı C3 bitkilerinde %10-20, C4 bitkilerinde ise %0-10 olduğu ortaya çıkmıştır. Cullen ve ark. (2009), atmosferde bulunan CO_2 miktarının 380 ppm'den 550 ppm'ye yükseldiği senoryada Güney Avustralya'da C_3 bitkilerinin yoğunlukta olduğu meralarda ortalama mera veriminin %24-29, C_4/C_3 bitkilerinin karışık olarak bulunduğu meralarda %17 ve C_4 bitkilerinin yoğun olduğu meralarda ise %9 artış göstereceğini tahmin etmişlerdir. Bitkilerin CO_2 artışına kuru madde verimi tepkilerinin linear olduğu kabul edildiğinde, atmosferdeki CO2'nin 1 µmol /mol artışı kuru madde veriminde %0,1-0,12 yükselmeye sebep olmaktadır. Bu bilgiler doğrultusunda endüstri devriminin başladığı yıldan 1990'lı yıllara kadar olan dönemde C_3 bitkilerinin kuru madde verimi CO_2 konsantrasyonunun 280 ppm'den 355 pppm'e çıkmış olması nedeniyle %7,5-9,0 artmış olması gerekir. Fakat, İngiltere'deki Rothamsted araştırma istasyonunda 100 yıldır otlatılmayan bir meradan alınan veriler CO_2 artışının herhangi bir kuru madde verimi artışına neden olmadığını ortaya koymuştur.

Yapılan bazı araştırmalara göre C_4 bitkilerinin artan karbondioksit konsantrasyonuna fotosentetik ve büyüme olarak ortalama tepkilerinin C_3 bitkilerine göre daha düşük olmasına karşılık bu farklılıkların beklendiği kadar yüksek olmadığı gösterilmiştir (Hatipoğlu ve ark., 2019).

Yükselen CO_2 miktarı bitki stomalarının kapanmasına neden olarak, daha az su kullanmalarını ve daha fazla karbonhidrat üretmelerini sağlamaktadır. Gerçekleşen bu kısmi kapanma, fotosentezden çok transpirasyona etki etmektedir. CO_2 konsantrasyonunda olan artış hem C_3 hem de C_4 bitkilerinde stoma geçirgenliğini %30-40 oranında azaltmakta ve terlemede %23-46 oranında azalma görülmektedir (Özer ve Özer, 2003).

Bitkilerde stoma kapanması transpirasyonu azaltmakta ve daha yüksek bitki ve toprak su potansiyeline sebep olarak su kullanımını artırıp daha fazla biyomas üretimine neden olmaktadır. Özellikle su faktörünün kısıtlayıcı olduğu doğal meralarda bu durum biyomas üretiminde fazlaca etkili olabilmektedir. Öte yandan, uzun zaman yüksek CO_2 konsantrasyonuna uğrayan C_3 bitkilerinin fotosentez miktarlarını düşürerek fotosentetik uyum sağlaması bu bitkilerin yüksek CO_2 şartlarında gösterdikleri fotosentez artışını azaltabilir ve hatta artışı tamamen ortadan kaldırabilir. Yükselen CO_2 konsantrasyonuna fotosentezin uyum sağlaması C_3 ve C_4 bitkileri arasındaki yüksek karbondioksite karşı gösterilen tepki farklılığını azaltır.

Kimi bitkiler karbon asimilasyonu ve bu asimilatların büyüme gelişmelerinde kullanımı arasındaki denge stratejilerindeki değişiklikler sebebiyle yüksek CO_2 konsantrasyonuna daha çok tepki gösterebilmektedirler. Otsu C_3 bitkilerinin karbondioksit artışına tepkisi, yabani C_3

bitkilerine göre daha fazla olduğu bildirilmektedir (Poorter, 1993). Ayrıca hızlı büyüyen yabani C_3 bitkilerinin yavaş büyüyen C_3 bitkilerine göre CO_2 konsantrasyon artışına gösterdiği tepki daha fazla olmaktadır.

Baklagiller CO_2'e en fazla reaksiyon gösteren bitki grubudur. Bu durumun nedenlerinden biri de bu bitkilerin atmosferik azotu fikse edebilmeleridir. Yeterli olmayan azot bitkilerin yüksek CO_2 konsantrasyonu şartlarına fotosentetik uyum göstermesi ve zayıf büyüme yapmasının en önemli nedenlerinden biridir. Bu yüzden baklagil bitkilerinin atmosferik azotu organik bileşiklere dönüştürmesi baklagil dışındaki bitkilere göre bir avantajdır. Ancak, baklagil bitkileri fosforca fakir topraklarda ve fazla miktarda azot uygulanan topraklarda bu avantajını kaybeder.

Geniş yapraklı bitkiler buğdaygillerle karşılaştırıldığında yüksek CO_2 konsantrasyonuna daha fazla reaksiyon gösterirler. Bunun nedeni ise tam olarak açıklanamamıştır.

Yüksek CO_2 konsantrasyonunda gelişim gösteren bitkilerin solunumu da etkilenebilir. Bu durum hem atmosfer hem de bitki açısından önemlidir. Çünkü, C_3 fotosentez mekanizmasında fikse edilen C'nun yarısı solunumla atmosfere geri gönderilebilir. Yüksek CO_2 koşullarında solunumun azaldığı ile ilgili bazı araştırma sonuçları vardır. Bununla birlikte CO_2 genellikle kök/sürgün oranını arttırdığı için ve kök sisteminin spesifik solunum oranı sürgünlerden daha fazla olduğu için CO_2 konsantrasyonu arttıkça bitki solunumu da artma gösterebilmektedir (Hatipoğlu ve ark., 2019).

3.2.KÜRESEL ISINMA VE YÜKSEK CO_2 KONSANTRASYONUNUN ÇAYIR-MERALAR ÜZERİNDEKİ ETKİSİ

İklim değişikliğinin olumsuz etkilerinden en belirgini, bitki gelişmesinde görülen yüksek sıcaklığın vermiş olduğu zararlardır. Bu durumun olumsuz etkileri genellikle tuzluluk ve kuraklık stresiyle beraber değerlendirilmektedir. Yükselen sıcaklıkların olumsuz etkileri arasında en önemli görüleni gelişme dönemi sürelerinin farklılaşması olarak belirtilmiştir. Sıcaklığın meristem/organ büyümesine yardımcı olarak daha hızlı gelişime neden olacağı ve bunun da daha küçük bitki organeli ve daha az biyokütle birikimine yol açacağı ve çoğunlukla generatif döneme erken geçişi teşvik edeceği söylenmiştir. Yüksek sıcaklıklar bitkiyi bütün gelişim evrelerinde etkilemekle birlikte özellikle tozlanma ve dane dolum gibi gelişme dönemlerinde daha fazla etkilemektedir (Yavaş ve Ünay, 2018).

Rustad ve ark. (2001), küresel ısınmanın etkileri sonucunda 21. Yüzyılda tundra, çayır-mera ve orman biyomlarında primer üretimin %19 artacağını tahmin etmişlerdir. Primer üretimin özellikle tundra gibi serin ekosistemlerde daha çok olacağı öngörülmüştür. Yüksek CO_2 konsantrasyonunun bitki büyümesindeki olumlu etkisi sıcaklık artışıyla doğru orantılı olarak artar. C_3 bitkilerinde yükselen sıcaklıklarda CO_2 artışı ile büyümenin teşvik edilmesi fotorespirasyondaki değişim ve CO_2'i fikse eden RuBisCo enziminin aktivitesi ile alakalıdır. Birden fazla bitkide yüksek sıcaklık karbonhidrat üretiminde kullanılacak CO_2 isteğini artırır ve böylece büyüme teşvik edilir. Bu yüzden, yüksek CO_2 konsantrasyonunun ılıman bölge çayır-meralarında primer üretime katkısının büyük ölçüde mevsime bağlı olması muhtemeldir (Hatipoğlu ve ark., 2019).

Gerçeğe yakın tahminlerin çoğunluğunda atmosferin CO_2 içeriğinin artması ve yüzey sıcaklığı ve yüzey sıcaklıklarında artışla çayır-meraların çoğunluğunda primer üretimin artacağı tahmin edilmektedir. Primer üretim artışının derecesi ise ekosistemlere ve diğer çevre koşullarına bağlı olarak değişecektir. Yüksek sıcaklığın primer üretimi artırıcı yönü özellikle düşük sıcaklıkların yüksek CO2 konsantrasyonuna tepkiyi azalttığı yüksek yerlerde ve yüksek ve orta enlem derecelerindeki bölgelerde bulunan çayır-meralarda olabilir.

3.3.YAĞIŞ, SICAKLIK VE YÜKSEK CO2'İN ÇAYIR-MERALAR ÜZERİNDEKİ ETKİSİ

Çayır-meralarda primer üretimdeki farklılıkların %90'ının sebebi yıllık yağışta görülen değişimlerdir. Gao ve ark., (2016), 1982-2011 yılları içerisinde sıcaklık ve yağış miktarlarını değerlendirerek iklim değişikliğinin yeryüzündeki meraların %40'ında verimi büyük ölçüde etkilediğini, bahsedilen dönemde iklim değişikliğinin çayır-meraların verimliliğindeki varyasyona katkısının %15,2-%71,2 olduğunu, uzun dönemde özellikle Kuzey Amerika, Orta Avrasya, Orta Afrika ve Okyanusya'daki meraların iklim değişikliğine duyarlı olduğunu, iklim değişikliğinin çayır-meraların verimindeki varyasyona katkısının batı yarım kürede doğu yarım küreye göre daha yüksek olduğunu bildirmişlerdir.

Nemi oldukça fazla ve verimli meralarda yağış miktarındaki farklılıklar çok büyük değişime yol açmayacaktır. Fakat mevsimlik üretim yağışın miktar ve dağılımıyla ilişkili olduğu için iklim değişikliği ile ilgili yağış rejimi değişimi bu tip meralarda da etkili olacaktır. Yağış miktarındaki artış çoğunlukla çayır-meralarda verime olumlu etki eder. Kuvvetli yağışlar yüzey akışı ve erozyon artışına sebep olacaktır. Küresel ısınmanın kuraklık etkisi iklim değişikliği ile yağışın fazla etkilenmeyeceği veya azalacağı dünyanın kurak veya yarı kurak kısımlarında özellikle önem kazanacaktır. Aynı zamanda CO_2 konsantrasyonunun artışı su kullanım etkinliğinin yükselmesine neden olacaktır. Bundan dolayı küresel iklim değişikliği sonucu yağış miktar ve dağılımında oluşacak değişime hidrolik ve bitkisel üretim açısından tepki yağışın sıcaklık ve karbondioksitle olan karmaşık interaksiyonlarına bağlıdır. Reeves ve ark. (2014), iklim değişikliği neticesinde ABD meralarında ortalama yıllık net primer üretimin %0.26 yükseleceği, ancak bu artışın 2030 yılına kadar bariz olarak ortaya çıkmayacağını ve artışın bölgelere göre önemli derecede farklılık göstereceğini bildirmişlerdir. ABD'nin güneybatı bölgelerinde bulunan meralarda 2100 yılına kadar net primer üretimde %7 azalma olacağı, kuzey ve güney ovaları, iç batı ve doğu ovalarındaki meralarda ise primer üretimin %25 artacağı öngörülmüştür.

3.4..İKLİM DEĞİŞİKLİĞİNİN ÇAYIR-MERALARDA BİTKİ ÜREMESİNE ETKİSİ

Üreme, tohumla çoğalan bitki türlerinin hayatta kalması ve evrimi için hayati öneme sahiptir. Üreme safhası bitki yaşam döngüsüne bakıldığında kısa olarak gözükse de, bu aşama özellikle olumsuz koşullara karşı oldukça hassastır (Gellesch ve ark., 2017).

Atmosferde görülen CO_2 konsantrasyonundaki artış ve iklim değişikliği bitkinin gelişmesi yanında bitki üremesinde de etkisi olması bakımından çayır-meralarda üretimi, tür kompozisyonunu ve özellikle biyoçeşitliliği etkiler. CO_2'in bitki popülasyonunda yeni türlerin

meydana gelmesi üzerine etkili olduğu birkaç mekanizma vardır. Yükselen CO_2 konsantrasyonu çoğunlukla tohum sayısında ve tohum büyüklüğünde artışa neden olur. Ancak bu olgu türlere ve çevre koşullarına bağlıdır. Genellikle artan CO_2 konsantrasyonu üreme ile alakalı bir özelliği olumlu etkilerken diğerini olumsuz etkiler (Hatipoğlu ve ark., 2019). Bu olumsuzluk tohum sayısı ve tohum iriliği arasında görülür. CO_2 konsantrasyonundaki artışın tohum sayısı, büyüklüğü ve dağılımı üzerindeki etkisi kurak ve yarı kurak bölge meralarında görüldüğü gibi fide oluşumunun tohum sayısını etkilediği durumlarda etkili olabilir. Bu durum nemli meralarda daha az önem taşır. Tohum iriliği üreme başarısının iyi bir belirtisi olmayabilir. Mera bitkilerinde çimlenme ve fide gelişimi için uygun toprak sıcaklığı ve nem önemli faktörlerdir. Bu yüzden toprak su dinamiğine etki eden sıcaklık ve yağıştaki herhangi bir farklılık çimlenme ve fide gelişimini de etkiler. Yüksek CO_2 konsantrasyonu bitki transprasyonunu azaltmasıyla beraber toprak su içeriğini olumlu yönde etkileyerek dolaylı olarak fide gelişimini de etkiler (Hatipoğlu ve ark., 2019).

3.5. İKLİM DEĞİŞİKLİĞİNİN ÇAYIR-MERALARDA BİTKİ KÖK BÜYÜMESİNE ETKİSİ

Çayır-meralarda bulunan bitkilerin kök sistemiyle birlikte yeraltı kısımlarının çoğunda C depolanmaktadır ve bu yüzden iklim değişikliğinden doğrudan etkilenmektedirler. Fakat bazı çalışmalarda ise sıcaklık ve CO_2 artışına kök sistemlerinin farklı tepkiler gösterdiği belirtilmiştir. Artan CO2 konsantrasyonunda kök üretimi çoğalabilir, azalabilir veya hiç yanıt vermez. Bugüne kadar sıcaklık artışı, yağış azalması ve artan CO_2'nin bitki kök bölgesi üzerine etkilerinin incelendiği çok az çalışma bulunmaktadır (Pilon ve ark., 2013).

Verimli çayır-mera alanlarında CO_2 artışına büyüme tepkisi çoğunlukla daha fazladır ve bu fazla büyüme toprak altı organlarında toprak üstü organlara göre daha fazladır. Küresel sıcaklığın artmasıyla birlikte toprak sıcaklığı da artar. Sonuç olarak ise toprak su besin maddeleri miktarı yeterli düzeyde olduğu kabul görüldüğünde kök üretimi ve ölümü artar. Su ve besin maddelerinin yeterli düzeyde olmadığı doğal ekosistemlerde artan sıcaklıklara karşı kök aktivitesinin reaksiyonlarını tahmin etmek zordur. Kuraklığın hakim olduğu meralarda yağış artışı kök aktivitesini artıracaktır. Nemli meralarda ise yağışın artmasıyla beraber kök aktivitesi hem olumlu hem de olumsuz sonuçlar verebilir. Kurak koşullarda artan yağışa toprak altı organların tepkisi besin maddeleri mineralizasyonunun ve kök aktivitesinin artması olarak sonuçlanacaktır. Nemli durumlarda köklerle ilgili olumsuz etkiler; mobil elementlerin yıkanması, azotun denitrifikasyon ile kaybı ve toprak erozyonu olabilir.

Atmosferik CO2'nin artışı verimi yüksek meralarda toprak altı sistemlerin verimini ağırlıklı ölçüde artırabilmesine karşılık, düşük verimli meralarda bu artış sınırlıdır (Hatipoğlu ve ark., 2019).

3.6.İKLİM DEĞİŞİKLİĞİNİN ÇAYIR-MERALARDAKİ BESİN MADDELERİ DÖNGÜSÜ VE TOPRAK ÜZERİNDEKİ DİĞER ETKİLERİ

İklim değişikliği, yağış rejimlerinde ve sıcaklık desenlerinde değişikliğe neden olarak topraktaki besin maddelerinin dağılımını ve miktarını etkileyebilir. Yükselen sıcaklıklar ve

azalan yağışlar bitki örtüsünü etkileyerek, bitkiler tarafından kullanılan besin maddelerinin miktarını değiştirebilir. Bunun sonucunda toprak verimliliği ve besin döngüsü üzerinde etkiler görülebilir. Yüksek CO_2 konsantrasyonlarında yapılan ve CO_2'e bağlı koşullarda verim değişikliğinin ortaya çıktığı çalışmalarda bitki toprak üstü aksamında azot içeriği düşük olmaktadır. Yüksek CO_2 koşullarında bitkinin kaynak kullanım etkinliğinin artması bu durumun kısmen nedenlerinden sayılabilir. Yüksek CO_2 konsantrasyonu sebebiyle verimin artışa geçmesi toprağa daha çok karbonlu madde girişine neden olur. Bu durumunda etkisiyle mikrobiyal büyümeyi gerçekleştirir ve başlangıçta toprak besin maddeleri hareketsiz kalır. Fakat, mikrobial biyomasın artışı sonucunda daha fazla besin maddesi mineralizasyonla toprağa geri döner. Uzun zaman içinde toprak besin maddesi döngüsü organik madde girişindeki değişimle uyum içine girer ve bitkilerin alabileceği formdaki besin maddeleri miktarı CO_2 zenginleşmesi sonucu ortaya çıkan talebi karşılayacak hale gelebilir. Yapılan denemelerin çoğunda CO_2 zenginleşmesi sonucu kök-sürgün oranının artışı karbondioksit zenginleşmesi sonucu bitkide ortaya çıkan azot açığına dolaylı bir tepki olarak yorumlanmıştır. Böyle durumlarda bitki topraktan alacağı azot miktarını artırmak için toprak altı organlara daha fazla karbonhidrat göndermektedir. Uzun süreli karbondioksit zenginleşmesi koşullarında bitkinin bu duruma uyum sağlayarak zaman içerisinde karbondioksit zenginleşmesine fotosentetik ve büyüme açısından daha az tepki göstermesinin bitkinin azot eksikliği koşullarında karbonhidrat depolaması ile ilgili olduğu ortaya çıkmıştır (Hatipoğlu ve ark., 2019).

Nemli bölgelerde görülen yüksek sıcaklıklar, çayır-meralarda daha çok organik madde ayrışmasına neden olabilir. Ancak bu durum kurak bölge meraları için geçerli değildir. Genellikle sıcak bölgelerde soğuk bölgelere kıyasla toprak solunumu ve organik madde ayrışmasının daha fazla olduğu bilinir. Bununla birlikte organik maddenin ayrışması sıcaklık ve toprak suyu ile ilgilidir. Bitki ihtiyaç duyduğu suyu bulamadığı için çürüme ve toprak solunumu üzerindeki sıcaklık etkisi azalır. Atmosferik karbondioksit konsantrasyonu artışı toprak su dinamiğini etkilediği ölçüde organik madde ayrışmasını da etkileyecektir (Hatipoğlu ve ark., 2019).

3.7. İKLİM DEĞİŞİKLİĞİNİN ÇAYIR-MERA BİTKİ TOPLULUĞUNA ETKİSİ

Bitkilerin dağılış şekilleri yağışın miktar ve dağılımı ile sıcaklıktan çok önemli boyutta etkilenir. Toprak-su dengesine etki eden herhangi bir iklim değişikliği bitki popülasyonunu büyük derecede etkileyecektir. İklim değişikliğiyle beraber dünyanın belirli yerlerinde yağışın artacağının öngörülmesi yanında yağış şiddetinin artması sebebiyle suyun arazi üzerindeki dağılımı düzensiz olacak ve bazı bölgeler daha kurak olacaktır. Çayır-meralara düşen yağış şekli suyun düşey dağılımını ve bitki kök sistemlerinin derinliğini önemli derecede değiştirecektir.

Bitki topluluklarının dağılımında önemli faktörlerden biri de sıcaklıktır. Bugün tropikal enlem derecelerinde C_4 buğdaygilleri daha yoğunlukta görülmektedir. İklim değişikliğinin hem sıcaklık hem de yağışlarda görülen etkilerini dikkate alan iklim modellerinde Kuzey ve Güney Amerika çayır-meralarında C_4 buğdaygillerinin artacağı ve C_3 buğdaygillerinin azalacağı tahmin edilmektedir.

Çayır-mera bitki topluluklarının küresel ısınma ve yağış değişikliklerine uzun dönemdeki tepkileri daha çok toprak besin maddeleri döngüsü ve su dinamiği tarafından belirlenecektir. Bitki topluluklarının yayılışının değişimi iklim değişikliğinin derecesine bağlı olacaktır (Hatipoğlu ve ark., 2019).

3.7.1. ATMOSFERİK CO2 KONSANTRASYONU ARTIŞININ BİTKİ TOPLULUĞUNA ETKİLERİ

Atmosferik karbondioksit konsantrasyonunun artışına bitkilerin bireysel tepkilerinin ne olduğu bakımından birçok araştırma yapılmıştır. Fakat, çeşitli bitkilerin bir araya gelerek karmaşık bir yapı oluşturduğu topluluklarda yapılan araştırmalarda bireysel bitkilerin CO_2 artışına tepkisinin söz konusu bitkinin karmaşık bitki topluluğundaki tepkisinin iyi bir göstergesi olmadığını göstermiştir. Örneğin, baklagiller CO_2'e karşı çok iyi tepki gösteren bitkilerdir. Bunun yanında, He ve ark. (2002), fazlaca tür zenginliği gösteren bitki topluluklarında N fikse eden bitkilerin yüksek CO_2 konsantrasyonlarında daha az miktarda biyomas ürettiğini belirlemişlerdir. Zengin çeşitlilik gösteren ekosistemlerin yükselen CO_2 konsantrasyonuna daha iyi adapte olduğu ve daha yüksek reaksiyon gösterebildiği açıklanmıştır. İklim değişikliğinde olduğu gibi atmosferik karbondioksit artışının su ve besin maddesi döngüsü üzerindeki uzun dönemdeki etkileri türlerin ve ekosistemlerin bu değişime tepkisini belirleyecektir.

3.7.2. ÇOK YÖNLÜ KÜRESEL DEĞİŞİMLERİN BİTKİ TOPLULUĞUNA ETKİSİ

Var olan bilgilere göre, C_3 fotosentez işleyişine sahip bitkilerin, geniş yapraklıların ve baklagillerin çoğalan atmosferik CO_2 konsantrasyonuna daha fazla tepki gösterecekleri ve sonuç olarak gelecekte CO_2'ce zengin çevrelerde daha geniş alanlara yayılacağı öngörülmektedir. Bununla birlikte, sıcaklık artışı ve yağış rejimindeki değişikliklerin bu bitkilerin yüksek CO_2 konsantrasyonlarına karşı reaksiyonlarını etkileyecektir. Sıcaklık ve kuraklığın daha fazla olduğu iklim modelleri C_4 metabolizmasını teşvik edecektir. Bu durumda sıcaklıktaki belirgin artış C_3 bitkilerinin yüksek CO_2 konsantrasyonunda meydana gelen avantajlarını kısıtlayacaktır. Ek olarak, atmosferde ozon ve N konsantrasyonunun artması gibi diğer küresel değişimler özellikle şehirleşmenin olduğu yerlerde yüksek CO_2'e tepkiyi etkileyecektir. Endüstriyel ülkelerin kırsal bölgelerinde kirliliğe sebep olan atmosferik ozon yükselişi buğdaygil-baklagil karışımlarında baklagil oranını azaltabilir. Hayvansal üretimin ve endüstriyel faaliyetlerin sonucunda artan azot birikimi çayır-meralara azot olarak döner.

4. SONUÇ

Atmosferde bulunan gazların içeriğinin ve miktarının değişmesi sonucunda iklimde görülen değişiklikler çayır-mera vejetasyonlarının dağılımına ve işlevine büyük etki yaratacağı ortadadır. Şu anda vejetasyonun iklim değişikliğine karşı gösterdiği tepkileri anlamak için fazlaca emek harcanmaktadır. Fakat, çayır-meralarda görülecek olan değişiklikler küresel boyuttadır ve bu durumun çözümü de bilimsel boyutta kısıtlamalarla karşı karşıyadır. Gelecekle ilgili öngörülerde bulunmak için detaylı araştırmalar yapılması gerekir.

İklim değişikliğinin çayır meralar üzerine etkisi ciddidir. Artan sıcaklık, iklim değişikliği ve ekstrem hava koşulları, çayır meraların üretkenliğini önemli derece etkilemektedir. Bu değişiklikler, ot türlerinin dağılımını ve çeşitliliğini değiştirmekte, mera verimliliğini ve hayvan otlatma kapasitesini olumsuz etkilemektedir. Ayrıca erozyon riski ve toprak kalitesindeki bozukluklar artabilmektedir. Bu nedenle iklim değişikliğiyle mücadelede çayır meraların korunması ve doğru biçimde yönetilmesi önemlidir. Sürdürülebilir tarım uygulamalarının ve iklim uyum stratejilerinin geliştirilmesi gerekmektedir.

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GENOME DYNAMICS OF *Cannabis sativa* L.

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ABSTRACT

Cannabis sativus L. belong to Cannabaceae family and the Cannabis genus. The species is a diploid in constitution with 2n = 20 chromosomes (9 autosomes + XX/XY sex chromosomes). Due to countless studies, especially genomic research, people are now able to better understand the plant. The haploid genome size of female individuals is approximately 818 Mb, while that of males is around 843 Mb. Studies to date have identified approximately 27,000 to 38,000 protein-coding genes in the cannabis genome, most of which are validated through transcriptome analyses. The chloroplast genome is approximately 153,850 bp, and the mitochondrial genome is about 415,837 bp in size. Tandem repeats constitute about 29% of the genome, while retrotransposons account for 28.8%, indicating active transposon activity during the evolution. The most extensively studied gene families in cannabis include those involved in cannabinoid biosynthesis, protection against pathogens, biotic and abiotic stress, flower biology, CBD, and THC terpene production. Despite this, there are many missing links in the current genomic sequence data, particularly in the rDNA gene family, centromeric regions, and some repetitive elements, remain insufficiently defined. Future studies are desired to fill data about missing gaps and generate high-accuracy related to annotated reference genome to resolve issues related to epigenomic modifications and understand gene-environment interactions and their expressions.

Keywords: Hemp, *Cannabis sativa* L., Genome, Genetics

Cannabis sativa L. TÜRÜNÜN GENOM DİNAMİKLERİ

ÖZET

Cannabis sativus L., Cannabaceae familyasına ve Cannabis cinsine aittir. Tür, 2n = 20 kromozomlu (9 otozom + XX/XY cinsiyet kromozomları) diploid bir yapıya sahiptir. Sayısız çalışma, özellikle genomik araştırmalar sayesinde insanlar artık bitkiyi daha iyi anlayabiliyor. Dişi bireylerin haploid genom büyüklüğü yaklaşık 818 Mb iken, erkeklerinki yaklaşık 843 Mb'dir. Bugüne kadar yapılan çalışmalar, çoğu transkriptom analizleriyle doğrulanan, cannabis genomunda yaklaşık 27.000 ila 38.000 protein kodlayan gen tanımlamıştır. Kloroplast genomu yaklaşık 153.850 bp ve mitokondriyal genom yaklaşık 415.837 bp boyutundadır. Tandem tekrarlar genomun yaklaşık %29'unu oluştururken, retrotranspozonlar %28,8'ini oluşturur ve bu da evrim sırasında aktif transpozon aktivitesini gösterir. Kenevirde en kapsamlı çalışılan gen aileleri arasında kanabinoid biyosentezi, patojenlere karşı koruma, biyotik ve abiyotik stres, çiçek biyolojisi, CBD ve THC terpen üretimi ile ilgili olanlar yer alır. Buna rağmen, özellikle rDNA gen ailesinde, sentromerik bölgelerde ve bazı tekrarlayan elementlerde mevcut genomik dizi verilerinde birçok eksik halka vardır ve bunlar yeterince tanımlanmamıştır. Eksik boşluklar hakkında veri doldurmak ve epigenomik modifikasyonlarla ilgili sorunları çözmek ve gen-çevre etkileşimlerini ve ifadelerini anlamak için açıklamalı referans genomuyla ilgili yüksek doğruluk üretmek için gelecekteki çalışmalar istenmektedir.

Anahtar Kelimeler: Kenevir, *Cannabis sativa* L., Genom, Genetik

1. GİRİŞ

Kenevir (*Cannabis sativa* L.), Orta Asya ülkeleri (Tacikistan, Pakistan, Afganistan, Çin'in Sincan ve Henan eyaletleri), Japonya ve Tayvan'ın tıbbi, farmasötik, biyomalzeme ve bazı dini-kültürel alanlarında tarih boyunca değerli bir bitki olmuştur. Bu türdeki genomik çalışmaların ilerlemesi, türdeki bitkilerin çeşitli ontogenetik gelişim aşamalarında meydana gelen biyolojik potansiyeli ve moleküler mekanizmaları daha iyi anlamamızı sağlamıştır (Small, 2015; Zhang vd., 2018).

Kenevir, 9 çift otozom ve 1 çift cinsiyet kromozomundan (XX/XY) oluşan diploid (2n = 20) bir bitkidir (Divashuk vd., 2014). Cinsiyet kromozomlarıyla cinsiyet belirleme mekanizması nadir görülen bir durumdur. Dikotiledon formlarda, erkek bireyler XY ve dişi bireyler XX kromozom setlerine sahipken, monokotiledon bireyler sadece XX kromozom setlerine sahiptir ve cinsiyet genellikle epigenetik mekanizmalar tarafından belirlenir (Prentout vd., 2020).

Kenevirin haploid genom büyüklüğü dişi bireylerde yaklaşık 818 Mb ve erkek bireylerde yaklaşık 843 Mb olarak belirlenmiştir. Erkeklerde genom büyüklüğünün daha büyük olmasının nedeni cinsiyet kromozomlarıdır. Heterokromatik bölgenin Y kromozomunda yer aldığı kabul edilmektedir (Zhang vd., 2018).

İn silico analizlere göre, kenevir genomunda 27.000 - 38.000 protein kodlayan gen tanımlanmıştır. Bu genlerin yaklaşık 27.640'ı transkriptom analizleri yoluyla desteklenmekte ve doğrulanmaktadır (Laverty vd., 2019).

Filogenetik analizler, biyosentetik yolların evrimi ve plastid işlevlerinin anlaşılması için önemli olan kloroplast ve mitokondriyal genom boyutlarını sırasıyla 153.850 bp ve 415.837 bp olarak belirlemiştir (van Bakel ve ark., 2011).

Genomun büyük bir kısmı tekrarlayan DNA dizilerinden oluşur. Kenevir genomunun yaklaşık %29'u tandem tekrar dizilerinden oluşurken, %28,8'i transpozon elementlerinden oluşur. Bu durum, genomun evrimsel süreçte transpozon aktivitesine maruz kaldığının ve genom dinamiklerinin aktif olduğunun bir göstergesidir (Pisupati ve ark., 2018). Tekrarlayan elementler, genom çalışmalarında açıklanması en zor bölgelerden biridir. Kenevir genomunun yaklaşık %60'ını oluşturan tekrarlayan DNA elementleri, genomun hala dinamik olduğunu gösterir. Ayrıca genom boyutunu artıran ve seks kromozomu evriminde rol oynayan önemli bir faktör olduğu düşünülmektedir. Çünkü erkek çiçekler monoecious formlarda epigenetik mekanizmalar tarafından kontrol edilir ve epigenetik mekanizmalar doğrudan tekrarlayan DNA elemanlarıyla ilişkilidir (Prentout vd., 2020). C. sativa genomunda moleküler ve metabolik düzeylerde kritik rollere sahip gen aileleri bulunmaktadır. Bu gen aileleri bitkinin metabolit üretimi, stres toleransı ve gelişimsel süreçlerinin genetik kontrolünde rol oynar. Özellikle kanabinoid biyosentezi, terpen üretimi, stres tepkisi, çiçek biyolojisinin kontrolü ve patojen savunma sistemleri gibi süreçleri düzenleyen gen aileleri yoğun olarak araştırılmaktadır (Liu vd., 2021; Gülck & Møller, 2020). Bu gen aileleri, kenevirin biyotik ve abiyotik streslere verdiği yanıtlar, sekonder metabolit üretimi, çevresel adaptasyon ve tarımsal değerinin artırılması için kritik öneme sahiptir. Bu genlerin genom ve transkriptom düzeyinde karakterizasyonu hem temel biyoloji hem de endüstriyel uygulamalar için güçlü bir altyapı sağlar (Liu vd., 2021; Gülck & Møller, 2020; Laverty vd., 2019; Zhang vd., 2018; Booth vd., 2020; Zhao vd., 2021).

Şekil 1.1. Kenevirin kullanım alanları

2. KENEVİRİN GENOM DİNAMİKLERİ

Kenevir *(Cannabis sativa* L.) tıbbi, endüstriyel ve kültürel alanlarda tarih boyunca değerli bir bitki olmuştur. Özellikle bu türde yapılan genomik çalışmaların ilerlemesi, bu türün biyolojik potansiyelini ve moleküler mekanizmalarını daha iyi anlamamıza olanak sağlamıştır (Small, 2015; Zhang vd., 2018).

Kenevir, 9 çift otozom ve 1 çift cinsiyet kromozomundan (XX/XY) oluşan diploid (2n = 20) bir bitkidir (Divashuk vd., 2014). Cinsiyet kromozomları ile cinsiyet belirleme mekanizması nadir görülen bir durumdur. Çift evcikli formlarda erkek bireylerde XY, dişi bireylerde ise XX kromozom seti bulunurken, tek evcikli bireylerde ise sadece XX kromozom seti bulunur ve epigenetik mekanizmalarla cinsiyet oluşur (Prentout vd., 2020).

Kenevirin haploid genom büyüklüğü, dişi bireylerde yaklaşık 818 Mb, erkek bireylerde ise yaklaşık 843 Mb olarak saptanmıştır. Erkek bireylerde genom büyüklüğünün daha büyük

olmasının sebebi cinsiyet kromozomlarıdır. Y kromozomunda yer alan heterokromatik bölgeden kaynaklı olduğu düşünülmektedir (Zhang vd., 2018).

Yapılan *in silico* analizler doğrultusunda kenevir genomunda genomunda 27.000 – 38.000 arasında protein kodlayan gen tespit edilmiştir. Bu genlerin ~27.640 tanesi transkriptom analizleri ile desteklenmiş ve gen ifadeleri doğrulanmıştır (Laverty vd., 2019).

Filogenetik analizler, biyosentetik yolakların evrimi ve plastid işlevlerinin anlaşılması açısından önem taşıyan kloroplast ve mitokondri genom büyüklükleri sırasıyla 153.850 bp, ve 415.837 bp olarak tespit edilmiştir (van Bakel vd., 2011).

Genomun büyük bir kısmını tekrarlayan DNA dizileri oluşturmaktadır. Kenevir genomunun yaklaşık %29'u ardışık tekrar dizileri oluştururken, %28.8 kadarı transpozon elementlerinden oluşmaktadır. Bu durum, genomun evrimsel süreçte transpozon aktivitesine maruz kaldığını ve genom dinamiklerinin aktif olduğunun göstergesidir (Pisupati vd., 2018). Tekrarlayan elementler, genom çalışmalarındaki aydınlatılması en zor olan bölgelerdendir. Kenevir genomunun ~%60'ını oluşturan tekrarlayan DNA elementleri, genomun hala dinamik bir yapıda olduğuna işaret eder. Ayrıca Genom büyüklüğünü artıran ve cinsiyet kromozomu evriminde rol oynayan önemli faktörlerden birisi olduğu düşünülmektedir. Çünkü tek evcikli formlarda erkek çiçeklerin epigenetik mekanizmalarla kontrol edildiği düşünülmekte ve epigenetik mekanizmalar tekrarlayan DNA elementleri ile doğrudan ilişkilidir (Prentout vd., 2020).

Kenevir *(Cannabis sativa* L.) genomunda moleküler ve metabolik düzeyde kritik rol oynayan çeşitli gen aileleri bulunmaktadır. Bu gen aileleri, bitkinin metabolit üretimi, stres toleransı ve gelişimsel süreçlerinin genetik kontrolünde yer alır. Özellikle kanabinoid biyosentezi, terpen üretimi, stres yanıtı, çiçeklenme kontrolü ve patojen savunması gibi süreçleri düzenleyen gen aileleri yoğun olarak araştırılmıştır (Liu vd., 2021; Gülck & Møller, 2020). Bu gen aileleri, kenevirin biyotik ve abiyotik streslere yanıtları, ikincil metabolit üretimi, çevresel adaptasyonu ve tarımsal değerinin artırılması açısından kritik öneme sahiptir. Genom ve transkriptom düzeyinde bu genlerin karakterizasyonu, hem temel biyoloji hem de endüstriyel uygulamalar için güçlü bir altyapı sunmaktadır (Liu vd., 2021; Gülck & Møller, 2020; Laverty vd., 2019; Zhang vd., 2018; Booth vd., 2020; Zhao vd., 2021).

3. SONUÇ

i. Kenevir (*Cannabis sativa* L.) hem tıbbi hem de endüstriyel açıdan çok yönlü ve önemli bir bitkidir. Ancak uzun yıllar boyunca yasal kısıtlamalar nedeniyle tarım bitkilerine göre daha az araştırılmıştır. Son yıllarda güncellenen yasal düzenlemelerle beraber agronomik, ıslah ve tabiki genomik çalışmalar ivme kazanmıştır. Kenevir kannabinoidler yönünden zengin bir bitkidir ve onu tıbbi açıdan değerli kılar. Kannabinoid biyosentez yollarının moleküler temellerini anlamak, ıslahçıların da üzerine yoğunlaştığı yüksek oranlı CBD ve düşük oranlı THC sentezi için ışık tutacaktır. Lif, tohum ve ilaç amaçlı ıslah programlarında kenevir varyetelerinin genetik markörlerle, moleküler düzeyde çalışmaları önem arz etmektedir. Ayrıca ıslah programları için erken cinsiyet tespiti için gereklidir.

ii. Gerek filogenetik analizler gerek evrimsel olarak kenevirin aydınlatılması için yapılan genom çalışmaları önemlidir. Kenevir genomunda çalışılması gereken öncü konular

arasında yüksek tekrarlayan DNA bölgelerinin karakterizasyonu, cinsiyet kromozomlarının yapısı ve evrimi, kannabinoid ve terpen biyosentez lokuslarının yapısal varyasyonları, gen düzenleyici bölgelerin ve epigenetik profillerin belirlenmesi, popülasyon genetiği, organel genomları ve sitogenetik haritalama yer almaktadır.

iii. Kenevir genomunun çalışılması, hem bilimsel (temel biyoloji, genom evrimi, genetik varyasyon) hem de uygulamalı (ilaç, endüstri, tarım, ıslah) alanlarında önemli kapılar açmaktadır. Ancak tekrarlayan DNA bölgeleri, cinsiyet kromozomları, gen düzenleyici elementler ve metabolit biyosentez yolları gibi konular hala detaylı araştırılmamıştır. Bu eksiklerin tamamlanması, kenevirin tarımsal, endüstriyel ve farmasötik potansiyelini artırmada temel bir adım olacaktır.

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IDENTIFICATION OF XY AND XX SEX CHROMOSOMES IN *Cannabis sativa* L.

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ABSTRACT

Only approximately 5% of plant species worldwide (including cannabis) are dioecious. Therefore, for dioecious plants to produce fruit, a proper ratio of male and female plants must be present in the same field or garden. Cannabis sativa L. possesses a diploid genome structure with 2n = 20 chromosomes and carries a distinct XX/XY sex chromosome system, which is relatively rare among plant species. In dioecious plants, female individuals have an XX karyotype, while male individuals have an XY karyotype. Monoecious forms, on the other hand, carry only the XX karyotype and are therefore genetically predisposed to form female flowers. However, under the influence of hormones, stress conditions, or epigenetic factors, they can also develop male flowers. Studies in this field have shown that not only genetic, but also epigenetic mechanisms play active roles in the sex determination processes of cannabis. To this day, the instability of monoecious forms has not been fully clarified due to factors such as genetic heterogeneity, environmental influences, and epigenetic regulations. In the future, studies focusing on the construction of physical and genetic maps of cannabis's evolutionary sex chromosomes, complete sequencing of the Y chromosome, advancement of pachytene karyotype analyses, elucidation of molecular mechanisms in monoecious individuals, and functional analyses of epigenetic regulators will be of great importance. Such research is critical not only for basic science, but also for agricultural practices aimed at developing high-yielding and genetically uniform cannabis varieties. In this context, ongoing hybridization studies are being conducted at Yozgat Bozok University at both molecular and traditional levels with the goal of developing hybrid cannabis varieties.

Keywords: Hemp, male plants, female plants, Cytogenetics, Molecular Markers

XY VE XX SEKS KROMOZOMLARININ *Cannabis sativa* L. TÜRÜNDE TANIMLANMASI

ÖZET

Dünya çapında bulunan bitki türlerin (kenevir türü dahil) yalnızca ~ %5'i iki evciklidir (Dioik). Dolayısıyla, dioik bitkilerin meyve üretebilmeleri için bir bahçede dişi bitkiler ile beraber uygun miktarda erkek bitkilerin bulunmasının ihtiyaç duyulmaktadır. *Cannabis sativa* L. bitkisi, 2n=20 kromozomdan oluşan diploid bir genom yapısına sahiptir ve bitkiler aleminde oldukça nadir görülen belirgin bir XX/XY seks kromozom sistemi taşımaktadır. Çift evcikli bitki türlerde dişi bireyler XX, ve erkek bireyler ise XY karyotipine sahip olmktadırlar. Tek evcikli formlar yalnızca XX karyotipe sahiptir. Bu yüzden monoik bitki formlar genetik olarak dişi çiçek oluşturmaktadır., Ancak hormonal, stress koşullar veya epigenetik etkileri ile erkek çiçeklerde oluşturabilmektedir. Bu alanda yapılan çalışmalar, kenevirin sadece genetik değil, aynı zamanda epigenetik seviyede de cinsiyet belirleme mekanizmaların belirlenmesinde aktif rol oynamaktadırlar Günümüzde tek evcikli formların istikrarsızlığı; genetik heterojenlik, çevresel etmenlerin etkisi ve epigenetik düzenlemeler gibi unsurlar nedeniyle hâlâ açıklığa kavuşmamıştır. Gelecekte, kenevirin evremsel cinsiyet kromozomlarına dair fiziksel ve genetik haritaların oluşturulması, Y kromozomunun tam genom dizilenmesi, pakiten karyotip analizlerinin geliştirilmesi, tek evcikli bireylerin moleküler mekanizmalarının çözülmesi ve epigenetik düzenleyicilerin fonksiyonel analizi gibi çalışmalar ve çeşit geliştirilmesi gibi hibridleşme çalışmalarındaki önemi büyük önem taşımaktadır. Bu tür araştırmalar, sadece temel bilim açısından değil, aynı zamanda yüksek verimli ve homojen kenevir çeşitlerinin geliştirilmesi için de tarımsal uygulamalarda doğrudan katkı sağlamaktadır. Bu kapsamda, Hali hazırda Yozgat Bozok üniversitesinde hibrit çeşitler geliştirmek amacıyla hem moleküler hemde geleneksel seviyesinde çalışmaları devam etmektedir.

Anahtar Kelimeler: Kenevir, Erkek Bitkiler, Dişi Bitkiler, Sitogenetik, Moleküler Markörler

4. GİRİŞ

Kenevir (*Cannabis sativa* L.), hem dioik (iki evcikli) (Görsel 1.1.) hem de monoik (tek evcikli) formlarda bulunabilen nadir bir bitki türüdür. Dünya genelindeki bitki türlerinin yalnızca yaklaşık %5'i dioik özelliktedir; bu da dioik bitkilerin evrimsel açıdan daha sınırlı ve nadir bir üreme stratejisi sergilediğini gösterir (Renner & Ricklefs, 1995). Dioik bitkilerde, erkek ve dişi bireylerin ayrı bitkilerde bulunması, meyve ve tohum üretimi için aynı alanda uygun oranda erkek ve dişi bitkilerin varlığını zorunlu kılar (Small, 2015).

Görsel 1.1. Çift evcikli kenevir bitkisi. **(a)** Dişi form. **(b)** Erkek form. (Yozgat Bozok Üniversitesi, Kenevir Araştırmaları Serasında yetiştirilmiş bitkilere ait bir görseldir.)

Kenevir, 2n = 20 kromozoma sahip diploid bir türdür. 9 çift otozom ve 1 çift cinsiyet kromozomundan oluşur ve bitkilerde nadir görülen bir XX/XY cinsiyet kromozomu sistemi ile cinsiyet belirler. Dioik formlarda dişi bireylerde XX, erkek bireylerde ise XY karyotipi bulunur (Divashuk et al., 2014). Bu sistem, hayvanlardaki XY cinsiyet belirleme mekanizmasına ile benzerdir fakat bitkilerde bu durum evrimsel olarak dinamiktir. (Prentout et al., 2020). Kenevirin monoik formlarında ise yalnızca XX karyotipi gözlenir. Bunun anlamı monoik formların genetik olarak dişi olduğudur. Ancak epigenetik mekanizmalar aracılığı ile bu

bireylerde erkek çiçekler de gelişebilir. Ayrıca çevresel stres faktörleri (sıcaklık, ışık, su stresi) nedeniyle de cinsiyet değişikliği gözlenir (Sakamoto et al., 2005). Monoik bireylerin cinsiyet yönünden istikrarsızlığı (yani mevsimden mevsime veya çevresel koşullara bağlı değişken cinsiyet ifadesi), hâlen tam olarak anlaşılmamıştır. Bu istikrarsızlık; genetik heterojenlik, çevresel etkiler ve epigenetik mekanizmaların etkileşimiyle açıklanmaktadır (Prentout et al., 2020).

Kenevirde cinsiyet belirleme mekanizmalarını anlamak, tarımsal üretim, medikal kenevir geliştirme ve lif üretimi için büyük önem taşır. Özellikle dişi bireyler reçine ve kannabinoid üretimi için tercih edilirken, erkek bireyler lif üretimi için kullanılır. Bu nedenle erkenden cinsiyet tayini üretim amacına göre ekonomik kayıpların önlenmesinde kritik rol oynar (Divashuk et al., 2014).

Bu alandaki çalışmalar, sadece genetik düzeyde değil, epigenetik seviyede de cinsiyet regülasyonunun çözülmesine odaklanmaktadır. DNA metilasyonu, histon modifikasyonları ve küçük RNA'ların cinsiyet belirlemede etkili olabileceği öne sürülmektedir (Ming et al., 2011; Prentout et al., 2020).

Yozgat Bozok Üniversitesi, Kenevir Araştırmaları Enstitüsü hem moleküler düzeyde hem de geleneksel ıslah yöntemleriyle hibrit kenevir çeşitleri geliştirmek amacıyla çalışmalar yürütmektedir. Bu amaçla bazı kenevir genotiplerinin genetik çeşitliliği ve akrabalık dereceleri moleküler yöntemlerle belirlenmiştir (Alsaleh & Yılmaz, 2025). Enstitü bünyesinde yapılan çalışmalar, Türkiye de kenevirin endüstriyel üretim kapasitesinin artırılması ve yerel adaptasyon gösteren yüksek verimli çeşitlerin geliştirilmesi açısından büyük bir potansiyele sahiptir.

Bu bildiride kenevirin cinsiyet tayininin önemine ve cinsiyet belirleme mekanizmasının anlatılması amaçlanmıştır.

5. KENEVİRDE CİNSİYET TAYİNİ

Kenevir bitkisinin cinsiyetinin belirlenmesi fenotipik olarak gözlenebilmektedir. Erken dönem tespiti için bazı markörler kullanılır. Kenevir *(Cannabis sativa* L.), XX/XY cinsiyet belirleme sistemi taşıyan nadir bitki türlerinden biridir ve bu sistemin moleküler ve sitogenetik düzeyde aydınlatılması, cinsiyet kromozomlarının evrimi, yapısı ve işlevi hakkında bilgi verir (Divashuk et al., 2014; Alexandrov et al., 2014). Kenevirde yapılan ileri sitogenetik analizlerde kullanılan yöntemler ve bulgular sayıca az olmakla beraber önem arz etmektedir.

Kenevirde yapılan DAPI ve C-banding analizlerinde Y kromozomu diğer kromozomlara kıyasla daha belirgin heterokromatik bir yapıya sahip olarak gözlemlenmiştir. Bu durum Y kromozomundaki heterokromatin miktarı, onu X kromozomundan morfolojik olarak ayırt etmeyi mümkün kılmaktadır ve bu bulgu, Y kromozomunun transpozonlar ve tekrar dizileriyle zenginleştiğini ve evrimsel süreçte heterokromatinleştiğini gösterir (Divashuk et al., 2014). Ayrıca dişi ve erkek bireyler arasındaki genom büyüklüğü farklılığının da sebebi olduğu düşünülmektedir. CS-1 probu, *Cannabis sativa* genomuna özgü bir subtelomerik tekrar dizisidir. X kromozomunda hem kısa hem uzun kolda (iki uçta) bu subtelomerik tekrarların bulunduğunu ve Y kromozomunda ise sadece ökromatik kolda yer aldığı saptanmıştır. Bu

durum, Y kromozomunun heterokromatik kolunun tekrarlayan DNA elementleri ve yapısal farklılıklar nedeniyle CS-1 probu tarafından işaretlenmediğini gösterir. Böylece, X ve Y kromozomlarının uç bölgelerinin ayırt edilmesinde CS-1 probu önemli bir moleküler markör olmuştur (Alexandrov et al., 2014). Bir diğer önemli moleküler markör olan CS-237, kenevir genomunda türüne özgü bir tandem tekrar dizisi olarak tanımlanmıştır. FISH yöntemiyle yapılan analizlerde CS-237 tekrarlarının kenevir kromozomları üzerinde spesifik lokalizasyon gösterdiği özellikle heterokromatik bölgelerde zenginleştiği gözlenmiştir. CS-237 probu, kenevirin tür tanımlamasında, filogenetik analizlerde ve sitogenetik haritalamada kullanılabilecek özgül bir markördür. Bu tekrar dizisi, ayrıca cinsiyet kromozomu bölgelerinin ayırt edilmesinde de ek bilgi sağlar (Divashuk et al., 2014). Kenevirde yapılan moleküler sitogenetik çalışmalar, pseudo-otozomal bölge (PAR) adı verilen ve X ve Y kromozomlarının homolog dizileri paylaştığı bölgenin tanımlanmasını sağlamıştır. Bu bölgede X ve Y kromozomları rekombinasyon yapabilir. Kenevirde pseudo-otozomal bölgenin varlığı, cinsiyet kromozomları arasındaki evrimsel ilişkiyi ve homologlukları gösterir. Buna ek olarak Pseudo-otozomal bölge, cinsiyet belirleyici genlerin tespitinde ve Y kromozomunun genetik içeriğinin anlaşılmasında kritik bir ipucu sağlamaktadır (Prentout et al., 2020).

Yapılan ileri sitogenetik çalışmalara ek olarak moleküler çalışmalar erken cinsiyet tayini için önemlidir. MADC2 ve SCAR323, *Cannabis sativa* genomunda erkek bireylere özgü DNA dizileri olarak tanımlanmış moleküler markörlerdir. Bu belirteçler, erkek bireylerin Y kromozomu üzerinde bulunan özel DNA dizilerini hedef alır. Böylece erken dönem cinsiyet tayini sağlanmış, ıslah programlarında avantaj elde edilmiş olur. (Sakamoto et al., 1998; Törjék et al., 2002). Bu avantajlar arasında erkek bireyler sahadan erkenden elimine edilerek dişi-dominant popülasyonlar oluşturulması ve tohumluk üretiminde, kontrollü çaprazlama programlarında cinsiyet kontrolü sağlanması yer alır. Ek olarak, bu özellikler, tıbbi kenevir (CBD/THC üretimi) ve endüstriyel kenevir üretiminde verim ve kalite artışı sağlamaktadır. (Sakamoto et al., 1998; Divashuk et al., 2014).

6. SONUÇ

Kenevir (Cannabis sativa L.), tıbbi, endüstriyel ve kültürel önemi nedeniyle giderek artan bilimsel ilginin odağında yer almaktadır. Bitkinin 2n = 20 kromozomdan oluşan diploid bir genom yapısına sahip olması ve nadir görülen XX/XY cinsiyet kromozomu sistemi taşıması, genetik ve sitogenetik araştırmalar açısından eşsiz bir model sunmaktadır. Özellikle moleküler sitogenetik yöntemler (DAPI, C-banding, FISH-CS1, FISH-CS237) ve erkek özgül moleküler markerlar (MADC2, SCAR323), kenevirde cinsiyet kromozomlarının ve cinsiyet belirleme mekanizmalarının aydınlatılmasında önemli rol oynamıştır. Bu çalışmalar, erken dönemde cinsiyet tayini, cinsiyet kromozomlarının haritalanması, epigenetik regülasyonun anlaşılması ve genetik ıslah programlarına katkı sağlanması açısından doğrudan uygulama potansiyeline sahiptir .

Gelecekte, kenevir genom araştırmalarının; Y kromozomunun tam dizilenmesi, pseudo-otozomal bölgelerin karakterizasyonu, sentromer ve telomer bölgelerinin incelenmesi, epigenetik düzenleyicilerin işlevsel analizi ve genomik seleksiyon tabanlı ıslah stratejileri gibi öncü konulara odaklanması beklenmektedir. Bu çalışmalar, hem temel bilimde yeni bilgiler

üretilmesine, hem de yüksek verimli, hedefe yönelik ve homojen kenevir çeşitlerinin geliştirilmesine katkı sağlayacaktır .

Özetle, kenevir genomuna yönelik multidisipliner yaklaşımlar; genetik, moleküler biyoloji, sitogenetik, epigenetik ve genomik ıslah alanlarını birleştirerek, bitkinin potansiyelini hem bilimsel hem de endüstriyel düzeyde maksimuma çıkaracak stratejik bir temel oluşturmaktadır.

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PHYSIOLOGICAL RESPONSES OF STRAWBERRY PLANTS TO DROUGHT STRESS

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ABSTRACT

Drought is a global threat that results in increasingly destructive consequences due to global warming, possessing all living organisms. It leads to losses in water sources and in especially agricultural production. Due to its location in Mediterranean climate zone and varying climatic conditions across the region, Türkiye is one of the most dramatically impacted countries by drought stress. Strawberry is the most commercially produced and consumed berry in *Rosaceae* family owing to its rich nutrient value and high adaptation ability to grow various regions. Besides fresh fruit, it can be consumed by humans as processed products such as jam, jelly, beverage, yogurt. It has a significant market value in terms of imports and exports. Also, our country ranks 5th among strawberry producer countries in the world. But, strawberries are excessively sensitive to water deficit conditions on account of some morphological characteristics such as root system, leaf area, fruit texture etc. Depending on plant developmental stages, duration time and severity of stress, water deficiency could significantly reduce strawberry production and fruit quality and lead to even plant death. Even though there are some solutions such as efficient management of water sources, changing cultural practices etc., it is needed to find effectual solutions such as determination of drought tolerance existing cultivars and enhancement of new drought tolerant strawberry cultivars. For this purpose, it is requisite to understand the impact of drought stress on plants and plant responses to drought such as physiological response. In this review, various physiological responses of strawberries on water deficit condition will be discussed. Understanding those plant responses could provide valuable sights for drought tolerant strawberry cultivar enhancement. This study is supported by Çukurova University BAP Coordination Office within the scope of project number FDK-2023-15809.

Keywords: Strawberry, Drought, Stress, Physiological responses

ÇİLEK BİTKİLERİNİN KURAKLIK STRESİNE KARŞI FİZYOLOJİK TEPKİLERİ

ÖZET

Kuraklık, küresel ısınma nedeniyle giderek daha yıkıcı sonuçlara yol açan, tüm canlı organizmaları etkileyen küresel bir tehdittir. Su kaynaklarında ve özellikle tarımsal üretimde kayıplara yol açar. Türkiye, Akdeniz iklim kuşağında yer alması ve bölge genelinde iklim koşullarının değişmesi sebebiyle kuraklık stresinden en çok etkilenen ülkelerden biridir. Çilek, zengin besin değeri ve yüksek adaptasyon yeteneği nedeniyle Gülgiller familyasında en çok üretilen ve tüketilen meyvedir. Taze meyvenin yanı sıra reçel, jöle, içecek, yoğurt gibi işlenmiş ürünler olarak da insanlar tarafından tüketilebilir. İthalat ve ihracat açısından önemli bir pazar değerine sahiptir. Ayrıca, ülkemiz Dünyada çilek üreticisi ülkeler arasında 5. sırada yer almaktadır. Ancak çileğin kök sistemi, yaprak alanı, meyve dokusu vb. bazı morfolojik özellikleri nedeniyle su eksikliği koşullarında aşırı duyarlı olduğu belirlenmiştir. Bitkinin gelişim evrelerine, stresin süresine ve şiddetine bağlı olarak su eksikliği çilek üretimini ve meyve kalitesini önemli ölçüde azaltmakta ve hatta bitki ölümü bile neden olabilmektedir. Su kaynaklarının etkin yönetimi, kültürel uygulamaların değiştirilmesi vb. bazı çözümler olsa da, mevcut çeşitlerin kuraklığa dayanıklılığının belirlenmesi ve yeni kuraklığa toleranslı çilek çeşitlerinin geliştirilmesi gibi etkili çözümler bulmak gereklidir. Bu amaçla, kuraklık stresinin bitkiler üzerindeki etkisini ve bitkilerin kuraklığa karşı fizyolojik tepkilerini anlamak gerekir. Bu derlemede, çileklerin su eksikliği durumundaki çeşitli fizyolojik tepkileri tartışılacaktır. Bu bitki tepkilerinin anlaşılması, kuraklığa dayanıklı çilek çeşidinin geliştirilmesi için değerli bakış açıları sağlayabilir. Bu çalışma, Çukurova Üniversitesi BAP Koordinatörlüğü FDK-2023-15809 nolu proje kapsamında desteklenmektedir.

Anahtar Kelimeler: Çilek, Kuraklık, Stres, Fizyolojik tepkiler

1. INTRODUCTION

Global climate change is among the most critical global issues impacting all organisms in the world due to its increasingly severe impact. As for, drought is one of the most devastating consequences of global climate change, which has restrictive impacts on the environment, agriculture, economic, social, and humanitarian. Rapid depletion of water sources restricts agricultural productivity and livestock activities, leading to crop yield and economic losses. Also, it limits biodiversity and species in flora and fauna. Regarding humankind, water deficiency directly is limiting access to food and to clean water, forcing people to migrate. In addition, it is expected that the world population will exceed 12 billion to 2100, which will make difficult to feed their growing populations for counties (Dockterman, 2014). To overcome these problems, all countries need to consider the impacts and future risks of climate change, adaptation and mitigation options.

The cultivated strawberry knows as *Fragaria* × *ananassa* Duch. is one of the most commercially produced berries, having a unique taste, flavor and attractive color. It has high essential nutrient value, such as vitamin C and Calcium (Ca), and is rich in phenolic compounds beneficial to human health. Besides fresh fruit, it can be consumed as processed products such as jam, jelly, beverage, and yogurt (Kafkas, 2016). Due to its high nutrient content and high market value, it is the most commercially produced and consumed berry, accounting for approximately 10.5 M tons from more than 400 ha area in the world (FAO, 2023). China, United States of America, Mexico, Spain and Türkiye are main strawberry producers, respectively. In our country, strawberry production is possible at altitudes from sea level up to 2000 m which providing us advantage both in terms of import and export activities (Aslantaş and Karakurt, 2007). Mediterranean, Aegean and Marmara regions are prominent strawberry producing regions.

Rising the severity of drought in recent years has negatively affected the regions where strawberry production is intensive worldwide (Figure 1.1) (Ariza et al.,2021). Türkiye possesses a wide range of different climatic zones and microclimate areas in terms of its geographical location and climate characteristics which provides cultivation of different agricultural products (Kapluhan, 2013). However, factors such as environmental and soil pollution, excessive use of groundwater, insufficient management of water resources, and excessive application of fertilizers and pesticides are among the main factors that accelerate drought and desertification processes in our country. Some experts state that alteration of climate structure and precipitation regime are results of global climate change, combined with these incorrect practices and behaviors mentioned, will bring about serious restrictions on agricultural production and economic losses in future (Özüpekçe, 2021).

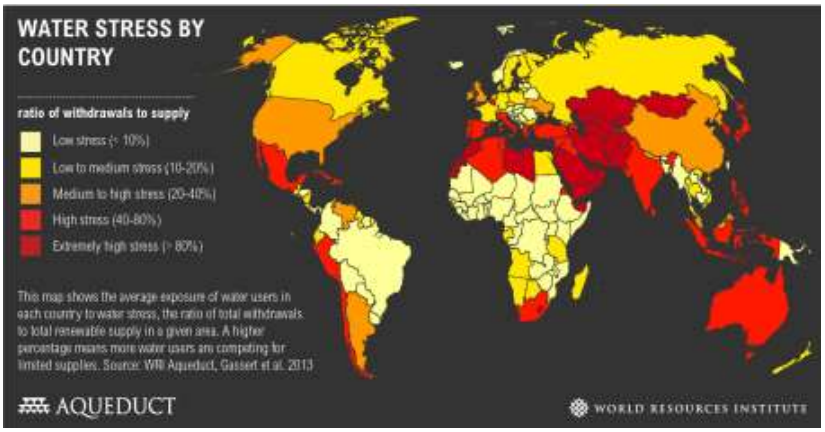

Figure 1. 1. World water stress map (Source: World Resources Institute)

As known, plants have been under pressure from some stress factors that negatively affect their growth and development. Drought is one of the most important abiotic stress factors affecting the growth, development and survival of plants caused by global climate change and cause ecological and economic losses (Akbaş, 2014). According to United Nations Convention to Combat Desertification (UNCCD, 1997), drought is termed as a natural event that causes land and water resources to be adversely affected and the hydrological balance to be disrupted due to precipitation falling significantly below normal levels. As agricultural drought is the consequence of the synergistic effect of meteorological, hydrological, and agricultural factors and defined as the lack of sufficient water in the soil to meet plant requirements. Cultivated strawberries are extremely sensitive to water deficit conditions since their wide leaf area, superficial root systems, and juicy fruit texture. It has been established that water deficiency could cause a decline in plant growth, fruit/crop quality and yield up to 70%, and eventually plant death (Boyer, 1982; Wandel et al., 2016). Depending on plant species, their growth stages, severity and duration of stress, exposure time and combination with other stress factors, it injures plants at various stages of development and undermines cellular activities (Du et al., 2020). It is known that water deficiency during especially flowering and fruit ripening stages in strawberry have limited its fruit size, quality and yield (GinÃ© Bordonaba and Terry, 2008).

Drought stress brings about a range of changes on plants such morphological, physiological, biochemical, and molecular changes. Leaves are the main indicator of drought stress. Insufficient water content inhibits plant growth and development such as decreases the leaf area, number and shoot length (Zhang et al., 2024). Water deficiency initially perceives from roots which triggers them extension deeper since decrease in turgor pressure in plants cells (Seleiman et al., 2021). This stress causes ABA (abscisic acid) synthesis in roots and ABA transportation to aerial parts of plants via xylem to protect plants against water losses. ABA accumulation in guard cells leads to stomatal closure (Brunetti et al., 2019). Hampering gas influx-exflux for plants due to closure reduces plant transpiration and photosynthesis. Low CO_2 and high O_2 levels in plant cells increases photorespiration (Mozafari et al., 2019) and enzyme

activity which disrupts the light and dark reactions. Drought stress also stimulation extensive production and accumulation of reactive oxygen species (ROS).

Their accumulation leads to losses in fruit production, its quality and yield losses and eventually plant death (Hossain et al., 2015; Dar et al., 2017; Gholami and Zahedi, 2019). Plants also synthesize some osmolytes and osmo-protectants which are secondary indicators of drought stress such as glycine betaine and proline. It is also inevitable that some gene expressions are responsible for drought stress such as transcription factors, some proteins (Heat shock (HSPs) proteins etc. (Yang et al., 2021).

Drought stress is one of the most detrimental abiotic stress factors affecting strawberry production, which is still to be well-characterized. It is requisite to determine the effect of drought stress on strawberries at blooming and fruit ripening stages and their responses. This review could be beneficial to understand the physiological responses of strawberries against water deficiency and to improve and enhance new drought tolerant strawberry cultivars in breeding studies.

1.1. Plant Drought Strategies

Drought stress disturbs plant structural and metabolic activities, delays plant growth and development, damages photosynthetic activity, disturbs protein synthesis and even plant death. However, plants show some response mechanisms to cope with stress factors (Figure 1.2). Their responses to drought stress depend on duration and severity of stress, genetic background of plants to be exposed to stress and their developmental stages. In strawberry, flowering and fruit ripening stages are critical stages in terms of exposing drought stress. However, stress factors could trigger the plant to adapt to adverse conditions. It is stated that severe stress causes irreversible distribution on plant physiology and even plant death while mild stress induces the defense mechanism of plants such as root extension deeper into soils, stomatal closure, accumulation of osmo-protectant etc. (Bandurska, 2022). Plants evolutionary have enhanced three basic strategies against drought stress: escape, avoidance and tolerance.

Escaping strategy from the drought stress allows the plant to adjust and shorten its life cycle to the appropriate time. Early flowering is a common escaping strategy for plants which inhibits plant growing period and but leads to production losses (Vassileva et al., 2023). Drought avoidance strategy is a plant adaptation that enhances water use efficiency (WUE) under dry conditions. This strategy can be focused on two main mechanisms: maximizing water uptake by the plant root system (water spender) and minimizing water loss from the shoot parts (water saver) (Basu et al., 2016; Delfin et al., 2021). But WUE depends on plant species and the duration and severity of drought. It is stated that plants having higher WUE is generally related to increased yields under water deficit condition (Hatfield and Dold, 2019). Water saver plants tend to limit water loss via maintaining metabolic activity at low stages such as stomatal closure, decreasing transpiration and photosynthesis rates or via morphological adjustments such as developing thicker cuticles, increased wax deposition, decreasing leaf area, radiation absorption and curling the leaf (Kim et al., 2007). In contrast, water spenders plants tend to increase root proliferation at depth especially deeper tap root to maintain water uptake and enhance hydraulic conductance (Mori et al., 2011; Caine et al., 2019). Although drought avoidance strategies could

be effective for plant water saving, it may lead to limited vegetative growth which reduces crop productivity. Drought tolerance is another mechanism that allows plants to produce and reproduce their economic product with minimum loss under water deficit environment. During this process, plants protect their cells by synthesizing protective substances such as osmolyte or osmo-protectants and overexpression of some drought-responsive genes and elements, transcription factors and some proteins against osmotic and ionic stress (Yang et al., 2021). Those plants also repair the damage that occurs when the stress ends.

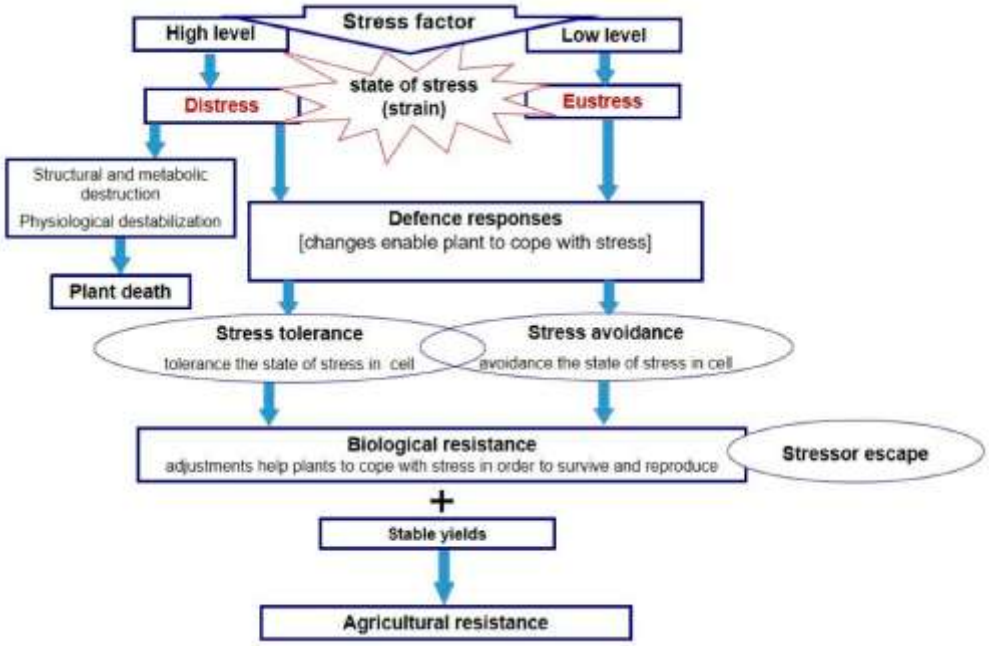

Figure 1.2. Plant responses mechanism to drought stress, escape, avoidance and tolerance (Bandurska, 2022).

1.2. Physiological Responses of Strawberry Plants Against Drought Stress

Drought stress is a multifaceted stress factor inhibits plant physiology and metabolic activity and further fruit quality and yield (Bhargava and Sawant, 2013). Strawberries are vulnerable to drought stress due to their morphological characteristics. Water deficiency is one of the main factors limiting growth, stomatal conductance and net photosynthesis in strawberry plants (Dehghanipoodeh et al., 2018). Limiting gas exchange between the plant and the environment due to stomatal closure cause stomatal conductivity, net photosynthesis and respiration to decrease in strawberry cultivars “Earlibrite, California and Sweet Charlie” (Ibrahim et al., 2022). High O_2 levels in the chloroplast promotes Rubisco oxygenase activity, increasing photorespiration. This energy-consuming process reduces photosynthetic efficiency and leads to carbon loss, further affecting plant growth.

Several studies showed that decline in relative water content (RWC), leaf water potential and osmotic potential are the main key indicators of drought stress. Ibrahim et al. (2022) determined that decrease in plant growth, transpiration rate, net photosynthesis, stomatal conductance and

relative water content depending on different strawberry cultivars under water deficit condition. It is also stated that total chlorophyll content and leaf water potential decreased when limited irrigation regime for strawberry cultivar "Camarosa" (Ödemiş et al., 2020). Accumulation of ABA induces higher amount of ROS production which causes oxidative stress in plant cell. Their accumulation disrupts cell membrane stability due to lipid peroxidation which enhances the electrolyte leakage (Zahedi et al., 2023). Quantum efficiency of photochemistry (Fv/Fm) is one of the most frequently used methods to measure amount of light absorbed by the chlorophyll which allows to accurate prediction on severity of stress via measuring the maximum photosystem II (PSII) quantum efficiency value (Arief et al., 2023). Conversely, it is considered that the increase in leaf canopy temperature of strawberries under drought stress due to stomatal closure thereby limiting gas exchange (Ödemiş et al., 2020). As mentioned above, plants also possess the drought stress tolerance mechanisms allowing them to produce their economic product with minimum loss. Several studies on strawberries have proved that tolerant cultivars have developed mechanisms to increase their water use efficiency (WUE) (Klamkowski and Treder, 2008; Ghaderi and Siosemardeh, 2011; Zahedi et al., 2020).

2. CONCLUSION

Drought stress is one of the most important stress factors that inhibit agricultural production and cause dramatic losses. Depending on plant species and their developmental stages, stress duration time and severity, drought stress limits vegetative growth, disrupts plant physiological and metabolic activities. Impact of drought stress on plant is like cascade containing the series of changes on plant starting with perceiving water deficiency by root ending up tolerance to stress or plant death. Even though efficient water sources management and better cultural practices is effective for agricultural production under water deficit conditions, determination of drought tolerant cultivars among current ones and enhancement of new tolerant ones could give better and accurate solutions. Integration of marker assistant selection (MAS), Quantitative trait locus (QTL) analysis, genetic engineering, genome editing technologies into traditional breeding to determine drought tolerant plants or their improvement would be beneficial for future of humankind against food scarcity and sustainable for agricultural production against global climate change.

3. ACKNOWLEDGEMENTS

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POSSIBILITIES OF USING *Lactobacıllus plantarum* AS A MICROBIAL INOCULANT IN BARLEY SILAGE

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ABSTRACT

This study was conducted to determine the effects of Lactobacillus plantarum (MF098786) strains isolated from homemade traditional pickles on the quality characteristics, microbiological structure and aerobic stability of barley straw (Hordeum vulgare) silages. In the study, three different L. plantarum strains were used in the experimental groups together with the control group (K): LP106 (LAB6), LP108 (LAB8) and LP109 (LAB9). Barley plants were harvested at the dough stage, chopped into 2,5-3,5 cm pieces, filled into 2 kg vacuum bags for each group and the bags were left to ferment for 90 days. After the fermentation period, chemical (pH, crude protein, ADF, NDF, etc.), physical (color, temperature, structure) and microbiological (lactic acid bacteria, yeast and mold counts) analyses were performed on the samples taken from the silages. In addition, microbiological evaluations were made after the aerobic stability process. According to the findings, pH values of 4.88 and 4.92 in LAB6 and LAB8 groups, respectively, indicated that fermentation was more effective and silage was preserved in a more acidic environment. Low pH prevented the growth of undesirable microorganisms, reduced nutrient loss and increased aerobic stability. Crude protein content in LAB6 group (9.90%) was higher than the control group (8.80%). Post-aerobic stability evaluations revealed significantly lower yeast counts and reduced CO_2 production in LAB6 and LAB9 groups, indicating enhanced shelf life and microbial quality. LAB6, in particular, produced the most favorable outcomes across all parameters. In conclusion, inoculation with *L. plantarum*, especially strain LAB6, significantly enhanced the fermentation quality, nutrient preservation, and aerobic stability of barley silage. The use of LAB6 as a microbial inoculant is therefore recommended as an effective biotechnological strategy for improving silage production under modern livestock feeding systems. In addition, the decrease in ADF and NDF contents indicates that digestibility increased. In the analysis after aerobic stability, it was observed that yeast counts decreased significantly and CO_2 production was reduced in LAB6

and LAB9 groups. These results reveal that the shelf life and microbiological quality of silage improved. Especially LAB6 strain gave the most favorable results in all parameters. In conclusion, the use of L. plantarum, especially LAB6 strain, as an inoculant is recommended as an effective biotechnological approach to improve fermentation quality, preserve nutritional values and improve aerobic stability in barley silages.

Keywords: Silage Fermentation, Aerobic Stability, Silage Quality, *Lactobacillus plantarum*

Lactobacillus plantarum'un ARPA HASILI SİLAJINDA MİKROBİYEL İNOKÜLANT OLARAK KULLANILMA OLANAKLARI

ÖZET

Bu çalışma, ev yapımı geleneksel turşulardan izole edilen *Lactobacillus plantarum* (MF098786) suşlarının arpa hasılı (*Hordeum vulgare*) silajlarının kalite özellikleri, mikrobiyolojik yapısı ve aerobik stabilitesi üzerindeki etkilerini belirlemek amacıyla yürütülmüştür. Araştırmada, kontrol grubu (K) ile birlikte üç farklı *L. plantarum* suşunun kullanıldığı deney grupları oluşturulmuştur: $LP10^6$ (LAB6), $LP10^8$ (LAB8) ve $LP10^9$ (LAB9). Arpa bitkisi, hamur olum döneminde hasat edilip 2,5–3,5 cm boyutlarında doğranarak, her grup için 2 kg'lık vakumlu torbalara doldurulmuş ve torbalar 90 gün boyunca fermentasyona bırakılmıştır. Fermentasyon süresinin ardından silajlardan alınan örnekler üzerinde kimyasal (pH, ham protein, ADF, NDF vb.), fiziksel (renk, sıcaklık, yapı) ve mikrobiyolojik (laktik asit bakteri, maya ve küf sayıları) analizler gerçekleştirilmiştir. Ayrıca, aerobik stabilite süreci sonrasında mikrobiyolojik değerlendirmeler yapılmıştır. Elde edilen bulgulara göre, LAB6 ve LAB8 gruplarında pH değerlerinin sırasıyla 4.88 ve 4.92 olması, fermentasyonun daha etkili gerçekleştiğini ve silajın daha asidik ortamda muhafaza edildiğini göstermiştir. Düşük pH, istenmeyen mikroorganizmaların gelişimini engelleyerek besin maddesi kaybını azaltmış ve aerobik stabiliteyi artırmıştır. LAB6 grubunda ham protein oranı (%9,90), kontrol grubuna (%8,80) göre daha yüksek bulunmuştur. Ayrıca ADF ve NDF içeriklerindeki azalma, sindirilebilirliğin arttığını göstermektedir. Aerobik stabilite sonrası yapılan analizlerde, LAB6 ve LAB9 gruplarında maya sayılarının belirgin şekilde azaldığı ve CO_2 üretiminin düşürüldüğü gözlemlenmiştir. Bu sonuçlar, silajın raf ömrünün ve mikrobiyolojik kalitesinin iyileştiğini ortaya koymaktadır. Özellikle LAB6 suşu, tüm parametrelerde en olumlu sonuçları vermiştir. Sonuç olarak, *L. plantarum*'un özellikle LAB6 suşunun inokülant olarak kullanımı, arpa silajlarında fermentasyon kalitesini artırmak, besin değerlerini korumak ve aerobik stabiliteyi geliştirmek açısından etkili bir biyoteknolojik yaklaşım olarak önerilmektedir.

Anahtar Kelimeler: Silaj Fermantasyonu, Aerobik Stabilite, Silaj Kalitesi, *Lactobacillius Plantarum*

1. GİRİŞ

Küresel ısınma, iklim değişikliği, artan yem maliyetleri ve azalan tarımsal kaynaklar, daha sürdürülebilir hayvancılık üretim sistemlerine olan ihtiyacı artırmıştır (FAO, 2021). Sera gazı emisyonlarının önemli bir kısmından sorumlu olan hayvancılık sektörü, yem verimliliğini optimize etme ve çevresel etkileri azaltma konusunda artan bir baskı altındadır (Gerber ve ark., 2013). Bu bağlamda, özellikle çeşitli agroekolojik koşullara uyum sağlayabilen ve kuraklıkla ilişkili riskleri azaltmak amacıyla erken hasat edilebilen arpa (Hordeum vulgare) gibi yem bitkileri için etkili silaj tekniklerinin uygulanması, otların korunmasında umut vadeden bir strateji olarak öne çıkmaktadır (Sleugh ve ark., 2000).

Yem bitkilerini silaj yapma, yıl boyu yem teminini sağlamak için yaygın olarak benimsenmiş bir yöntemdir. Ancak, kötü fermantasyon kalitesi ve aerobik stabilite, silajların besin değerini ve güvenliğini tehlikeye atmaktadır (Muck, 2010). Mikrobiyal inokülantların, özellikle *Lactobacillus plantarum* gibi homofermentatif laktik asit bakterilerinin kullanılması, pH'ı hızla düşürerek ve istenmeyen mikrobiyal büyümeyi baskılayarak silaj korumasını iyileştirmek için dikkat çekici bir yöntem olmuştur (Kung ve ark., 2018). Bu, yalnızca silaj kalitesini ve raf ömrünü iyileştirmekle kalmaz, aynı zamanda yem israfını azaltmaya da katkı sağlar. Bu da hayvan beslenmesinin sürdürülebilirlik önemli bir bileşenidir.

Lactobacillus plantarum, özellikle farklı silaj türlerinde adaptasyon kabiliyeti ve etkinliği ile dikkat çeken, bir fakültatif homofermentatif Laktik asit bakterisi (LAB) türüdür. Fermantasyon sırasında mikrobiyal ekosistemde baskın olma yeteneği, düzenli olarak laktik asit üretimini sağlar, bu da hem silajın stabilitesini hem de yapı özelliklerini iyileştirir (Kleinschmit ve Kung, 2006). Ayrıca, LAB suşlarını geleneksel ve bölgesel olarak uyarlanmış fermente gıdalardan örneğin ev yapımı turşulardan temin etmek, ticari inokülantlara düşük maliyetli bir alternatif sunar, bu da yerel dayanıklılığı ve döngüsel biyoteknoloji yaklaşımlarını artırır (Zheng ve ark., 2020).

İklim değişkenliği ve kaynak kıtlığı kısıtlamaları altında verimli yem yönetimi için artan talep göz önüne alındığında, bölgesel olarak temin edilen *L. plantarum* suşlarının arpa silajı üretiminde kullanılması, ruminant beslenmesinde daha büyük sürdürülebilirlik için geçerli bir yol sunabilir. Bu çalışma, ev yapımı turşulardan izole edilen *L. plantarum* suşlarının arpa yem silajının fermantasyon kalitesi, aerobik stabilitesi ve mikrobiyal gelişimi üzerindeki etkilerini değerlendirmeyi amaçlamaktadır.

2. MATERYAL VE METOT

Silaj materyali olarak kullanılan arpa bitkisi, Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü'ne ait araştırma alanından (Enlem: 39.1286°K, Boylam: 34.1078°D) temin edilmiştir. Arpa, hamur olum döneminde hasat edilmiş ve hasattan sonra 2,5–3,5 cm uzunluğunda olacak şekilde doğranmıştır. Doğrama işlemi tamamlandıktan sonra, 1000 g bitki materyali 2 kg'lık plastik torbalara konulmuş ve üzerine sırasıyla 1×10^6 kob/g, 1×10^8 kob/g ve 1×10^9 kob/g yoğunluklarında *Lactobacillus plantarum* laktik asit bakterisi püskürtülmüştür. Uygulama sonrası paketlerin içindeki hava, vakum cihazı yardımıyla boşaltılarak ortamdan uzaklaştırılmıştır. Çalışmada 4 farklı grup oluşturulmuş, her bir gruptan 4 tekrar olacak şekilde toplamda 32 silaj hazırlanmış ve laboratuvar koşullarında 18±2,5 °C sıcaklıkta, karanlık bir

ortamda 90 gün süreyle fermentasyona bırakılmıştır. Çalışma grupları: kontrol (K), Arpa hasılı + *L. Plantarum* 10^6 (LAB6), Arpa hasılı + *L. Plantarum* 10^8 (LAB8), Arpa hasılı + *L. plantarum* 10^9 (LAB9) olarak hazırlanmıştır. Silajlar hazırlandıktan sonra 90 gün süreyle fermentasyona bırakılmıştır. Belirtilen sürenin tamamlanmasının ardından, dört grup halinde ve her birinden üç paralel örnek alınarak; fiziksel analizler (sıcaklık, renk, pH), kimyasal (hava kuru madde, kuru madde, ham kül, ham yağ, ham protein, ham selüloz, ADF, NDF, suda çözünür karbonhidrat, aerobik stabilite), mikrobiyolojik (Laktik asit bakterisi, maya ve küf sayımı), ve istatistik analizleri yapılmıştır.

Silajların kuru madde (%KM), havada kuru madde (%HKM), ham protein (%HP), ham yağ içeriği (EE), ve ham kül (%HK) analizleri AOAC (1998) standart prosedürüne göre, AOCS (2005) protokolüne uygun olarak analiz edilmiştir. Ham selüloz (%HS), %ADF ve %NDF analizleri Van Soest ve (1991)'e göre ANKOM 200 Fiber Analyzer cihazı kullanılarak yapılmıştır. pH değerleri Chen ve ark. (1994); toplam çözülebilir madde (TÇM) içerikleri Singh ve ark. (2020)'de açıklandığı şekilde gerçekleştirilmiştir. Bu çalışmada silajların içerdiği laktik asit bakterisi, maya ve küf sayımı Seale ve ark. (1990) tarafından bildirilen yöntemler ile belirlenmiştir. Silajların TC (Total Carbonhydrate), NFE (Nitrogen Free Extract), NFC (Nitrogen Free Carbonhydrate) ile metabolize edilebilir enerji ve protein değerleri Filik (2020)'nin bildirdiği şekilde hesaplanmıştır. Silajların nispi yem değeri ve nispi yem kalitesi hesaplamaları ise Kılıç ve Abdiwali (2016) ve Filik (2020)'in bildirdiğine göre hesaplanmıştır. Çalışma sonucunda elde edilen bulguların istatiksel analizlerinde SAS (2001) paket programı kullanılmış olup, çalışmanın deneme modeline (tesadüf parselleri deneme planı) uygun olarak General Linear Model (PROC GLM) prosedürü ile varyans analizine tabi tutulup, deneme grupları arasındaki linear ilişkiler aynı paket programda ortogonal polinom kontrast uygulanarak belirlenmiştir. Duncan Çoklu Karşılaştırma Yöntemi kullanılarak gruplar arasındaki farkları çoklu karşılaştırmayla analiz edilmiştir (Genç ve Soysal, 2018)

3. BULGULAR VE TARTIŞMA

Tablo 1. Silajın fiziksel analiz sonuçları

Gruplar	Kontrol	LAB6	LAB8	LAB9
°C	23.03a±0.05	23.13a±0.27	23.10a±0.18	22.73a±0.05
pH₁	6.00a±0.04	4.88c±0.05	4.92c±0.01	5.33b±0.00
WSC (°Brix)	23.05ba±0.57	21.38b±0.87	23.70a±0.25	21.38b±0.48
L*	40.38a±3.17	42.19a±1.19	45.10a±3.02	44.16a±1.78
a*	3.45ba±0.27	2.53b±0.15	4.07a±0.74	3.48ba±0.18
b*	14.98a±0.93	15.84a±0.99	17.53a±2.13	16.83a±0.96
ΔE*	43.21a±3.28	45.15a±1.42	48.90a±3.60	47.40a±1.98
h	77.03b±0.66	80.85a±0.57	77.20b±1.09	78.16ba±1.15
C*	15.37a±0.95	16.04a±0.99	18.00a±2.24	17.20a±0.91

°C: Santigrat derece; **WSC**: Suda çözünebilir karbonhidrat (Brix derecesi 0- 25°); **L***: Açıklık; **a***: Kırmızılık; **b***: Sarılık; **ΔE***: Toplam renk farkı, **h**: hue aangle, **C***: Renk veya yoğunluk. ^{a,b,c} Aynı sütundaki ortak üst simge olmayan ortalamalar önemli ölçüde farklıdır ($p<0.01$). Kontrol: Arpa hasılı, LAB6: Arpa hasılı + L. Plantarum $1x10^6$, LAB8: Arpa hasılı + L. Plantarum $1x10^8$, LAB9: Arpa hasılı + L. plantarum $1x10^9$.

Tablo 1'de gösterildiği üzere, tüm gruplarda silaj paketlerinin açılmasının ardından yapılan pH değerleri 4,88 ile 6,00 arasında değişmiş, en düşük pH değeri LAB6 grubunda, en yüksek pH ise kontrol (K) grubunda ölçülmüştür. Bu durum, inokülant ilavesinin fermentasyon sırasında asitleşmeyi sağlamada daha başarılı olduğunu göstermektedir. Renk değerleri açısından bakıldığında, L*, a*, b*, ΔE* ve C* parametrelerinde anlamlı bir farklılık gözlenmemiştir. Ancak, LAB8 grubu en yüksek renk doygunluğu ve açıklığı değerlerini göstermiş, Kontrol grubunda ise diğer gruplara göre daha düşük renk farkı değerleri gözlenmiştir.

Tablo 2. Silajın yem kalitesi özellikleri

Gruplar	Kontrol	LAB6	LAB8	LAB9
SKM	$65.71^{c}\pm0.02$	$66.65^{a}\pm0.05$	$65.27^{d}\pm0.07$	$65.97^{b}\pm0.02$
KMI	$2.26^{a}\pm0.02$	$2.29^{a}\pm0.04$	$2.19^{a}\pm0.01$	$2.22^{a}\pm0.03$
TSB	$62.88^{a}\pm0.04$	$62.65^{b}\pm0.00$	$62.19^{c}\pm0.02$	$62.70^{b}\pm0.01$
NYD	$115.06^{ba}\pm1.04$	$117.96^{a}\pm2.39$	$110.84^{b}\pm0.46$	$113.24^{ba}\pm1.66$
NYK	$115.48^{a}\pm1.07$	$116.30^{a}\pm2.25$	$110.76^{a}\pm0.54$	$112.87^{a}\pm1.70$

Kontrol: Arpa hasılı, LAB6: Arpa hasılı + L. Plantarum $1x10^{6}$, LAB8: Arpa hasılı + L. Plantarum $1x10^{8}$, LAB9: Arpa hasılı + L. plantarum $1x10^{9}$, (%) kuru madde; **SKM**: Sindirilebilir kuru madde (%); **KMI**: Kuru madde alımı (Canlı ağırlık: LW, %); **TSB:** Toplam sindirilebilir besin maddesi(%); **NYD**: Nispi besleme değeri, **NYK**: Nispi hasıl kalitesi. ^{a,b,c} Aynı sütun içinde ortak üst simge içermeyen ortalamalar önemli ölçüde farklıdır, ($P<0.01$).

Gruplar arasında (Tablo 2), LAB6 ve LAB8 grupları, kontrol grubuna kıyasla daha yüksek SKM değerleri göstermiştir (sırasıyla %66,65 ve %65,27; kontrol %65,71). Daha yüksek SKM, daha iyi sindirilebilirlik anlamına gelir ve bu da yemler için arzu edilen bir özelliktir. Bu bulgular, daha iyi sindirilebilirliğin süt ineklerinde yem alımı ve süt verimiyle ilişkili olduğunu bildiren Oba ve Allen (1999) çalışmasıyla uyumludur. KMI değerleri gruplar arasında anlamlı farklılık göstermemiştir.

LAB6 ve LAB8 ayrıca daha yüksek TSB değerlerine vermiştir. LAB6 %62,65, LAB8 ise %62, 19, TSB ile kontrol grubunun (%62,88) üzerinde yer alarak besin değerinde iyileşme göstermiştir.

Tüm silajların NYD değerleri II. kalite yem (103-124) hesaplamalarına uygun olarak belirlenmiştir (Kılıç ve Abdiwalli, 2016). Silajların NYK değerleri, tüm silajların 18-24 aylık düvelerin ve kuru ineklerin beslenmesinde kullanılabilecek yemler (100-120) olduğu sonucuna varılmıştır (Filik, 2020). LAB6 grubu en yüksek NYD (117,96) ve NYK (116,30) değerlerini göstermiş, ardından LAB8 ve LAB9 gelmiştir. NYD ve NYK için P değerleri istatistiksel olarak anlamlı olmasa da ($P>0,05$) sayısal iyileşmeler, *Lactobacillus plantarum* ile inoküle edilen silajlarda kaba yem kalitesinin arttığını bildiren önceki çalışmalarla tutarlıdır (Kleinschmit ve Kung, 2006; Weinberg ve Muck, 1996).

Genel olarak LAB6 ve LAB8, arpa silajlarının sindirilebilirliğini ve enerji içeriğini artırmıştır;

Tablo 3. Silajın kimyasal analizleri

Gruplar	Kontrol	LAB6	LAB8	LAB9
KM[1-4]	929.10b±0.10	929.55ba±0.05	930.50a±0.60	929.75ba±0.05
OM[2]	93.30a±0.02	92.99b±0.00	92.90c±0.02	92.93cb±0.02
HK[2]	6.70c±0.02	7.01b±0.00	7.11a±0.02	7.07ba±0.02
HP[2]	13.58a±0.04	13.30b±0.00	12.90c±0.01	13.37b±0.01
HY[2]	5.14a±0.04	4.74b±0.02	5.07a±0.06	4.80b±0.01
HS[2]	23.61a±0.04	22.64c±0.00	23.43a±0.14	23.07b±0.04
ADF[2]	29.78b±0.03	28.57b±0.07	30.33a±0.09	29.44c±0.03
ADFom[3]	23.08a±0.05	21.56c±0.07	23.23a±0.12	22.37b±0.01
NDF[2]	53.13a±0.45	52.58a±1.02	54.78±0.28	54.21a±0.81
NDFom[3]	46.43a±0.47	45.57a±1.02	47.68a±0.25	47.14a±0.83

Kontrol: Arpa hasılı, LAB6: Arpa hasılı + L. Plantarum 1x10^{6}, LAB8: Arpa hasılı + L. Plantarum 1x10^{8}, LAB9: Arpa hasılı + L. plantarum 1x10^{9}, g/kg hammadde, (%) kuru madde, **ADFom**=ADF kül, **NDFom,** NDF kül; **HKM**: Havada kuru madde (g/kg); **OM**: Organik Madde (%); **HK**: Ham Kül (%); **HP**: Ham Protein (%); **HY**: Ham Yağ (%); **HS**: Ham Selüloz (%); **ADF**: Asit Deterjan Lifi (%), **NDF**: Nötral Deterjan Lifi (%). [a,b,c,d] Veriler her bir muamelenin dört uygulamasının ortalamasını temsil etmektedir; aynı sütun içinde ortak üst simge içermeyen ortalamalar farklıdır (P<0.01).

Farklı *Lactobacillus plantarum* suşları ile muamele edilen arpa hasılı silajının besin kompozisyonuna ilişkin sonuçlar Tablo 3'te gösterilmiştir. Uygulama grupları arasında Kuru madde (KM) ve Organik madde (OM) içeriğinde önemli bir farklılık gözlenmezken (P>0,005), ham protein, ham lif ve ham yağ değerlerinde değişiklikler tespit edilmiştir.

Ham protein (HP) içeriği LAB8 (%12,90) ve LAB9 (%13,37) gruplarında kontrol grubuna (%13,58) kıyasla önemli ölçüde artmıştır (P<0,001); bu durum, inokülantların silolama sırasında proteolizi sınırlandırarak daha fazla azotlu bileşiği koruyabildiğini bildiren Oliveira ve arkadaşlarının (2017) bulgularıyla uyumludur. Benzer şekilde, Liu ve arkadaşları (2021) tarafından *L. plantarum* ile muamele edilen arpa hasılı silajlarında, düşük pH sayesinde protein parçalanmasının yavaşladığı gözlenmiştir. Ayrıca, ham selüloz, ADF ve NDF analizlerinde gözlenen azalma, sindirilebilirliğin arttığını ortaya koymakta olup, bu durum Oba ve Allen (1999) tarafından bildirilen bulgularla da tutarlıdır. Özellikle LAB6 uygulaması, gruplar arasında en iyi sindirilebilirlik profilini sunmuştur.

Ham selüloz (HS), Asit Deterjan fiber (ADF) ve Nötr Deterjan fiber (NDF) değerleri LAB6 ve LAB8 gruplarında önemli ölçüde azalmıştır, bu da selüloz sindirilebilirliğinin arttığını göstermektedir. En düşük NDF (%52,58) ve ADF (%28,87) değerlerine sahip LAB6, yem sindirilebilirliği açısından.

Buna karşılık, ham yağ (HY) içeriği, en düşük değer LAB6'da (%4,74) gözlenirken (P>0,005), aşılanan tüm gruplarda kontrole kıyasla hafifçe azalmıştır. Bu durum, Muck (2010) tarafından tartışıldığı gibi, fermantasyon sırasında bazı lipid bileşenlerinin mikrobiyal kullanımına bağlanabilir.

Bu sonuçlar, *L. plantarum'un*, özellikle LAB6 ve LAB8 suşlarının, proteinleri koruyarak ve ruminant yem verimliliği için kritik olan sindirilemeyen lifi azaltarak silajın beslenme kalitesini iyileştirebileceğini göstermektedir.

Tablo 4. Silajın enerji değerleri

Gruplar	Kontrol	LAB6	LAB8	LAB9
NFE	$50.99^{c}\pm0.04$	$52.32^{a}\pm0.02$	$51.50^{b}\pm0.17$	$51.71^{b}\pm0.09$
NFC[1]	$21.46^{a}\pm0.45$	$22.38^{a}\pm1.05$	$20.15^{a}\pm0.25$	$20.57^{a}\pm0.76$
TK[1]	$74.59^{c}\pm0.01$	$74.96^{a}\pm0.02$	$74.93^{a}\pm0.02$	$74.78^{b}\pm0.04$
SE	$2.77^{a}\pm0.00$	$2.76^{b}\pm0.00$	$2.74^{c}\pm0.00$	$2.76^{b}\pm0.00$
ME	$2.27^{a}\pm0.00$	$2.27^{a}\pm0.00$	$2.25^{b}\pm0.00$	$2.27^{a}\pm0.00$
NE_L	$1.42^{a}\pm0.00$	$1.42^{a}\pm0.01$	$1.40^{b}\pm0.00$	$1.42^{a}\pm0.00$
NE_M	$1.41^{a}\pm0.01$	$1.40^{a}\pm0.00$	$1.38^{b}\pm0.00$	$1.40^{a}\pm0.00$
NE_G	$0.82^{a}\pm0.00$	$0.82^{a}\pm0.00$	$0.80^{b}\pm0.00$	$0.82^{a}\pm0.00$

NFE: Azotsuz ekstrat (g/kg); **NFC**: Lifsiz karbonhidratlar (g/kg), **TK**: Toplam Karbonhidrat (g/kg), **SE**: Sindirilebilir enerji(Mcal/kg); **ME**: Metabolik enerji (ME Mcal/kg), **NE_L**: Net enerji laktasyon (Mcal/kg), **NE_M**: Net enerji metabolizması (Mcal/kg), **NE_G**: canlı ağırlık artışı (Mcal/kg). ^{a,b,c} Aynı sütundaki ortak üst simge olmayan ortalamalar önemli ölçüde farklıdır ($P<0.01$).

Lactobacillus plantarum inokülasyonunun arpa hasılı silajlarının enerjiyle ilişkili parametreleri üzerindeki etkilerini Tablo 3'te özetlenmektedir. Bu parametreler arasında azotsuz ekstrakt (NFE), lifsiz karbonhidratlar (NFC), toplam karbonhidratlar (TK), sindirilebilir enerji (SE), metabolik enerji (ME) ve net enerji değerleri (NEL, NEM, NEG) yer almaktadır.

LAB6, %52,32 ile en yüksek NFE içeriğini göstermiş ve bu değer, kontrol grubuna göre (%50,99) daha yüksek bulunmuştur. Bu artış, karbonhidrat fermentasyonunun ve enerji veriminin iyileştiğini göstermektedir. Benzer bir durum NFC ve TK değerlerinde de gözlemlenmiş olup, LAB6 sırasıyla 22,38 g/kg ve 74,96 g/kg ile kontrol grubunun üzerinde değerler vermiştir. ($P<0,01$).

Sindirilebilir enerji (SE) ve metabolik enerji (ME) değerleri de LAB6 ve LAB8 gruplarında anlamlı bir farklılık gözlenmemiştir.

Lactobacillus plantarum, özellikle LAB6 suşu, muhtemelen fermantasyon verimliliğini artırarak ve yapısal olmayan karbonhidratları koruyarak arpa hasılı silajının enerji profilini iyileştirmektedir.

Tablo 5. Silajın açılma zamanındaki mikroorganizma sayım sonuçları

Gruplar	Kontrol	LAB6	LAB8	LAB9
Laktik Asit Bakterisi (Log10^5 kob/g)	-	-	3.0±0.00	-
Maya (Log 10^5 kob/g)	1.0^a±0.00	1.0^a±0.00	1.0^a±0.00	-

Kontrol: Arpa hasılı, LAB6: Arpa hasılı + L. Plantarum 1x10^6, LAB8: Arpa hasılı + L. Plantarum 1x10^8, LAB9: Arpa hasılı + L. plantarum 1x10^9, ^{a,b,c} *Aynı sütundaki ortak üst simge olmayan ortalamalar önemli ölçüde farklıdır (P<0.01).*.

Tablo 6: Silajın aerobik stabilite sonrası pH_2, CO_2 değerleri ve mikroorganizma sayıları

Gruplar	Kontrol	LAB6	LAB8	LAB9
pH_2	5.97^a±0.08	5.14^b±0.16	5.02^b±0.08	5.00^b±0.11
CO_2	19.24^a±3.78	5.60^{b}a±1.83	3.40^b±0.13	15.65^{ba}±5.72
Aerobik stabilite sonrası Küf	-	1.00±-	-	-
Aerobik stabilite sonrası Maya (Log 10^5 kob/g)	64.67^a±2.67	12.0^b±0.00	55. 33^a±10.73--	17.33^b±5.20

Kontrol: Arpa hasılı, **LAB6**: Arpa hasılı + L. Plantarum 1x10^6, **LAB8**: Arpa hasılı + L. Plantarum 1x10^8, **LAB9**: Arpa hasılı + L. plantarum 1x10^9 **CO_2:** Karbondioksit miktarı, **pH_2**: Aerobik stabilite sonrası pH**, Maya:** Aerobik stabilite öncesi toplam maya.

Lactobacillus plantarum inokülasyonunun arpa hasılı silajlarının mikrobiyal sayımları ve aerobik stabilitesi üzerindeki etkilerini Tablo 5'de göstermektedir. Değerlendirilen parametreler arasında silaj açımında ve aerobik stabilite analizi sonrası pH, karbondioksit üretimi ve maya/küf gelişimi yer almaktadır. Aerobik stabilite sonrası pH değerleri, LAB ile muamele edilen gruplarda kontrol grubuna kıyasla anlamlı şekilde daha düşük bulunmuştur (Kontrol: 5,97^a; LAB6: 5,14^b; LAB8: 5,02^b; LAB9: 5,00^b). pH'nın düşmesiyle ortamda mikrobiyal gelişimin baskılandığı ve kontrol grubuna göre besin maddelerinin korunduğu anlamına gelmektedir.

Aerobik mikrobiyal solunumun bir göstergesi olan karbondioksit (CO_2) seviyeleri kontrol grubunda en yüksek düzeyde ölçülmüştür (19,24) ve LAB6 (5,60) ile LAB8 (3,40) gruplarında anlamlı şekilde azalmıştır. En düşük CO_2 üretimi LAB8 grubunda görülmüş, bu da aerobik mikrobiyal aktivitenin güçlü bir şekilde baskılandığını göstermektedir. Böylece, aerobik stabilite sonrası maya sayılarındaki düşüşle de paralellik göstermektedir: LAB6 (12,0 log kob/g) ve LAB9 (17,33) gruplarında kontrol grubuna (64,67 log kob/g; P<0,001) göre belirgin şekilde daha düşük maya sayıları kaydedilmiştir.

Aerobik stabilite sonrası sadece LAB6 grubunda küf sayısı tespit edilmiş olup, oldukça düşük bir düzeyde kalmıştır (1,00 log kob/g). Bu durum, tüm LAB uygulamalarında küf gelişiminin oldukça iyi baskılandığını göstermektedir.

Tablo 6'da görüldüğü üzere, LAB6 ve LAB9 grupları aerobik stabilite sonrası maya sayısını anlamlı derecede düşürmüş (sırasıyla 12,0 ve 17,33 log kob/g) ve CO_2 üretimini azaltmıştır. Bu da mikrobiyal bozulmanın azaldığını ve raf ömrünün uzadığını göstermektedir (Kleinschmit ve Kung, 2006; Muck, 2010). Ayrıca, LAB8 grubundaki laktik asit bakteri sayısı 3,0 log kob/g olarak belirlenmiş böylece inokülantın silaj ortamında başarılı şekilde çoğaldığını ve baskın hale geldiğini göstermektedir.

Bu sonuçlar, Weinberg ve Muck (1996) ve Oude Elferink ve ark. (2001) tarafından bildirilen bulgularla uyumludur. Söz konusu çalışmalarda, laktik asit bakterisi inokülasyonunun yalnızca fermentasyonu iyileştirmekle kalmayıp, maya ve küf gibi bozulma yapan organizmaların gelişimini sınırlayarak aerobik stabiliteyi de artırdığı ifade edilmiştir.

5. SONUÇ

Bu çalışmada, ev yapımı turşulardan izole edilen *Lactobacillus plantarum* suşlarının ($LP10^6$-LAB6, $LP10^8$- LAB8, $LP10^9$- LAB9), arpa (*Hordeum vulgare*) hasılı silajının kalite, kimyasal, enerji ve mikrobiyolojik analizleri yapılmış ve aerobik stabilitesi üzerindeki etkileri araştırılmıştır. Kontrol grubuna kıyasla, LAB6 ve LAB8 uygulamaları silajın pH'sını anlamlı şekilde düşürmüştür (sırasıyla 4,88 ve 4,92) ve bu durum daha verimli bir fermentasyona işaret etmektedir. Daha düşük pH değeri, bozulmaya karşı direnci artırarak aerobik stabiliteyi geliştirmektedir. Genel olarak, LAB6 suşu, mikrobiyal kaliteyi artırma, besin kayıplarını azaltma ve arpa hasılı silajının aerobik stabilitesini iyileştirme açısından en etkili suş olarak öne çıkmıştır. Bu sonuçlar, *Lactobacillus plantarum*'un mikrobiyal inokülant olarak değerini ortaya koymakta ve yem kıtlığı ile iklim-dostu tarım gibi güncel zorluklarla uyumlu, daha güvenli, verimli ve sürdürülebilir hayvan besleme uygulamalarına katkı sunduğunu göstermektedir.

Sonuç olarak, *Lactobacillus plantarum* inokülasyonu, özellikle LAB6 ve LAB8 suşları ile yapılan uygulamalar, pH seviyelerini düşük tutup, CO_2 salınımını azaltarak ve maya ile küf gelişimini anlamlı düzeyde sınırlamış arpa hasılı silajının aerobik stabilitesini artırmıştır. Bu durum, kimyasal ve enerji analizlerinden elde edilen önceki bulgularla uyuşmakta ve silaj kalitesinde pozitif iyileştirmeler gerçekleştirmiştir. Bu çalışmanın farklı materyallerle tekrar çalışılması önerilmektedir.

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DWARFING MECHANISMS IN TEMPERATE FRUIT TREES

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ABSTRACT

Temperate fruit cultivation has an important agricultural activity worldwide. In fact, these species constitute approximately 48% of global fruit production. Temperate fruit species have adapted to the temperate climate in the mid-latitudes; however, approximately 50% of these fruit species are grown in different climate zones in China, Turkey, USA, Brazil, Italy and Spain; these countries constitute the majority of the world's total production. The most effective use of unit area in fruit cultivation has also necessitated the planting of more production material on the land and the use of intensive inputs. Fruit species, whose consumption demand has increased in parallel with the increase in the world population, have had higher productivity per unit area due to the effect of intensive input use in recent years.

In particular, global warming, deteriorating soil structure and unsuitable environmental conditions, as well as biotic stress conditions, significantly threaten the productivity and spread of fruit cultivation. The use of more production material per unit area has enabled cultivation with different density and shape planting intervals depending on the use of compact species/varieties and rootstocks. While fruit trees grow more strongly on their own roots, they form smaller crowns on some clonal rootstocks. However, the fact that the tree grows slowly but forms large trees during the fruiting period, in other words, the long juvenile sterility period, does not indicate that the tree or rootstock is dwarf. Dwarfism can essentially be described as both compact development, the formation of small and numerous fruit branches, and a short juvenile sterility period. Many variables such as the rootstocks used, genetic factors, growth regulators, and maintenance techniques can affect the development strength and shape of dwarf trees. Dwarfism is also a mechanism that allows the tree to quickly reach a balance of vegetative and generative development. Many studies have been conducted to date in different fruit species

in the fields of morphology, anatomy, histology, and molecular in order to reveal this mechanism. In these studies, it was stated that dwarfing is closely related to carbon/assimilation/nitrogen ratios, and that it may be a mechanism provided by a complex interaction of root morphology, bark characteristics, density and dimensions of vascular bundles, water and mineral contents, and constitutional hormone levels.

This study aimed to summarize the publications investigating the mechanisms of dwarfing development under certain headings in temperate climate fruit trees and the current status of information on the dwarfing mechanism.

Keywords: Temperate fruit trees, rootstock, dwarfing mechanism, vigour

ILIMAN İKLİM MEYVE AĞAÇLARINDA BODURLUK VE MEKANİZMASI

ÖZET

Ilıman iklim meyve yetiştiriciliği, dünya genelinde önemli bir tarımsal faaliyet alanına sahiptir. Nitekim bu türler, küresel meyve üretiminin yaklaşık %48'ini oluşturur. Ilıman iklim meyve türleri, orta enlemlerdeki ılıman bölge iklimine adapte olmuştur; ancak bu meyve türlerinin yaklaşık %50'si Çin, Türkiye, ABD, Brezilya, İtalya ve İspanya'daki farklı iklim bölgelerinde yetiştirilmektedir; bu ülkeler dünyanın toplam üretiminin çoğunu oluşturmaktadır.

Meyvecilikte birim alanın en etkili şekilde kullanılması, araziye daha fazla üretim materyali dikimini ve yoğun girdi kullanımını da zorunlu kılmıştır. Dünya nüfusunun artışına paralel olarak tüketim talebi artan meyve türleri, son yıllarda yoğun girdi kullanımının etkisiyle birim alandan daha yüksek verimliliğe sahip olmuştur. Özellikle global ısınma, bozulan toprak yapısı ve uygun olmayan çevre koşulları ile birlikte biyotik stres koşulları da meyveciliğin verimliliğini ve yaygınlaşmasını önemli ölçüde tehtid etmektedir. Birim alana daha fazla üretim materyalinin kullanılması, kompakt gelişim gösteren tür/çeşit ve anaçların kullanımına bağlı olarak farklı yoğunlukta ve şekilde dikim aralıklarıyla yetiştiriciliğe imkân vermiştir. Meyve ağaçları kendi kökleri üzerinde daha kuvvetli büyürken, bazı klonal olarak nitelendirilen anaçlar üzerinde daha küçük taç yaparlar. Bununla birlikte ağacın yavaş büyümesi, fakat meyve döneminde büyük ağaçlar oluşturması yani gençlik kısırlığı periyodunun uzun olması o ağacın ya da anacın bodur olduğunu göstermez. Bodurluk asıl olarak hem kompakt gelişim, küçük ve çok sayıda meyve dalı oluşturma hem de gençlik kısırlığı periyodunun kısa olması olarak nitelendirilebilir. Bodur ağaçların gelişme kuvvetleri ve şekline, kullanılan anaçlar, genetik faktörler, büyüme düzenleyiciler ve bakım teknikleri gibi birçok değişken etki edebilmektedir. Bodurluk, ayrıca ağacın hızlı bir şekilde vejetatif ve generatif gelişim dengesine ulaşmasına da imkân veren bir mekanizmadır. Bu mekanizmanın açığa çıkarılması ile ilgili bugüne değin farklı meyve türlerinde morfolojijk, anatomik, histolojik ve moleküler alanlarda birçok çalışma yürütülmüştür. Bu çalışmalarda bodurluğun, karbon/ asimilasyon / nitrojen oranları ile sıkı bir ilişkide olduğu, kök morfolojisinin, kabuk özelliklerinin, iletim demetlerinin yoğunluk ve boyutlarının, su ve mineral içeriklerinin ayrıca bünyesel hormon düzeylerinin bir arada kompleks bir etkileşimle sağlanan bir mekanizma olabileceği belirtilmiştir.

Bu çalışma, ılıman iklim meyve ağaçları özelinde bodur gelişimin belli başlıklar altında mekanizmalarını araştıran yayınları ve bodurluk mekanizmasına ilişkin bilgilerin mevcut durumunu özetlemeyi amaçlamıştır.

Anahtar Kelimeler: Ilıman iklim meyve ağaçları, anaç, bodurluk mekanizması, gelişme kuvveti

1.Giriş

Vejetatif büyümenin kontrol edilmesi, daha küçük meyve ağaçlarının elde edilme isteği, uzun bir geçmişe dayanmaktadır. Bitki büyütücülerinin yönlendirilmesiyle sürgünlerin aşırı artmasını engelleme, sıcaklık ve meyve verimini teşvik etmek için yüzyıllar boyunca uygulanan bir yöntemdir. Antik bahçeciler ve modern meyve yetiştiricileri, büyümeyi kontrol altına almak veya düzenlemek için kabuk soyma, halka alma, bodur anaç kullanımı, budama ve dal yönlendirme gibi teknikler kullanmışlardır.

Bahçe yönetimi ve kaliteli meyve üretiminde ağaç büyüklüğü, kritik bir rol oynar. Bodur ağaçlar birçok avantaj sunar. Daha iyi ışıklanma ve fotosentez bu sayede ağaçların, daha fazla ve kaliteli meyveler üretimi sonucunu doğururur. Ayrıca bodur ağaçlarda püskürtülerek uygulanan çözeltilerin daha etkili dağılması mümkündür. Bu ağaçlarda hasat daha kolay, bahçecilik işlemlerinde daha az işgücü kullanımı söz konusudur. Bu avantajlarından dolayı bodur meyve ağaçlarına olan ilgi uzun süredir devam etmektedir (Eşitken, 2020).

Anaçların kalem gelişimi üzerindeki etkisinin doğru bir şekilde değerlendirilmesi oldukça önemlidir. Bodur anaçlar, kendi kökleri üzerinde büyüyen ağaçlara kıyasla önemli ölçüde daha küçük ağaç olma eğilimindeki anaçlardır. Ancak eğer bir ağaç yalnızca yavaş büyüyor ama yetişkinlik döneminde büyük bir taç oluşuyorsa, bu tür anaçlar her zaman bodur olarak kabul edilmez. Anaçların dallanma şekli ve sürgün uzunluğu üzerindeki etkilerin belirginleştiğinde bodurluk tanımından söz edilebilir. Bol ve kısa sürgünlü ağaçlar ile az sayıda fakat uzun sürgünlü ağaçlara karşı, kütle olarak benzer olmalarına rağmen, uzun sürgünlü ağaçların taç boyutu daha dayanıklı. Genellikle, yoğun dallanmış, kütlece büyük fakat küçük taç hacmine sahip ağaçlar bodur olarak nitelendirilebilir (Webster, 1995).

Bodurlaşma oranlarıyla ilgili olarak anatomik, yapısal ve kimyasal açıdan farklı seçenekler bulunmaktadır. Elma ağaçlarında bodurlaşma aralıkları üzerinde yapılan incelemeler, taç ve kök arasındaki iletimleri ve büyümeyi düzenleyen oksin, sitokinin, giberellin, absisik asit, nitrojen oranları ve fenoller gibi iç parametreleri kapsar. Bu maddeler, başlangıç büyüme süreçlerini kontrol ederek bodurlaşma üzerinde önemli bir etkiye sahiptir (Lockard ve Schneider, 1981).

2. Bodurluğu Etkileyen Faktörler

Meyve ağaçlarında bodurluk, birçok faktörden etkilenir ve bu faktörler genellikle bitkinin büyüme ve gelişme süreçleriyle yakından ilişkisi vardır. Öncelikle, genetik faktörler bodurluğun temel belirleyicisidir; bazı meyve ağaçları genetik olarak daha kısa ve kompakt bir yapıya sahipken, diğerleri daha uzun ve yayvan bir formda büyüyebilir. Bodurlaştırıcı işlevi morfolojik, anatomik, fizyolojik ve biyokimyasal değişiklikleri içerir. Meyve ağaçlarının bodurluğunu etkileyen faktörlerin dikkate alınması, tarımsal verimliliği artırmak için kritik öneme sahiptir.

2.1. Morfolojik ve Anatomik Faktörler

2.1.1. Anaç-Kalem Etkileşimi:

Aşılama, yeni bir bitki oluşturmak için hava kısmını (filiz) başka bir kısım (anaç) ile birleştiren çoğaltma tekniğidir (Koepke ve Dhingra, 2013). Anaçlar üzerine aşılanmış bitkiler farklı çevresel streslere karşı daha iyi bir tolerans sağlar (Darvis ve ark., 2008). Bahçe kuruluşunda uygun anaç seçimi, farklı ekolojik bölgelerde ağaç performansını etkilediği için en önemli kararlardan birisi içerisinde yer alır. Anaçlar meyve üretimini, kalitesini ve tadını artırır ve çeşitli stres koşullarına karşı toleransı artırarak besin emilimini ve taşımasını iyileştirmek için kullanılmaktadır (Castle, 2010).

Anaçlar ve aşı kalemleri arasındaki etkileşim hem çok geniş hem de karmaşıktır. Aşı kalemi karbonhidratları özümseyip bunları hormonlarla birlikte kök sistemine taşır. Öte yandan kök sistemi, toprakta emilen su ve besinlerle birlikte aşı kalemi için hormon da sağlayabilir. Bodur anaçların etkisinin periderm kalınlığı, korteks kalınlığı, öz yarıçapı ve elek borusu alanı, kuvvetli anaçlardan önemli ölçüde daha düşükken, floeme yakın damar alanı/elek borusu alanı, merkezi damar alanı/elek borusu alanı bodur anaçlarda son derece daha yüksektir (Li ve ark., 2019). Bodurlaştırıcı anaç ve ara anacın bitki boyunu, taç boyutunu ve ağaç hacmini kısıtlamaya katkıda bulunduğunu göstermiştir. Ancak kuvvetli anaçlarda aşılanan bitkiler daha fazla besin özelliğine sahip olurken daha düşük verime sahiptir (Lliso ve ark., 2004, Karlıdağ ve ark., 2014). Elma kalemlerinin bodur anaçlara aşılanması, sürgün büyümesinin erken durması ve daha yavaş uzama ile sonuçlanırken, boğum arası uzunluk genellikle etkilenmez (Seleznyova ve ark., 2008). Bu değişmiş sürgün büyüme deseni, sürgüne su taşınmasından etkilenebilir. Özellikle bodur anaçların köklerinde daha düşük hidrolik iletkenlik sıklıkla gözlemlenmektedir. Aşı birleşim yeri ksilem özsuyunun iyonik birleşimini etkilemektedir. M9 anacının birleşiminden son derece düşük akış hızıyla geçiş özsuyu ozmolalitesini ve Ca^{+2} iyon konsantrasyonunu azaltmıştır (Else ve ark., 2018). Kuvvetli anaçlarla karşılaştırıldığında, yarı bodur anaç M26 anacı üzerindeki Granny Smith elmasının yapraktaki Ca ve Fe konsantrasyonları optimum aralığın altında değerler sunmuştur. (Jobir ve ark., 2017). Bodur anaçlar üzerine aşılanmış elma ağaçlarının yapraklarında nişasta içeriğinin arttığı ve bu gözlemlemenin yanında erkenciliğe katkıda bulunan bir faktör olduğunu desteklemektedir (Zhou ve ark., 2020). Nişasta konsantrasyonları, M9 anacı köklerinde, gövdelerinde ve aşılanmış Royal Gala (RG) elma filizlerinde, iki kat daha yüksek seviyeler tespit edilmiştir. Glikoz ve Fruktoz seviyeleri, M9 anaç üzerine aşılanmış Royal Gala elma ağaçlarının üç dokusunda da önemli ölçüde azaldığı görülmüştür. Bu bulgular, bodur anaçların, muazzam nişasta rezervlerine sahip olmalarına rağmen, şeker tükenmesi ve azalmış hücresel aktiviteden yoksun olduğunu göstermektedir (Foster ve ark, 2017). Riparia Gloire anaçlarının genellikle filizlere sağladığı düşük canlılık, sürgünlere azot taşınmasının azalması ve köklere doğru daha fazla biyokütle tahsisi kombinasyonundan kaynaklanıyor olabilir (Rossdeutsch ve ark., 2021). Gjamovski ve Kiprijanovski (2011) yapmış olduğu çalışmada daha kuvvetli anaçlarla aşılanan 'Granny Smith' elma ağaçlarının, zayıf anaçlardan (Panjam 1, M.9 T337 ve Mark 9) daha yüksek vejetatif büyümeye sahip olduğunu belgelemiştir. Birkaç çalışma, bodur anaçlarına aşılanmış elma filizlerinin daha kısa sürgün uzunluklarına, daha düşük gövde kesit alanına (TCSA) ve zayıf büyüme özelliklerine sahip olduğunu göstermiştir. Bodur anaçlar üzerinde aşılı ağaçların yaprak üretiminin durmasını hızlandırdığı ve daha hızlı yaprak yaşlanmasını ve dökülmesine neden olduğu iddia edilmiştir (Marini ve ark., 2017).

2.1.2. Aşı Birleşiminin Etkileri

Bodur anaçlar üzerindeki elma ağaçlarında aşı birleşimi üzerinde özsu akışı sırasında besin maddelerinin tüketildiği bildirilmiştir (Jones, 1984). Jones'un çalışmalarında, aşı birleşiminin üst kısmındaki özsudaki çözünen madde konsantrasyonunun alt kısımdakine göre daha düşük olduğunu ortaya konmuştur. Ancak Webster (2004), bu hipoteze şüpheyle yaklaşmış ve East Malling deney istasyonunda yapılan çalışmalara dayanarak besin maddesi tüketiminin yalnızca düşük özsu akış hızlarında meydana geldiğini belirtmiştir. Webster'a göre, tipik özsu akış hızlarında bu tür bir tükenme gözlemlenmemektedir. Bu bulgular, bodur anaçların besin maddesi taşınmasında oluşturduğu etkilerin yalnızca belirli koşullarda ortaya çıktığını göstermektedir. Uyumsuz anaçların kullanımı uyumsuz kalem anaç kullanımıyla bodurluk oluşabilir. Ancak ticari olarak kullanılmaz. Quince C bodur anaç üzerine aşılanan armut çeşitleinde aşı birleşimindeki damarsal kesintiye nitelenecek küçük yaprak boyutu ve erken yaprak sararması gibi belirli uyumsuzluk belirtileri gözlemlenmiştir (Askari-Khorasgani ve ark., 2019). *Zizyphus nummularia* anacı üzerine aşılanan Ber kalem çeşiti, aşı uyuşmazlığı ile bodurluğa neden olabilir. (Saroj ve Singh, 2018). Dikimden 64 ay sonra Flying Dragon üzerine aşılanan 'Pera' portakalı arasında görsel uyumsuzluk belirtileri gözlemlenebilir. Bodurluk ve aşı uyuşmazlığı damar boyutu ve sıklığı ile kambiyal bölgenin boyutu ve düzensizliği ile bağlantılıdır (de Carvalho ve ark., 2018). Aşılamadan 10 ve 21 gün sonra, ParPAL1 (fenilalanin amonyak-liyaz) transkrip seviyeleri, *Prunus spp.*'nin uyuşmaz birleşmelerinde uyumlu birleşimlere göre üç kat daha fazla artış göstermiştir. Bu durum, ParPAL1'in uyumsuz aşı birleşmelerinde daha aktif olduğunu ve bu süreçte bitkinin stres yanıt merkez mekanizmalarına dahil olabileceğini düşündürmekterdir. Diğer yandan ParPAL2 transkript seviyeleri de incelenmiş ve özellikle uyuşmaz aşı birleşimelerinde yukarı doğru düzenlendiği görülmüştür. Bu durum ParPAL2'nin de uyumsuzluk süreçlerinde önemli bir rol oynayabileceğine işaret etmektedir. Ancak ParPAL1'e kıyasla, ParPAL2'nin biyolojik işlevleri ve uyumsuzluk süreçlerindeki spesifik rolü daha fazla araştırmayı gerektirmektedir. (Irisarri ve ark., 2016).

2.1.3.Ara Anaç Kullanımı

Bodur elma anaçları ve ara anaçlar yıllık büyüme döngüsü sırasında üretilen büyüme maddelerinin tipini, ayrıca erken çiçek açmaya geçiş yıllık sürgünlerin kompozisyonunu ve canlılığını da etkiler. Bu etki, özellikle bodur anaçlar tarafından tetiklenen çiçeklenmeye geçişle daha da artmaktadır. Yıllık sürgünün büyüme birimlerine bölünmesi, yaşın elma ağacı mimarisi üzerindeki etkilerini ölçmek ve modellemek için de yararlı olacaktır (Seleznyova ve ark., 2008). Yüksek verimliliği ve meyve kalitesinin olmasıyla hibrit HTR-051 anaçları turunçgil türlerinde bodurlaşmayı teşvik eder ve yüksek yoğunluklu bahçeler için iyi beklenti sunmaktadır. (de Carvalho ve ark., 2019). Dikim derinliği de bodurlaşma üzerine belirleyici faktörler arasında yer almaktadır. Derin dikim uygulamalarının, bodurlaşma etkisini artıracağı düşünülmektedir. Örneğin, Kviklys ve Samuolienė (2020), ara anaçların dikim derinliğine bağlı olarak farklı büyüme davranışları sergilediğini göstermiştir.

2.1.4. Kabuk kalınlığı

Kabuk kalınlığı ve bitki büyümesi arasındaki ilişki, özellikle bodur anaçlar ve oksin gibi büyüme düzenleyicilerle bağlantılı olarak dikkat çekmektedir. Oksinler, bitki büyümesini düzenleyen en önemli hormonlardan birisidir. Ancak oksinler, çeşitli enzimler tarafından parçalanarak etkisiz hale getirilir. Bu durum, bitkilerin büyüme hızını etkileyip sınırlayabilir. Kabuk kalınlığı fazla olan bitkilerde, oksinlerin parçalanma oranı daha yüksek olabilir. Bu da bu tür bitkilerin genellikle bodur bir yapıya sahip olmasına neden olur. Harrison ve ark. (2016), yaptığı araştırma, kabuk kalınlığı ile bitki büyümesi arasındaki ilişkiyi anlamak için önemli veriler sunmaktadır. Çalışmada, Royal Gala elma çeşidi ile aşılanmış iki farklı anaç türü olan M116 ve M27'nin kök kabuğu yüzdeleri incelenmiştir. Araştırmanın sonuçlarına göre, bodur bir anaç olan M27'nin kök kabuğu yüzdesi %85,3 olarak bulunmuştur. Buna karşın, yarı kuvvetli bir anaç olan M 116'nın kök kabuğu yüzdesi daha düşük olup %62,6 olarak ölçülmüştür. Bu sonuçlar, kabuk kalınlığı ile bitki büyümesi arasında güçlü bir negatif korelasyon olduğunu göstermektedir (Yang ve ark., 2016). Kabuk kalınlığının artması, bitki büyümesini çeşitli mekanizmalarla etkileyebilir. Öncelikle, kalın kabuklu bitkilerde su ve besin maddelerinin taşınmasında sınırlamalar oluşabilir. Bu durum, bitkinin büyüme hızını yavaşlatabilir. Ayrıca, kalın kabuklu bitkilerde oksinlerin parçalanma hızı daha yüksek olduğu için hücre bölünmesi ve uzaması sınırlanabilir. Bu durum, kabuk kalınlığının yalnızca köklerde değil, aynı zamanda sürgünlerde de büyümeyi olumsuz etkileyebileceğini göstermektedir. Özellikle meyve ağaçlarında bu durumun verim üzerinde önemli etkileri olabilir.

2.1.5. Aşı Yüksekliği ve Güneşlenme

Aşılama yüksekliği, anaçların büyüme hızı üzerine önemli bir etkiye sahiptir. Daha uzun anaç kısımlarının güneşe maruz kalması, büyüme düzenleyici hormonların başında gelen oksin gibi hormonların taşınmasını etkileyebilir. Hrotko ve Magyar (2004), aşılama yüksekliğinin artması ile filiz büyümesinin azaldığını bildirmiştir. Grzyb (2002), ise oksin taşımasının azalması ve kök kabuğunda ayrışmanın artmasının büyüme üzerinde etkili olabileceğini öne sürmüştür.

2.1.6. Budama

Budama yoluyla bodurlaşma elde edilebilir ve yavaş büyüyen ağaçların budamaya daha fazla tepki verdiği gözlemlenmiştir. Bodur ağaç, yan tomurcuk büyümesini uyaran sürgün apikal kısmının çıkarılmasıyla elde edilir. Budama yoluyla ağaç büyüklüğü kontrolü asma, elma ve bazı ılıman iklim meyve türleri ile sınırlıdır. M9 anaç üzerine aşılanmış Topaz elma çeşidinde, modifiye edilmiş ince iğ şeklinde yetiştirilen ağaçlar ince iğ şeklinde yetiştirilen ağaçlara kıyasla daha düşük kanopi hacmi ve daha iyi ağaç büyüklüğü kontrolü göstermiştir. (Mészáros ve ark., 2017). Gisela5 anaç üzerine aşılanmış ve iğ şeklinde yetiştirilen 0900 Ziraat kiraz çeşidi ağaçları daha düşük ağaç yüksekliği vermiştir (Aglar ve ark., 2016). Guttingen V şekli budama sistemiyle elma ağaçlarının ağaç canlılığını azalttırmıştır ve Geneva Y kafes budama sistemine (1680 ağaç/ha) kıyasla daha yüksek dikim yoğunluğuna (3000 ağaç/ha) olanak sağladığı gözlemlenmiştir (Dadashpour ve ark., 2019). Fuji elmasında dal bükme açıları arttıkça mahmuz sayısı ve yüzdesi artarken uzun ve orta boy sürgünlerin sayısı ve oranı azalmıştır (Zhang ve ark., 2017).

3. Fizyolojik Esaslar

Fizyolojik düzeyde bodurluk, bitkinin su, mineral ve fotosentez ürünlerini taşıma kapasitesinde yaşanan değişimlerle doğrudan ilişkilidir. Bodur anaçlar genellikle daha düşük iletim dokusu kapasitesine sahiptir. Bu ağaçlarda ksilem çapı ve iletim elemanlarının sayısı azalır, bu da hem su iletimini hem de mineral taşınımını sınırlandırır (Tworkoski ve Fazio, 2016). Özellikle su iletimi sınırlı olan bodur anaçlarda, gövde kısmındaki hücre bölünme sayısı azalmakta, bunun sonucunda internod uzunluklarının kısalmasına neden olmaktadır. Ayrıca, bu durum bodur anaçlarda karbon asimilasyonunu da azaltmaktadır. Bitkinin yaprak yüzeyi küçüldükçe, toplam fotosentez kapasitesi de azalır. Bu, meyve verimi üzerinde sınırlayıcı etki yaratırabilir; ancak kontrollü koşullarda bu durum üretim kalitesi açısından yararlı hale getirilebilir.

3.1.Hormonal Değişimler

Bitkilerde büyüme ve gelişme büyük ölçüde hormonların etkisi altındadır. Bodurluk durumunda hormonların sentezlenme miktarı, taşıma yolları ve etki alanları önemli derecede değişir.

3.1.1. Giberallinler (GA)

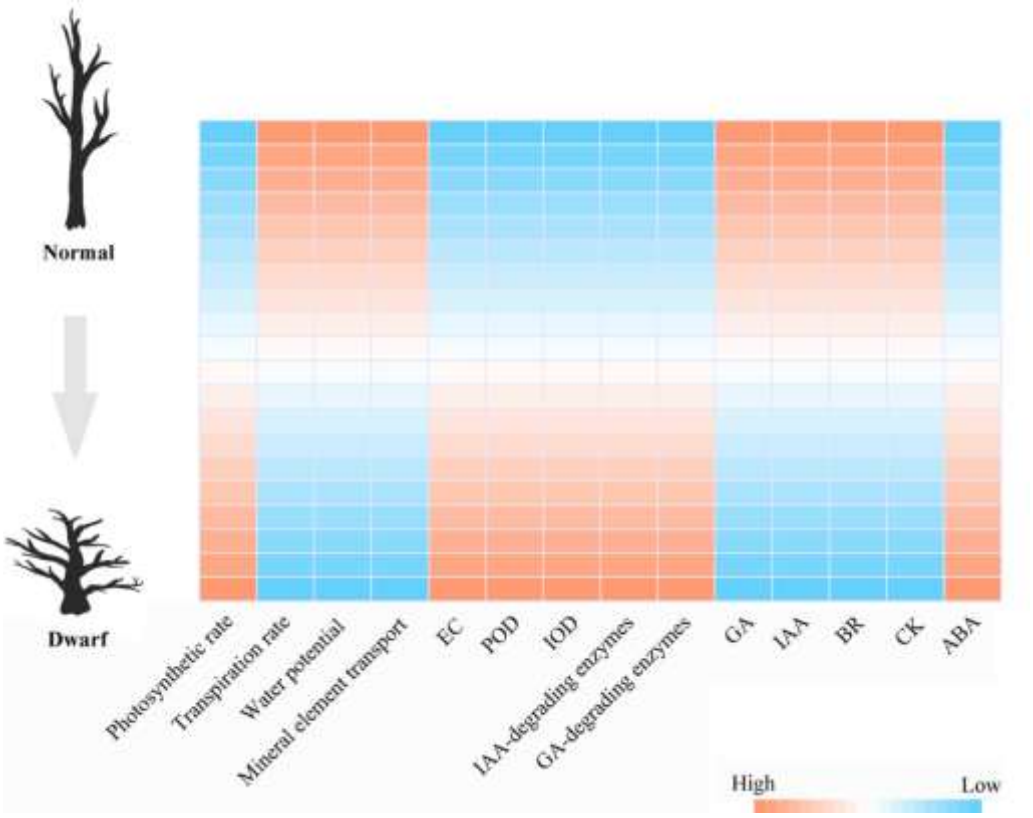
Gibberallinler, hücre uzamasını ve internod büyümesini teşvik eden başlıca hormon grubudur. Bodur anaçlarda GA biosentez genlerinin ekspresyonu düşüktür ya da bu hormonun yıkımına neden olan *GA2ox* genlerinin aşırı aktif olması nedeniyle gövde uzaması sınırlanabilir. GA_2-oksidaz (*GA2ox*), GA_1 dahil olmak üzere aktif GA'ların inaktif metabolitlere dönüşümünü katalize eder (Hedden, 2001;, Tworkoski ve Faizo 2016; Hu ve ark., 2018; Cheng ve ark., 2019). GA metabolizmasındaki bozulmalar bodurluğun indüklenmesinde önemli bir faktör olarak gösterilmiştir (Chu ve ark., 2023, Wang ve ark., 2024; He ve ark., 2024). Özellikle, bodur anaç M9 üzerine aşılanmış 'Royal Gala' elmasının ksilem özündeki GA_{19} konsantrasyonunun bodurlaşmayan anaçlardakinin iki katı olduğu bulunmuştur. Bodur anaçlara aşılanmış filizlerde GA uygulaması, birincil ve ikincil dallardaki nod sayılarının normalleşmesine ve tipik sürgün büyümesinin geri kazanılmasına yol açmıştır (Schomburg ve ark., 2003; van Hooijdonk ve ark., 2011). Bazı çalışmalar sonucunda bodur ağaçlara GA_3 uygulamasının geçici olarak gövde uzamasını artırdığı gösterilmiştir, bu da endojen GA eksikliğinin bodurluğun temel sebeplerinden biri olduğunu doğrulamıştır.

3.1.2. Sitokininler

Kökte sentezlenen sitokininler, gövdeye taşınarak hücre bölünmesini teşvik eder. Bodur anaçlarda sitokinin taşınımı yavaşladığından, gövdedeki meristematik aktivite azalır (Buban ve Faust, 1982). Ayrıca sitokin/oksin oranındaki dengesizlik, vegetatif gelişimi baskılayabilir. Sitokininler tomurcuk başlangıcı ve IAA taşınması için gereklidir. İlk çalışmalar, yetersiz CK sentezinden kaynaklanan aksiller tomurcuklardaki sınırlı IAA üretiminin elma ağaçlarındaki bodur fenotipte rol oynadığını öne sürmektedir (Şekil 1) (Tan ve ark. 2018).

3.1.3. Oksin (IAA)

Oksin, büyüme yönünün belirlenmesinde ve apikal dominansın sürdürülmesinde görev alır.bodur anaçlarda oksin taşınımına aracılık eden *PIN* proteinlerinin ekspresyonunda azalma gözlenmiştir (Gao ve Chu, 2020). Bu durum, ağaçlarda hormonal sinyalin yukarı taşınmasını sınırlandırır ve kalemin büyümesi olumsuz etkiler. Bodur meyve ağaçları ayrıca daha düşük IAA, BR ve sitokinin içerikleriyle de karakterize edilir (Şekil 1). 1997'de, beş elma anaç üzerinde yapılan bir çalışma, bodur anaçlarda kuvvetli olanlara kıyasla daha düşük IAA alımı ve taşınması olduğunu ortaya koymuştur (Kamboj ve ark. 1997). Kuvvetli anaçlara (Fuji/MM111) aşılanan elma ağaçlarında, bodur anaçlara (Fuji/M9) aşılananlara göre daha yüksek IAA konsantrasyonları gözlemlenmiştir (Song ve ark., 2016), bu da IAA eksikliğinin bodur fenotipe katkıda bulunduğunu göstermektedir.



Şekil 1. Bodur ve normal meyve ağaçlarının fizyolojik özelliklerinin karşılaştırmalı analizi. Bodur meyve ağaçları daha yüksek fotosentez oranı, elektriksel iletkenlik (EC), su potansiyeli, mineral element taşınması, terleme hızı ve peroksidaz (POD), indol-3-asetik asit oksidaz (IOD), IAA-parçalayıcı enzimler, gibberellik asit (GA)-parçalayıcı enzimler ve absisik asit (ABA) aktiviteleri sergiler. Bunun aksine, bodur bitkilerde daha düşük GA, IAA, brassinolid (BR) ve sitokinin (CK) seviyeleri gözlemlenmiştir. "Yüksek" ve "Düşük" bu fizyolojik özelliklerin göreceli seviyelerini gösterir (Chu ve ark., 2025).

3.1.4. Absisik Asit (ABA)

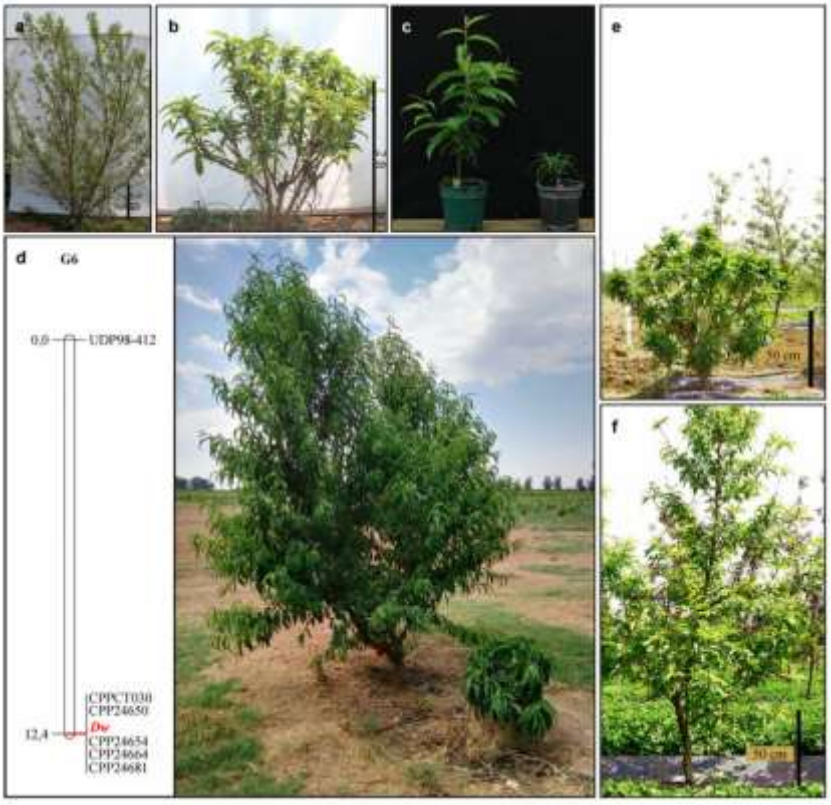
Absisik asit, genellikle stres koşullarında yükselir ve stomaların kapanmasını tetikleyerek büyümeyi sınırlandırır. Bodur anaçların genellikle daha düşük su iletim kapasitesine sahip

olması, endojen absisik asit düzeylerinin artmasını tetikleyerek büyümenin baskılanmasına katkı sağlamaktadır. ABA hem hava hem de kök büyümesini düzenler ve yüksek bitkilerde bodurlaşmaya neden olduğu bilinmektedir (Kavi Kishor ve ark., 2022, Lu ve ark., 2022, Michaud ve ark., 2023). Golden Delicious ve Cortland elmalarının bodur mutantlarında, tomurcuklardaki ABA konsantrasyonları yabani tip tomurcuklara kıyasla yüksekti (Jindal ve ark., 1974). Bodur anaçlar ayrıca gövde kabuğunda normal anaçlara göre daha yüksek ABA seviyeleri göstermiştir (Foster ve ark., 2017). Benzer şekilde, bodur anaçlara aşılanan elma bitkilerinin gövdelerindeki ABA konsantrasyonları standart anaçlara aşılanan bitkilerdekinden daha yüksekti (Tworkoski ve ark., 2016). Turunçgillerdeki benzer bulgular, yüksek ABA seviyelerinin sürgün büyümesini etkileyen kritik bir faktör olduğunu göstermektedir (Şekil 1).

3.2. Bodurluğun Genetik Temelleri

Bodurluk karakteri, bazı meyve türlerinde genetik olarak taşınan bir özelliktir. Elmada Dw1**,** Dw2, kirazda PpD gibi lokuslar tanımlanmıştır (Foster, 2022). Bu gen bölgelerindeki, hormonal sinyallerin iletimi, hücre duvarının uzaması ve ksilem gelişimi gibi büyümeyle ilgili çeşitli süreçleri düzenleyen genleri içerir. Örnek olarak, elmada *MdDWF4* geni gibberallinlerin biyosentezinde görev alırken, bodur çeşitlerde bu genin baskınlığı düşüktür. Kirazda ise *GAI* ve *RGL* genlerinin baskın aktivitesi, GA sinyallerini baskılayarak bodur fenotipin oluşumuna neden olmaktadır (Zhang, 2019).

Bitki genetik iyileştirmesi, sadece istenen özelliklerin altında yatan moleküler mekanizmaların derinlemesine anlaşılmasını değil, aynı zamanda bu özellikleri kontrol eden anahtar genlerin tanımlanmasını ve klonlanmasını da gerektirir. Çeşitli meyve ağacı türlerinde bodurlaşmanın düzenlenmesinde rol oynayan çok sayıda gen açıklanmıştır (Elmada Dw1, Dw2 ve Dw3 gibi) (Foster ve ark., 2017, Harrison ve ark., 2016). M9 ve MM106 nın yakın zamanda yapılan karşılaştırmalı genomik analizi, iki ayrışan popülasyonda bodurluk özelliği ile birlikte ayrışan, DwTE olarak adlandırılan 9.723 bp alel-spesifik uzun terminal tekrar retrotranspozon/ gypsy insersiyonunu ortaya koydu ve bunun bodur anaç ıslahında gelecekteki uygulama potansiyelini vurgulamıştır (Li ve ark., 2024). Şeftali'de çekinik bir bodurluk aleli (dw), GA reseptör geni GID1c'nin promotöründe anlamsız bir mutasyonla bağlantılıdır (Şekil 2) (Cantín ve ark. 2018; Hollender ve ark. 2016).



Şekil 2. Meyve ağaçlarında bodurlukla ilgili genlerin lokalizasyonu. a-c Haritalama popülasyonundan standart (Std) ve brakitik bodur (BD) şeftali ağaçlarının büyüme özellikleri. Dört yaşındaki Std (a) ve BD şeftali ağaçları (b); Bir yaşındaki Std (sol) ve BD (sağ) şeftali ağaçları (c) (Hollender ve Dardick, 2015, Hollender ve ark., 2016). Bodur (Dw) geninin pozisyonunu gösteren ve genetik ayrımların santimorgan cinsinden ifade edildiği Nv⊗ suşu için bir genetik harita. Sağdaki iki üç yaşındaki Nv⊗ bitkisinin görüntüleri, zıt fenotipleri vurgular: kısa boğum aralarına sahip bodur bitkiler ve tipik fenotip (Cantín ve ark., 2018). e–f İki yaşındaki 'FHSXT' (e) cüce ağacının ve 'QMH' (f) standart ağacının fenotipleri (Chen ve ark., 2016)

Erikte GID1'in susturulması da bodurlaşma ile sonuçlanmıştır ve bu da GID1c'nin cücelikteki rolünü doğrulamıştır. Bununla birlikte, meyve ağaçlarında bodurlaşmayla ilgili çok sayıda genetik ilişki bildirilmiş olsa da, söz konusu belirli genlerin daha fazla tanımlanması ve doğrulanması gerekmektedir (Lee ve ark. 2015). Belirlenen bodurlukla ilgili genlerin sayısı artmaya devam etse de, birçok meyve ağacında bodurluktan sorumlu olan anahtar genler yeterince karakterize edilmemiştir.

3.2.1. Giberallin Metabolizması ve Dengeleyici genler

Gibberellin (GA), hücre uzamasını ve meristem aktivitesini teşvik etmesiyle bodur anaçlarda düşük GA aktivitesi, büyümeyi baskılamaktadır. Bu durum da ***GA20ox*** **ve** ***GA3ox*** genleri,aktif GA formlarının sentezinden sorumlu olup bodur anaçlarda bu genler down-regüle edilir. ***GA20ox*** gen ailesi, ağaçlarda inaktif GA formlarını artırarak bodurluk oluşturmaktadır. Bu durumun en belirgin etkisi M9 elma anacında bu genlerin ekspreyonu yüksektir. Yine elma anaçlarında *MdGA2ox1* ve *MdGA2ox8* genlerinin bodurluğa doğrudan etki ettiği kanıtlanmıştır (Foster, 2015).

3.2.3 Della Proteinleri

DELLA proteinlerinde ise *GAI, RGLI, RGL2* gibi çeşitler büyüme sinyallerini baskılar ve GA ile parçalanmadıklarından hücre uzamasını durdurur. Kirazda *PaGAI ve PaRGLI* genleri bodur çeşitlerde etkileri aşırı derecede fazladır. Japon armudunda da bodur fenotipe yatkınlık sağlayan CRISPR/Cas9 ile *GAI* geninin mutasyonuyla elde edilmiştir (Liu ve ark., 2025).

3.2.4. Sitokinin Oksin Oranını Dengeleyici Genler

Sitokinin oksidaz/dehidrogenaz (*CKX*) genleri, bodur anaçlarda sitokinin düzeyini düşürürken bu durum M9 anacında *MdCKXI* ekspresyonu artmıştır (Wang ve ark, 2024). Oksin taşıma genleri de ise *PIN, AUX/LAX* ve *PILS* aileleri, oksin'in çift yönlü taşınımını düzenler. Örneğin; *MdPINI* ve *MdAUXI* bodur anaçlarda baskılanarak vegetatif büyümeyi kısıtlarken, bir başka durumda ise *ARF* gen ailesi (Auxin Response Factor) büyüme genlerinin aktivasyonunda yer alır ve bodur anaçlarda *ARF10/16* gibi baskılayıcı üyeler öne çıkar (Gao ve Chu, 2020).

3.2.5. Transkripsiyon Faktörleri ve Bodurluk

Transkripsiyon faktörleri, yüzlerce hedef geni kontrol ederek bodurluğu sistematik şekilde düzenler. Bunlardan NAC ailesi, meristem büyümesini ve hormonal tepkileri düzenlerken, bu durum elmada *MdNACI*'in aşırı ekspresyonu, sürgün apikal meristem (SAM) aktivitesini baskılayarak bodurluk oluşturmasıyla açıklanmıştır. TCP, MYB ve WRKY gen ailelerinde ise *TCP20* ve *TCP24'*ler hücre döngüsünü durdurarak bodurluk sağlayabilir. Stres durumunda da *MYB44* ve *MYB124* gen aileleri büyümeyi sınırlandırıcı rol oynar. Savunma mekanizmalarıyla büyüme arasında da WRKY genleri denge kurar, ağaç gelişimini dolaylı yoldan baskılar. Bodurluğa etkisi olan bir başka faktörde mikro-RNA'lar ve epigenetik etkidir. Mikro-RNA'lar, gen etkilerini post-transkripsiyonel düzeyde düzenleyerek bodurlukta önemli rol oynar. SPL transkripsiyon faktörleri büyümeyi teşvik eder, miR156 ise bu durumu baskılar. Bodur anaçlarda miR156 seviyesi yüksektir (Zhao ve ark., 2020). miR159, miR167, miR393 gibi diğer mikroRNA'lar oksin, gibberallin ve brassinosteroid sinyallerinin engellenmesini hedef alır. DNA metilasyonu ve histon modifikasyonları, bodurlukla ilişkili genleri kalıcı olarak baskılanmasını sağlayabilir (Tan ve ark., 2018).

4. Epigenetik Düzenleme ve Kültürel Uygulamalar

Bodurluğun yalnızca genetik düzeyde değil, aynı zamanda epigenetik yollarla da kontrol edildiği bilinmektedir. DNA metilasyonu gibi epigenetik mekanizmalar, büyüme ile ilgili genlerin baskılanmasına da sebep olmaktadır. Bu özellikleriyle doku kültüründe üretilen klonal anaçlarında ortaya çıktığı gözlemlenmiştir. Ayrıca kültürel uygulamalar (budama, sulama, azot dengesi gibi) da bodurluk fizyolojisine etki etmektedir. Örneğin yüksek azot uygulaması internod uzunluklarını artırarak gövde uzamasına neden olmaktadır (Chu ve ark.,2025).

5. Anaç Kalem Etkileşimi

Anaç ve kalem arasında gerçekleşen fizyolojik etkileşim, bodurluğun derecesini belirleyen temel faktörlerden biridir. Bodur bir anaç, aşılanan kalemin internod uzamasını ve vegetatif gelişimini sınırlar. Bu etki ise hormon taşınımı, ksilem ve floem çapı, anaç kalem uyumu, ve mikro-RNA ve epigenetik sinyal taşınımı gibi mekanizmalarla gerçekleşmektedir. Hormon taşınımında özellikle oksin ve sitokinin anaçtan kaleme taşınma miktarı azaldığında belirti gösterir. Ksilem ve floem çapları bodur anaçlarda daha dar iletim kanalları, su ve besin

taşınımını sınırlandırarak ağaçlarda bodur etkisi yaratır (Tworkoski ve Fazio, 2016). Anaç kalem uyumunda ise anaç-kalem birleşim bölgesindeki vasküler uyum, ağaçlardaki büyüme kapasitesini etkiler. Mikro-RNA ve epigenetik sinyalin taşınımında anaçtan kaleme taşınabilen küçük RNA'lar, kalemin gen ekspresyonunu modifiye edebilmektedir (Gao ve Chu, 2020).

6. SONUÇ

Meyve ağaçlarında bodurluk, modern bahçecilik uygulamalarında verimlilik, kalite ve yönetim kolaylığı açısından stratejik bir öneme sahiptir. Bodur ağaçlar, küçük taç yapıları sayesinde ışığı daha etkin kullanır, daha kaliteli meyve üretir ve özellikle sık dikim yapılan yüksek verimli bahçeler için büyük avantaj sunar. Ayrıca, hasat, budama, ilaçlama gibi işlemler bodur ağaçlarda daha az iş gücüyle, daha kolay ve düşük maliyetle gerçekleştirilebilir. Bodurluk olgusunu oluşturan genetik, fizyolojik, anatomik, hormonal ve epigenetik düzeyde gerçekleşen etkileşimler, bir ağacın büyüme kuvvetini doğrudan etkileyebilir. Özellikle anaç-kalem etkileşimi, bodurluğun derecesini belirlemede en temel unsurlardan biridir. Bodur anaçlar, aşılanan kalem üzerinde su ve besin taşınımını sınırlayarak vegetatif büyümeyi yavaşlatır. Bu sınırlama, iletim dokularının (ksilem ve floem) daha dar çaplı olması, hidrolik iletkenliğin düşmesi ve hormonların (özellikle oksin ve sitokinin) taşınmasındaki azalmayla ilgilidir. Hormonal düzenlemeler bodurluk mekanizmasının temel bileşenlerinden biridir. Gibberellin (GA) sentezinde görevli genlerin düşük ekspresyonu, bu hormonun yıkımında rol alan GA2ox genlerinin artmış aktivitesi, bitkide internod uzamasını sınırlar ve bodur gelişim profili oluşturur. Sitokininlerin kökten gövdeye taşınması yavaşladığında, meristematik hücre bölünmesi azalır ve büyüme hızı düşer. Aynı şekilde oksin taşınımında görevli PIN proteinlerinin azalması, büyüme yönünün düzenlenmesinde aksaklıklara yol açar. Ayrıca, stres hormonlarından biri olan absisik asit (ABA), bodur anaçlarda daha fazla üretildiğinden büyümeyi baskılayıcı rol oynar. Genetik ve moleküler düzeyde yapılan çalışmalar, bodurluğun birçok genetik bölgeyle ilişkili olduğunu ortaya koymuştur. Elmada Dw1 ve Dw2, kirazda GAI ve RGL gibi gen bölgeleri bodur fenotipe neden olan kritik lokuslar arasında yer alır. Bu bölgeler, hücre uzaması, hormonal sinyal iletimi ve iletim dokusu gelişimi gibi büyümeyle ilişkili süreçleri düzenler. Ayrıca, mikroRNA'lar ve DNA metilasyonu gibi epigenetik faktörler de bodurluğun kalıtsal olmayan düzenleyicileri arasında gösterilmiştir. Bu durum, doku kültürü gibi tekniklerle üretilen klonal anaçların bodurluk profillerinde değişikliklere yol açabilir. Araştırmalar, ayrıca kabuk kalınlığı, tomurcuklanma yüksekliği, güneşe maruz kalma süresi, budama şekilleri ve ekim derinliği gibi kültürel uygulamaların da bodurluk üzerinde belirleyici etkiler oluşturabileceğini göstermektedir. Bodurluk mekanizmasının tüm türlerde ortaya konması, yeni anaçların ıslahı ile ilgili çalışmalara da katkı sunacaktır. Bu doğrultuda yapılacak araştırmalar ve geliştirilecek yeni anaçlar, meyve üretiminde sürdürülebilirliği ve kaliteyi daha ileriye taşıyacaktır.

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PASSIVE IMMUNITY AND ITS IMPORTANCE IN CALVES

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ABSTRACT

Calf diseases cause significant economic losses in dairy cattle farm. The level of immunity conferred against various infections immediately after birth is crucial in determining calf mortality and morbidity rates. In ruminant, antibodies cannot be transferred to the fetus before birth; hence, calves rely on colostrum for acquiring necessary antibodies. It is critical that they receive high-quality colostrum within the first hours of birth. Therefore, effective development of passive immunity in calves relies on timely ingestion of colostrum in sufficient quantity and quality. Newborn calves require immune components from their mothers' colostrum during the first 28 d post-birth, known as the neonatal period, which extends until their immune system becomes active. Thus, passive immune transfer in newborn calves is assessed by measuring serum IgG concentrations between 24 h and 48 h after colostrum consumption. In this regard, the timely intake of colostrum in sufficient quantity and quality significantly contributes to the development of passive immunity in calves. There are five different Ig fractions in colostrum: IgM, IgG, IgA, IgD and IgE. Among these, IgG is the predominant antibody isotype, constituting approximately 75% of the total Ig level in bovine colostrum. Colostrum containing over 50 g/L IgG is classified as quality colostrum. Serum TP ≥5.5 g/dL is considered as sufficient colostral antibody level, while TP<5.5 g/dL is considered as insufficient. Effective colostrum management is, therefore, essential for ensuring calf health, survival, and future productivity. Successful passive transfer is associated with reduced veterinary expenses, increased live weight gain, improved performance, and longevity. Therefore, newborn calves should receive a minimum of 2 L of colostrum, approximately 10% of their birth weight, within 2 h of birth.

Keywords: Calf, Passive Immunity, Colostrum, IgG

BUZAĞILARDA PASİF BAĞIŞIKLIK VE ÖNEMİ

ÖZET

Buzağı hastalıkları süt sığırcılığı işletmelerinde önemli ekonomik kayıplara yol açmaktadır. Doğumdan hemen sonra çeşitli enfeksiyonlara karşı kazanılan bağışıklık düzeyi, buzağı ölüm ve hastalık oranlarını belirlemede oldukça önemlidir. Ruminantlarda, antikorlar doğumdan önce fetüse aktarılamaz; bu nedenle buzağılar gerekli antikorları edinmek için kolostruma ihtiyaç duyarlar. Buzağıların doğumdan sonraki ilk saatlerde yüksek kaliteli kolostrum almaları kritik öneme sahiptir. Bu nedenle, buzağılarda pasif bağışıklığın etkili bir şekilde gelişmesi, yeterli miktar ve kalitede kolostrumun zamanında alınmasına bağlıdır. Yenidoğan buzağılar, bağışıklık sistemleri aktif hale gelene kadar neonatal dönem olarak bilinen doğumdan sonraki ilk 28 gün boyunca annelerinin kolostrumundan gelen bağışıklık maddelerine ihtiyaç duyarlar. Nitekim, yenidoğan buzağılarda pasif bağışıklık transferi, kolostrum tüketiminden sonraki 24 saat ile 48 saat arasında serum IgG konsantrasyonlarının ölçülmesiyle belirlenir. Bu bağlamda, yeterli miktar ve kalitede kolostrumun zamanında alınması buzağılarda pasif bağışıklığın gelişmesine önemli ölçüde katkıda bulunur. Kolostrumda IgM, IgG, IgA, IgD ve IgE olmak üzere beş farklı Ig fraksiyonu bulunur. Bunlar arasında IgG baskın antikor izotipidir ve sığır kolostrumundaki toplam Ig seviyesinin yaklaşık %75'ini oluşturur. 50 g/L'den fazla IgG içeren kolostrum kaliteli kolostrum olarak sınıflandırılır. Serum TP ≥5.5 g/dL yeterli pasif transfer olarak değerlendirilirken TP<5.5 g/dL yetersiz olarak kabul edilmektedir. Bu nedenle, etkili kolostrum yönetimi buzağı sağlığını, hayatta kalmasını ve gelecekteki üretkenliğini sağlamak için gereklidir. Başarılı pasif transfer, veteriner masraflarının azalması, canlı ağırlık artışının artması, performansın iyileşmesi ve uzun ömürle ilişkilidir. Bu nedenle, yeni doğan buzağılar doğumdan sonraki 2 saat içinde doğum ağırlıklarının yaklaşık %10'u kadar en az 2 L kolostrum almalıdır.

Anahtar Kelimeler: Buzağı, Pasif Bağışıklık, Kolostrum, IgG

1. GİRİŞ

Yenidoğan buzağı ölüm ve hastalıkları süt çiftliğinde ekonomik kayıplara neden olur. Bu nedenle, doğumdan hemen sonra çeşitli enfeksiyonlara karşı kazanılan bağışıklık düzeyi, buzağı ölüm ve hastalık oranlarını belirlemede çok önemlidir (Murphy ve ark., 2005). Buzağıların genetik potansiyellerine ulaşmalarını sağlamak için onlara immünolojik kaynaklı uygun ve dengeli bir diyet sağlamak süt çiftliklerinin ilk işidir. Buzağıların temel besin kaynağı olan kolostrum (Indra ve ark., 2012), doğumdan sonra yeterli miktar ve kalitede derhal sağlanmalıdır. Bu nedenle etkili kolostrum yönetimi, buzağı sağlığını, hayatta kalmasını ve gelecekteki üretkenliğini sağlamak için esastır (Soufleri ve ark., 2019).

Plasentanın türü ve yapısı, farklı hayvan türlerine göre önemli ölçüde değişir. Doğum öncesi dönemde plasentadan yavruya antikor aktarma yeteneği doğrudan plasentanın tipi ve yapısından etkilenir (Arda, 1994). Ruminant plasentaları, antikorların doğumdan önce fetüse aktarılamadığı sindesmokorial tipe aittir ve bu nedenle buzağılar gerekli antikorları edinmek için kolostruma güvenirler. Bunun nedeni, makromoleküler yapıya sahip bağışıklık bileşenlerinin gebelik sırasında plasenta bariyerini geçememesi ve fetal dolaşıma girememesidir. Sonuç olarak, yeni doğan buzağılar, bağışıklık sistemleri aktif hale gelene kadar uzanan neonatal dönem olarak bilinen doğumdan sonraki ilk 28 gün boyunca annelerinin kolostrumundan gelen bağışıklık bileşenlerine ihtiyaç duyarlar (Kara ve ark., 2020). Bu nedenle, doğumdan sonraki ilk saatlerde yüksek kaliteli ve miktarda kolostrumun zamanında tüketilmesi buzağı sağlığı için çok önemlidir. Bu bağlamda buzağılarda yeterli miktar ve kalitede kolostrumun zamanında alımı pasif bağışıklığın gelişmesine önemli katkı sağlamaktadır (Zarei ve ark., 2017; Soufleri ve ark., 2019).

2. PASİF BAĞIŞIKLIK VE ÖNEMİ

Pasif bağışıklık transferi, buzağıların sindirim sistemi yoluyla kolostrumdan immünoglobulinleri (Ig) emerek bağışıklık kazandığı süreci ifade eder (Kara vd., 2020). Kolostrum, buzağılara pasif bağışıklık sağlayarak onları potansiyel olarak ölümcül bakteriyel enfeksiyonlara karşı koruyarak hayati bir avantaj sunar (Abdullahoğlu vd., 2019). Kolostrumu tüketmeden önce, buzağının kan serumu minimum Ig içerir ve bakterisidal ve lizozim aktivitesi ile bağışıklığı ya yoktur ya da çok düşüktür (Gerov vd., 1987). Buzağıların doğumdan sonraki ilk saatlerde yüksek kaliteli kolostrum almaları sağlıkları için kritik öneme sahiptir. Bu nedenle, buzağılarda pasif bağışıklığın etkili bir şekilde gelişmesi, yeterli miktarda ve kalitede kolostrumun zamanında alınmasına bağlıdır (Zarei vd., 2017).

3. PASİF TRANSFER YETERSİZLİĞİ

Pasif transfer yetersizliği, buzağılarda yaşamın ilk 36 saati içinde yetersiz serum IgG konsantrasyonu olarak tanımlanmaktadır. Gelişmiş hayvancılık ülkelerinde pasif bağışıklığın iyi bilinen önemine rağmen, önemli bir pasif transfer başarısızlığı oranı (%35-40) devam etmektedir (Demir ve Tütüncü, 2022). Başarılı pasif transfer, daha düşük veteriner masrafları, artan canlı ağırlık artışı, gelişmiş performans ve uzun ömür ile ilişkilidir (Dunn ve ark., 2017). Buzağılarda pasif transferin başarısızlığı daha yüksek ölüm ve hastalık oranlarına yol açar (Cummins ve ark., 2017). Bu nedenle, yeni doğan buzağılar doğumdan sonraki 2 saat içinde

doğum ağırlıklarının yaklaşık %10'u olan en az 2 L kolostrum almalıdır (Kehoe ve ark., 2007). Doğumdan hemen sonra kolostrum sağlanması kritik öneme sahiptir, çünkü yeni doğan buzağıların antikorları emme yeteneği zamanla hızla azalır (Kehoe ve ark., 2007; Yang ve ark., 2015).

4. PASİF TRANSFER DURUMUNUN TESPİTİ

Yenidoğan buzağılarda pasif bağışıklık transferi, kolostrum tüketiminden sonraki 24 saat ile 48 saat (36 saat) arasında serum IgG konsantrasyonlarının ölçülmesiyle değerlendirilir (Smith ve Foster, 2007; Godden, 2008). Bu dönemde serum IgG konsantrasyonları 10 g/L'nin altında olan buzağılar pasif transferin başarısız olduğu şeklinde tanımlanır (Filteau ve ark., 2003; Godden, 2008). Doğumdan 28 güne kadar uzanan neonatal dönem, en fazla buzağı kayıplarının yaşandığı dönem olması nedeniyle kritik öneme sahiptir (Yüceer ve Özbeyaz, 2010). Ancak, bir süt sığırcılığı çiftliğinin başarısı için buzağı sağlığının doğumdan sütten kesime kadar sağlanması esastır (Genc ve Coban, 2017). Bu nedenle, serum IgG konsantrasyonunun ve kolostrumun ölçülmesi esastır.

Kolostrum ve serum Ig konsantrasyonlarını belirlemek için çeşitli yöntemler kullanılmaktadır ve bazıları radyal immünodifüzyon (RID) ve doğrudan biyosensör SPR immünolojik testi gibi geleneksel laboratuvar tekniklerini kullanmaktadır. Ancak bu yöntemlerin yüksek maliyet, teknik ekipman gereksinimi ve laboratuvar olanaklarına bağımlılık gibi çeşitli dezavantajları vardır. Öte yandan dijital Brix refraktometreleri önemli avantajlar sunmaktadır: daha kolay, daha uygun maliyetli, kullanıcı dostu, dayanıklı ve süt çiftliklerinde dış etkilere karşı daha az hassastır (Abdullahoğlu vd., 2019). Çalışmalar, brix refraktometrelerinin saha koşullarında güvenilir araçlar olduğunu göstermiştir (Quigley vd., 2013; Demir ve Tütüncü, 2022).

5. KOLOSTRUM VE YAPISI

Doğumdan hemen sonra memeden salgılanan süte kolostrum veya ağız sütü denir (Christensen, 1999). Kolostrum renk ve bileşim bakımından normal süte göre oldukça farklı olup (Erdem ve Atasever, 2005), buzağılarda laksatif etki yaparak sindirim sistemini temizlemekte ve yavruya bol miktarda protein, mineral ve vitamin sağlamaktadır (Özhan ve ark., 2001).

Tablo 1. Kolostrumun içeriğinin normal sütle karşılaştırılması*

İçerik (%)	Kolostrum	Transit süt		Normal süt
	(1. gün)	(2. gün)	(3. gün)	
Kuru Madde	23.9	17.9	14.1	12.6
Yağ	6.7	5.4	3.9	3.6
Yağsız KM	16.7	12.2	9.8	9.6
Top. Protein	14.0	8.4	5.1	3.2
Laktoz	3.3	4.0	4.7	5.0
Mineral	1.03	0.90	0.81	0.74
Ig	6.0	4.2	2.4	0.09

*Wattiaux ve Howard, 1997; Erdem ve Atasever, 2005

Kolostrum, A, D, E ve B-12 vitaminlerinin yanı sıra fosfor (P), magnezyum (Mg), potasyum (K) ve çinko (Zn) gibi mineraller açısından zengindir (Bayram ve ark., 2008). Ayrıca, süt proteini ile birlikte vücut ısısının korunmasına yardımcı olan yağ ve şeker formundaki enerji kaynakları da içerir (Selk, 2007). Kas ve kıkırdak dokusunun onarımında etkili olan büyüme faktörleri de kolostrumun yapısında yer almaktadır (Christensen, 1999). Kolostrum, doğumdan sonra yaklaşık 48 saat içinde geçiş sütüne, 72 saat içinde ise olgun süte dönüşmektedir (Erdem ve Atasever, 2005). Tablo 1'de görüldüğü üzere kolostrum, diğer sütlerle karşılaştırıldığında daha fazla kuru madde, yağ, yağsız kuru madde, protein ve immünoglobulin içermektedir. Bununla birlikte, laktoz miktarı ise olgun süte kıyasla daha düşüktür.

Kolostrum, normal süte oranla yapısında daha fazla büyüme faktörü ve antimikrobiyal bileşen içermektedir. Büyüme faktörleri arasında büyüme hormonu (GH), insülin benzeri büyüme faktörleri (IGF-I ve IGF-II), IGF bağlayıcı protein, insülin, epidermal büyüme faktörü (EGF), fibroblast büyüme faktörleri (FGF1 ve FGF2) ile dönüştürücü büyüme faktörü-beta (TGF-β1, TGF-β2 ve TGF-β3) yer almakta olup, bu faktörler yeni doğanların büyümesini, gelişimini ve bağırsaklardaki hücre çoğalmasını desteklemektedir. Antimikrobiyal faktörler arasında ise immunoglobulinler, laktoferrin, lizozim, laktoperoksidaz, antikorlar, prolinden zengin polipeptitler (PRP), sitokinler, glikoproteinler ve tripsin inhibitörü bulunmaktadır. Bu bileşenler, yaşamın ilk haftalarında enfeksiyonlara karşı pasif bağışıklık sağlayarak koruyucu etki göstermektedir (Kul ve ark., 2014).

6. KOLOSRUMDA BULUNAN İMMONGLOBULİNLER

Kolostrumda IgM, IgG, IgA, IgD ve IgE olmak üzere beş farklı immünoglobulin (Ig) tipi bulunur (Butler, 1969; Aghakhani ve ark., 2022). Bu immünoglobulinler arasında en yüksek oranda bulunan IgG, toplam Ig miktarının yaklaşık %75'ini oluşturur (Korhonen ve ark., 2000; McGuirk ve Collins, 2004; Georgiev, 2008). Doğum öncesinde kandan meme epitel hücrelerine transfer edilen IgG, meme bezinde birikerek kolostrumdaki en baskın Ig haline gelir. Bu

nedenle, kolostrumdaki IgG düzeyi, buzağı sağlığı açısından büyük önem taşır. Bu bağlamda, kolostrumun kalitesini değerlendirmek için IgG konsantrasyonu belirleyici bir gösterge olarak kabul edilir (Conneely ve ark., 2013). IgG konsantrasyonu 50 g/L'nin üzerinde olan kolostrum, yüksek kaliteli kolostrum olarak nitelendirilir (McGuirk ve Collins, 2004).

7. KOLOSTRUM KALİTESİ ÜZERİNE ETKLİ FAKTÖRLER

Kolostrumun bileşimi ve kalitesi üzerinde birçok faktör etkili olmaktadır. Kolostrum ağırlığı ile kalitesi arasında önemli bir ilişki olduğu belirtilmektedir (Conneely ve ark., 2013; Chuck ve ark., 2017). Ayrıca, laktasyon sırası ile kolostral IgG konsantrasyonu arasında pozitif bir ilişki söz konusudur (Conneely ve ark., 2013; Dunn ve ark., 2017). Birden fazla doğum yapmış ineklerin, ilk doğumunu yapan ineklere kıyasla daha fazla kolostrum ürettiği bildirilmiştir (Zarei ve ark., 2017). Bunun temel nedeni, yaşça büyük ineklerin daha fazla hastalık etkeniyle karşılaşmış olması ve dolayısıyla kolostrumda daha fazla antikor üretmesidir (Göncü ve Gökçe, 2015). Bu durum, yaşlı ineklerin daha yüksek IgG konsantrasyonuna sahip kolostrum üretmesine yol açmaktadır (Larson ve ark., 1980).

Buzağılama mevsimi de kolostrum kalitesini etkileyen bir diğer faktördür. İlkbahar ve sonbaharda doğum yapan ineklerle karşılaştırıldığında, kış aylarında buzağılayan ineklerin kolostral IgG düzeyleri daha yüksek bulunmuştur (Zarei ve ark., 2017). Kısa kuru döneme sahip ineklerde ise kolostrum kalitesinin genellikle daha düşük olduğu ifade edilmektedir. Kuru dönem uzunluğu ve doğum sırasında VKP (Vücut Kondisyon Puanı) değişiklikleri, doğum sonrası hastalık görülme riski ve süt verimi üzerinde de etkili olmaktadır (Dirandeh ve ark., 2020; Melendez ve ark., 2020).

Bunun yanı sıra, annenin sağlık durumu (Imler ve ark., 2021), güç doğum (Perino ve ark., 1995), buzağının cinsiyeti (Filteau ve ark., 2003; Yüceer ve Özbeyaz, 2010; Martin ve ark., 2021), davranışsal faktörler (Arthington, 1999), doğum ağırlığı (Yüceer ve Özbeyaz, 2010; Pritchett ve ark., 1991; Conneely ve ark., 2013) ve çevresel stres etmenleri (Pritchett ve ark., 1991; Conneely ve ark., 2013) de kolostrum kalitesini etkileyen diğer önemli unsurlar arasında yer almaktadır.

7. SONUÇ

Doğumda bağışıklık sisteminin tam olarak gelişmediği ve bu nedenle yeni doğan buzağıların olgun ineklere göre enfeksiyon kapma riskinin daha fazla olduğu sonucuna varılmıştır. İmmünoglobulinler esas olarak doğumdan yaklaşık 24 saat sonra ince bağırsakta gelişigüzel bir pinositotik süreçle emilir. Kolostrumun buzağı sağlığını ve hayatta kalmasını belirlemedeki önemi iyi bilinmektedir. Zamanında ve yeterli kolostrum alımı, sütten kesilmemiş buzağılarda morbidite ve mortaliteyi etkileyen en önemli yönetim faktörüdür. Sığırlarda anneden yenidoğana bağışıklık aktarımı esas olarak kolostrum beslemesi yoluyla yapılır. Buzağılarda yüksek mortalitenin en önemli nedeni yetersiz kolostrum beslemesi ve yönetimidir. Bu nedenle buzağılara enfeksiyonlara ve hastalıklara karşı korunmak için ≥50 mg/mL IgG konsantrasyonuna sahip olan ve immünoglobulinler açısından zengin olan kolostrumu doğumdan en geç iki saat içerisinde canlı ağırlığın yaklaşık %10'u kadar tüketmeleri gerekmektedir

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FACTORS AFFECTING THE SURVIVAL OF LAMBS AND KIDS

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ABSTRACT

Survival, defined as the ability of a living creature to survive, is an important factor in sheep breeding, but it also determines the evaluation of fertility capacity on farms and also determines profitability in livestock farming. Fertility, defined as the ratio of offspring or the number of offspring produced by female mothers during the gestation period, is a term used in animal breeding. Animals with a high fertility produce as many offspring as possible in a gestation period and have a high survival rate. The number of live offspring at weaning is one of the most important criteria for determining fertility. It is very important to know the main factors affecting the survival in order to avoid unnecessary losses of lambs. Keeping animal losses in flocks at the lowest possible level is the most effective and important factor in all livestock and small ruminant farming in terms of economic production. These losses occur more frequently in young animals than in adult animals. Survival rate is expressed as the ability to survive from birth to a certain age and is an important indicator of adaptation to environmental conditions. In this context, the aim of this study was to investigate the factors affecting the survival of lambs and kids.

Keywords: Lamb, Kid, Survival, Weaning.

KUZU VE OĞLAKLARDA YAŞAMA GÜCÜ ÜZERİNE ETKİLİ FAKTÖRLER

ÖZET

Canlının hayatta kalabilme kabiliyeti olarak nitelendirilen yaşama gücü, koyun yetiştiriciliğinde önemli bir faktör olmakla birlikte işletmelerde ki döl verimi kapasitesinin değerlendirilmesinde ve aynı zamanda hayvancılıkta kârlılığı da tayin etmektedir. Gebelik döneminde anaç dişilerden elde edilen yavru oranı veya yavru sayısı olarak belirtilen döl verimi bir hayvan yetiştirme terimi olarak ifade edilir. Döl verimi yeteneği yüksek hayvanlar bir gebelik döneminde mümkün olduğu kadar fazla sayıda ve yaşama gücü yüksek yavrular meydana getirmektedir. Sütten kesimdeki canlı yavru sayısı döl veriminin belirlenmesinde en önemli kriterlerden biridir. Kuzularda yaşama gücünü etkileyen başlıca faktörlerin bilinmesi, gereksiz kuzu kayıplarının önlenmesi açısından son derece önemlidir. Sürülerde hayvan kayıplarının mümkün olan en az seviyede tutulması tüm çiftlik hayvanlarında ve küçükbaş hayvan yetiştiriciliğinde de üretimin ekonomik olmasında en etkili ve önemli faktördür. Yavrularda bu kayıplara ergin hayvanlardan daha yaygın olarak karşılaşılmaktadır. Yaşama gücü canlının doğumundan belirli yaşa ulaşıncaya kadar hayatta kalabilme yeteneği olarak ifade edilmekle birlikte çevre koşullarına uyumun önemli bir göstergesidir. Bu bağlamda bu çalışmada kuzu ve oğlaklarda yaşama gücü üzerine etkili faktörlerin incelenmesi amaçlanmıştır.

Anahtar Kelimeler: Kuzu, Oğlak, Yaşama Gücü, Sütten Kesim.

1. GİRİŞ

Hayvansal üretim dallarında başarılı olmanın ilk koşulu mevcut hayvanlardan düzenli döl alınmasıdır (Selvi, 2021). Koyun ve keçilerde döl verimi, üreme fizyolojisi ile gelişme kabiliyeti ve yaşama gücüne bağlıdır. Döl veriminin belirlenmesinde gebelik oranı, doğum oranı, doğumda kuzu sayısı gibi çeşitli kriterler kullanılır. Ancak pratikte kullanılan esas ölçü sütten kesimdeki kuzu ve oğlak sayısıdır (Akçapınar, 2000). Hayvansal üretimde temel amaç, yem ve diğer kaynakların etkin kullanımı ile maksimum büyümedir. Büyüme üzerine besinler, hormonlar, enzimler, sıcaklık gibi pek çok faktör etkilidir (Indu vd., 2014) ve bu süreç döllenmeden itibaren yetişkinliğe kadar olan döneme kadar değişerek devam eder. Hayvanların büyüme ve verim performansları, farklı stres etkenlerinden olumsuz etkilenir. Strese yanıt olarak artan glukokortikoid seviyeleri, ön hipofizden büyüme hormonu (GH) salgılanmasını engelleyen somatostatinin hipotalamik salgılanmasını uyarır. Hayvanların büyümesi bu stres hormonlarından etkilenir (Rushton, 2009).

Kuzu ve oğlaklarda yaşama gücü, koyun ve keçilerin genel üreme performansı üzerinde direkt bir etkiye sahip olmasının yanında, hayvan refahı noktasında da önemli bir göstergeyi oluşturması ile sürülerde büyüme, karlılık ve sürdürülebilirliğin temel göstergesidir (Mellor ve Stafford, 2004). Bu kriter üzerine hem genetik hem de sürü yönetim uygulamaları önemli rol oynamaktadır (Hinch ve Brien, 2014). Özellikle sürü yönetim uygulamaları içinde önemli bir yer tutan gebeliğin son döneminde koyunların doğru beslenmesi, yavrunun uterus içi gelişimi ve buna bağlı olarak doğum sonrası hayatta kalma noktasında önemlidir (Koyuncu ve Duymaz, 2017).

Gebeliğin ilk döneminde koyunun vücut kondisyonu, verilen yem miktar ve bileşimiyle ilişkili olup doğrudan plasenta gelişimi, uterus ve plasenta kan akışının etkilenmesi ile embriyonun gelişimi için önemli etkiye sahiptir (Koyuncu ve Duymaz, 2017; Şen, 2016). Gebeliğin başlangıcı ve doğuma kadar olan süreçte annenin beslenmesi yavrunun sağlıklı olmasını ve yaşama gücünü arttırır. Ayrıca bu dönemde annenin beslenme seviyesi plasenta yavru ilişkisi, yavrunun doğum ağırlığı ve doğumdan sonra yaşama gücü ile pozitif ilişkilidir (Brien vd., 2014; Oldham vd., 2011). Küçükbaş hayvan yetiştiricilerinin en çok karşılaştığı yönetim zorluklarından biri yeni doğan kuzu ve oğlakların canlı olması ve yaşatılmalarında devamlılığının sağlamasıdır (Dwyer, 2008). İşletmelerde verimliliği yükseltmede temel amaç, bir anaç başına doğan kuzu-oğlak sayısı ve dönem içinde kayıpları azaltarak büyütülen kuzu-oğlak sayısını arttırmaktır (Koyuncu ve Duymaz, 2017).

Bir kuzuyu ya da oğlağı doğumdan sütten kesime kadar ki yaşatma başarısı, fizyoloji, davranış, genetik, gebeliğin sonu, kuzulama-oğlaklama dönemi beslenme ve mevcut çevre koşulları gibi bir seri karmaşık bileşkenin sonucudur (Hatcher ve ark., 2010). Yavru kayıplarının önemli bir kısmı doğumu takiben ilk 48 saatte görülür (Brien ve ark., 2009) ve bunların büyük çoğunluğunda zor doğum, ananın kaybedilmesi ve besin yetersizlikleri gibi noktalar öne çıkmaktadır (Nowak ve Poindron 2006; Geenty ve ark., 2014).

Büyüme ağırlık ve boyut artışı olarak tanımlanır ve canlıların en önemli biyolojik özelliklerinden birisidir (Van der Merwe ve ark.,2019; Hızlı ve Yazgan, 2021). Yaşama gücü oranı canlının doğumundan itibaren belirli yaşlara kadar hayatta kalabilme yeteneği olarak tanımlanmaktadır (Özbey ve ark., 2000). Yaşama gücü karlı bir hayvancılık işletmesi için önemli bir kriterdir (Ünal ve ark.,2018). Büyüme ve hayatta kalma oranı üzerinde genotip ve

çevre faktörleri (cinsiyet, doğum ağırlığı, doğum tipi, doğum yılı, doğum mevsimi, ananın yaşı ile canlı ağırlığı ve bakım ve beslenme gibi) rol oynamaktadır (Akçapınar ve Özbeyaz, 1999; Ghotbaldini ve ark., 2019). Bu sebeple büyüme ve hayatta kalma oranı çevre koşullarına uyumun önemli bir göstergesi olarak kabul edilir ve kârlı hayvancılık yapabilmek için belli dönemlerde hesaplanmaktadır (Gürsoy, 2005). Farklı tür ve ırklarda yapılan çalışmada, farklı yaşlarda hayatta kalma üzerine ana yaşı, cinsiyet, doğum tipi, doğum mevsimi gibi farklı çevresel faktörlerin etkisinin olduğu bildirilmiştir (Çelik ve Oflaz, 2017; Koyuncu ve Duymaz, 2017; Taşkın ve ark., 2010; Türkyılmaz ve ark., 2021; Tüfekci, 2023)

2. DOĞUM AĞIRLIĞI, DOĞUM TİPİ, CİNSİYET

Araştırmacılar çevresel koşullar ve beslenmenin yanı sıra doğum ağırlığı, cinsiyet, yavru sayısı ve anaya ait davranışların yeni doğanlarda adaptasyon parametreleri üzerinde etkin rol oynadığını bildirmektedir (Awemu ve ark., 1999; Moors, 2005). Kuzu ve oğlaklarda yaşama gücü üzerine etkili olan faktörler olarak kuzunun doğum ağırlığı, doğum tipi, cinsiyet, ananın beslenmesi ve yaşı öncelikli olarak sıralanır (Hatcher ve ark., 2009). Bunlar içinde doğumu takip eden ilk birkaç günde yaşama gücü üzerinde en fazla etkisi olan yavrunun doğum ağırlığıdır. Yavru ölümlerinin önemli bir kısmı doğumdan sonraki ilk günlerde yoğunlaşır ve bu da genellikle doğum ağırlığı ile ilişkilendirilmektedir (Nowak ve Poindron, 2006). İdeal doğum ağırlığı aralığı, ırklar arasında farklılık göstermektedir. Reshauge ve ark., (2016) yaptıkları çalışmada düşük doğum ağırlığında doğan kuzuların aç kalmaya bağlı sorunlardan dolayı ölüm oranlarının daha yüksek olduğu bildirmişlerdir. Düşük canlı ağırlıkta doğan kuzular, vücut büyüklüğü ve enerji rezervleri ile ilişkili daha zayıf ısı düzenleme yeteneğine sahiptirler. Bu tip kuzularda gebeliğin son döneminde oksijen ve enerjinin yetersiz olması ile ilişkili olarak gelişimleri yavaşlamaktadır. Everett-Hincks ve Dodds (2008) tarafından ifade edildiği gibi optimum doğum ağırlığının ortalamanın 0.5-1 kg üzerinde olan kuzlarda açlığa bağlı ölüm riskinin düşük, zor doğum olgunun daha az ve kuzularda yaşama gücünün daha yüksek olduğu ifade edilmektedir. Daha ağır doğum ağırlığına sahip kuzularında azalan yaşama gücü, zor doğum ve doğumun uzun sürmesinin direkt bir sonucudur (Dwyer, 2003).

Doğumdan sonra yavrunun "yaşama gücü" göstergesi olarak kullanılabilecek iyi bir kriter olan canlılık puanı, özellikle doğum sonrası yavru ile doğum öncesini ve yavru büyümesini ele alan çalışmalarda yer alabilir (Konyalı ve ark., 2004). Hayvanın canlılığını subjektif olarak değerlendirmeyi hedefleyen ve çeşitli çalışmalarda canlılık puanının oluşturulmasında kullanılan en önemli kriterler oğlağın doğumdan sonra ilk defa ayağa kalkması ve anasını emme özellikleridir (Werning, 1993; Cloete ve Scholtz., 1998; Wollny, 2000; Leenhouvers ve ark., 2001). Doğum sonrası oğlak kayıplarının önemli bir nedeni düşük doğum ağırlığıdır (Husain ve ark., 1995; Perez-Razo ve ark., 1998; Miah ve ark., 2002). Doğum ağırlığı ile sütten kesim sonrası yaşama gücü arasında güçlü bir ilişki bulunmaktadır (Singh ve ark., 1991). Çoğuz doğan oğlaklarda, doğum ağırlıklarının tekiz doğanlara göre nispeten daha düşük olması nedeniyle ölüm riski daha yüksektir (Miah ve ark., 2002; Milligan ve ark., 2002).

Doğum tipinin tek başına kuzularda doğum ağırlığı üzerine önemli bir etkisi vardır (Gardner ve ark., 2007). Doğum tipi, kuzularda yaşama gücünü özellikle de ikiz kuzu kayıplarıyla önemli oranda etkiler. İkiz kuzularda ölüm nedenleri olarak açlık veya doğum sırasında yaralanma öne çıkarken, tekiz kuzularda ise ölü doğum veya zor doğum kaynaklı kayıplar daha yüksek

gerçekleşmektedir (Refshauge ve ark.,2016). Doğumdan sütten kesime kadar kuzu ölümlerinin önemli bir kısmı çoğuz doğan kuzularda görülmektedir. Çoğuz doğan kuzlarda yaşama gücünün düşük olmasına neden olan faktörler doğum güçlükleri, düşük doğum ağırlığı, doğum pozisyonu, vücut yağ rezervlerinin az olması, diğer kardeşi ile kolostrum ve süt içme rekabeti, ananın sütünün yetersiz olması olarak sıralanmaktadır (Hatcher ve ark., 2010).

Doğum tipi ve cinsiyetin kuzu ve oğlakların doğum ağırlıkları üzerine önemli bir etkisi vardır. Kuzu ve oğlaklarda doğum tipi, doğum ağırlığının değerlendirilmesinde dikkate alınması gereken bir faktördür. Doğum ağırlığı üzerinde cinsiyetin, erkeklerin dişilere nazaran daha yüksek doğum ağırlığına sahip olmaları şeklindeki bilinen etkisi (Ünalan ve Cebeci, 2001), ancak doğum tipinin de dikkate alınması koşuluyla doğru bir ifadedir (Daş ve Savaş, 2002). Bunun ötesinde doğum ağırlığı üzerinde oldukça belirgin bir cinsiyet-doğum tipi etkileşimi bulunmaktadır (Savaş, 2007).

3. BESLEME, BARINMA

Küçükbaş hayvanlarda beslenme, yavrularda yaşam boyu etkili olan prenatal dönemde etkisi olan önemli çevresel bir faktördür. Gebelik döneminde yetersiz beslenme ve aşırı beslenme fetal beslenmeyi olumsuz etkileyebilir (Igwebuike, 2010). Gebelik döneminde yetersiz beslenme gerekli besinlerin eksik alınmasına neden olur. Gebelikte yavru sayısı ve besin yetersizlikleri arasında önemli ilişki vardır (Igwebuike, 2010). Gebeliğin başlangıcından ortasına kadarki enerji alımının kuzu doğum ağırlığına etkisinin az (Gardner ve ark., 2007), gebelik öncesi vücut kondisyonu ve gebeliğin son dönemindeki enerji alımı ise doğum ağırlığına önemli etki etmektedir (Gardner ve ark., 2007; Igwebuike, 2010). Gebelik döneminde aşırı besin alımı plasental ve fetal büyümede gerileme ve ölüme (Wallace ve ark., 2003), gebelik süresinin düşmesine neden olabilir (Wallace ve ark., 2005). Gebelikteki beslenme karaciğer ve iskelet kasları gibi fetal organların büyümesini etkileyebilir (Brameld ve ark., 2000). Yetersiz besin alımı plasental büyümeyi etkileyerek fetal endokrin çevresinde değişmelere neden olup yumurtalık gelişimine zarar verebilir (Da Silva ve ark., 2003). Aynı zamanda bu durum kemik gelişimini ve organların ağırlıklarını olumsuz etkileyebilir (Osgerby ve ark., 2002), erken doğuma ve düşük doğum ağırlığına neden olabilmektedir. İvesi koyunlarında annenin doğumdaki canlı ağırlığı ve vücut kondisyon puanının kuzu doğum ağırlığına etkisi önemli olduğu belirtilmiştir (Şireli, 2019). Tozlu Çelik ve Tüfekci, (2022) yaptıkları çalışmada; plasenta gelişimi, yavru doğum ağırlığını etkilediği, laktasyon sırası ve yaşa göre besleme yapılması plasenta gelişimini olumlu etkileyebileceği ve kuzu yaşama gücüne doğum ağırlığının etkisinin oldukça önemli olduğu bildirilmiştir.

Gebeliğin son döneminde ek yoğun yemlemeyle koyunlarda ağırlık kaybının azaldığı ve erken laktasyon devresinde süt veriminin artışı yanında kuzularda doğum ağırlığı ve yaşama gücünün yükseldiği bildirilmiştir (Treacher, 1970; Ergin ve ark., 1989). Koyunlarda fötüsün gelişmesi gebeliğin 4. ayından itibaren hızlanmaktadır. Bu dönemde fötüste protein, yağ, Ca ve P birikimi sonucunda ağırlık artmaktadır. Diğer yandan süt bezlerinin laktasyon için hazırlanması da bu dönemde olmaktadır. Gebeliğin son 6 haftalık süresi olan bu dönemdeki besleme ve kuzuların doğum ağırlıkları ile yaşama güçleri ve gelişme hızları arasında bir ilişki olduğu da saptanmıştır (Orr and Treacher, 1984; Apolant and Chestnutt, 1985).

Hooda ve ark. (2014) yaptıkları çalışma sonucunda, yem kısıtlaması ve termal stresin fizyolojik reaksiyonlar, mineral dengeleri, enzim aktiviteleri, hormon salgısı ve kan metabolitlerinde meydana gelen değişikliklerle ortaya çıktığı üzere oğlaklar üzerinde ciddi etkileri olduğu bildirilmiştir. Ayrıca yem kısıtlaması ve termal strese maruz kalan grup daha fazla stres yaşamış ve bu grupta vücut ağırlığında meydana gelen kayıplar grup stres sonrası dönemde telafi edilemediği bildirilmiştir.

Araştırmacılar çevre sıcaklıklarının ani değişimleri sonucu termal değişimden kaynaklanan sıcaklık stresi gibi olumsuzlukların yavru kayıplarına neden olabileceğini bildirmektedir (Ayağ ve Konyalı, 2019). Solunum ve vücut sıcaklığı gibi fizyolojik parametreler, özellikle yeni doğanların başarılı bir şekilde hayatta kalabilmeleri üzerinde önem taşırken, kötü sürü idaresi ve uygun olmayan barınak koşulları, kuzu ve oğlaklarda doğumdan hemen sonraki erken dönem için bir risk faktörü oluşturmakta aynı zamanda fizyolojik kondisyonun gelişimini önemli derecede olumsuz yönde etkileyebilmektedir (Piccione ve ark., 2007).

Ardahan (2018) yaptıkları çalışmada; büyütme döneminde yapılan hataların, oğlakların ömür boyu verimliliğini etkilediğini ve bu nedenle oğlaklara büyütme sırasında optimum çevre koşullarının sağlanması olmazsa olmaz ön koşul olduğunu bildirmiştir. Ek olarak oğlakların çevre koşullarına duyarlılıklarının üst seviyede olduğu bu dönemde, besin madde gereksinimlerini tam anlamıyla karşılayacak şekilde beslenmeleri, iklimsel isteklerine uygun barındırılmalarına dikkat edilmesi gerektiği belirtilmiştir.

Ölüm nedeni olarak soğuk etkisi, geniş ölçüde sonuç niteliğindedir. Soğuk, rutubetli ve rüzgarlı havalarda vücut ısısının düşmesi ile ölümlerin artması kuzuların emememe nedenine dayanır ve aç kalırlar. Diğer yandan düşük doğum ağırlığı, doğum zedelenmeleri ve seyrek yapağı soğuktan etkilenmeyi artırır. Halbuki bu gibi kuzuların yumuşak hava koşullarında yaşama şansları daha yüksektir. Soğuğa maruz kalma nedeniyle meydana gelen ölümlerin fizyolojik esası; ısı kaybı ve ısı üretimi arasındaki ilişkilidir. Kuzuların ısı yitirmeleri, ısı üretme kapasitelerini aştığı durumlarda vücut ısıları düşmeye başlar ve ölümler görülür. Bu gibi durumlarda en önemli ölüm nedeni; aşırı soğukla karşı karşıya kalan kuzuların vücut rezervlerinin tükenmesi ile "şok" a girmeleri ve ağız sütü alamamalarından aç kalmalarıdır. Yeni doğan kuzuların ilk 36 saat içinde ekstrem soğuk hava koşulları ile karşılaşması durumunda yalıtım ile vücut ısısının düzenlenmesi yaşamsal önem taşımaktadır (Demirören et al. 1992).

Alexander (1964) ve Dupchak (1991)'in farklı yıllarda yaptıkları araştırmaları sonucunda, doğum mevsiminden başka, doğum yılının yaşama gücüne etkisinin bulunduğunu, büyük batın genişliğinden dolayı, düşük ağırlıklı kuzuların soğuk yıllarda yaşama güçlerinin daha düşük olduğunu bildirmişlerdir.

Besleme ve barınak gibi çevresel faktörler kuzu yaşama gücünü etkileyen önemli unsurlardan biridir. Kuzuların barınak içinde doğdukları durumlarda daha çok hastalıklara direnç ve kolay kuzulama, yaşama gücünün belirleyicisi olarak önem kazanır (Orr and Treacher, 1984).

4. BAZI STRES FAKTÖRLERİ

Değişen iklim koşulları tüm canlıların yaşamlarını etkilemektedir. İklim değişikliği sıcaklıkların ani değişmesine neden olarak yem ve su kaynaklarında azalma ve otlaklarda yem

bitkilerinde tür ve çeşitliliğinin azalmasına neden olmaktadır. Küçükbaş hayvan yetiştiriciliği meraya dayalı olarak yapılmaktadır. Yem ve su kaynaklarındaki değişim strese sebep olmaktadır. Stres hastalıklara yakalanmayı kolaylaştırmakta tedavi için ilaç kullanımını artırmaktadır (Altınçekiç ve Koyuncu, 2012). Yüksek ortam sıcaklıkları, bağıl nem (RH), hava akışı ve güneş radyasyonu ile birlikte vücut sıcaklığını kritik seviyenin üzerine çıkarır. Bu da hayvansal üretimde fizyolojik yan etkilere neden olmaktadır (Kadim vd., 2008). Sıcaklık stresinin etkisinde, hayvanlar gıda alımını ve sindirim kapasitesini azaltacak ve sonuç olarak besin emilimi daha küçük olacaktır. Bu durumda, ilk etkilenecek olan üreme, ardından üretim ve büyüme olacaktır. Sıcaklık stresinin ileri safhalarında sadece hayati faaliyet için enerji kullanılacaktır (McManus ve ark., 2020). Kuzularda termoregülasyon merkezinin olgunlaşmaması nedeniyle sıcaklık stresini daha az tolere ederken, laktasyondaki koyunlar daha yüksek metabolik hıza ve metabolik ısı üretimine sahip oldukları için yüksek sıcaklıklara daha az toleranslıdır (Macías-Cruz ark., 2018).

Sakar (2024) yaptığı çalışmada belirli agroklimatik koşullar altında büyüme, bir koyun ırkının hayvanın konforunun azalmasıyla birlikte performansının düşmesine neden olan bir uyarlanabilirlik parametresi olduğunu bildirmiştir. Çalışma sonucunda incelenen iklim indeks değerlerinin genel olarak soğuk koşullarda kuzuların büyüme ve gelişme değerleri üzerinde olumsuz bir etkiye sahip bulunmazken, sıcak koşullarının hayvanları olumsuz yönde etkilediği bildirilmiştir.

Yapılan bir çalışmada kronik sıcaklık stresine maruz kalan kuzularda iskelet kasına özgü glikoz metabolizmasının bozulduğu bildirilmiştir (Barnes ve ark., 2019). Elde edilen çalışma sonuçlarında daha önce varsaydıkları gibi, sıcaklık stresinin en azından kısmen kronik inflamatuar ve adrenerjik tepkiler yoluyla kuzularda büyümeyi ve metabolik verimliliği azalttığı sonucuna varmışlardır (Barnes ve ark., 2019).

Yapılan çalışmalarda; sıcaklık stresi koşulları altında, kuzuların termal dengelerini yeniden sağlamak için farklı fizyolojik ve metabolik ayarlamaları aktive ettiği bildirilmiştir (Macías-Cruz ve ark., 2018a; Macías-Cruz ve ark., 2016, Macías-Cruz ve ark., 2018b). Ayrıca, su alımını artırarak ve yeterli vücut su dengesini koruyarak homeotermiyi gerçekleştirirler (Al-Dawood, 2017). Bununla birlikte, bu termoregülasyon mekanizmalarının aktivasyonu, sıcaklık stresine maruz kalan kuzularda büyüme hızını ve yem verimliliğini azaltır, çünkü termoregülasyon nedeniyle bakım için artan enerji gereksinimleri ile kuru madde alımını korurlar (Macías-Cruz ve ark., 2013; Vicente-Pérez ve ark., 2020).

Nicolás-López ve ark. (2021) yaptıkları çalışmada; erkek kuzuların mevsimsel sıcaklık stresinin üretken performansları, fizyolojik yanıtları, metabolizmaları ve hematolojik profilleri üzerine etkisini değerlendirmeyi amaçlamışlardır. Sonuç olarak, yaz mevsiminin kronik koşullarına yanıt olarak kuzuların büyümesi yavaştı, ancak fizyolojik, metabolik ve endokrin düzenlemelerin aktivasyonu nedeniyle hipertermiden kaçındığı bildirilmiştir.

Mahjoubi ve ark. (2014) Afshari koyunlarında yaptıkları çalışmada, besi kuzularında orta derecede sıcaklık stresine yanıt olarak kuru madde tüketimini değiştirmeden ortalama günlük canlı ağırlık kazancında bir azalma olduğu bildirmiştir. Mahjoubi ve ark. (2015) yaptıkları çalışmada; Afshari kuzularında döngüsel ve şiddetli ısı stresinin büyüme performansı ve metabolizma üzerine etkisini araştırmışlardır. Çalışma sonucunda sıcaklık stresinin büyüme

sırasında kilo alımının enerjisini önemli ölçüde değiştirdiğini ve sıcaklık stresinin etkilerinin ısı yükünün şiddetine bağlı olduğu bildirilmiştir.

Shi ve ark. (2020) yaptıkları çalışmada, sıcaklık stresinin kuzuların antioksidan durumu ve immün yanıtı üzerindeki etkilerini değerlendirmeyi amaçlamışlardır. Çalışma sonucunda, sıcaklık stresinin kuzuların antioksidan durumunu ve immün yanıtını olumsuz yönde etkilediğini ve sıcaklık stresinin olumsuz etkilerinin sadece stres süresi ile değil, stres şiddeti ile de ilişkili olduğunu bildirmişlerdir.

Öğdüm (2010) yaptıkları çalışmada Akkeçilerin Orta Anadolu koşullarında yaz aylarında etkili olan yüksek sıcaklığa karşı fizyolojik tepkilerini belirlemeyi amaçlamıştır. Yaz aylarında dakikada solunum sayısı oğlaklarda 53.3 adet, çebiçlerde 51.6 adet ve keçilerde 50.1 adet olarak bulunmuştur. Çalışma sonucunda ortalama nabız sayısı oğlaklarda 111.7 adet/dakika, çebiçlerde 106.4 adet/dakika ve keçilerde 105.8 adet/dakika olarak bulunmuştur. Elde edilen sonuçlar Akkeçi oğlak, çebiç ve keçisinin ölçüm yapılan 19 hafta boyunca yüksek sıcaklık ve nemden etkilendiklerini göstermiştir. Oğlaklar yüksek sıcaklık stresinden en çok etkilenen grup olurken, çebiç ve keçiler özellikle de keçiler sıcak zorlanımından daha az etkilenmişlerdir.

Kayabaşı (2011) yaptığı çalışma sonucunda; sırası ile Şubat (soğuk çevre), Nisan (optimal çevre), Haziran (sıcak çevre) aylarında rektal sıcaklık değerleri; Çukurova Saaneni keçilerde 39.52ºC, 39.72ºC, 40.02ºC, Balcalı keçilerinde ise 39.56 0C, 40.02 0C ve 40.00 0C olarak bulmuştur. Nabız sayısı bakımından aynı koşullarda Çukurova Saanen keçilerinde 69.84, 72.64, 80.86 adet /dk. Balcalı keçilerinde 69.10, 72.54, 79.32 adet/dk., solunum hızı bakımından da Çukurova Saanen keçilerinde 42.76, 49.82, 54.32 adet/dk., Balcalı'da ise 40.54, 52.88, 51.77 adet/dk. olarak bulunmuştur. Sonuç olarak her 2 genotip için elde edilen verilerden fizyolojik adaptasyon parametreleri yönünden Balcalı grubunun daha avantajlı bir konumda olduğu ve sıcak, nemli koşullardaki sıcaklık direncini Saanen genotipine oranla daha yüksek olduğu bildirilmiştir.

Çeşitli araştırmalar, termal maruziyet sırasında büyüme parametrelerinde değişiklik olduğunu bildirmiştir (Habibu ve ark., 2016; Popoola ve ark., 2014). Çeşitli büyüme değişkenleri arasında, canlı ağırlık, hayvancılıkta sıcaklık stresi nedeniyle etkilenen ilk ve en önemli faktördür. Yaz sıcağı stresine (32.9°C) maruz kalan Batı Afrika Cüce keçilerinde yapılan bir çalışmada, ortalama günlük kazancın azaldığı bildirilmiştir, bu da bu hayvanlarda yem alımındaki azalmaya bağlanabilir (Popoola ve ark., 2014). Ayrıca, benzer olarak Habibu ve ark. (2016)'da yaptıkları çalışmada termal (38.8° C) maruziyetten sonra Sahel ve Red Sokoto oğlaklarında vücut kitle indeksinde önemli bir azalma olduğunu bildirmiştir.

5. SONUÇ VE ÖNERİLER

Hayvansal üretimde üreme sürecinin sorunsuz olarak tamamlanabilmesi, doğumların sorunsuz bir şekilde gerçekleşebilmesinin yanında doğan yavrunun da hayatta kalabilmesi önemlidir. Çiftlik hayvanı yetiştiriciliğinde, üretim sistemlerindeki sorunların, yeni doğanlarda ölüm oranlarının artmasına ve bunun yanında ciddi ekonomik kayıpların oluşmasına neden olduğu bilinmektedir. Bu açıdan doğum ve doğum sonrası dönemde yavruya ait özelliklerin iyi tanınmasının, yavrunun maruz kaldığı etkilere karşı fizyolojik adaptasyon yeteneğinin incelenmesi ve mevcut sorunların daha iyi irdelenebilmesi ile gerekli üretim stratejilerinin

geliştirilebilmesi açısından faydalı olabilir. Kuzu ve oğlaklarda mortalite ve yaşama gücü üzerine etkili faktör sayısının oldukça çok olduğu bilinmektedir. İşletmelerdeki doğum dönemi ve sonrasındaki kuzu kayıpları refah probleminin ve önemli bir ekonomik kaybın göstergesidir. Doğum ve doğum sonrasına ilişkin bazı özellikler ile yaşamın ilerleyen dönemlerinde kuzu ve oğlakların yaşama gücü ve performans özellikleri üzerine birçok çalışma yapılış olmasına karşın bu alanda yapılacak yeni çalışmalarla refah anlamında sergileyecekleri tavır arasındaki ilişkilerin anlaşılması ve değerlendirilmesine gereksinim duyulmaktadır.

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SHEEP MILK PRODUCTION AND IMPORTANCE

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ABSTRACT

Sheep farming is an important sector of the livestock industry with meat and milk production, which plays an important role in human nutrition worldwide. Sheep farming not only meets the need for animal protein for global food security and a healthy nutrition, but is also important for the utilisation of land that is not suitable for agricultural production and for the livelihoods of low-income families, especially in rural areas. According to research, global demand for food is estimated to increase by 35-50% between 2012 and 2050. The quantity and quality of products obtained from sheep can vary depending on genetic structure and environmental effects. Changes in environmental factors can have a positive or negative effect on the quantity and quality of the product.

Milk obtained from sheep is important for the cheese industry. Various types of cheese, yoghurt, butter, etc. are made from the milk obtained. In recent years, organic products have become increasingly popular. In sheep farming, sheep-derived products are in demand by consumers, as the animals are generally kept under extensive production conditions. In addition, it is becoming increasingly important in sheep farming to support and economise traditional breeding with production for the welfare of the animals and the authenticity of the products. This study aims to highlight the production and importance of sheep milk.

Keywords: Sheep Milk, Milk Yield, Milk Components, Milk Production.

KOYUN SÜTÜ ÜRETİMİ VE ÖNEMİ

ÖZET

Koyun yetiştiriciliği, dünya genelinde insan beslenmesinde önemli yeri olan başta et ve süt üretimiyle hayvancılık sektöründe önemli bir alandır. Küresel gıda güvenliği ve sağlıklı beslenmede hayvansal protein ihtiyacını karşılamanın yanı sıra tarımsal üretim için kullanıma uygun olmayan alanların değerlendirilmesi ve özellikle kırsal bölgelerde dar gelirli ailelerin geçimi için koyun yetiştiriciliği önemli bir yere sahiptir. Yapılan araştırmalara göre gıda ürünlerine yönelik küresel talebin, 2012 ile 2050 yılları arasında %35-50 oranında artacağı tahmin edilmektedir. Koyunlardan elde edilen ürünlerin miktar ve kalitesi genetik yapı ve çevresel etkilere bağlı olarak değişebilmektedir. Çevresel etkilerin değişimi ürün miktar ve kalitesini olumlu ya da olumsuz olarak etkileyebilmektedir.

Koyunlardan elde edilen süt peynir endüstrisi için önemlidir. Elde edilen sütten farklı peynir çeşitleri, yoğurt, tereyağı vb. ürünler üretilmektedir. Son yıllarda organik ürünler daha fazla tercih edilmektedir. Koyun yetiştiriciliğinde yaygın olarak hayvanların ekstansif üretim şartlarında yetiştirilmesi sebebiyle elde edilen ürünler tüketici tarafından talep edilmektedir. Ayrıca koyun yetiştiriciliğinde hayvan refahına ve ürünün özgünlüğüne yönelik üretime sahip geleneksel yetiştirmenin desteklenmesi ve ekonomik hale getirilmesi giderek önemli hale gelmektedir. Bu çalışmada koyun sütü üretimi ve öneminin ortaya konulması amaçlanmıştır.

Anahtar Kelimeler: Koyun Sütü, Süt Verimi, Süt Bileşenleri, Süt Üretimi.

1. GİRİŞ

Gelişmekte olan ülkelerde koyun yetiştiriciliği, ticari fayda değil, öncelikle geçim güvenliği amaçlıdır (Mohapatra ve ark., 2019). Koyun yetiştiriciliği, dünya genelinde insan beslenmesinde önemli yeri olan başta et ve süt üretimiyle hayvancılık sektöründe önemli bir alandır. Küresel gıda güvenliği ve sağlıklı beslenmede hayvansal protein ihtiyacını karşılamanın yanı sıra tarımsal üretim için kullanıma uygun olmayan alanların değerlendirilmesi ve özellikle kırsal bölgelerde dar gelirli ailelerin geçimi için koyun yetiştiriciliği önemli bir yere sahiptir.

Dünya genelinde yaklaşık 10,5 milyon ton, Avrupa'da ise yaklaşık 3,1 milyon ton koyun sütü üretilmektedir. Avrupa'da koyun sütü üretimi son yıllarda biraz durgunlaşmıştır ve şu anda küresel üretimin yaklaşık 1/3'ünü oluşturmaktadır. Yüksek kuru madde, süt yağı, toplam protein ve kazein içeriği nedeniyle koyun sütü peynir üretimi için mükemmel bir hammaddedir. Süt işleme ve peynir yapımı sadece ekonomik açıdan önemli değil, aynı zamanda genellikle kırsal ve az gelişmiş bölgelerde gerçekleşen uzun bir geleneğe dayanan kültürel mirasın bir parçasıdır. Süt üretimi ve kalitesi üzerine etkili faktörler oldukça karmaşıktır ve en önemlileri ırk, besleme, vücut kondisyonu, laktasyon dönemi, sağım, meme sağlığı ve çevresel faktörler olmak üzere çok sayıda faktörden etkilenir. Buna ek olarak, ısı stresi, beslenme stresi, sütten kesme stresi, kırkım stresi gibi farklı stres türleri koyunların refahı ve sağlığı üzerinde olduğu kadar üretilen süt miktarı, kimyasal bileşimi, işleme özellikleri ve sürünün ekonomik verimliliği üzerinde de önemli bir etkiye sahiptir. Son yıllarda, iklim değişikliği nedeniyle, ısı stresinin koyunların üreme ve üretim özelliklerinin yanı sıra refah ve sağlıkları üzerindeki etkileri üzerine artan sayıda çalışma yapılmıştır. Buna ek olarak, ısı stresi genellikle yem ve su eksikliği ile ilişkilendirilmektedir. Stresin etkileri özellikle koyun yetiştiriciliğinde yaygın olan ekstansif koyun yetiştiriciliğinde ve süt üretiminde daha belirgindir (Mioč ve ark., 2024).

Küresel koyun sütü üretimi son yıllarda önemli ölçüde artmıştır; daha fazla artış için açık bir eğilim de belirgindir (Pulina ve ark., 2018). İnek sütünün aksine, koyun sütü doğrudan tüketilmemekte, daha çok başta yoğurt veya peynir ürünleri olmak üzere çeşitli süt ürünleri üretiminde kullanılmaktadır (Dennett, 2016). Dünya genelinde koyun sütünün en büyük kısmı Asya'da (yaklaşık %45) (özellikle Çin ve Türkiye'de); daha küçük bir kısmı Avrupa'da (yaklaşık %30) (özellikle Fransa, Yunanistan, İtalya ve İspanya'da) ve Afrika'da (yaklaşık %25) (özellikle Cezayir'de); en az kısmı ise Amerika kıtasında (özellikle Meksika'da) ve Okyanusya'da (toplamda %2'den az) üretilmektedir (Skapetas and Kalaitzidou, 2017; Pulina ve ark., 2018). Küresel olarak, süt koyunu çiftlikleri çoğunlukla ılıman ve tropikal bölgelerde yer almaktadır. Bu bölgelerde, koyun sütünden elde edilen süt ürünleri yerel halkın beslenmesinde önemli bir yer tutmaktadır (Katsarou ve ark., 2024).

(Balthazar ve ark. (2017) yaptıkları çalışmada; koyun sütünün diğer evcil türlerin sütlerine kıyasla yüksek besin değerine ve yüksek konsantrasyonlarda protein, yağ, mineral ve vitamin içerdiğini belirtmiştir. Ayrıca koyun sütünün fizikokimyasal ve besinsel özellikleri, fonksiyonel gıda pazarında ana kategoriler olan prebiyotik bileşenler ve/veya probiyotik bakteriler içeren ürünlerin üretimi için avantajlı olabileceğini bildirmiştir. Ek olarak; koyun sütü mükemmel bir besin kaynağıdır ve yüksek peynir verimine katkıda bulunan yüksek toplam katı madde içeriği nedeniyle çoğunlukla peynir üretiminde kullanılır. Bununla birlikte, bu gıda matrisinin fonksiyonel faydaları süt endüstrisi tarafından keşfedilmemiştir. Endüstriyel ölçekte ürünlerin

geliştirilmesi, bu matrisin kendine has özellikleri nedeniyle teknik bilgi ve mevcut protokollerin uyarlanmasını gerektirmektedir. Peynir, yoğurt, dondurma ve diğer sütlü tatlılar gibi koyun sütü ürünlerine probiyotik mikroorganizmaların ve özellikle prebiyotik bileşenlerin eklenmesinin etkilerini araştırmak için daha fazla çalışmaya ihtiyaç vardır.

2. DÜNYA'DA VE TÜRKİYE'DE KOYUN SÜTÜ ÜRETİMİ

Dünya sağılan hayvan varlığında 2022 yılı verilerine göre; koyun 247 milyon baş, sığır 277 milyon baş, keçi 214 milyon baş ve manda 72 milyon baştır. Dünyada toplam sağılan hayvan varlığının %30,4'ü koyun, %34,3'ü sığır, %26,4'ü keçi ve %8,8'i mandadan oluşmaktadır.

FAO'ya göre 2021 yılında 936 milyon ton olan dünya süt üretimi (inek, manda, koyun, keçi) 2022 yılında yaklaşık %1 oranında azalarak 926 milyon ton gerçekleşmiştir (Tablo1).

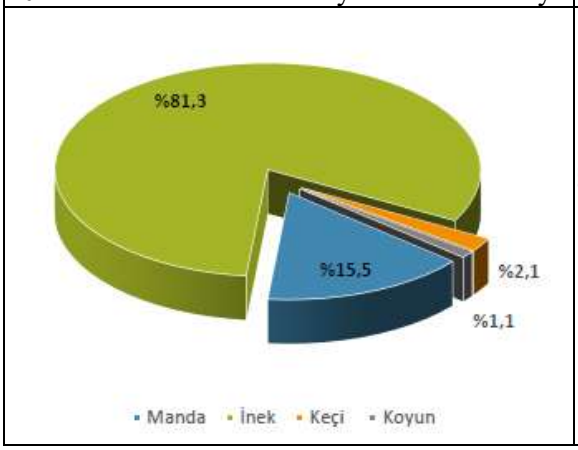
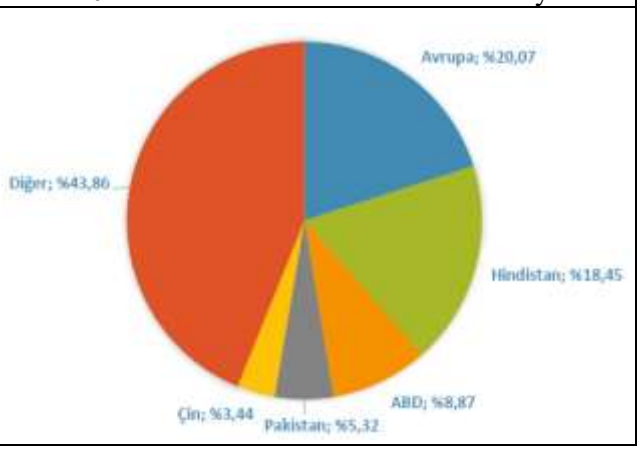
Tablo 1. 2016-2022 Yılları arası bazı ülkelerin inek, manda, koyun ve keçi hayvan varlığı, süt üretimi ve süt verimi (FAO, 2023, Anonim, 2023)

		2016	2017	2018	2019	2020	2021	2022	2016-2022 Değişim %
Sığır	Sağılan hayvan varlığı (milyon baş)	270	270	272	277	275	275	277	2,6
	Süt üretimi (milyon ton)	671	685	701	715	742	757	753	-12,2
	Süt verimi (kg/baş)	24.521	25.356	25.914	26.213	26.813	27.490	27.160	-10,8
Manda	Sağılan hayvan varlığı (milyon baş)	67	68	70	71	70	71	72	7,5
	Süt üretimi (milyon ton)	120	126	132	137	137	149	144	-20
	Süt verimi (kg/baş)	2	2	2	1,94	1,97	2,10	2,00	-11,1
Koyun	Sağılan hayvan varlığı (milyon baş)	246	246	248	257	256	248	247	-0,4
	Süt üretimi (milyon ton)	10	10	10	11	10	10	10	0
	Süt verimi (kg/baş)	41	42	42	41	41	42	41	0
Keçi	Sağılan hayvan varlığı (milyon baş)	207	210	214	224	222	212	214	3,4
	Süt üretimi (milyon ton)	19	20	20	20	21	19	19	0
	Süt verimi (kg/baş)	94	96	96	91	95	92	90	-4,3

Toplam süt üretiminde 2022 yılında en büyük payı %81 (753 milyon ton) ile inek sütü alırken, manda sütü %15 (144 milyon ton), koyun sütü %1 (10 milyon ton) ve keçi sütü %2 (19 milyon ton) paya sahiptir.

Dünya süt üretiminde (koyun, keçi, inek, manda) AB-28 %20 üretim payı ile ilk sırada yer alırken %18 ile Hindistan ikinci sırada yer almaktadır. Dünyanın en büyük süt üreticisi olan AB 2022 yılında bir önceki yıla göre %0,44 düşüşle 232 milyon ton üretim gerçekleşirken, ikinci en büyük üretici olan Hindistan 2022 yılı üretimi %3,31 düşüşle 214 milyon ton olmuştur.

AB, Hindistan ve ABD dünya süt üretiminin (inek, manda, koyun, keçi) yaklaşık %47'sini oluşturmaktadır.

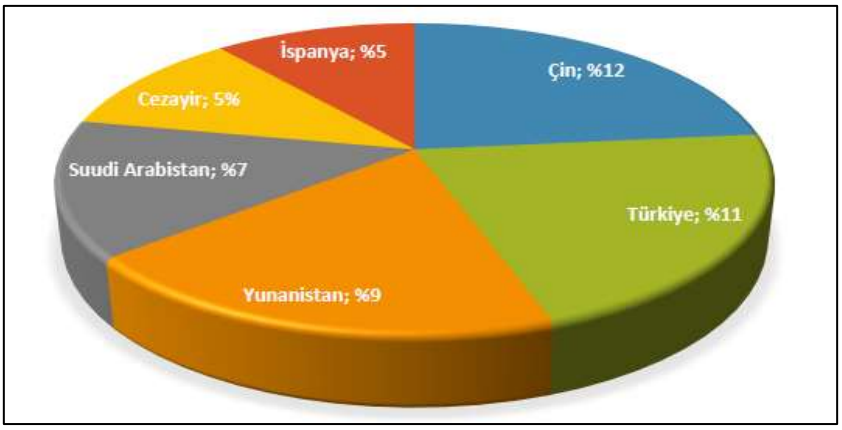
2022 Yılı Türlere Göre Dünya Süt Üretim Payı	2022 Yılı Ülkelere Göre Süt Üretim Payı
	

Şekil 1. 2022 Yılı türlere göre dünya süt üretim payı ve ülkelere göre süt üretim payı (FAO, 2023, Anonim, 2023)

Dünya koyun sütü üretimi 2022 yılında, 2021 yılına göre %2 artarak 10.087 bin ton olarak gerçekleşmiştir. AB dünya koyun sütü üretiminin %28 gibi büyük bir payını karşılarken Çin dünya koyun sütünün %12'lik kısmını üretmektedir. Türkiye 1.166 bin ton ile koyun sütü üretimi ile Çin'den sonraki en büyük üretici ülkesi olmuştur.

Tablo 2. 2021-2022 Yılı Ülkelerin Koyun Sütü Üretimi (FAO, 2023, Anonim, 2023)

Sıra	Ülkeler	2021 (bin ton)	2022 (bin ton)
1	Çin	10.292	10.087
2	Türkiye	1.273	1.166
3	Yunanistan	1.144	1.067
4	Suriye	952	956
5	İspanya	703	707
6	Cezayir	525	547
DÜNYA		10.292	10.087

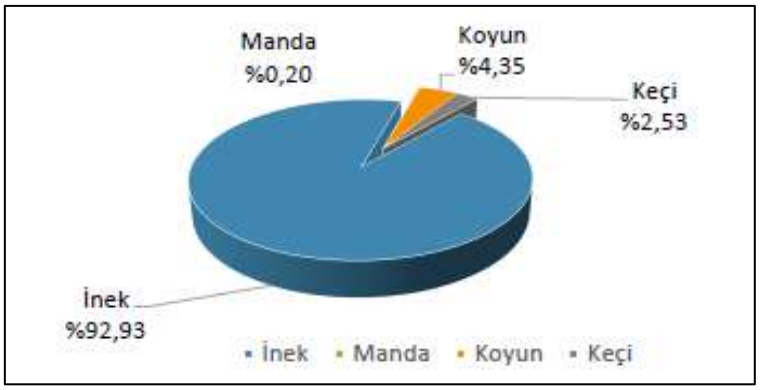


Şekil 2. 2022 Yılı Ülkelerin Koyun Sütü Üretim Payı (FAO, 2023, Anonim, 2023)

Ülkemiz toplam süt üretiminin %92,93'ünü inek sütü, %4,35'ini koyun sütü, %2,53'ünü keçi sütü ve %0,20'sini ise manda sütü oluşturmaktadır.

Tablo 3. 2020-2023 Yılları türlere göre süt üretimi ve değişimi (TÜİK, 2023, Anonim, 2023)

Miktar (Ton)	2020	2021	2022	2023	2022/23 Değişimi (%)
Toplam	**23.503.790**	**23.200.306**	**21.563.492**	**21.481.567**	-0,4
İnek Sütü	21.749.342	21.370.116	19.912.135	19.961.908	0,3
Manda Sütü	63.767	63.643	43.589	43.025	-1,3
Koyun Sütü	1.101.065	1.143.762	1.067.342	933.576	-12,5
Keçi Sütü	589.617	622.785	540.426	543.058	0,5



Şekil 3. Türkiye 2023 yılı türlere göre süt üretimi (TÜİK, 2023, Anonim, 2023)

İllere göre süt üretimine bakıldığında 2022 yılında küçükbaş hayvan sütü üretiminin %25'i Van, Şanlıurfa, Konya, Diyarbakır ve Mersin illerinden sağlanmaktadır. Koyun sütü üretiminde Van, Konya, Şanlıurfa, Diyarbakır; keçi sütü üretiminde Mersin, Antalya ve Şırnak en önemli illerdir.

Şekil 4. 2022 yılı illere göre küçükbaş hayvan süt üretimi (TÜİK, 2023, Anonim, 2023)

3. KOYUN SÜTÜ ÖZELLİKLERİ

Sütün fiziko-kimyasal özellikleri, belirli bir hayvan türü için bileşimi ile ilgilidir. Koyun sütünün bileşimi ve fiziko-kimyasal özellikleri hakkında bilgi, koyun sütü endüstrilerinin başarılı bir şekilde gelişmesi ve ürünlerin pazarlanması için gereklidir (Park ve ark., 2007).

Süt, fiziksel özellikleri ve bileşimi türler arasında farklılık gösteren bir memeli bezi salgısıdır. Yağ, proteinler, laktoz, mineraller, enzimler, hücreler, hormonlar, immünoglobulinler ve vitaminler içeren kompleks bir su içinde yağ emülsiyonudur. Proteinler, laktoserumda bulunan çözünmeyen proteinler (kazeinler) ve çözünen proteinler (peynir altı suyu proteinleri) olarak kategorize edilir. Kazeinler αs1, αs2, β ve κ-kazeinleri içerir, ancak peynir altı suyu proteinleri α-laktalbumin ve β-laktoglobulindir. Süt ayrıca serum albümini, immünoglobulinler, laktoferrin, transferrin, kalsiyum bağlayıcı protein, prolaktin, folat bağlayıcı protein ve proteosepton gibi önemli minör proteinler de içerir (Selvaggi ve ark., 2014).

Koyun sütünün kimyasal bileşimi, laktasyon dönemi, mevsim, çevre sıcaklığı, laktasyon verimliliği, hayvanın yaşı ve beslenmesi, genetik faktörler (tür ve ırk) ve meme hastalıkları gibi çeşitli faktörlere bağlı olarak zaman içinde ve hayvanlar arasında değişiklik gösterir (Tamime ve ark., 2011; Claeys ve ark., 2014). Mevsimsel farklılıklar, merada beslenen hayvanların yem bileşimindeki değişiklikler nedeniyle yağ asidi bileşimini güçlü bir şekilde etkiler (Zlatanos ve ark., 2002; Revilla ve ark., 2017). Diğer süt bileşenlerinin yanı sıra lipitler de genetik, fizyoloji ve çevresel faktörler nedeniyle değişkenliğe maruz kalmaktadır. Mevsimsel ve iklimsel değişiklikler (Jaworski ve Kuncewicz, 2008), hayvan yemlerindeki besin maddelerine ve dolayısıyla hayvan fizyolojisine müdahale ederek süt kalitesini etkilediği için son derece önemli hale gelmiştir.

Koyun sütünün besin değeri keçi ve inek sütünden daha yüksektir; insan sağlığı için gerekli protein, lipit, mineral ve vitaminleri daha yüksek oranda içerir ve kalori değeri 5932 kJ/kg'a karşılık gelir (Haenlein, 2001; Kaminarides ve ark., 2007; Park ve ark., 2007; Barłowska ve

ark., 2011). Tablo4 ve Tablo 5'de farklı türlerden elde edilen bazı süt bileşenleri, fizikokimyasal özelliklere ait ortalama değerler ve süt yağlarının yağ asidi dağılımı verilmiştir.

Koyun sütü yağı, %11 kısa ve orta zincirli yağ asitleri ile yüksek oranda doymuştur (65 ila 75 g/100 g to-tal yağ asidi) (Revilla ve ark., 2017); koyun sütünün yağ asidi içeriği, bütirik asit (C4:0) içeriği bakımından inek sütünden önemli ölçüde farklılık göstermez, ancak kaproik (C6:0), kaprilik (C8:0) ve kaprik (C10:0) asitler gibi daha fazla doymuş yağ asidi içerir. Kaproik, kaprilik ve kaprik asitler vücut ağırlığını ve vücut yağını azaltabilmesine rağmen, düşük bütirik asit konsantrasyonları insan kanser hücre hatlarının vitroof inhibisyonuna katkıda bulunur (Rasmussenand ve ark., 2010; Foglietta ve ark., 2014)

Koyun sütü yağındaki çoklu doymamış yağ asitleri (PUFA'lar) esas olarak linoleik (cis-9, cis-12 C18:2) ve α-linolenik (cis-9, cis-12, cis-15 C18:3) asitlerin yanı sıra bunların daha az miktarda konumsal ve geometrik izomerlerinden oluşur (Recio ve ark., 2009). Koyun sütündeki tekli ve çoklu doymamış yağ asitleri, Balthazar ve ark. (2016) tarafından açıklandığı gibi, aterojenik ve trombojenik indeksler nedeniyle kardiyovasküler hastalıkların önlenmesine katkıda bulunabilir.

Tablo 4. Koyun, keçi ve inek sütlerinde bazı süt bileşenleri ve fizikokimyasal özelliklere ait ortalama değerler

Bileşenler	Keçi	Koyun	İnek	İnsan
Yağ (%)	3,8	7,9	3,6	4,0
Yağsız kuru madde (%)	8,9	12,0	9,0	8,9
Laktoz (%)	4,1	4,9	4,7	6,9
Protein (%)	3,4	6,2	3,2	1,2
Kazein (%)	2,4	4,2	2,6	0,4
Albumin, globulin (%)	0,6	1,0	0,6	0,7
Non-protein azot (%)	0,4	0,8	0,2	0,5
Kül (%)	0,8	0,9	0,7	0,3
Ca (mg/100 g)	134	193	122	33
Mg (mg/100 g)	16	18	12	4
P (mg/100 g)	121	158	119	43
K (mg/100 g)	181	136	152	55
Na (mg/100 g)	41	44	58	15
Cl (mg/100 g)	150	160	100	60
Vit A (IU)	185	146	126	190
Vit B1 (mg/100 ml)	68	0,41	0,08	0,17
Vit B12 (µg)	0,065	43	2	3,6
Vit B2 (mg/100 g)	0,14	0,35	0,17	0,03
Vit B3 (mg)	0,20	0,42	0,09	0,1
Vit B5 (mg/100 g)	0,31	0,41	0,34	0,18
Vit C (mg/100 ml)	1,29	4,16	0,94	5,00
Vit D (µg)	0,06	0,18	0,08	0,06
Özellik	**Keçi**	**Koyun**	**İnek**	
Yoğunluk	1,029-1,039	1,0347-1,0384	1,0231-1,0398	-
Viskozite (Cp)	2,12	2,86-3,93	2	-
Yüzey gerilimi (Dyn/cm)	52	44,94-48,7	42,3-52,1	-
İletkenlik ($\Omega^{-1}cm^{-1}$)	0,0043-0,0139	0,0038	0,0040-0,0055	-
Refraktif indeks	1,450±0,39	1,3492-1,3497	1,451±0,35	-
Donma noktası (- °C)	0,540-0,573	0,57	0,53-0,57	-
Laktik asit (%)	0,14-0,23	0,22-0,25	0,15-0,18	-
pH	6,5-6,8	6,51-6,85	6,65-6,71	-

Kaynak: Park, 2006; Park ve ark., 2007; Raynal-Ljutovac ve ark., 2008; Önür, 2015

Koyun sütü çoğunlukla peynir yapımında kullanıldığından, peynir olgunlaşması sırasında biyoaktif peptitlerin oluşumu özel bir ilgi konusudur. Peynir olgunlaşmasında rol oynayan proteolitik sistemlerin çeşitliliği ve peynir türüne bağlı olarak olgunlaşma sırasında farklı proteoliz yoğunlukları nedeniyle peynirler önemli bir peptit kaynağı oluşturmaktadır. Bununla birlikte, peynir gibi karmaşık matrislerde biyolojik olarak aktif peptitlerin tanımlanması zor bir görev olduğundan, koyun peynirinin olgunlaşması sırasında kazeinden serbest kalan peptitlerin ACE inhibitör aktiviteleri ile ilgili sadece birkaç makale vardır (Recio ve ark., 2009). G´omez-Ruiz ve ark. (2002, 2004) Manchego peynirlerinden (İspanya'nın La Mancha bölgesinde üretilen tipik pas-teurize edilmemiş koyun sütü) ACE-inhibitör aktiviteye sahip 2 peptit (VRYL ve KKYNVPQL) izole etmiştir. Rizzello ve ark. (2005), bazıları koyun sütü ile formüle edilmiş çeşitli İtalyan peynir çeşitlerinin suda çözünür ekstraktından antibakteriyel özelliklere sahip 4 peptit (GLSPEVLNENLL, RFVVAPFPE, VVAPFPEV ve RFVVAPFPE) izole etmiştir. Pisanu ve ark. (2015) çiğ koyun sütü veya pastörize koyun sütü kullanılarak üretilen peynirleri peptit profilindeki farklılıklar açısından karşılaştırmış ve çiğ koyun sütü peynirlerinde bağışıklık düzenleyici ve ACE inhibitörü özelliklere sahip peptitlerin önemli ölçüde daha fazla olduğunu gözlemlemiştir. Bu farklılıklar muhtemelen çeşitli süt bileşenlerinin ısıya maruz kalmasıyla ilgilidir, bu da hem proteinlerin enzimatik bölünmeye uygunluğu hem de olgunlaşma sırasında peptitlerin oluşumundan sorumlu olan yerli bakteriler veya proteolitik enzimler üzerinde etkili olabilir.

Koyun sütü tatlı ve yumuşak bir tada, aromaya ve süt içinde dağılmış küçük yağ globüllerinin varlığı nedeniyle kremsi bir dokuya sahiptir ve bu da sütün daha kolay sindirilmesini sağlar (Park ve ark., 2007). Koyun sütünde, bu benzersiz aromadan sorumlu olan serbest yağ asidi seviyeleri nedeniyle koyunsu olarak bildirilen ayırt edici bir lezzet gözlenir (Chandan ve ark., 1992). Bu tat, tereyağı ve peynir gibi koyun sütü türevlerinde de görülmektedir (Jooyandeh and Aberoumand, 2010). Lipaz süt üretiminde önemli bir rol oynar. Doğal koyun sütü lipazı trigliseritleri katalize ve hidrolize ederek yağ asitlerinin üretimine neden olur, ancak koyun sütündeki lipaz aktivitesi inek sütündekinin yaklaşık onda biri kadardır (Chandan ve ark., 1968). Ayrıca koyun sütü, uzun zincirli yağ asitlerine kıyasla orta zincirli yağ asitleri içeren trigliseritler için daha yüksek bir hidroliz oranı sunar (Ch´avarri ve ark., 1998).

Koyun sütü proteinleri çoğunlukla kazein (ısıya dayanıklı) ve peynir altı suyu proteinlerinden (ısıya duyarlı) oluşur ve bunlar yoğurdun dokusundan ve viskozitesinden sorumludur ve koyun sütüne benzersiz özellikler sağlar. Bu özellikler, yoğurt üretimi durumunda kıvam arttırıcılar, süt tozu veya membran teknolojisi ile elde edilen konsantre süt gibi katı maddeler eklenmeden sütün peynir ve yoğurda kolayca dönüştürülmesini sağlar (Tamime ve ark., 2011). Koyun sütünün yüksek katı madde içeriği ile koyun yoğurdu yüksek jel gücüne sahiptir ve inek ve keçi yoğurtlarına kıyasla minimum sinerezis gösterir. Yüksek titre edilebilir asitlik ve kalsiyum içeriği nedeniyle, koyun yoğurdu hafif grenli bir gövdeye ve dokuya sahip olma eğiliminde olabilir (Wendorff, 2005).

Tablo 5. Koyun, keçi, inek ve manda süt yağlarının yağ asidi dağılımı (%)

Yağ Asidi	Keçi	Koyun	İnek	Manda
C4:0	5,3±1,0	10,3±1,5	6,0±0,8	7,2±0,2
C6:0	2,9±0,8	3,4±0,7	2,9±0,6	0,7±0,2
C8:0	3,5±0,1	2,5±0,5	1,7±0,2	1,0±0,0
C10:0	11,4±1,4	6,1±2,1	3,4±0,6	2,4±0,1
C12:0	3,8±1,1	3,0±0,7	3,9±0,9	2,8±0,1
C14:0	8,8±0,1	7,0±0,4	13,1±1,2	11,7±0,2
C16:0	23,1±2,4	19,8±0,7	31,6±2,6	34,2±0,5
C16:1n-7	0,5±0,0	0,7±0,1	1,8±0,3	2,1±0,0
C18:0	11,2±0,9	11,8±1,2	6,6±1,4	10,5±0,4
C18:1n-9	19,0±1,3	22,8±2,1	19,2±4,3	18,8±0,5
C18:2n-6	1,6±0,2	2,7±1,5	1,9±0,2	2,0±0,0
C18:3n-3	0,5±0,1	0,8±0,2	0,2±0,1	0,2±0,0
Diğerleri	8,4	9,2	7,7	6,7
n-6/n-3 oranı	3,2	3,4	9,5	10,0

Kaynak: Blasi ve Montesano, 2008

4. SONUÇ VE ÖNERİLER

Koyun sütü besin elementlerinin zenginliği ve beslenmeye yönelik faydaları bakımından, özellikle yaşlı ve çocukların beslenmesinde önemli role sahiptir. Koyun sütünün bileşimi diğer türlerde de olduğu gibi beslenme, ırk, yaş, doğum sayısı, doğum tipi, mevsim, laktasyon periyodu, canlı ağırlık, vücut kondisyon puanı, sürü yönetimi ve çevresel koşullardan etkilenmektedir. Ayrıca hayvancılık açısından bakıldığında süt üretimi üzerine mevsimsellikte etkilidir. Koyun sütü; keçi ve inek sütünden daha yüksek kuru madde oranına sahiptir. Kazein ve yağ oranı yüksek olduğundan, içme sütünden ziyade, peynir, yoğurt ve tereyağı üretiminde tercih edilmektedir. Yüksek yağ içeriğine rağmen, koyun sütünde yağ globülleri ince, tekdüze dağılımlıdır ve kolay sindirilebilirliği bakımından dikkat çekicidir. Ayrıca koyun sütünün anti-kanserojen özellik gösteren yüksek linoleik asit miktarı gibi ayırt edici özelliklerinden ve sağlık açısından önemlidir.

Koyun sütünün içme sütü olarak kullanımı yaygın değildir. Genellikle tek başına veya keçi ve inek sütleri ile karıştırılarak çeşitli ürünlere dönüştürülerek tüketilmektedir. Bu ürünlerin başında peynir gelmektedir. Özellikle Ege bölgesinde ve Çanakkale civarında üretimi yapılan Ezine peynirinin üretiminde keçi, koyun ve inek sütleri karışımı kullanılmaktadır. Bunun dışında koyun ve keçi sütleri çiğ olarak veya pastörize edilerek tek başlarına da peynir üretiminde kullanılabilmektedirler. Koyun sütünün daha fazla elde edildiği yaz aylarında "kış yoğurdu" olarak bilinen yoğurt çeşidi Türkiye'nin çeşitli bölgelerinde üretilmek te ve elde edilen bu ürün kış mevsiminde tüketilmektedir.

Koyun sütünün beslenme ve özellikle sağlık üzerine olumlu etkilere sahip olması, elde edilen ürünlerin karakteristik hoş bir tat ve aroma içerdiği bilinmektedir. Kırsal kesimde geleneksel olarak birçok ailenin tükettiği koyun sütü ve ürünleri, lezzeti, aroması ve kalitesiyle önem kazanmış, kentsel yoğunlaşma ve turizmin gelişmesiyle de giderek aranır hale gelmiştir. Koyun sütünün pazarlanmasında üreticiler alıcılara tam bağımlıdır. Elde edilen sütün bir kısmı işletme içinde tüketilmekte, bir kısmı ise süt işleyen işletmelere çiğ olarak pazarlanmakta, bir kısmı da

peynire işleyerek yerel pazarlarda satılmakta veya tüccarlara pazarlanmaktadır. Küçük ve dağınık işletmelerin büyümesi ve birleştirilmesi, uzmanlaşmış işletmeler durumuna dönüştürülmesi, bu üreticilerin aynı zamanda işleyici de olması sağlanması ile koyun sütü üretimi desteklenebilir.

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A REVIEW OF GENOMIC BREEDING STRATEGIES IN THE CASE OF STRAWBERRY YIELD AND FRUIT QUALITY TRAITS

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ABSTRACT

Strawberries belong to the genus Fragaria, from the family Rosaceae, and the cultivated strawberry cultivars are known as octoploid (2n = 8x = 56), and have a haploid chromosome number of n = 7. Strawberry is the most commonly known cultivated and preferred among berry fruit groups due to, its unique aroma, economic significance, high nutritional quality, and benefit to human health. In recent years, studies on the aroma and its benefits to human health have been intensified in strawberry breeding studies. Especially in strawberry breeding, quality parameters such as sugar, organic acid, brix, and aroma are also critical factors that directly affect consumer satisfaction and market success. For this reason, strawberry breeding studies focus on the development of new fruit varieties that meet the expectations of consumers stand out in terms of aroma, sugar, and organic acid in market competition, and are less sensitive to stress conditions. In strawberry breeding, the use of QTL and GWAS methods to identify genes associated with sugar, organic acid, and aroma and to select superior individuals in terms of these traits at an early stage by molecular analysis and to transfer the genes controlling these components to the fruit or to change the expression of existing genes in a shorter time provides significant convenience in breeding strategy. Consequently, many strawberry breeding programs aim to enhance new varieties that have improved yield, resilience, and fruit quality traits, such as sweetness, firmness, aroma, and shelf life. The aim of this study is to review the recent studies on the determination of the genomic location of QTLs associated with biochemical fruit quality traits, disease and pest tolerance traits in strawberries through some biotechnological approaches in strawberry breeding studies and to create a data pool.

Keywords: Strawberry, breeding, quality parameters, QTL, GWAS

ÇİLEK VERİM VE MEYVE KALİTE ÖZELLİKLERİ BAKIMINDAN GENOMİK ISLAH STRATEJİLERİ ÜZERİNE BİR DERLEME

ÖZET

Çilek, Rosaceae familyasından Fragaria cinsine ait olup ve kültüre alınmış çilek çeşitleri oktoploid (2n = 8x = 56) ve haploid kromozom sayısı n = 7 olarak bilinmektedir. Çilek, kendine özgü aroması, ekonomik önemi, yüksek besin değeri ve insan sağlığına olan faydaları nedeniyle üzümsü meyve grupları arasında en çok bilinen, yetiştirilen ve tercih edilen meyvedir. Son yıllarda çilekte yapılan ıslah çalışmalarında aroma ve insan sağlığına faydaları konusunda çalışmalar yoğunluk kazanmaktadır. Özellikle çilek ıslahında şeker, organik asit ve aroma gibi kalite paramatreleri, aynı zamanda tüketici memnuniyetini ve pazar başarısını doğrudan etkileyen kritik bir faktörlerdendir. Bu nedenle çilek ıslah çalışmaları, tüketicilerin beklentilerini karşılayan ve pazar rekabetinde aroma, şeker ve organic asit bakımından öne çıkan, ayrıca stres koşullarına az duyarlı yeni meyve çeşitlerinin geliştirilmesine odaklanılmaktadır. Çilek ıslahında şeker, organik asit ve aroma ile ilişkili genlerin belirlenmesi ve moleküler analizlerle bu özellikler bakımından üstün bireylerin erken aşamada seçilmesi ve bu bileşenleri kontrol eden genlerin meyveye aktarılması veya mevcut genlerin ekspresyonunun değiştirilmesi gibi işlemlerin daha kısa sürede yapılması için QTL, GWAS yöntemlerinin kullanılması ıslah stratejisinde önemli kolaylıklar sağlamaktadır. Sonuç olarak, birçok çilek ıslah programının amacı, verim, dayanıklılık ve tatlılık, sertlik, lezzet ve raf ömrü gibi meyve kalitesi özelliklerini geliştiren yeni çilek çeşitlerini geliştirmektir. Bu nedenle, bu çalışmanın amacı, çilek ıslah çalışmalarında bazı biyoteknolojik yaklaşımlar aracılığıyla çileklerde biyokimyasal meyve kalitesi özellikleri, hastalık ve zararlılara karşı toleranslılık özellikleri ile ilişkili QTL'lerin genomik konumlarının belirlenmesi hakkında mevcut çalışmaları özetlemek ve bir veri havuzu oluşturmaktır.

Anahtar Kelimeler: Çilek, ıslah, kalite parametreleri, QTL, GWAS

INTRODUCTION

Strawberry belongs to the genus Fragaria of the Rosaceae family, and cultivated strawberry varieties are known as octoploid (2n = 8x = 56) and have n = 7 haploid chromosome number. The strawberry plant is not very selective in terms of climate demand, but since it has high adaptation abilities, it can be widely cultivated in a wide geographic area. For this reason, strawberry is a very preferred fruit for consumers among berries. In addition, the strawberry fruit is a very useful fruit for human health. Since it does not contain excess calories, it is especially ideal among the diet fruits. Because of this reason, its cultivation has become quite widespread worldwide. According to FAO (2025), China is the leader with 4.216.716,93 tonnes of strawberry production in the world. When we observe the distribution of Türkiye's strawberry production by provinces, Mersin ranks first with 135.527 tonnes, Aydın ranks second with 112.877 tonnes, and Konya ranks third with 80.192 tonnes (TUIK, 2025). In recent years, determination of various biochemical compounds such as aroma, sugar, organic acids, total phenol, total phenol, total anthocyanin, brix, and colour values has become important in strawberry breeding studies. Nowadays, many strawberry producers and researchers have started to prefer and focus on strawberry varieties with high quality in terms of some quality parameters such as uniform fruit shape, firmness, rich in volatile compounds, large fruits, high colour appeal, rich in fruit quality parameters such as sugar, organic acids, brightness and also resistant to diseases and pests of strawberry plants, high resistance to abiotic and abiotic conditions. Thus, researchers are focusing not only on fruit quality parameters but also on the development of new genotypes or lines that are resistant or tolerant to various abiotic and biotic stress conditions of strawberry plants. In addition to these, strawberry breeding strategy emphasizes new and rapid breeding methods. However, it will be possible to select promising lines resistant to various abiotic stress conditions with traditional breeding methods as well as biotechnological approaches in strawberry breeding. In fruit breeding, identifying minor or major QTL regions associated with such complex traits, which are intensely influenced by environmental factors and regulated by multiple genes, is an inherently difficult and time-consuming task in genetically heterozygous and open-pollinated plants in terms of fertilisation biology. In strawberry breeding studies, the development of new varieties with high season-long productivity, tolerance to post-harvest diseases, resistance to long-distance transport, high fruit firmness and very good fruit quality parameters has long been the primary objective. For this reason, many studies and projects are intensively carried out not only in European countries but also in countries such as the USA and China on the breeding of new varieties with the above-mentioned characteristics (Kafkas 2023; Karci et al., 2022; Prohaska et al 2024). For example, the Breeding Value project, supported by the European Union's Horizon 2020 research and innovation programme, aims to develop new breeding strategies for resistant and high-quality strawberry, blueberry, and raspberry varieties by ensuring genetic diversity and meeting consumer demands for quality and sensory attributes. In addition, the PRIMA MedBerry project has international project units aimed at developing new breeding strategies to ensure genetic diversity and to achieve high-quality berries (strawberries, blueberries, and raspberries) that are road and storage resistant and respond to the quality and sensory preferences of the consumer. The aim of this study is to review the recent studies on the determination of the genomic location of QTLs associated with biochemical fruit quality traits, disease, and pest tolerance traits in strawberries through some biotechnological approaches in strawberry breeding studies and to create a data pool.

Studies on morphological and biochemical traits in strawberry

The use of QTL mapping and GWAS (genome-wide association studies) techniques to understand the morphological, biochemical, and genetic characteristics of strawberries in strawberry breeding studies is increasing gradually. These new breeding techniques, in addition to the research carried out from the past to the present, make an important contribution to the determination of important genetic regions related to fruit quality, plant resistance to diseases, yield, and morphological variations in plants. For example, in a study conducted by some researchers to determine the genome of wild woodland strawberry (Fragaria vesca) they determined that the genome of wild woodland strawberry (Fragaria vesca) is 240 Mbp (megabits) with GWAS (Shulaev et al.,2011). In another study, high-resolution genetic mapping using GWAS analysis and SNP markers was reported to be an effective technique for breeders to use such techniques in fruit species in the Rosaceae family to obtain new varieties (Yamamoto and Terakami, 2016; Zahid et al 2022). In a study conducted by Ayvaz Sonmez et al. (2024), genetic maps of 'Fortuna × Rubygem' F1 strawberry population were analysed using these techniques to identify quantitative trait loci associated with various agronomic traits. Then, they examined the locus with the highest association with phenotypic variation in Turkey, and researchers found that the Ax-184476583 marker had a significant QTL with a LOD score of 5.24 and a phenotypic variance (PV) value of 13.3% for xylose, and these values were located within 5.2 Mb of Fvb2-3. They reported that the markers associated with the lightness value of the flesh colour were produced in the range of 5.6 and 25.3% PV, and the Ax-184139018 marker for the chroma value of the flesh colour separated the accessions according to their phenotype. As a result, they reported that they detected a total of 28 QTL for 9 quality traits in the strawberry population used in this study (Ürün et al. 2025).

In another study, Amaya et al., (2025) conducted a study on the determination of carotenoid levels and fruit flesh colour in cultivated strawberries (*Fragaria* × *ananassa*), which are desirable traits for their visual appeal and nutritional contribution. By analysing a population segregating for yellow and white flesh, they successfully identified an important quantitative trait locus (QTL), qYellow Flesh-4B, located on chromosome 4B. They explained that this region accounts for 82% of the variation observed in fruit pigmentation.Rehman et al. (2025) investigated the genetic basis of powdery mildew resistance in strawberry by genome-wide association and multivariate analyses. They used a population crossed between the wild ancestors *Fragaria chiloensis* and *Fragaria virginiana*. Field observations were carried out over multiple growing seasons under natural disease pressure and the researchers used a dense set of 20,779 SNP markers and identified a novel major QTL q.LPM.Rec-3B.2 marker located on chromosome 3B. They found that this locus consistently contributed to high levels of powdery mildew resistance in both leaves and fruits. In conclusion, these QTL values contribute significantly to the understanding of disease resistance in strawberry and support the application of marker-assisted selection in breeding programmes. In a molecular study conducted in the strawberry species *Fragaria vesca*, they found that the FveTRM5 protein plays a crucial role in the shape of strawberries. It was reported that FveTRM5 protein plays an important role in the regulation of strawberry fruit shape by affecting cell elongation and cell division, providing an excellent target gene for breeding new fruit-shaped varieties (Zheng et al., 2025).

Muñoz et al. (2023) analysed vitamin C in samples from crosses of 'Candonga' X 'Senga Sengana' cultivars and identified candidate genes that may be associated with vitamin C

content. According to the results of this study, environmentally stable QTLs for AsA content were detected in linkage group (LG) 3A, LG 5A, LG 5B, LG 6B and LG 7C. They identified candidate genes within the stable QTL intervals and suggested that the GDP-L-Galactose Phosphorylase FaGGP(3A) and the AsA transporter gene located in the chloroplast [FaPHT4;4(7C)] could be the genetic factors underlying the QTLs in LG 3A and 7C, respectively.

In another study, researchers developed a high-density genetic map in strawberry (*Fragaria* × *ananassa*) and identified QTL regions associated with fruit traits such as soluble solids content, fruit width, fruit length and fruit weight using the ddRAD-seq approach. As a result of this study, 12,698 SNP markers were identified and 1,554 of them were found to follow the expected Mendelian segregation patterns. Furthermore, six QTL values were reported for fruit length, which accounted for 24% to 35% of the phenotypic variance. In addition, four QTL values were identified for fruit width, fruit weight and water soluble solids content, explaining 21-42%, 24-54% and 23-50% of the phenotypic variation, respectively (Natarajan et al., 2020).

Fan et al 2024 analyzed at QTL regions associated with soluble solid content and yield in a total of 3399 Florida strawberry cultivars. They reported that they identified two stable quantitative trait loci (QTL) on chromosomes 3B and 6A for soluble solid content. On the other hand, favourable haplotypes at both QTL for this soluble solid content reduced yield, but they identified optimal allelic combinations with decreased affect on yield.

In a study by Serra et al. (2021), fruit variability was analysed over four growing seasons from 2016 to 2019, evaluating samples from two populations for several traits, including fruit shape, firmness and taste. Through QTL mapping in the 'FC50 × FD54' population, they identified a total of 33 consistent QTL. In particular, they emphasised that three genomic regions, LG 3A, LG 4D and LG 6D, were associated with fruit shape traits.

Siddique et al. (2021) used two independent F2 mapping populations (BS-F2 and BC-F2), an Axiom 35K strawberry chip, and genotyping-by-sequencing-derived single nucleotide polymorphisms to create linkage maps and identify the quantitative trait loci (QTLs) controlling leaf chlorophyll content. Seven QTLs were identified across the strawberry genome, including those with major and minor effects and those that were common or specific to populations. These QTLs explained phenotypic variation (R^2) ranging from 1.4% to 26.4%. Candidate genes associated with photosynthesis and chlorophyll content were inferred in the commonly detected QTLs.

Alafraj et al. (2021) constructed linkage groups using SNP markers in an F1 population and performed QTL analysis related to fruit quality traits. They developed a linkage map consisting of 28 linkage groups (LGs) representing the whole genome of the octoploid strawberry Rg × H population. The map covered a total genetic length of 2624.7 centimorgans (cM), with an average distance of 0.7 cM between SNPs, and included 3933 SNP markers. Among the linkage groups, LG6.1 and LG5.2 had the highest and lowest number of mapped SNPs, with 272 and 72 markers, respectively.

In another study, Petrasch et al. (2022) identified a total of nine QTLs associated with resistance to *Botrytis cinerea*, a fungal pathogen that significantly limits the shelf life of strawberry fruits. Although the effects of these QTLs were relatively minor, eight were located on the LD linkage group, while one was found on the EM group.

CONCLUSIONS

In conclusion, QTL and GWAS studies in strawberry provide useful tools to understand the genetic control of important fruit quality traits, especially in strawberry breeding, as well as traits expected in breeding and to integrate this information into breeding programmes. It is thought that the use of such advanced techniques in breeding will make a significant contribution to the development of new strawberry varieties that are more productive, high quality, resistant to diseases and adaptable to different growing conditions. In addition, it contributes significantly to yield, disease and pest resistance, adaptation to different climatic conditions, genome-wide association studies, understanding the basis of complex traits (complex genetic characters), rapid and direct candidate gene identification, marker-assisted selection studies, genomic selection, accelerating the breeding of new varieties. However, studies on new methods that can be used in much more detailed and breeding in the future are continuing at a rapid speed. It is thought that this study may shed light on future studies.

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PHYTOPATHOLOGICAL PROBLEMS OBSERVED IN TOMATO PLANTS IN KIRŞEHİR AHI EVRAN UNIVERSITY R&D GREENHOUSE DURING THE CULTIVATION SEASON

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ABSTRACT

Kırşehir Ahi Evran University R&D Greenhouse was established in 2020 within the scope of Pilot Agriculture and Geothermal Coordinatorship - Clustering in Thermal Greenhouses Project, it is a Venlo-type unit with a full automation system, heated by geothermal source and where various R&D projects are carried out. In addition, the R&D Greenhouse, which constitutes the infrastructure of the 'Geothermal Advanced Greenhouse Technologies and Production Techniques Collaborative Application and Research Center (JISTUAM)' established in partnership with Ankara and Selçuk University under the coordination of Kırşehir Ahi Evran University, is established on a total area of 1512 m^2 and consists of a total of 7 compartments, one with soil, one with a nursery and 5 hydroponic compartments. In various R&D and production projects carried out in the greenhouse, vegetables such as tomato, pepper, cucumber and melon were cultivated.

Tomato is one of the most cultivated product groups in the R&D greenhouse. Although all nutritional and plant protection precautions are practiced during the cultivation season, some phytopathological problems may occur. While greenhouse cultivation provides the optimum conditions required for the cultivation of horticultural crops, the same conditions provide an environment for the rapid propagation of disease agents and make it difficult to control diseases. The aim of this study was to share the results of the observations in terms of tomato diseases and tests carried out for some viral diseases, in the R&D greenhouse during the cultivation season and to propose solutions to common phytopathological problems in tomato cultivation.

Phytopathological problems observed during tomato cultivation in the R&D greenhouse were blossom-end rot, vascular wilt diseases and virus diseases such as *Tomato mosaic tobamovirus* (ToMV), *Cucumber mosaic cucumovirus* (CMV), *Tomato spotted wilt orthotospovirus* (TSWV), *Tomato brown rugose fruit tobamovirus* (ToBRFV). Blossom-end rot, vascular wilt and ToMV, CMV, and TSWV are diseases observed on tomato plants from time to time whereas ToBRFV was observed in the winter growing period 2024-2025. In this paper, symptomatological examination photographs of the disease symptoms and DAS-ELISA test results for virus diseases, are presented to provide information about the diseases and suggestions for control.

Keywords: Tomato, Tomato Diseases, Tomato Viruses.

KIRŞEHİR AHİ EVRAN ÜNİVERSİTESİ AR-GE SERASINDAKİ DOMATES BİTKİLERİNDE YETİŞTİRME SEZONU BOYUNCA GÖZLENEN FİTOPATOLOJİK SORUNLAR

ÖZET

Kırşehir Ahi Evran Üniversitesi Ar-Ge Serası, Pilot Tarım ve Jeotermal Koordinatörlüğü-Termal Seralarda Kümelenme Projesi kapsamında 2020 yılında kurulmuş, tam otomasyon sistemine sahip, jeotermal kaynakla ısıtılan Venlo tipinde ve çeşitli Ar-Ge projelerinin yürütüldüğü bir birimdir. Ayrıca, Kırşehir Ahi Evran Üniversitesi koordinatörlüğünde Ankara ve Selçuk Üniversitesi ortaklığında kurulan 'Jeotermal İleri Sera Teknolojileri ve Üretim Teknikleri Ortak Uygulama ve Araştırma Merkezi (JİSTUAM)' altyapısını oluşturan Ar-Ge Serası toplam 1512 m^2 alanda kurulu olup biri topraklı, bir tanesi fidelik ve 5 âdeti de topraksız olmak üzere toplam 7 kompartımandan oluşmaktadır. Serada yürütülen çeşitli Ar-Ge ve üretim projelerinde domates, biber, hıyar, kavun gibi sebzelerin yetiştiriciliği yapılmıştır.

Ar-Ge serasında en çok yetiştiriciliği yapılan ürün gruplarından birisi de domatestir. Yetiştirme sezonu boyunca tüm besleme ve bitki koruma önlemleri alınmasına rağmen bazı fitopatolojik sorunlar oluşabilmektedir. Örtü altı yetiştiriciliği, bahçe bitkileri ürünlerinin yetiştiriciliği için gereken optimum koşulları sağlarken, aynı koşullar hastalık etmenlerinin hızlı bir şekilde çoğalmasına ortam hazırlamakta ve hastalıklarla mücadeleyi zorlaştırmaktadır. Bu çalışma, Ar-Ge serasındaki domates bitkilerinde yetiştirme sezonu boyunca yapılan gözlemlerin ve özellikle viral hastalıklar konusunda yapılan testlerin sonuçlarını paylaşmak ve domates yetiştiriciliğinde sık karşılaşılan fitopatolojik sorunlara çözüm önerileri sunmak amacıyla ele alınmıştır.

Ar-Ge serasındaki domates yetiştiriciliği sırasında gözlemlenen fitopatolojik sorunlar, çiçek burnu çürüklüğü, vasküler solgunluk hastalıkları ve *Tomato mosaic tobamovirus* (ToMV), *Cucumber mosaic cucumovirus* (CMV), *Tomato spotted wilt orthotospovirus* (TSWV) ile *Tomato brown rugose fruit tobamovirus* (ToBRFV) gibi virüs hastalıkları olmuştur. Çiçek burnu çürüklüğü, vasküler solgunluk ve ToMV, CMV, TSWV zaman zaman domates bitkilerinde gözlenen hastalıklar olup ToBRFV ise 2024-2025 kış yetiştirme periyodunda gözlenmiştir. Bu bildiride hastalıklar sonucu meydana gelen hastalık belirtilerine ait simptomatolojik inceleme fotoğrafları ve özellikle virüs hastalıkları konusunda yapılan DAS-ELISA test sonuçlarına dayanarak hastalıklar konusunda bilgi verilmiş ve mücadele önerileri sunulmuştur.

Anahtar Kelimeler: Domates, Domates Hastalıkları, Domates Virüsleri.

1. GİRİŞ

Domates (*Solanum lycopersicum* L.), patatesten sonra dünyada en çok yetiştiriciliği yapılan sebzelerden birisidir. Meyvelerinin besleyici ve insan sağlığına faydalı (içeriğindeki likopenin antikanser özelliği) özelliklerinden dolayı dünyanın hemen hemen her yerinde hem açık alanda hem de örtü altında yetiştirilmektedir (Ally et al., 2023). Patates, biber, patlıcan gibi *Solanaceae* familyası üyesi olan domates (Gebhardt, 2016), Güney Amerika ve And dağları kökenli olup 16. yüzyılda Avrupa'ya tanıtıldıktan sonra Orta Doğu, Asya ve Afrika'ya yayılmıştır (Naika et al., 2019). Meyveleri yenen bir sebze olan domates sofralık olarak taze şekilde tüketilmesinin yanında yemeklerin içinde pişirilerek de tüketilmektedir (Anonim, 2024). Ayrıca sanayilik olarak domates meyvelerinden konserve, püre, sos, salça ve ketçap üretilmekte (Anonim, 2024); kurutulmuş, salça ve konserve domates gibi ürünler, üretimin zayıf olduğu dönemlerde taze domatese göre daha uygun fiyatlı olduğundan ekonomik açıdan avantaj sağlamaktadır (Ally et al., 2023).

Tüketimdeki artışa paralel olarak domates üretimi, dünyada katlanarak artmaktadır (Khan, 2018). 2020-2021 döneminde küresel domates üretiminde 251 milyondan 257 milyon tona %2.5'luk bir artış olmuştur. 2023 yılında dünya domates üretimi, 6.572.247 hektar ekili alanda 263 milyon tona ulaşmıştır (FAO, 2025). Domates sektörünün önümüzdeki yıllarda (2020-2025) genişlemeye devam etmesi ve küresel olarak üretilen domatesin kg değerinin 51.930 ABD dolarına ulaşması beklenmektedir (Branthôme, 2020). Kısa sürede ürün vermesi ve iyi verim vermesi nedeniyle domates ekim alanları her geçen gün genişlemektedir. Öyle ki, domates üretimi gelişmekte olan ülkelerde kırsal ve yarı-kentsel üreticinin çoğu için önemli bir gelir kaynağı haline gelmiştir. Üretim miktarları incelendiğinde Çin, Hindistan, Türkiye ve ABD, büyük miktarlı üretimleriyle ilk sıralarda yer almaktadır (Nag, 2020). Türkiye 2023 yılında 13.3 milyon tonluk domates üretimiyle Çin ve Hindistan'ın ardından 3. sırada yer almıştır (FAO, 2025).

Domates bitkilerinin optimum sıcaklık isteği 23-27°C arasında değişmekte olup sıcaklık 15°C'nin altına düştüğünde ya da 35°C'nin üzerine çıktığında domates üretimi olumsuz etkilenmektedir. Ilık sıcaklıklar ve bol güneş ışığı domates bitkilerinin büyümesi için ideal ortam yaratmaktadır. Kış aylarında ışık seviyesindeki azalma, meyve veriminin düşmesine sebep olmaktadır. Domates bitkileri, derine giden ve yayılmış kök sistemine sahip olduğundan yetiştiriciliği için iyi drene edilmiş topraklar idealdir. Optimum toprak PH'sı isteği 6-7.5 arasında olup çimlenme için fazla miktarda yağışa ihtiyaç duymadığından kurak mevsimlerde de iyi yetişebilmektedir (Naika et al., 2019).

Domates hem açık alan hem de örtü altı yetiştiriciliğine uygun bir bitkidir. Özellikle son yıllarda kontrollü koşullarda üretime izin veren örtü altı domates yetiştiriciliği (yüksek tüneller ve seralarda), tarımda yeni bir trend haline gelmiştir (Ally, 2023). Öyle ki, 2024 yılında Türkiye'nin 8 milyon tonluk toplam örtü altı sebze üretiminin 4.2 milyon tonluk %52.5 gibi önemli bir kısmını domates oluşturmuştur (TÜİK, 2025). Seralarda domates yetiştiriciliği yapmanın ürünlerin mevsimi dışında da yetiştirilmesine izin vermesi, kısıtlı alandan daha yüksek verim elde edilmesi ve yetiştiricilikte daha az işçilik gerekmesi gibi bazı avantajları bulunmaktadır (Goncharova, 2004; Ally, 2023). Öte yandan, domates gibi sebzelerin yetiştirilmesi için sağlanan optimum ortam koşulları (sıcaklık, nem, ışık vb.), hastalıkların hızlı

bir şekilde çoğalması ve yayılması için elverişli ortam yaratmaktadır. Özellikle yüksek sıcaklık ve nem, hastalık oluşumuna zemin hazırlamaktadır (Mohapatra ve Sahoo, 2023).

Yetiştirme döneminden hasat sonrası aşamaya kadar domates bitkileri 200'den fazla hastalığa karşı hassastır. Bitki hastalıkları domates üretimini sınırlandıran en önemli faktör olup ciddi verim ve dolayısıyla ekonomik kayıplara neden olmaktadır (Singh et al., 2017). Sözü edilen bitki hastalıkları, abiyotik ve biyotik (mikrobiyal) hastalıklar olmak üzere iki gruba ayrılmaktadır. Seralarda yetiştirilen domatesleri etkileyen abiyotik yani bulaşıcı olmayan hastalıklar, yüksek sıcaklık ve nem gibi elverişsiz iklim koşulları, sulama düzenindeki değişiklikler ve besleme bozuklukları gibi faktörlerden kaynaklanmaktadır. Öte yandan, mikrobiyal hastalık olarak da isimlendirilen biyotik hastalıklar (bulaşıcı hastalıklar), ise fungus, bakteri ve virüs gibi patojen mikroorganizmalar tarafından meydana getirilmektedir. Patojenlerin neden olduğu hastalıklar, ortam koşulları uygun olduğunda hızlı bir şekilde çoğalmakta ve bir bitkiden diğerine hızlı bir şekilde yayılmaktadır (West et al., 2012). Bu nedenle sera yapılarının yetiştiriciliğe uygun şekilde kurulması, basit sera yapıları yerine yetiştiricilik için modern sera sistemlerinin tercih edilmesi, özellikle nemin uzaklaştırılması ve yüksek sıcaklığın düşürülmesi amacıyla iklim kontrollü koşulların sağlanması, uygun yetiştiricilik ve bitki koruma yöntemlerinin uygulanması hastalıklarla mücadelede önem arz etmektedir (Yıldız vd., 1990; Javis et al., 1993).

Kırşehir Ahi Evran Üniversitesi Ar-Ge Serası, YÖK tarafından açılan 'Bölgesel Kalkınma Odaklı Misyon Farklılaşması' çağrısı kapsamında üniversitenin tarım ve jeotermal alanda Pilot Üniversite seçilmesiyle onaylanan 5 proje içerisindeki 'Termal Seralarda Kümelenme Projesi' kapsamında kurulmuş bir birimdir. Projenin amaçlarından birisi olan bölgede yer alan jeotermal kaynakların sera ısıtmasında kullanılması ve jeotermal seracılığın bölgede yaygınlaştırılması kapsamında kurulduğu günden bu yana (2020), Ar-Ge serasında çok çeşitli araştırma-geliştirme ve üretim projeleri yürütülmüştür. Alt projeler kapsamında elde edilen başarılar sonucunda Kırşehir Ahi Evran Üniversitesi Koordinatörlüğü, Ankara ve Selçuk Üniversiteleri ortaklığında kurulan 'Jeotermal İleri Sera Teknolojileri ve Üretim Teknikleri Ortak Uygulama ve Araştırma Merkezi (JİSTUAM)'nin alt yapısını da yine Ar-Ge serası oluşturmaktadır.

KAEÜ Ar-Ge Serası, toplam 1512 m^2 alana kurulu 7 kompartımana sahip tam otomasyon sistemli Venlo tipinde bir işletmedir. Kompartımanlardan birisi fidelik olarak kullanılmakta olup sulama ve iklimlendirme sistemleri oldukça modern şekilde tasarlanmıştır. Ayrıca seranın diğer 4'ü topraksız, 1'i hidroponik (su kültürü) ve 1'isi topraklı olmak üzere 6 kompartımanı tüm gelişmiş sistemlerle donatılmıştır. Serada yetiştiricilik teknikleri, bitki ıslahı, topraksız tarıma uygun alternatif ortamların geliştirilmesi, biyosistem (enerji, kısıntılı sulama, iklimlendirme vb.) ve bitki koruma alanlarında pek çok Ar-Ge çalışması yürütülmüştür. Bu çalışmalar sırasında domates, kavun, hıyar, biber gibi sebzeler yetiştirilmiş olup Ar-Ge serasında en çok deneme kurulan ve yetiştiriciliği yapılan ürün grubu domates olmuştur. 2020 yılından bu yana hemen hemen her dönem domates bitkileri Ar-Ge çalışmalarında ve üretim programlarında kullanılmıştır.

Seramız her ne kadar otomasyon sistemli ve modern üretim teknikleriyle Ar-Ge çalışmalarının yürütüldüğü bir sera olsa da bazı dönemlerde bazı fitopatolojik sorunlar ortaya çıkabilmektedir. Bu hastalıklardan bazıları koruyucu ve tedavi edici önlemlerle kontrol edilebilir nitelikte olup bazıları dönem dönem görülebilmektedir. Bu çalışmada Ar-Ge serasında görülen hastalıklar

sonucu meydana gelen hastalık belirtilerine ait simptomatolojik inceleme fotoğrafları ve özellikle virüs hastalıkları konusunda yapılan DAS-ELISA test sonuçlarına dayanarak hastalıklar konusunda bilgi verilmiş ve mücadele önerileri sunulmuştur.

2. ABİYOTİK HASTALIKLAR

Domates bitkilerindeki abiyotik hastalıklar, aşırı sıcaklıklar, normal olmayan aydınlatma koşulları, besin eksiklikleri, su alımındaki dengesizlikler, genetik mutasyonlar ve hatalı kimyasal uygulamalar sonucunda meydana gelmektedir (Volesky et al., 2021). Abiyotik faktörlerin neden olduğu hastalıklardan birisi de çiçek burnu çürüklüğüdür. Çiçek burnu çürüklüğü başta domates olmak üzere, biber, karpuz ve patlıcan gibi çeşitli kültür bitkilerini etkileyen en yıkıcı fizyolojik bozukluklar arasında yer almaktadır (Díaz-Pérez and Hook 2017; Taylor and Locascio 2004). Bu fizyolojik bozukluk ile ilgili yapılan ilk çalışmalarda çiçek burnu çürüklüğü, bitkilerin üst aksamında gerçekleşen transpirasyon hızı ve amonyum bazlı gübre kullanımından kaynaklı ürün kayıplarıyla ilişkilendirildiği için önemli bir endişe kaynağı olmuştur (Chamberlain, 1933; Topçu et al., 2022; Wedgworth et al., 1927).

Çiçek burnu çürüklüğü, sulama düzensizliğine bağlı meyvedeki kalsiyum eksikliğinden kaynaklanan abiyotik bir hastalıktır. Bilindiği gibi kalsiyum hücre duvarının sağlamlığına katkıda bulunan önemli bir bitki besin elementi olup eksik olması durumunda hücrelerin parçalanması (hücre plazmolizi) nedeniyle meyvelerin çiçek ucu dediğimiz dip kısmında kahverengi suda ıslanmış gibi görünen açık renkli, küçük lekeler meydana gelmektedir (Saure, 2001; Volesky et al., 2021). Çiçek burnu çürüklüğünden etkilenen alanlar daha sonra genişlemekte ve kahverengi nekrotik bir hal almaktadır. Bu nekrotik alanlar genellikle meyvenin büyük bir kısmını kaplamaktadır (Hochmuth and Hochmuth, 2009). Çiçek burnu çürüklüğünden etkilenen alanlar, genellikle *Alternaria* spp. gibi saprofitik fungus türlerinin saldırısına açık hale gelmektedir (Brust, 2004; Topçu et al., 2022). Domateste çiçek burnu çürüklüğünün ilk belirtileri, tozlaşmanın ardından ikinci haftada görülürken; tozlaşmadan sonraki ilk beş hafta içinde de oluşabilmektedir (Rached et al., 2018). Belirtilerin tozlaşmadan hemen sonra ortaya çıkması durumunda hastalık daha tahripkâr seyretmekte ve meyveler hiçbir zaman istenen ya da olması gereken boyuta ulaşamamaktadır (Brust, 2004). Çiçek burnu çürüklüğü simptomları, genellikle meyvenin dip kısmındaki perikarp üzerinde görülmekle birlikte bazen uç kısımda belirti görülmeden uç bölümün iç kısmında yer alan plasenta dokusunda da oluşabilmektedir (Hochmuth and Hochmuth, 2009).

2.1. KAEÜ Ar-Ge Serasında Çiçek Burnu Çürüklüğü Hastalığının Durumu

Domates yetiştiriciliği yapılan tüm alanlarda olduğu gibi KAEÜ Ar-Ge serasında da çiçek burnu çürüklüğü, yetiştirme sezonu boyunca gözlenen en önemli abiyotik hastalıktır. 2020 yılından bu yana domates yetiştiriciliği yapılan tüm sezonlarda meyvelerde çiçek burnu çürüklüğü belirtileri görülmüştür. Ancak bazı sezonlarda hastalık belirtileri birkaç bitkinin meyveleri ile sınırlı kalırken bazı sezonlarda bitkilerin çoğunda gözlenmiştir. Bu fizyolojik bozukluğa ait simptomatolojik inceleme fotoğrafları Şekil 1'de görülmektedir.

Şekil 1. KAEÜ Ar-Ge serasından çiçek burnu çürüklüğü hastalığı belirtileri gösteren meyvelerden görünüm.

Çiçek burnu çürüklüğü yaklaşık 120 yıldan daha uzun bir süre önce domateste düzensiz sulamanın neden olduğu bir fizyolojik bozukluk olarak tanımlanmış (Selby, 1896) ve bu kavram günümüze kadar geçerliliğini korumuştur (Topçu et al., 2022). Ar-Ge serasında yürütülen kısıntılı sulama denemesinde %15 ve 30 kısıntılı sulama uygulanmış domates bitkilerinin meyvelerine göre %45 kısıntılı sulama uygulanmış meyvelerde daha fazla çiçek burnu çürüklüğü görülmüştür. Bu durum sulama düzensizliğinin çiçek burnu çürüklüğü belirtilerinin ortaya çıkmasındaki etkisini doğrular niteliktedir. Hastalık üzerine yapılan araştırmalar, Ca^{2+} dengesinin ve çevresel strese bağlı olarak reaktif oksijen türevlerinin (ROS) birikiminin hastalığın gelişiminde kritik rol oynadığını ortaya koymuştur. Dolayısıyla çevresel stres ve beslenme faktörlerinin kombinasyonu, çiçek burnu çürüklüğü simptomlarının ortaya çıkma sıklığını büyük ölçüde etkilemektedir (Görlach et al., 2015).

Çiçek burnu çürüklüğü ile ilgili yapılan araştırmalar domatesin meyve morfolojisi ve bitkinin genetik özelliklerinin de hastalığın ortaya çıkma sıklığı ile ilişkili olduğunu ortaya koymuştur. Domateste meyve büyüklüğü ve çiçek burnu çürüklüğü arasında pozitif bir ilişki bulunmaktadır (Marcelis and Ho, 1999; Heuvelink and Körner 2001). Dünya genelinde yapılan çalışmaların hiçbirisinde domatesin yabani akrabalarında ve küçük meyveli çeşitlerinde çiçek burnu çürüklüğü belirtisi rapor edilmediği, sadece kültür bitkilerinde bulunduğu için ıslah çalışmaları sırasında hastalığın tetiklendiği düşünülmektedir (Ho and White 2005; Topçu et al., 2022). Seramızda ıslah çalışmalarında kullanılan yabani domates bitkilerinin meyvelerinde çiçek burnu çürüklüğü belirtilerine rastlanmazken küçük meyveli kültür domates çeşitlerinde büyük meyveli çeşitlere oranla daha az oranda olmakla birlikte hastalık belirtileri gözlenmektedir (Şekil 1). Domateste hücre boyutu düzenleyici (*CSR= Cell Size Regulator*) olarak görev yapan

FW11.3/CSR geni, hücre boyutunu arttırarak meyve ağırlığında da artış sağlamaktadır (Mu et al., 2017). *CSR*'den türemiş alleli taşıyan *FW11.3* yakın izogenik hatlarda (NIL'ler), yabani tip alleli taşıyan *FW11.3* NIL'lere kıyasla daha yüksek oranda çiçek burnu çürüklüğü belirtileri gelişmiştir. Bu durum, *FW11.3/CSR*'nin çiçek burnu çürüklüğü gelişiminde bir rolü olabileceğini göstermektedir (Mu, 2015). Bu meyve ağırlığı genleri ile çiçek burnu çürüklüğü ilişkisinin dolaylı olduğu, nedensel olmadığı düşünülmektedir. Çünkü *CSR*'den türemiş meyve ağırlığı geni alleline sahip birçok domates çeşidinin çiçek burnu çürüklüğüne dayanıklı olduğu görülmüştür (Topçu et al., 2022).

Fizyolojik faktörlere ek olarak, domates çeşitleri farklı derecelerde çiçek burnu çürüklüğü belirtileri göstermekte, bu durum da hastalığın genetik bir temeli olduğunu düşündürmektedir (Adams and Ho 1992; Ho et al. 1995; Ho and White 2005). Çiçek burnu çürüklüğünün genetik temelleri üzerine yapılan çalışmalarda, Ca^{2+} iletimi ve meyve büyüme hızı ile ilgili genlerin hastalık gelişimine katkıda bulunduğu ortaya koyulmuştur (Ikeda et al., 2016; 2017). Çalışmalar sırasında bir lokus üzerinde yer alan 78 genden birinin hastalığı kontrol ettiği düşünülmüş (Ikeda et al., 2017) olsa da bu lokus ayrıntılı olarak haritalandırılamamıştır (Matsumoto et al. 2021). KAEÜ Ar-Ge serasında domates ıslah çalışmaları sırasında yetiştirilen genotiplerin farklı derecelerde çiçek burnu çürüklüğü göstermelerinin sebebinin hastalığın genetik arka planı ile ilgili olduğu düşünülmektedir. Öyle ki, bazı genotipler hastalığa oldukça hassas reaksiyonlar verirken bazı genotiplerin ise oldukça dayanıklı olduğu gözlenmiştir.

2.2. Çiçek Burnu Çürüklüğü Hastalığıyla Mücadele Önerileri

Çiçek burnu çürüklüğü ile ilgili yapılan çalışmalar ve Ar-Ge serasında domates bitkilerinde yaptığımız gözlemler değerlendirildiğinde, beslenme düzensizliği ve çevresel stres faktörlerinin kombinasyonu, bu fizyolojik bozukluğun ortaya çıkma oranını büyük ölçüde etkilemektedir. Bundan dolayı açık alan ve sera domates yetiştirme koşullarında hastalığın mücadelesi oldukça zordur. Yetiştiricilere hastalığa karşı dikkatli olmaları, özellikle seralarda etkili su drenajı, uygun sulama sistemi seçimi, dengeli gübreleme programı tercih etmeleri ve topraklı yetiştiricilikte tuzun kök bölgesinden uzaklaştırılması gibi kontrol stratejileri önerilmektedir (Machado and Serralheiro, 2017; Hagassou et al., 2019). Her ne kadar Ar-Ge serasında çiçek burnu çürüklüğünü azaltmak için kalsiyumlu gübreleme programları uygulanıyor olsa da farklı domates çeşitlerinin yetiştirildiği denemelerde hastalığın önüne geçilmesi mümkün olamayabilmektedir. Bu nedenle, ticari olarak yapılan yetiştiricilikte farklı çeşitlerin bir arada bulundurulmaması önerilmektedir. Bunun nedenlerinden birincisi her bir çeşide özgü gübreleme programı yapılmasının zor olması, ikincisi ise farklı çeşitlerin çiçek burnu çürüklüğüne hassasiyetinin farklı olmasıdır.

Çiçek burnu çürüklüğünün bitki ve meyve büyüme hızıyla da ilişkisi bulunmaktadır. Hızlı büyüme gösteren bitkilerde, özellikle de meyvelerde sağlıklı bir kalsiyum iletimi sağlanamamaktadır. Bu nedenle, çiçek burnu çürüklüğünün simptomlarını hafifletebileceği düşünüldüğünden, özellikle ticari domates yetiştiricileri için bazı büyüme geciktiricilerin kullanımı önerilmektedir. Öte yandan, yapılan çalışmalar sonucunda çiçek burnu çürüklüğünü en azından azaltmak için domates germplazmındaki genetik çeşitlilikten yararlanmaya vurgu yapılmıştır. Örneğin yüksek antioksidan üreten aksesyonlar, lipit ve protein oksidasyonunu, membran parçalanmasını, hücre plazmolizini ve dolayısıyla da çiçek burnu çürüklüğünü

engelleyeceği için ıslah programlarında bu aksesyonlardan yararlanılması önerilmektedir. (Topçu et al., 2022). Daha önce de bahsedildiği üzere farklı domates genotipleri çiçek burnu çürüklüğüne farklı hassasiyet göstermektedir. Bu duruma neden olan genetik faktörler tam olarak haritalanmamış olsa da en azından seleksiyon yapılırken çiçek burnu çürüklüğüne toleranslı ya da dayanımlı genotiplerin seçilmesi, bu hatların ıslah programlarında ve yetiştiricilikte kullanılması hastalığın ortaya çıkma sıklığının düşürülmesinde büyük fayda sağlayacaktır.

3. FUNGAL VE BAKTERİYEL HASTALIKLAR

Hava sirkülasyonunun zayıf olduğu sera yapıları nemli koşullar meydana getirmekte, bu nemli koşullar ise açık alan domates yetiştiriciliğinde sık rastlanmayan külleme ve yaprak küfü gibi fungal hastalıkların gelişme sıklığını arttırmaktadır (Scherer and Meadows, 2020). Buna ek olarak, seralarda nemli koşullar altında gelişen bakteriyel hastalıklar nedeniyle ciddi boyutlarda ürün kayıpları meydana gelmektedir (Kolomiets et al., 2017). Öte yandan, uygun iklim koşullarının sağlanamadığı, düşük sıcaklık ve yüksek nemin hâkim olduğu sera ve yüksek tünellerde ise domateste kurşuni küf ve mildiyö gibi hastalıklar yaygın bir şekilde görülmektedir (Liao et al., 2019).

Seralarda yetiştirilen domates bitkilerinde en sık görülen bakteriyel hastalıkları; bakteriyel kanser ve solgunluk (*Clavibacter michiganensis* subsp. *michiganensis*), bakteriyel benek (*Pseudomonas syringae* pv. *tomato*) ve leke (*Xhanthomonas campestris* pv. *vesicatoria*), domates öz nekrozu (*Pseudomonas corrugata*, bazı floresan *Pseudomonas*'lar ve bazı *Erwinia* türleri) hastalıklarıdır. Öte yandan en yaygın görülen fungal hastalıklar ise; yaprak küfü (*Cladosporium fulvum*), kurşuni küf (*Botrytis cinerea*), erken yanıklık (*Alternaria solani* ve *Alternaria tomatophila*), mildiyö (*Phytophthora infestans*), solgunluk (*Fusarium oxysporum* f. sp. *lycopersici* ve *Verticillium* spp.) ve külleme (*Leveillula taurica, Oidium neolycopersici* ve *Oidium lycopersici*) şeklinde sıralanmaktadır (Tsitsigiannis et al., 2008; Yadeta and Tohomma, 2013; Ally et al., 2023).

3.1. KAEÜ Ar-Ge Serasında Fungal ve Bakteriyel Hastalıkların Durumu

Kırşehir Ahi Evran Üniversitesi Ar-Ge Serası, tam otomasyon sistemine sahip iklimlendirmesi uygun koşullarda yapılan bir seradır. Bu nedenle serada, sıcaklık ve nem gibi fungal ve bakteriyel hastalıkların gelişmesi için ortam yaratan faktörler etkili bir şekilde kontrol altında tutulmaktadır. Nemin ya da sıcaklığın arttığı koşullarda havalandırma yapılmakta ve bu sayede özellikle neme ihtiyaç duyan külleme, mildiyö, erken yanıklık, kurşuni küf gibi fungal hastalıklara çok sık rastlanmamaktadır. Ayrıca, bu hastalıkların domates bitkilerinde meydana gelmesini önlemek için uygun fungisitlerle koruyucu ilaçlama programları da uygulanmaktadır. Öte yandan, örtü altında yetiştirilen domates bitkilerini en çok etkileyen bakteriyel leke ve benek gibi bakteriyel hastalıklara da yetiştirme sezonu boyunca yapılan simptomatolojik incelemelerde rastlanmamıştır.

Serada yetiştirme sezonunda epidemi seviyesinde olmamakla birlikte bazı domates bitkilerinde tek tük solgunluk belirtileri görülebilmektedir. Domates bitkilerinde solgunluk belirtilerine neden olan bakteriyel patojenler, bakteriyel solgunluk ve kanser etmeni *Clavibacter*

michiganensis subsp. *michiganensis*, *Pseudomonas corrugata* başta olmak üzere öz nekrozuna neden olan diğer floresan *Pseudomonas* türleri ve patlıcangiller solgunluğu hastalığına neden olan *Ralstonia solanacearum* şeklinde sıralanmaktadır. Bunlara ek olarak, fungal patojenlerden *Fusarium oxysporum* f. sp. *lycopersici* ve *Verticillium* spp. de solgunluğa neden olmaktadır (Yadeta and Tohomma, 2013). Ar-Ge serasında yetiştirme döneminde domates bitkilerinde gözlenen solgunluk belirtilerine hangi patojenin neden olduğu bilinmemekle birlikte koruyucu ve tedavi edici fungusitler ve bakırlı preperatlarla (Tablo 1) hastalıkların önüne geçilmektedir. Tüm kontrol önlemlerine rağmen solgunluk belirtisi gösteren bir-iki bitki gözlenmesi durumunda ise bitkiler sökülerek seradan uzaklaştırılmakta ve ortam dezenfekte edilmektedir. Böylece hastalıkların başka bitkilere bulaşması ve yayılması önlenmektedir. Ayrıca, fungal ve bakteriyel hastalıkların kontrol altına alınması için kültürel işlemler sırasında hijyen koşullarına dikkat edilmekte, hastalıkların bir bitkiden diğerine yayılmasını önlemek amacıyla vektör böceklerle etkin şekilde mücadele edilmektedir.

3.2. Domates Fungal ve Bakteriyel Hastalıklarıyla Mücadele Önerileri

Fungal ve bakteriyel hastalıklara neden olan patojenler, sera gibi korunaklı alanlara; (i) Bulaşık, alet, ekipman ve giysi kullanımı, (ii) Patojenlerle enfekteli domates tohumlarının yetiştiricilikte kullanılması, (iii) Kültürel işlemler sırasında hijyen koşullarına dikkat edilmemesi, (iv) Bulaşık sulama suyu veya topraksız yetiştirme ortamı (kokopit gibi), (v) sera dışındaki enfekte bitkilerden hava akımlarıyla sera içine giren fungal sporlar, (vi) Yağmurlama sulama tercih edilen seralarda fungal sporların ve bakterilerin su damlacıkları içinde taşınması, (vii) Fungal ve bakteriyel hastalıkların yayılmasını destekleyen yüksek nem ve zayıf hava sirkülasyonu, (viii) Bitkilerin sık dikilmesi nedeniyle hava sirkülasyonuna izin verilmemesi gibi yollarla bulaşmakta ve bitkiden bitkiye hızla yayılmaktadır (Ally et al., 2023). Bununla birlikte, açık alan domates yetiştiriciliğinin aksine örtü altı yetiştiriciliğinin temel avantajı, hastalık yükünü optimize etmek için abiyotik ve biyotik faktörlerin etkilerini azaltacak çevre kontrollü üretim gerçekleştirilebilmesidir (Simko et al., 2007).

Domates bitkilerinde yaygın olarak görülen hastalıkların şiddetini azaltmaya yardımcı olacak sera içi iklim koşullarını sürdürme imkânı ve farklı hastalık etmenlerine karşı daha etkili bir kontrolün uygulanabiliyor olması, örtü altı domates yetiştiriciliğinden daha yüksek verim elde edilmesiyle sonuçlanmaktadır (Iddio et al., 2020). Bu nedenle, KAEÜ Ar-Ge serasında sıraladığımız yayılma yollarının engellenmesi adına tüm kültürel önlemler alınmakta ve hijyen koşullarına dikkat edilmektedir. Ayrıca, nemin seradan uzaklaştırılması amacıyla uygun şekilde havalandırma yapılmakta, otomasyon sistemiyle iklim koşulları kontrol altında tutulmaktadır.

Tablo 1. Ar-Ge serasında domates fungal ve bakteriyel hastalıkları için koruyucu ve tedavi edici kimyasal uygulamalar sırasında kullanılan etken maddeler ve dozları.

Etken Madde	**FRAC Kodu**	**Hedefe Göre Grubu**	**Etkili Olduğu Hastalık/ Etmen Adı**	**Uygulama Dozu**
%80 Fosetyl-Al	U:33	Sistemik Fungisit	Domates Mildiyösü (*Phytophhtora infestans*)	250 g/ 100 l su
%50 Captan	M4	Koruyucu ve Tedavi Edici Kontak Fungisit	Domates Mildiyösü (*Phytophhtora infestans*)	300 g/ 100 l su
			Yaprak Küfü (*Cladosporium fulvum*)	250 g/100 l su
			Kurşuni Küf (*Botrytis cinerea*)	
%13,3 Mancozeb + %30 Metalik bakıra eşdeğer bakıroksiklorür ve bakırsülfat + %4 Cymoxanil	M3; M1	Kontakt Fungisit	Domates Mildiyösü (*Phytophhtora infestans*)	250 g/ 100 l su
			Bakteriyel Benek (*Pseudomonas syringae* pv. *tomato*)	
			Domates Erken Yaprak Yanıklığı (*Alternaria solani*)	300 g/ 100 l su
%14 Metalik bakıra eşdeğer bakır hidroksit + %14 metalik bakıra eşdeğer bakır oksiklorid	M1	Fungisit	Domates Mildiyösü (*Phytophhtora infestans*)	225 g/da
%40 Iminoctadine tris (albesilate)	M7	Geniş Spektrumlu Kontak Fungisit	Kurşuni Küf (*Botrytis cinerea*)	45 g/ 100 l su
200 g/L Azoxystrobin + 125 g/L Difenoconazole	C3:11; G1:3	Hem Kontak Hem Sistemik Fungisit	Domates (Sera) Küllemesi (*Leveillula taurica*)	100 ml/ 100 l su
200 g/L Fluopyram + 200 g/L Tebukonazol	C2:7; G1:3	Kontakt ve Translaminar Fungisit	Domates (Sera) Küllemesi (*Leveillula taurica*)	30 ml/ 100 l su
%26,7 Boscalid + %6,7 Pyraclostrobin	C2:7; C3:11	Kontakt, Translaminar ve Lokal-sistemik Fungisit	Domates Küllemesi (*Leveillula taurica*)	Sera 60 g/ 100 l su
				Tarla 60 g/da

			Kurşuni Küf (*Botrytis cinerea*)	150 g/ 100 l su
500 g/l 8-Hydroxyquinoline sulphate	-	Sistemik Fungisit	Domates Bakteriyel Kanser ve Solgunluk Hastalığı (*Clavibacter michiganensis* subsp. *michiganensis*)	400 ml/da
			Fide Kök Çürüklüğü (Çökerten) (*Rhizoctonia solani*, *Fusarium* spp., *Pythium* spp)	200 ml/da
%50 Metalik bakıra eşdeğer bakır oksiklorid	M1	Kontakt ve Koruyucu Fungisit	Domateste Bakteriyel Leke (*Xhanthomonas campestris* pv. *vesicatoria*)	300 g/ 100 l su (1. ilaçlama) 400 g/ 100 l su (2. ilaçlama)
			Domateste Bakteriyel Benek (*Pseudomonas syringae* pv. *tomato*)	
			Domates Mildiyösü (*Phytophhtora infestans*)	300 g/ 100 l su
			Domates Erken Yaprak Yanıklığı (*Alternaria solani*)	500 g/100 l su

Tüm kültürel ve hijyen önlemlerinin alınmasına rağmen bazen hastalıklar ortaya çıkabilmektedir. Bu nedenle, Ar-Ge Serasında fungisitlerle ve bakteri hastalıklarının ortaya çıkmasını engellemek için bakırlı preparatlarla koruyucu ve tedavi edici ilaçlamalar yapılmaktadır. Tablo 1'de dönem dönem kullanılan etken maddeler verilmiştir. Ar-Ge serasında bazı durumlarda kimyasal mücadele yapılıyor olsa da çoğu zaman alınan kültürel önlemler, iklim kontrolü ve hijyen önlemleri yeterli olmaktadır. Kimyasal mücadele yapılırken doz ayarlamasına ve ilaçlama ile hasat arasındaki süreye dikkat edilmesi en önemli konulardan birisidir. Ayrıca hastalıklı bitki görüldüğünde bu bitkiler sökülerek seradan uzaklaştırılmakta, budama makasları ve kültürel işlem aletlerinin ise dezenfekte edilmesine dikkat edilmektedir.

4. VİRÜS HASTALIKLARI

Örtü altında yetiştirilen domates bitkilerini etkileyen ana viral hastalık etmenleri, *Tobacco mosaic tobamovirus* (TMV), *Tomato mosaic tobamovirus* (ToMV), *Cucumber mosaic cucumovirus* (CMV) ve *Tomato spotted wilt tospovirus* (TSWV)'tür (Tsitsigiannis et al., 2008; Ally et al., 2023). Son yıllarda, domates yetiştiriciliğinde oldukça yaygın hale gelen yeni *Tobamovirus* cinsi üyesi *Tomato brown rugose fruit virus* (ToBRFV), dünyanın dört bir yanındaki seralardan rapor edilmeye başlanmıştır (Zhou et al., 2024).

Virgaviridae familyası üyesi olan TMV, ToMV ve ToBRFV gibi tobamovirüsler, asıl bulaşma ve taşınması bitki özsuyu ile mekanik olarak gerçekleşen, domateste tohumla bulaşması ise oldukça düşük oranda olan viral etmenlerdir (Ally et al., 2023; Davino et al., 2020; Salem et al., 2022; Tsitsigiannis et al., 2008). Bu virüslerin virionları oldukça stabil olup bulaşık tohum,

meyve, bitki artıkları, kültürel işlemler sırasında kullanılan alet-ekipman, işçilerin ellerinde ve kıyafetlerinde uzun süre hastalık yapma yeteneğini kaybetmeden kalabilmektedir. Bahsettiğimiz tüm bu bulaşık materyal tobamovirüslerin seralarda önemli bulaş kaynaklarını oluşturmaktadır (Ally et al., 2023; Chanda et al., 2021a; Klap et al., 2020). Öyle ki, yapılan çalışmalarda ToMV'nin topraksız besin solüsyonunda 6 aydan fazla enfeksiyon yeteneğini kaybetmeden stabil kalabildiği rapor edilmiştir (Pares et al., 1992). Benzer şekilde, TMV ve ToMV gibi tobamovirüslerin bitki artıklarında veya kuru toprakta 2 yıl boyunca enfeksiyon yeteneğini kaybetmeden kalabildiği, ancak iyi drene edilen topraklarda sadece bir ay kalabildiği bildirilmiştir (Fillhart et al., 1998). *Tobamovirus* cinsinin yeni üyesi olan ToBRFV'nin ise hidroponik sistemlerde bulaşıcılığını yitirmeden uzun süre kalabildiğini ve seradaki tüm bitkileri enfekte etmek için tek bir enfekteli bitkinin dahi yeterli olabileceğini ortaya koyan çalışmalar bulunmaktadır (Panno et al., 2020; Zhou et al., 2024).

Domates bitkilerinin en tahripkâr hastalıklarından olan TMV ve ToMV'nin tekli ya da karışık enfeksiyonları sonucunda domates bitkilerinin yapraklarının damarları arasında mozaik belirtileri görülmektedir. Ayrıca, yapraklarda yukarı doğru (kaşık şeklinde) kıvrılma, nekrozlar, şekil bozukluğu ve normalden küçük yaprak oluşumu gözlenebilmektedir. TMV ve ToMV enfeksiyonlarının diğer belirtileri ise bitkide cüceleşme, çiçek dökülmesi ve meyvelerde kahverengi lekeler şeklinde sıralanmaktadır (Chin and Miller, 2010; Pozharskiy et al., 2022). Bu virüslere bağlı enfeksiyon oranı virüs ırkı, domates çeşidi ve çevre koşullarına bağlı olarak %10 ile %100 arasında değişmekte; domates yetiştiriciliğindeki kayıpların %20'lik kısmı sadece bu iki virüs nedeniyle gerçekleşmektedir (Pozharskiy et al., 2022).

Tobamovirus cinsinin nispeten yeni üyesi olan ToBRFV, ilk kez 2014-2015 üretim döneminde Orta Doğu (İsrail)'da keşfedilmesinden bu yana, dünyanın yaklaşık 40 ülkesinde rapor edilmiştir. Bu ülkeler arasında Türkiye de yer almaktadır (EPPO, 2025). Hızla yayılan bu virüsün birincil konukçusu domates olup ToBRFV, temas ve tohumla taşındığı için dünya çapında tahmin edilenden daha ciddi şekilde yayılmaktadır (Zang et al., 2022). ToBRFV enfeksiyonu sonucunda test edilen domates çeşitlerinin *Tm-22* dayanım geni bulundurup bulundurmaması önemli olmaksızın meyve veriminde %15 ila 55 oranında azalmaya neden olduğu rapor edilmiştir (Avni et al., 2021).

ToBFV'nin enfeksiyonları sonucunda oluşan belirtiler, diğer tobamovirüsler, özellikle de ToMV'nin belirtileriyle oldukça benzerdir (Alon et al., 2021). Enfeksiyon sonucunda meydana gelen yaprak belirtileri, bitkilerin genç tepe yapraklarında daha az olmakla birlikte domates bitkilerindeki tipik simptomları klorotik, benekli ya da mozaikli yapraklar ve nekrotik, benekli veya kahverengi rugoz meyveler şeklindedir. Simptom şiddeti virüsün varyantı, bitki türü ve çeşidi, vejetasyon aşaması ve yetiştirme koşullarına göre değişebilmektedir (Salem et al., 2016).

CMV seralarda domates üretimini sınırlandıran bir diğer bitki virüsüdür. CMV'nin 1916 yılında hıyar ve kabakgil bitkilerinde tespit edilmesinden bu yana özellikle ılıman ve subtropik bölgelerde 800'den fazla türde kültür bitkisini enfekte edebildiği görülmüştür. Virüsün özellikle seralarda afitlerle (birincil vektörü *Myzus persicae*) bir bitkiden diğerine hızlı bir şekilde yayılabildiği bilinmektedir (Suresh et al., 2017; Zitter and Murphy, 2009). Enfekteli domates meyvelerinde şekil bozukluğu ve iyi gelişememe şeklinde simptomlara neden olan CMV, yapraklarda yeşil beneklenme, kloroz ve nekroz gibi belirtiler oluşturmaktadır. Bazı CMV

ırkları, yaprak ayasında ciddi baskı oluşturmak suretiyle yaprakların cılız bir şekilde gelişmesine neden olmaktadır (Suresh et al., 2017).

Bir diğer önemli domates virüsü TSWV, *Frankliniella occidentalis* ve *Thrips tabaci* başta olmak üzere birçok trips türüyle taşınmaktadır. Enfekte tohumlarla taşınamayan TSWV enfeksiyonları sonucunda, genç yapraklarda küçük, koyu lekeler oluşurken hastalığın ilerleyen dönemlerinde gövdede koyu renkli çizgiler, olgunlaşan meyvelerde koyudan kırmızıya beneklenme gözlenmektedir (Suresh et al., 2017). Dünya genelinde tarımsal üretimi sınırlandıran en tahripkâr virüs hastalıkları arasında yer alan TSWV enfeksiyonları nedeniyle domates bitkilerinde %75-100 arasında kayıp yaşanmakta (Gitaitis et al., 1998); domateste meyve enfeksiyonları sonucunda ürünler, %96 gibi ciddi bir oranda pazarlanamaz hale gelmektedir (Sevik and Arlı-Sokmen, 2011).

4.1. KAEÜ Ar-Ge Serasında Viral Hastalıkların Durumu

2024 üretim dönemi boyunca KAEÜ Ar-Ge serasında virüs benzeri simptomlar gösteren bitkilerden yaprak örneği alınmış, bu örnekler TMV, ToMV, CMV ve TSWV'ye spesifik antikorlar kullanılarak firmanın protokolüne göre (Bioreba, 2017; Clark and Adams, 1977) DAS-ELISA ile test edilmiştir. Örnek alınan bitkilerdeki öne çıkan simptomlar yapraklarda hafif veya şiddetli kloroz, mozaik, kabarcıklı mozaik, şekil bozukluğu, yaprak kenarlarında nekrotik alanlar; bitkide gelişme geriliği ve cüceleşme şeklinde görülmüştür. Bitkilerin hiç birisinde herhangi bir meyve belirtisi gözlenmemiş olup yaprak belirtileri enfekteli bitkilerde oldukça yoğun olmuştur (Şekil 2).

Şekil 2. KAEÜ Ar-Ge serasında bitkilerde gözlenen virüs benzeri simptomlar.

Serada yetiştirilen domates bitkilerinden üretim dönemi boyunca alınan virüs belirtili toplam 52 yaprak örneğinin DAS-ELISA test sonuçları Tablo 2'de verilmiştir. Buna göre test edilen örneklerin 46 adetinde (%88.5) araştırılan virüslerin tekli ya da karışık enfeksiyonları saptanmıştır. Domates yaprak örneklerinin 20 tanesinde saptanan CMV, %38.5 enfeksiyon oranıyla en yaygın görülen virüs olurken bunu sırasıyla toplam 18 bitkide bulunan TSWV (%34.6), örneklerin 14'ünde bulunan TMV (%26.9) ve 10 adetinde bulunan ToMV (%19.2) izlemiştir. KAEÜ Ar-Ge serasında yetiştirilen simptomlu domates bitkilerinde karışık enfeksiyonların durumu değerlendirildiğinde ise örneklerin %11.5'inde TMV+CMV+TSWV ve %7.7'sinde CMV+TSWV enfeksiyonu belirlenmiştir. TMV, ToMV, CMV ve TSWV için test edilen 6 örnek, DAS-ELISA testi sonucunda negatif bulunmuş olup bu örneklerin *Tomato*

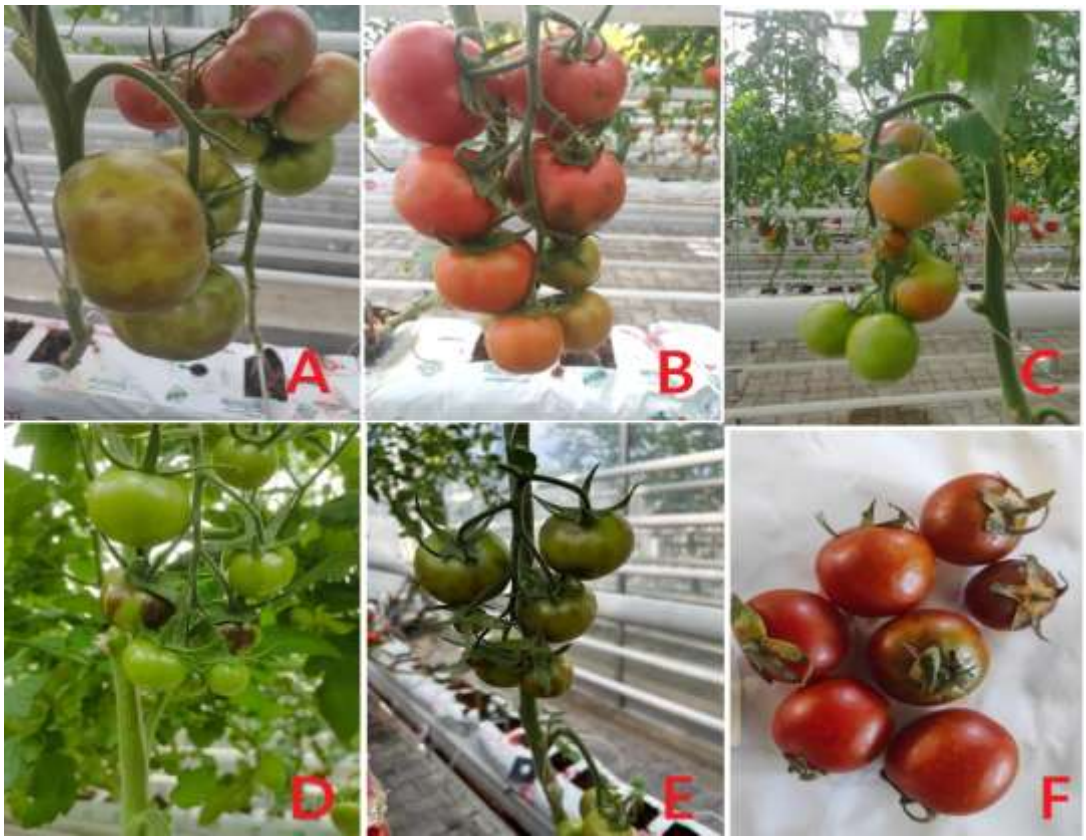
yellow leaf curl virus (TYLCV), *Potato virus* Y (PVY) veya *Potato virus* X (PVX) gibi açık alanda veya örtü altında yetiştirilen domates bitkilerinde yaygın bulunan (Arlı-Sökmen and Sevik, 2006) diğer virüslerle enfekteli olabileceği düşünülmüştür.

Tablo 2. Domates yaprak örneklerinde belirlenen virüs enfeksiyonları ve % bulunma oranları.

Saptanan Virüs	**Toplam Enfekteli Örnek Sayısı**	**Virüs Enfeksiyon Oranı (%)**
TMV	8	8/52 (15.4) 14/52 (26.9)*
ToMV	10	10/52 (19.2)
CMV	10	10/52 (19.2) 20/52 (38.5)*
TSWV	8	8/52 (15.4) 18/52 (34.6)*
CMV+TSWV	4	4/52 (7.7)
TMV+CMV+TSWV	6	6/52 (11.5)
Toplam Enfekteli Örnek Sayısı	**46**	**46/52 (88.5)**
Toplam Testlenen Bitki Sayısı	**52**	

* Karışık enfeksiyonlarla birlikte hesaplanan % enfeksiyon oranı

Ar-Ge serasında 2024-2025 kış üretim döneminde bitkilerin bazılarında çiçeklenme aşamasında bazı anormalilerin olduğu görülmüş, iri tomurcuk (stolbur) hastalığından şüphelenilmiştir. Ancak bu anomaliler birkaç bitkide gözlenmiş ve kısa sürede bitkiler toparlanarak normal meyve verimine başlamıştır. Yetiştirme döneminin başlangıcından itibaren gözlemlere devam edilmiş ve bitkilerde herhangi bir yaprak simptomu olduğu belirlenmemiştir. Belirli bir sürenin sonunda domates meyvelerinde nekrotik alanlar şeklinde belirtiler oluşmaya başlamıştır. Meyve olgunlaşma dönemine yakın yeşil meyvelerde başlayan ToBRFV belirtileri zamanla seradaki pek çok bitkiye yayılarak epidemi seviyesine ulaşmıştır. ToBRFV'nin Ar-Ge serasında yetiştirilen domates bitkilerindeki belirtileri Şekil 3'te görülmektedir.



Şekil 3. Domates bitkilerinde gözlemlenen ToBRFV belirtileri. A-B: Beef tipi domates çeşitlerinde yeşil ve olgunlaşmış meyvelerde kahverengi rugosite, C: Salkım tipi domates çeşitlerinin olgun meyvelerinde renk değişimleri, D-E: Salkım domateslerin olgunlaşmamış yeşil meyvelerinde kahverengi rugosite, F: Kokteyl tipi domates çeşitlerinin meyvelerinde kahverengi rugosite ile kaliks ve pedinküllerde nekroz.

ToBRFV'nin neden olduğu belirti tipi ve şiddeti, yetiştirme koşulları, virüsün ırkları veya varyantı ve bitki çeşidine göre değişmektedir (Salem et al., 2016). Öyle ki, dünya genelinde ToBRFV kayıtları incelendiğinde; Ürdün izolatı ile enfekte olan serada yetiştirilen domates bitkilerinin meyvelerinde şiddetli kahverengi rugosite gözlenirken bunun aksine bitkilerde çok hafif yaprak simptomu görüldüğü (Salem et al., 2016); Güney İsrail'de ağ evlerde yetiştirilen enfekte domates bitkilerinin yapraklarında hafif ile şiddetli arasında değişen oranda mozaik belirtileri ve hastalıklı bitkilerden elde edilen meyvelerin ise %10-15 oranında sarı benekli olduğu rapor edilmiştir (Luria et al., 2017). Yaprak daralması, klorotik beneklenme ve koyu yeşil şişkinlikler gibi yaprak belirtileri, Almanya ve Hollanda'dan gelen raporlarda belgelenmiş (Menzel et al., 2019; van de Vossenberg et al., 2020) ve Amerika Birleşik Devletleri ve Çin'de pediküller, kaliksler ve çiçekler üzerinde kuruma ve kahverengi nekroz lekeleri gözlenmiştir (Chanda et al., 2021b; Yan et al., 2019). Ülkemizde ToBRFV'nin ilk kaydı olan raporda, Antalya'nın Demre ilçesindeki seralarda yetiştirilen domates bitkilerinin yapraklarında klorotik mozaik, beneklenme, buruşukluk ve ara sıra daralma olduğu bildirilmiştir. Ayrıca, enfekteli bitkilerin yaprak sapı, pedinkül ve kalikslerinde nekrotik lekelerin olduğu; meyvelerin klorotik

ve nekrotik rugosite gösterdiği belirtilmiştir (Fidan et al., 2019). KAEÜ Ar-Ge serasında yetiştirilen beef tipi domates bitkilerinin olgunlaşmış ve olgunlaşmamış meyvelerinde nekrotik rugoz belirtilerinin yaygın olduğu, salkım tipindeki domates çeşitlerinin bazılarının meyvelerinde klorotik renk değişimlerinin, bazılarında ise nekrotik rugositenin olduğu gözlenmiştir. Serada yetiştirilen hiçbir domates çeşidinde yaprak belirtileri gözlenmezken, kokteyl tipi domates meyvelerinde nekrotik rugositeye ek olarak kaliks ve pedinküllerde de nekrotik lekelerin ve kurumaların olduğu tespit edilmiştir. Virüsün biyolojik, serolojik ve moleküler karakterizasyonu konusundaki çalışmalar seramızda devam etmektedir.

4.2. Domates Virüs Hastalıklarıyla Mücadele Önerileri

Bitki virüs hastalıklarının kontrolü için doğrudan etkili kimyasal mücadele stratejileri bulunmadığından dolayı hastalık yönetimi için pratikte virüslerin bitkilere bulaşma kaynaklarının azaltılması ya da mümkünse yok edilmesini sağlayacak ve böcek vektörleriyle yayılmalarını engelleyecek önlemler üzerinde yoğunlaşılmaktadır (Ally et al., 2023; Tsitsigiannis et al., 2008). Bugüne kadar virüs hastalıklarıyla ilgili yapılan çalışmalarda bazı kontrol önlemleri oldukça önemli olmuş ve bu doğrultuda örtü altında yetiştirilen domates bitkilerinde virüs hastalıklarının önüne geçilmesi amacıyla yetiştiricilere bazı önerilerde bulunulmuştur. Bu öneriler aşağıdaki şekilde sıralanabilmektedir;

- Fide üretimi yapılacak toprağın tohum ekiminden önce sterilize edilmesi; fideliklerin virüslerden ari, domateslerde yaygın görülen virüslere hassas *Solanaceae* familyası bitkilerinin yetiştirildiği alanlardan uzak bölgelerde kurulması (Özellikle TMV, ToMV ve ToBRFV gibi toprakta ve bitki artıklarında enfeksiyon yeteneğini yitirmeden uzun süre stabil kalabilen virüslerin üretim materyaline bulaşmasının engellenmesi için) (Cerkauskas, 2004; Panagopoulos, 2000).
- TMV, ToMV ve ToBRFV gibi tobamovirüsler toprakta, kokopit gibi topraksız tarım ortamlarında ve solüsyonlarında, sulama suyunda uzun süre stabil kaldıkları için seralarda bulaşık ortamların kullanılmamasına özen gösterilmesi (Ally et al., 2023; Chanda et al., 2021a; Klap et al., 2020; Pares et al., 1992).
- Tobamovirüsler başta olmak üzere örtü altı domates yetiştiriciliğinde zarar yapan virüslerin çoğunluğu tohumla taşındıkları için temiz tohumluk kullanılması veya enfekteli olduğundan şüpheli tohumların sodyum hipoklorit gibi uygun kimyasallarla dezenfekte edilmesi (Panagopoulos, 2000; Zitter, 1991).
- Seralarda enfekteli domates bitkilerinin vakit kaybetmeden sökülerek üretim alanından uzaklaştırılması ve kültürel işlemler sırasında bulaşmaların önüne geçebilmek için işçilerin hijyen önlemlerine dikkat etmesi (Panagopoulos, 2000; Tsitsigiannis et al., 2008; Zitter, 1991).
- Virüsün konukçu grubunu oluşturan ve virüse karşı hassas tepkiler veren bitki tür ve çeşitlerinin aynı serada polikültür halinde yetiştirilmesinden kaçınılması (Panagopoulos, 2000).
- Pek çok bitki virüsünün en önemli yayılma yollarından birisi olan enfekteli bitki artıklarının etkin bir şekilde sera ortamından uzaklaştırılması (Himmel, 2003; Panagopoulos, 2000; Zitter, 1991).

- Afitler (CMV kontrolü için), tripsler (TSWV için), beyaz sinekler (TYCLV için) ve domates güvesi *Tuta absoluta* (ToBRFV için) gibi virüslerin yayılmasında etkili olan böcek vektörlerle etkili bir şekilde mücadele edilmesi (Carusa et al., 2024; Himmel, 2003; Salati et al., 2002; Zitter, 1991).
- Mümkünse yetiştiricilikte virüslere dayanıklı ya da toleranslı olduğu bilinen çeşitlerin kullanılması (Tsitsigiannis et al., 2008).

5. SONUÇ VE ÖNERİLER

Bu çalışma, Kırşehir Ahi Evran Üniversitesi Ar-Ge serasında yetiştirilen domates bitkilerinde yetiştirme sezonu boyunca karşılaşılan önemli fitopatolojik sorunları ortaya koymayı amaçlamıştır. Serada yapılan gözlemler, simptomatolojik incelemeler ve analizler sonucunda, en sık rastlanan hastalıkların sulama düzensizliği, kalsiyum alınımı ve kalsiyumun bitki içindeki iletiminde dengesizlik sonucunda ortaya çıkan abiyotik bir hastalık olan çiçek burnu çürüklüğü; CMV, TSWV, TMV ve ToMV, 2024-2025 yetiştirme döneminde ise ToBRFV gibi viral hastalıkların olduğu tespit edilmiştir. Ar-Ge serasında fungal ve bakteriyel hastalıkların durumu değerlendirildiğinde ise etkin iklim kontrolü sağlanması, koruyucu ve tedavi edici kimyasal mücadele önlemlerinin etkin bir şekilde alınması dolayısıyla yaygın olmadığı belirlenmiştir.

Bildiri kapsamında abiyotik veya biyotik hastalıkların yönetiminde uygulanabilecek kontrol önlemleri tartışılmıştır. Araştırma sonuçlarımız ışığında, AR-GE serasında ve benzeri üretim ortamlarında domates yetiştiriciliğinde fitopatolojik sorunların etkin bir şekilde yönetilmesi için aşağıdaki öneriler sunulmaktadır:

- Kimyasal mücadeleye alternatif olarak veya kimyasal mücadeleyi destekleyici nitelikte biyolojik mücadele ajanlarının (örneğin, antagonist mikroorganizmalar, faydalı böcekler) ve kültürel uygulamaların (örneğin, uygun havalandırma, sulama ve besleme programlarının doğru yapılması, budama gibi kültürel işlemler sırasında mekanik bulaşmaları önleyici önlemlerin alınması, hastalıklı bitkilerin ve artıklarının üretim alanlarından uzaklaştırılması) entegre bir şekilde kullanılması hastalık ve zararlı baskısını azaltmada önemli rol oynayacaktır.
- Hastalık ve hastalıkları taşıyan zararlıların erken evrede tespit edilmesi için düzenli bitki kontrollerinin yapılması, uygun teşhis araçlarının (örneğin, yaprak analizleri, tuzak kullanımı) kullanılması ve elde edilen verilerin kayıt altına alınarak riskli dönemlerin belirlenmesi önemlidir.
- Seralarda sık karşılaşılan fitopatolojik sorunlara karşı dayanıklı veya toleranslı çeşitlerin tercih edilmesi hem abiyotik hem de biyotik hastalıklardan kaynaklı ekonomik kayıpları önemli ölçüde azaltmaktadır. Bu nedenle, ıslah programlarında hastalıklara dayanıklılık özelliklerinin belirlenmesine yönelik çalışmalara öncelik verilmelidir.
- Sera içerisine hastalıklı bitki materyali girişinin engellenmesi, kullanılan alet ve ekipmanların düzenli olarak dezenfekte edilmesi ve hasat sonrası bitki artıklarının seradan uzaklaştırılması gibi hijyen önlemleri hastalıkların yayılmasını önlemede kritik öneme sahiptir.
- Sera içi sıcaklık, nem ve havalandırma koşullarının bitki fizyolojisi için ideal aralıklarda tutulması, bitkilerin stres koşullarına karşı direncini artırarak hastalıkların olumsuz

etkilerini azaltmaktadır. Bu nedenle Ar-Ge serasında olduğu gibi otomatik iklim kontrol sistemlerinin örtü altı yetiştiriciliğinde yaygınlaştırılması önerilmektedir.

- Örtü altı domates yetiştiricilerine yönelik düzenli bilgilendirme ve eğitim etkinlikleri ile yaygın fitopatolojik sorunların tanınması, yayılma yolları ve kontrol yöntemleri hakkında farkındalık oluşturulması, mücadele stratejilerinin etkin bir şekilde uygulanmasına katkı sağlayacaktır.

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RESEARCH ON THE EFFECT OF SOME BIOFUNGICIDES ON PLANT VIRUS DISEASES

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ABSTRACT

Biological control agents or bio-agents have been used as an alternative to chemical control against many diseases and pests in recent years because they are environmentally friendly and do not harm human health. Bio-agents, called biofungicides, are substances of biological origin used to control fungi and fungi-like organisms (such as Oomycetes) that cause plant diseases and have been successful against different plant diseases in many studies. In recent years, the effect of these biofungicides on viral diseases has also started to be investigated.

Plant pathogenic viruses are very difficult to control due to their complex structure and the lack of effective chemicals. Therefore, there is a need to develop alternative control strategies. Secondary metabolites of some bio-agents, which are effective as biofungicides, or directly themselves, reduce infections by promoting plant growth and plant defence mechanisms and suppressing virus multiplication or spread.

The aim of this study was to determine the possibilities of biofungicides against plant virus diseases, their application methods to plants and their potential effects on reducing infections by reviewing the world literature. The main biofungicides investigated for their use against plant virus diseases are some *Bacillus* spp. species, also called plant growth promoting bacteria (PGPR bacteria), and some endophytic fungi, especially *Trichoderma* spp. species. The effects of these biofungicides on *Tobacco mosaic tobamovirus* (TMV), *Tomato mosaic tobamovirus* (ToMV) and *Cucumber mosaic cucumovirus* (CMV); *Tomato yellow leaf curl begomovirus* (TYLCV), *Potato potyvirus* Y (PVY) and other viruses were evaluated in the studies. In this paper, information about the mechanisms of action, possibilities of use and application methods of some biofungicides on virus diseases that can be reached within the scope of the research is given.

Keywords: Biofungicides, Biological Control, Plant Virus Diseases, Virus Diseases Control**1.**

BAZI BİYOFUNGİSİTLERİN BİTKİ VİRÜS HASTALIKLARINA ETKİSİ ÜZERİNE ARAŞTIRMALAR

ÖZET

Biyolojik kontrol ajanları veya biyo-ajanlar, çevre dostu olmaları ve insan sağlığına zarar vermemelerinden dolayı son yıllarda pek çok hastalık ve zararlıya karşı kimyasal mücadeleye alternatif olarak kullanılmaktadır. Biyofungisit olarak adlandırılan biyo-ajanlar, bitki hastalıklarına neden olan fungus ve fungus benzeri organizmaları (Oomisetler gibi) kontrol etmek için kullanılan biyolojik kökenli maddeler olup yapılan birçok çalışmada farklı bitki hastalıklarına karşı başarılı olmuştur. Son yıllarda bu biyofungisitlerin viral hastalıklara etkisi de araştırılmaya başlanmıştır.

Bitki patojeni virüslerin kompleks yapısı ve mücadelesinde etkili kimyasalların bulunmaması nedeniyle kontrolü oldukça zor olmaktadır. Bu nedenle, alternatif kontrol stratejilerinin geliştirilmesine ihtiyaç duyulmaktadır. Biyofungisit olarak etkili olan bazı biyo-ajanların sekonder metabolitleri veya doğrudan kendileri, bitki büyümesi ile bitkinin savunma mekanizmasını teşvik ederek ve virüsün çoğalmasını veya yayılmasını baskılayarak enfeksiyonları azaltıcı özellik göstermektedir.

Bu çalışma, dünya literatürü taranarak biyofungisitlerin bitki virüs hastalıklarına karşı kullanım olanakları, bitkiye uygulama yöntemleri ve enfeksiyonları azaltıcı potansiyel etkilerinin saptanması amacıyla ele alınmıştır. Bitki virüs hastalıklarına karşı kullanım olanakları araştırılan başlıca biyofungisitler, bitki gelişimini teşvik edici bakteriler (PGPR bakterileri) olarak da adlandırılan bazı *Bacillus* spp. türleri ve *Trichoderma* spp. türleri başta olmak üzere bazı endofitik funguslardır. Yapılan çalışmalarda bu biyofungisitlerin başta *Tobacco mosaic tobamovirus* (TMV), *Tomato mosaic tobamovirus* (ToMV) ve *Cucumber mosaic cucumovirus* (CMV) olmak üzere; *Tomato yellow leaf curl begomovirus* (TYLCV), *Potato potyvirus* Y (PVY) ve diğer virüsler üzerine etkileri değerlendirilmiştir. Bu bildiride, araştırma kapsamında ulaşılabilen virüs hastalıklarına bazı biyofungisitlerin etki mekanizmaları, kullanım olanakları ve uygulama yöntemleri hakkında bilgiler verilmiştir.

Anahtar Kelimeler: Biyofungisitler, Biyolojik Kontrol, Bitki Virüs Hastalıkları, Virüs Hastalıklarının Kontrolü

GİRİŞ

Küresel tarım sektörü, artan dünya nüfusunu besleme ve sürdürülebilir gıda üretimi sağlama gibi hayati zorluklarla karşı karşıyadır. Bu zorlukların en önemlilerinden biri, bitki sağlığını tehdit eden ve verimliliği önemli ölçüde azaltan bitki hastalıklarıdır. Fungus, bakteri ve virüslerin neden olduğu biyotik bitki hastalıkları, ekonomik açıdan önemli pek çok üründe verimi sınırlandırmakta ve ürün kalitesini etkileyerek ciddi ekonomik kayıplara neden olmaktadır (Manjunatha et al., 2022). Sözü edilen biyotik hastalık etmenleri arasında yer alan bitki virüslerinin, dünya genelinde meydana gelen bitki hastalığı epidemilerinin %47'lik kısmına neden olduğu bilinmektedir (Anderson et al., 2004).

Bugün tanılanmış olan 25'ten fazla bitki virüsü ailesi, geniş bir konukçu dizininde hastalık oluşturabilmekte ve dünya çapında ciddi ekonomik kayıplara neden olmaktadır (He and Krainer, 2020). Öyle ki, 1980'li yıllarda bitki virüs hastalıklarına bağlı kayıplar, 15-20 milyar ABD doları arasında seyrederken, 2014 yılına geldiğinde ekonomik kaybın değeri 30 milyar ABD dolarını aşmıştır (Jones, 2021). Küresel çapta bitki virüs hastalıklarının ekonomik etkisinin bu denli artmasındaki ana nedenler, iklim faktörlerindeki değişimler, bitki virüslerinin bu faktörlere bağlı olarak hızlı şekilde evrimleşmesi ve tarım ürünlerinin hızlı ticareti şeklinde sıralanabilmektedir (Chung et al., 2013; Rubio et al., 2020).

Bitki virüsleri, karmaşık konukçu-patojen etkileşimleri ve obligat parazit olmalarından kaynaklı olarak etkili doğrudan mücadele yöntemlerinin sınırlı olması ve kimyasal kontrol önlemlerinin başarısız olması nedeniyle tarımsal üretimde tehdit olmaya devam etmektedir (Manjunatha et al., 2022). Bitki patojeni virüslerin kontrol stratejileri arasında, yetiştiricilikte temiz üretim materyali ve dayanıklı veya toleranslı çeşitlerin kullanılması, hijyen önlemlerine dikkat edilmesi ve virüs taşıyan vektörlerle etkili şekilde mücadele edilmesi gibi sınırlı önlemler yer almaktadır (Varma, 2007). En sık kullanılan ve hastalık kontrolü için kaçınılmaz yöntemlerden birisi de virüs vektörlerinin kontrol altında tutulması, bu sayede üretim alanlarında viral hastalıkların bulaşmasının ve yayılımının engellenmeye çalışılmasıdır. Geleneksel olarak bitki virüslerinin vektörleriyle mücadelede sentetik kimyasal pestisitler yaygın olarak kullanılmaktadır. Ancak, bu kimyasalların aşırı ve bilinçsiz kullanımı, çevresel kirlilik, biyoçeşitliliğin azalması, hedef dışı organizmalar üzerinde toksik etkiler ve patojenlerde direnç gelişimine neden olabilmektedir (Aktar et al., 2009).

Bitki hastalıklarının ve onları taşıyan vektörlerin kontrolünde yoğun olarak kullanılan sentetik pestisitlerin çevre ve insan sağlığına olumsuz etkileri, çevre dostu, insan sağlığına daha az zararlı ve sürdürülebilir tarımsal üretim stratejisine uygun alternatif mücadele yöntemlerine ihtiyacı giderek arttırmaktadır. Bu nedenle, son zamanlarda biyolojik mücadeleye yoğun bir ilgi oluşmuştur (Elnahal et al., 2022; Whipps, 2001). Sentetik fungisitlere göre çok daha çevre dostu olan biyofungisitler, günümüzde pek çok bitki patojeni fungus ve Oomisetler gibi fungus benzeri organizmaların kontrolünde başarılı bir şekilde kullanılmaktadır (Daryaei et al., 2016; Nihorimbere et al., 2010; Thind, 2021; Verma et al., 2020). Biyofungisit tanımlamasına giren ürünler, doğal kaynaklardan elde edilen ve bitki fungal hastalıklarına baskılayıcı etki gösteren mikroorganizmalar (mikrobiyal biyofungisitler), bitki özleri (fitofungisitler: bitkisel kökenli biyofungisitler) ve doğal metabolitlerden üretilen nanopartiküller (nano-biyofungisitler) şeklinde sınıflandırılmaktadır (Meena, 2021; Whipps, 2001).

Biyofungisitler, fungal patojenler üzerinde; doğrudan patojen gelişimini ve çoğalmasını engelleme, bitkinin doğal savunma mekanizmalarını (Uyarılmış Sistemik Dayanıklılık- ISR) tetikleme, besin ve alan rekabeti yaratarak patojenin bitki dokuları içinde kolonizasyonunu önleme ve patojenin konukçu bitki dokularına girişini engelleme gibi çok çeşitli etki mekanizmalarına sahiptir (Fenta and Menkonnen, 2024). Sentetik alternatiflerine kıyasla daha özgül etki gösteren biyofungisitlerin, hedef dışı organizmalara zarar verme riskinin düşük olması, doğada genellikle hızlı parçalanmaları (Köhl et al., 2019) ve daha düşük sera gazı emülsiyonuna neden olmaları (Ayilara et al., 2023) dolayısıyla çevre dostu olmaları gibi avantajları bulunmaktadır.

Obligat intraselüler parazit olan virüslerin neden olduğu bitki hastalıklarının kontrolünde antiviral etkili kimyasalların geliştirilmesi ve bunların bitki dokularına uygulanması oldukça zordur. Mevcut mücadele stratejileri, genellikle virüsün yayılımını engellemeye (vektör kontrolü, sanitasyon), dayanıklı çeşitlerin kullanımına ve bitki bağışıklık sistemini güçlendirmeye odaklanmaktadır (Varma, 2007). Bu nedenle son yıllarda bitki bağışıklık sistemini güçlendirme ve savunma sistemlerini harekete geçirme özelliği olan biyofungisitlerin bitki virüs hastalıklarının yönetimindeki potansiyel rolleri konusundaki araştırmaların sayısı giderek artmaktadır (Manjunatha et al., 2022). Mikrobiyal kökenliler başta olmak üzere bazı biyofungisitlerin, virüsleri bitkiden bitkiye taşıyan vektör organizmalar üzerindeki etkileri, bitkilerde sistemik direnci tetikleme yetenekleri ve genel bitki sağlığını iyileştirerek virüs enfeksiyonlarının olumsuz etkilerini azaltma potansiyelleri umut vericidir.

Bu çalışma, güncel literatürdeki araştırmaları derleyerek, bazı önemli mikrobiyal biyofungisit gruplarının bitki virüs hastalıkları üzerindeki potansiyel etkilerini kapsamlı bir şekilde incelemeyi amaçlamaktadır. Söz konusu incelemede, farklı mikrobiyal biyofungisitlerin bitki virüs hastalıklarına etki mekanizmaları, virüs enfeksiyonlarını engelleme veya şiddetini azaltma potansiyelleri, antiviral ajan olarak kullanımındaki zorluklar ve konuyla ilgili gelecekteki araştırma yönleri ele alınmıştır. Buna ek olarak çalışma, sürdürülebilir tarım sistemlerine entegre edilen bazı mikrobiyal biyofungisitlerin bitki virüs hastalıklarını kontrol etmedeki olası katkılarının daha iyi anlaşılmasını hedeflemektedir.

2. BİTKİ VİRÜSLERİNİN KONTROLÜNDE MİKROBİYAL BİYOFUNGİSİTLER

Biyofungisit terimi, fungal patojenlerin gelişmesini ve çoğalmasını sınırlandıran veya tamamen engelleyen, canlı organizma konsorsiyumlarından (birlikteliklerinden) geliştirilen biyolojik kaynaklı formülasyonları ifade etmektedir (Kubheka et al., 2020). Bu biyolojik kökenli maddeler elde edildikleri organizma grubuna göre fitofungisit (bitkisel kökenli), mikrobiyal biyofungisit (bakteri, fungus, virüs, mavi-yeşil alg, likenlerden elde edilebilirler) ve nano-biyofungisit gibi farklı isimler almaktadır (Commisso et al., 2021; Meena, 2021; Whipps, 2001). Literatürde, mikrobiyal kökenli biyofungisitlerin etken maddesini oluşturan biyolojik kontrol ajanlarının antifungal etkilerinin araştırıldığı pek çok çalışma bulunmaktadır. Ayrıca günümüzde ticari pek çok mikrobiyal biyofungisit formülasyonu da piyasada mevcuttur ve tarım sektöründeki gelişmelerle birlikte bu formülasyonlar, organik tarım yapılan alanlarda entegre zararlı yönetimi stratejisine başarılı bir şekilde dahil edilmiştir (Subba and Mathur, 2022).

Önceki yıllarda yapılan çalışmaların birçoğunda bitki patojenlerinden ve zararlılardan bitkilerin korunması için mikrobiyal biyofungisitlerin etken maddesini oluşturan yararlı mikroorganizmaların önemine değinilmiştir (Bouizgarne, 2012; LeCocq et al., 2017; Siegel and Latch, 1991). Ancak transgenik yaklaşımlar ve kimyasal pestisitlere kıyasla aktinobakteriler, bitki gelişimini teşvik eden bakteriler (PGPR), endofitik mikroorganizmalar ile fungal ajanlar gibi yararlı heterojen grupların viral aktiviteyi doğrudan baskılayabildiği ve virüs vektörü böceklerin yumurtlama kapasitesini düşürebildiği veya engelleyebildiği son yıllarda yapılan çalışmalarla kanıtlanmıştır (Clay, 1988; Li et al., 2016; Maksimov et al., 2018; Maksimov et al., 2019).

2.1. Bakteriyel Biyofungisitler

2.1.1. Aktinobakteri grubu biyolojik kontrol ajanları

Aktinobakteriler, tarımsal açıdan önemli ve tedavi edici biyolojik aktiviteye sahip çok çeşitli sekonder metabolitleri yoğun şekilde üreten gram pozitif özellikte önemli bir bakteri sınıfıdır (Kunoh, 2002; Pandey et al., 2021). Sadece 1988-1992 yılları arasında aktinobakteri kaynaklı 1000'in üzerinde sekonder metabolit karakterize edilmiştir. Bu bileşiklerin çoğu *Streptomyces* cinsinin çeşitli üyeleri tarafından üretilmekte olup biyo-insektisit ve herbisitlerin %60'ının *Streptomyces* spp. kaynaklı olduğu rapor edilmiştir. (Tanaka and Omura, 1993). Aktinobakterilerin ürettikleri antibakteriyel, antifungal, nematisidal ve herbisidal etkili antibiyotik bileşiklerin birçoğu tarımda yaygın şekilde kullanılmaktadır. *Streptomyces* cinsi aktinobakterilerin çok sayıda antibiyotik ürettiği bilinmekte olup ürettikleri validamisin ve kasugamisin gibi pek çok antibiyotik bileşik, biyofungisit olarak ticarileştirilmiştir (Tanaka and Omura,1993; Mathivanan et al., 2008).

Birçok biyofungisitin üretiminde kullanılan *Streptomyces* türü aktinobakterilerin ve onların sekonder metabolitlerinin çeşitli bitki patojeni virüslere karşı etkilerinin araştırıldığı çalışmalar, Tablo 1'de özetlenmiştir. Yapılan çalışmalarda, *Streptomyces ahygroscopicus*, *Streptomyces* sp. ZX01 ve *S. noursei* var. *xichangensis* gibi türlerin, tütün bitkilerinde sinyal moleküllerinin üretimini arttırarak bitki savunma yollarını aktive ettiği ve bu şekilde *Tobacco mosaic virus* (TMV)'e karşı antiviral etki gösterdiği ortaya koyulmuştur (Dong et al., 2006; Han et al., 2014; Wang et al., 2006; Zhang et al., 2015). Ayrıca yapılan benzer bir çalışmada, *S. ahygroscopicus* ile hazırlanan solüsyonun TMV ile enfekteli *Nicotiana glutinosa* ve *N. tabacum* bitkilerinin özsuyunda virüsü inaktive ettiği rapor edilmiştir (Xing et al., 2012). Chen vd. (2019), TMV'yi bitki özsuyunda inaktive ederek antiviral özellik gösteren bileşiğin *S. ahygroscopicus*'un ürettiği 3454-4352 Da'luk ε-poli -l- lizin (ε-PL) olduğunu bildirmiştir (Chen et al., 2019).

Tablo 1. Aktinobakteri grubu biyo-kontrol ajanlarının bitki patojeni virüslere etkileri.

Aktinobakteri Grubu Biyokontrol Ajanı	**Hedef Virüs***	**Konukçu**	**Antiviral Etki**	**Kaynaklar**
Streptomyces ahygroscopicus	TMV	*Nicotiana glutinosa* ve *N. tabacum*	Özsuda virüs inaktivasyonu	Xing et al., 2012; Chen et al., 2019
			Sinyal moleküllerinin üretimini arttırarak bitki savunma sisteminin aktivasyonu	Dong et al., 2006; Wang et al., 2006
Streptomyces sp. ZX01				Zhang et al., 2015
S. noursei var. *xichangensis*				Han et al., 2014
Streptomyces olivaceus	TMV	*Nicotiana glutinosa* ve *Chenopodium quinoa*	Nekrotik lokal lezyon sayısında azalma	Mohamed and Galal, 2005
	PVY			
	CMV			
	CMV	Hıyar	Enfekteli bitki sayısında azalma	Latake and Borkar, 2017

* TMV: *Tobacco mosaic virus*; CMV: *Cucumber mosaic virus*; *Potato virus* Y

Streptomyces olivaceus denizlerde yaşayan aktinobakterilerden birisidir. Bu bakteri türünün *N. glutinosa* ve *Chenopodium quinoa* bitkilerinde TMV, *Cucumber mosaic virus* (CMV) ve *Potato virus* Y (PVY) enfeksiyonları sonucu meydana gelen nekrotik lokal lezyonların sayısını azalttığı görülmüştür (Mohamed and Galal, 2005). 28 farklı deniz aktinobakteri izolatı metabolitlerinin CMV'ye karşı antiviral aktivitesinin değerlendirildiği çalışmada ise bir izolatın tohum uygulaması ve yapraklara püskürtülerek uygulanması durumunda, sera koşullarında çift inokulasyonla hıyar bitkilerinde oluşturulan CMV enfeksiyonlarını azalttığı belirlenmiştir. Ardından anti-CMV etkisine sahip olan metabolitin elde edildiği izolat, moleküler olarak karakterize edilmiş; bu izolatın *Streptomyces olivaceus* olduğu morfolojik, fizyolojik ve biyokimyasal karakterizasyonla da doğrulanmıştır (Latake and Borkar, 2017).

2.1.2. *Bacillus* türü biyolojik kontrol ajanları

Biyofungisit olarak kullanılan biyokontrol ajanı bakteri gruplarından bir diğeri de Firmicutes şubesinde yer alan gram pozitif özellikteki *Bacillus* türleridir. *Bacillus* türlerinin ürettiği zwittermisin A (Smith et al., 1993), bacillomisinler, fungisin (Koumoutsi et al., 2004), kanosamin, rizoktisin C, iturinler (Kloepper et al., 2004; Paulitz and Belanger, 2001), ve saltavalin gibi birçok antibiyotik ve termostabil antimikrobiyal peptitler, bitki hastalıklarına karşı kullanılmaktadır (Emmert and Handelsman, 1999; Kavitha et al., 2005; Leclere et al., 2005; Zhao et al., 2010). Ayrıca, *Bacillus* spp.'nin ürettiği bakteriosinlerin gıdalarda biyo-koruyucu ve tarımda biyokontrol ajanı olarak kullanımı pek çok çalışmada rapor edilmiştir (Bais et al., 2004). Thurisin, thurisin 7, thurisin S, thurisin CD 19, thurisin 439A, thurisin 439B, bacthurisin F4, tochisin, kurstakin 18 ve entomosin gibi bakteriosinlerin ise antibiyotiklerin öncülleri olarak görev yapan sekonder metabolitler olabileceği bildirilmiştir (Sansinenea and Ortiz, 2011). *Bacillus* türü biyokontrol ajanlarının bitki virüs hastalıklarına karşı etkisinin belirlendiği birçok ümit verici çalışma olmasına rağmen bu etkisini hangi sekonder metabolit

ve etken madde sayesinde gerçekleştiğini kanıtlayan çalışmalar oldukça kısıtlıdır. Bitki virüslerine etkisi en fazla araştırılan türler *Bacillus amyloliquefaciens* ve *Bacillus subtilis* olmuştur (Tablo 2).

Tablo 2. *Bacillus* türü biyo-kontrol ajanlarının bitki virüslerine etkisi.

***Bacillus* türü Biyokontrol Ajanı**	**Hedef Virüs***	**Konukçu**	**Antiviral Etki**	**Kaynaklar**
Bacillus amyloliquefaciens	TSWV	*Nicotiana benthamiana*	Sinyal moleküllerinin üretimini arttırarak simptomlarda azalma, viral yükte azalma ve bitki büyümesinin teşviki	Khan et al., 2024
	TMV	*Nicotiana tabacum*	Test bitkilerinde lokal nekrotik lezyon sayısında azalma, bulaşık makasların daldırılması ile dezenfeksiyon ve tarladaki bitkilere püskürtüldüğünde enfeksiyon oranında %50 azalma	Shen et al., 2013
		Domates	Virüs inokülasyonundan 24 saat önce ve sonra yaprağa püskürtüldüğünde enfeksiyonda %90 azalma	Abdelkhalek et al., 2022a
	TYLCV	Domates	Bitkiler bakteri süspansiyonuna batırıldıktan sonra beyaz sinekle virüs inokulasyonu yapıldığında enfeksiyon oranı ve hastalık şiddetinde %48-52 azalma	Guo et al., 2019
Bacillus subtilis	ToMV	Domates	Enfekte fidelere bakterinin ürettiği antimikrobiyal bileşik surfaktin ile sulandığında simptomlarda önemli derecede azalma	Hussein et al., 2016
	PVY	Patates	Bitkilere virüs inokülasyonundan 48 saat önce ve 10 gün sonra yaprağa püskürtülerek ve topraktan uygulanmasıyla virüs simptomlarında ve konsantrasyonunda azalma	Amin et al., 2023
Bacillus subtilis subsp. *subtilis*	CMV	*Arabidopsis*	Virüs konsantrasyonunda ve hastalık şiddetinde azalma	Elsharkawy et al., 2022

* TSWV: *Tomato spotted wilt virus*; TMV: *Tobacco mosaic virus*; TYLCV: *Tomato yellow leaf curl virus*; ToMV: *Tomato mosaic virus*; PVY: Potato virus Y; CMV: Cucumber mosaic virus.

B. amyloliquefaciens'in *N. benthamiana* bitkilerindeki TSWV enfeksiyonlarına etkisi üzerine yapılan çalışmada bitkide sinyal moleküllerinin üretimini arttırarak simptomlarda azalmaya sebep olduğu, enfekte bitkilerdeki viral yükü azalttığı ve bitki büyümesini teşvik ettiği ortaya koyulmuştur. Yürütülen sera denemeleri, farklı ırkların %75 ila %88 oranında *Tomato spotted wilt virus* (TSWV) replikasyonunu azaltmasıyla sonuçlanmıştır (Khan et al., 2024). Aynı tür ile yürütülen başka bir çalışmada ise bakteri süspansiyonu *N. tabacum* türü test bitkilerine TMV inokulasyonundan önce, sonra ve eşzamanlı olarak püskürtülerek uygulanmış, en iyi sonuç inokulasyonla eşzamanlı yapılan uygulamada olmakla birlikte, bitkilerdeki lokal nekrotik lezyon sayısında önemli bir azalma gözlenmiştir. Ayrıca çalışmada TMV ile bulaşık makasların, bakteri süspansiyonuna daldırıldığında dezenfekte olduğu belirlenmiştir. Çalışmanın ikinci aşamasında tarla denemeleri yapılmış olup antiviral etki gösteren ningnanmycinin etkisine bağlı olarak 2009 yılında enfeksiyon oranında %49 ve 2010 yılında ise %50.5 azalma olduğu tespit edilmiştir (Shen et al., 2013). *B. amyloliquefaciens*, TMV inokülasyonundan 24 saat önce ve sonra domates bitkilerinin yapraklarına püskürtüldüğünde enfeksiyonda %90 azalmaya neden olmuştur (Abdelkhalek et al., 2022a). Benzer bir araştırmada, domates bitkileri *B. amyloliquefaciens* süspansiyonuna batırıldıktan sonra beyaz sineklerle *Tomato yellow leaf curl virus* (TYLCV) inoküle edilmiştir. Bitkilerin enfeksiyon oranında ve hastalık şiddetinde %48-52 oranında azalma olduğu gözlenmiştir (Guo et al., 2019).

Bir diğer önemli bakteriyel biyofungisit grubu da *Bacillus subtilis* ve bu bakterinin ürettiği metabolitlerdir. *B. subtilis*'in *Tomato mosaic virus* (ToMV) enfeksiyonlarına etkisinin araştırıldığı bir çalışmada, enfekte domates fideleri bu bakterinin ürettiği mikrobiyal bileşik surfaktin ile sulanmıştır. Uygulama sonunda fidelerin simptomlarında önemli azalmaların olduğu kaydedilmiştir (Hussein et al., 2016). *Bacillus subtilis* subsp. *subtilis* CMV inokule edilen *Arabidopsis* bitkilerine uygulandığında ise benzer şekilde virüs konsantrasyonunda ve hastalık şiddetinde önemli azalmalar olmuştur (Elsharkawy et al., 2022). Son olarak, patates bitkilerine PVY inokulasyonundan 48 saat önce ve 10 gün sonra yaprağa püskürtülerek ve toprağa olmak üzere 2 farklı *B. subtilis* uygulaması yapılmıştır. Bitkilere virüs inokulasyonundan önce *B. subtilis* bakteri süspansiyonu topraktan uygulandığında, uygulama yapılmamış kontrol bitkilerine göre simptomlarda ve virüs konsantrasyonunda önemli bir azalma olduğu hatta bazı bitkilerin serolojik olarak negatif sonuçlar verdiği gözlenmiştir. İnokulasyondan 10 gün sonra bakteri uygulaması yapılan bitkilerde PVY birikim oranında %32.8 azalma olduğu, bu azalmanın inokulasyondan 35 gün sonra %72.3'e kadar devam ettiği tespit edilmiştir. Bu veriler, topraktan *B. subtilis* uygulamasının PVY birimini ve enfeksiyon şiddetini azaltmada önemli bir rolü olduğunu göstermiştir (Amin et al., 2023).

2.2. Fungal Biyofungisitler

Endofitik funguslar, tarım ürünlerini yaygın görülen başta fungal patojenler olmak üzere virüs ve bakteri gibi hastalıklar ve nematodlar, akarlar gibi zararlılara karşı korumaktadır (Grabka et al., 2022). Bu nedenle, bazı fungal endofitler ve/veya onların çeşitli metabolitleri kullanılarak çok çeşitli mikrobiyal biyofungisitler üretilmiş ve bunların fungal patojenlerin hiflerini, klamidosporlarını, konidia, sporangia ve zoosporlarını parçalayarak hastalıklara karşı bitkilerin korunmasına katkı sağladığı tespit edilmiştir (Verma et al., 2020). *Ampelomyces, Aspergillus, Coniothyrium, Gliocladium, Laetisaria, Penicillium, Phlebiopsis, Sporodesmia, Talaromyces,*

Tilletiopsis, *Trichoderma*, *Trichothecium* ve patojenik olmayan *Fusarium* gibi pek çok cinste yer alan fungal biyo-kontrol ajanlarının bitki patojenlerini kontrol etme potansiyeli yüksek olan biyolojik olarak aktif sekonder metabolitleri ürettiği bilinmektedir (Doumbou et al., 2001; Prabavathy et al., 2008; Ramesh, 2009). Sözü edilen sekonder metabolitler bitki patojenlerine karşı antimikrobiyal özellik göstermekte ve özellikle biyofungisit olarak en yaygın kullanılan *Trichoderma* türlerinin uçucu ve uçucu olmayan metabolitleri, çeşitli patojenler için antibiyotik etki sağlamaktadır. Bu fungal antibiyotiklerden en bilineni ise antrakinonlardır (Verma et al., 2020).

Fungal endofitler, ya bitki savunmasını arttırarak ya da virüsleri taşıyan böcek vektörlere karşı entomopatojenik etki göstererek viral hastalıkları kontrol altına almaktadır. Endofitik biyo-kontrol ajanı fungusların bitki virüslerine karşı antiviral özelliklerini araştıran çalışmalar oldukça kısıtlı olmakla birlikte, genellikle bu çalışmalar endofit uygulanmış bitkilere virüslerin yapraktan inokulasyonu ile yürütülmüştür (Jaber and Salem, 2014). *T. viride*, *T. virens*, *T. harzianum* ve *T. koningii* trikodermin, viridol, peptaiboller, pironlar, akaronlar, daucene, trikoderrmol, emodin, steroller, heterosiklik azot bileşikleri (alkaloidler) ve seskiterpenler gibi sekonder metabolitlerin en iyi üreticileridir (Vyas and Mathur, 2002; Wiest et al, 2002; Mathivanan vd., 2008). Endofitik funguslar tarafından sentezlenen sekonder metabolitlerin, fungal biyofungisit ile virüs arasındaki etkileşim mekanizmasında doğrudan rolü olduğu düşünülmektedir. Ayrıca, yapılan araştırmalarda bitkilere fungal endofit uygulaması sonucunda üretilen alkaloidlerin antiviral özelliklere sahip olduğu belirlenmiştir (Jaber and Salem, 2014). Bu nedenle, bitki patojenlerine etkisi en çok araştırılan biyo-kontrol ajanları *Trichoderma* türleri olmuş; viral bitki hastalıklarının kontrolünde en başarılı sonuçların alındığı fungal biyofungisitlerin de bu türlerden oluştuğu belirlenmiştir (Tablo 3).

Tablo 3. Biyo-kontrol ajanı olarak endofitik *Trichoderma* türlerinin bitki virüslerine etkisi.

Biyokontrol Ajanı Olarak Endofitik Funguslar	**Hedef Virüs***	**Konukçu**	**Antiviral Etki**	**Kaynaklar**
Trichoderma spp. (*T. harzianum*, *T. polysporum* ve *T. atroviridae* konsorsiyumu)	PepLCV	Biber	%50'ye varan virüs inhibisyonu ve bitkide %183'ten fazla fenolik birikimi	Rochal et al., 2021
T. harzianum	TMV	Domates	Bitkide virüs enfeksiyonlarında azalma	Kolase et al., 2007
	ToMV		Bitkideki lokal nekrotik lezyon sayısında %51.5 azalma	Megahed et al., 2013
	CMV		Enfeksiyon oranında önemli derecede azalma	Vitti et al., 2015
T. asperallum	CMV	Hıyar	Virüsün çoğalmasını engelleyerek enfeksiyonu önleme	Tamandegani et al., 2021
	BCMV, BYMV, BLCV	Fasulye	Hastalık şiddetinde %91'e ve vektör popülasyonunda %96'ya varan azalma	Hossain et al., 2023
T. hamatum	TMV	Domates	Virüs birikiminde %85 azalma	Abdelkhalek et al., 2022b
T. viridae	PVY	Patates	Bitki gelişiminin teşviki ve bitki savunmasının tetiklenmesi	Aseel et al., 2023

* PepLCV: *Pepper leaf curl virus*; TMV: *Tobacco mosaic virus*; ToMV: *Tomato mosaic virus*; CMV: *Cucumber mosaic virus*; BCMV: *Bean common mosaic virus*; BYMV: *Bean yellow mosaic virus*; BLCV: *Bean leaf curl virus*; PVY: *Potato virus* Y.

Rochal vd. (2021)'nin yaptıkları araştırmada *T. harzianum*, *T. polysporum* ve *T. atroviridae*'den oluşan *Trichoderma* karşımının biber bitkilerine uygulandığında, *Pepper leaf curl virus* (PepLCV)'ü %50'ye varan oranda inhibe ettiği ve bitkide %183'ten fazla savunmayla ilişkili fenolik birikimine neden olduğu bildirilmiştir. Ayrıca bu fungal ajanlar, bitki dokularını endofitik olarak kolonize ederek oksin miktarında önemli bir yükselme sağlamış ve bitki büyüme hormonu oksinin biyolojik verimliliğini arttırmıştır. Farklı benzer çalışmalarda *Trichoderma harzianum* türü uygulanan domates bitkileri sırasıyla TMV, ToMV ve CMV ile inokule edilmiştir. Yapılan araştırmaların sonucunda TMV ve CMV ile enfekteli bitkilerde virüs enfeksiyonlarında önemli derecede azalma olduğu (Kolase and Sawant, 2007; Vitti et al., 2015), CMV ile enfekteli bitkilerde ise lokal nekrotik lezyon sayısında %51.5'lik bir düşüş olduğu rapor edilmiştir (Vitti et al., 2015).

Bitki virüs hastalıklarına potansiyel etkilerinin belirlenmesi amacıyla çalışma yapılan bir diğer fungal endofit ise *Trichoderma asperallum*'dur. Sözü edilen endofitin CMV inokule edilmiş bitkilere sulama suyuyla verilmesinden sonra virüs çoğalmasını engelleyerek bitkilerdeki enfeksiyonu önlediği ortaya koyulmuştur (Tamandegani et al., 2021). Benzer şekilde, *T.*

asperallum ile ıslatılmış toprakta yetiştirilen *Bean common mosaic virus* (BCMV), *Bean yellow mosaic virus* (BYMV) ve *Bean leaf curl virus* (BLCV) enfekteli fasulye bitkilerinin hastalık şiddetinde %91'e ve virüsün vektör popülasyonunda ise %96'ya varan azalma olduğu kaydedilmiştir (Hossain et al., 2023). Son olarak *T. hamatum*, TMV enfekteli bitkilere uygulandığında bitki dokularındaki virüs birikiminde %85 azalma sağlarken (Abdelkhalek et al., 2022b); PVY enfekteli patates bitkilerine *T. viridae* uygulandığında hem bitki savunması tetiklenmiş hem de bitki gelişimi önemli bir oranda teşvik edilmiştir (Aseel et al., 2023).

3. MİKROBİYAL BİYOFUNGİSİTLERİN ANTİVİRAL ETKİ MEKANİZMALARI

Son yıllarda, mikrobiyal biyofungisitlerin etken maddesini oluşturan biyo-ajanların bitki virüs hastalıklarına olan potansiyel etkilerine yönelik pek çok çalışma yapılmış ve çeşitli mekanizmalarla antiviral etki gösterdikleri kanıtlanmıştır. Bu mekanizmalar;

3.1. Doğrudan Antiviral Etki

Dezenfektan olarak adlandırılan bazı kimyasal bileşikler, bitki virüslerinin kılıf proteininin veya genetik materyalinin (DNA veya RNA) yapısını bozarak doğrudan antiviral etki gösterebilmektedirler. Örneğin, biyofungisitlerin üretildiği önemli bir biyo-kontrol ajanı olan *Bacillus amyloliquefaciens* solüsyonuna TMV ile bulaşık budama makasları daldırıldığında viral partiküllere zarar vererek dezenfeksiyon etkisi gösterdiği kanıtlanmıştır. Aynı çalışmada, bu in-vitro etki, tütün tohum yataklarına ve fidelik toprağına da uygulanarak da teyit edilmiş olup bakterinin ürettiği ningnanmisin isimli antibiyotik bileşikten kaynaklı doğrudan antiviral etki olduğu bildirilmiştir. Aynı antibiyotik maddenin *Streptomyces noursei* var. *xichangensis* isimli aktinobakteri tarafından da üretildiği bilinmektedir (Shen et al., 2013). Bununla birlikte, bitki dokuları içerisindeki virüslere doğrudan antiviral etki kavramı, bakteriyel ve fungal patojenlere göre biraz daha farklı bir yaklaşımı gerektirmektedir.

Bitki dokuları içindeki virüslere doğrudan antiviral etki kavramından anlamamız gereken biyo-kontrol ajanlarının bazı bileşikler üreterek virüsün çoğalmasını, replikasyonunu ya da kılıf protein üretimini engellemesidir. Öyle ki, fungal endofitlerden *Trichoderma asperallum*'un ürettiği antimikrobiyal bileşikler, CMV'nin bitki dokularında çoğalmasını engellemiştir (Tamandegani et al., 2021). Yapılan bazı araştırmalarda biyo-kontrol ajanlarının ürettiği antibiyotiklerin virüsle enfekte olmuş bitkilere verildiğinde virüslerin inhibisyonunun yanı sıra simptom ifadesinin de azalmasına yol açtığı bildirilmektedir (Kluge and Paunow, 1975; Misra and Nienhaus, 1977). Buna rağmen, antibiyotiklerin bitki virüslerine doğrudan etkileri, insan patojenleri üzerindeki etkileri kadar net bir şekilde aydınlatılamamıştır. Örneğin, kloramfenikolün bilinen birkaç antibiyotik aktivitesi arasında, esas olarak protein sentezine müdahale etmesi yer almaktadır (Malik, 1972). Aynı şekilde, antibiyotik daunomisin de birkaç protein sentezi basamağında etkiye sahiptir ve aktinomisin D'ye benzer olarak nükleik asit metabolizmasını engellemektedir (Conti, 1968). Ancak, daunomisinin konukçu bitki dokularındaki viral RNA sentezini önemsenebilecek düzeyde engellememesi, bu antibiyotiğin fitopatojen virüs partikülleri üzerinde doğrudan etkisi olduğunu düşündürmektedir (Betto et al., 1971).

Aktinobakteriler tarafından (özellikle *Streptomyces* spp.) üretilen aktinomisin D ve mitomisin C antibiyotiklerinin de nükleik asit metabolizmasını etkilediği ve DNA ile kompleks oluşturduğu tespit edilmekle birlikte, enfeksiyonun çok erken evreleri hariç bitki patojeni virüs sentezini engelleyebilecek kadar etkiye sahip olmadığı rapor edilmiştir (Dawson and Schlegel, 1976; Ohashi and Shimomura, 1972). Öte yandan CMV enfeksiyonlarının, DNA'ya bağımlı RNA sentezini engellediği bilinen miharamisin A antibiyotiği tarafından etkili şekilde baskılandığı birkaç çalışmada gösterilmiştir (Noguchi et al., 1968).

Ribonükleazlar, transkripsiyonun birkaç kritik aşamasında ribonükleik asitin (RNA'nın) daha küçük birimlere parçalanmasını dimerize ve katalize ederek virüs çoğalmasını engelleme özelliği olan bir grup hidrolitik enzim olup bağışıklık sisteminin klasik bileşenleridirler (Ilinskaya and Mahmud, 2014). Bakteriler tarafından sentezlenen ve dış ortama salınan binaz, baRNaz ve balifaz gibi ribonükleazların küçük konsantrasyonları, bitki büyümesini teşvik ederken; yüksek konstrasyonları viral RNA'nın yapısını bozarak antiviral özellik sergilemektedirler. *Bacillus* sp. TS2 ve *B. subtilis* 26D gibi yüksek endofitik oranlara ve RNaz aktivitesine sahip bakteriyel biyo-kontrol ajanları biyofungisit geliştirmek için kullanılmaktadır. Bilindiği üzere patates bitkilerinde yaygın olarak bulunan *Potato virus* S (PVS)+*Potato virus* Y (PVY) ve *Potato virus* M (PVM)+*Potato virus* Y (PVY) karşık enfeksiyonları, bu virüslerin tekli enfeksiyonlarına göre daha yüksek hastalık şiddetine neden olmaktadır (Hameed et al., 2014). Sorokan vd. (2020), yaptıkları çalışmada *Bacillus* sp. TS2, *Bacillus* sp. STL-7 ve *B. subtilis* 26D kültürlerinde daha yüksek oranda RNaz aktivitesi olduğunu ve bu endofit bakteri suşlarının birlikte uygulandığı durumda bitki dokularının içini daha iyi kolonize ettiğini göstermişlerdir. Ayrıca, bahsedilen bakteri konsorsiyumunun patates bitkilerinde PVM, PVS ve PVY tekli veya karşık enfeksiyon oranını ve hastalık şiddetini önemli ölçüde azalttığı rapor edilmiştir.

3.2. Bitki Savunma Mekanizmalarının Uyarılması ve Bitki Büyümesinin Düzenlenmesi

Biyo-kontrol ajanlarının bitki virüs hastalıklarıyla mücadelede sağladığı faydalardan en önemlisi bitki savunma mekanizmalarının uyarılmasını sağlayarak antiviral etki göstermesidir. Polisakkaritler, polisakkarit peptitler ve proteinler fungal biyo-kontrol ajanlarının ürettiği başlıca antiviral bileşiklerdir. *Trichoderma pseudokoningii* SMF2 fungusunun ürettiği peptaibol ve trikokoninler gibi antimikrobiyal maddeler, TMV'ye karşı dayanım sağlayan uyarılmış sistemik direnç (ISR) mekanizmasının belirleyici faktörüdür (Shen et al., 2009). Benzer şekilde, fungal ajanların ürettiği alkaloidlerin de antiviral özellikleri olduğu ortaya koyulmuştur (Wang et al., 2004). Örneğin *Trichoderma harzianum* ISR mekanizmasını aktive ederek domates bitkilerindeki TMV simptomlarını azaltmıştır (Kolase and Sawant, 2007).

Farklı bir *Trichoderma* türüyle yapılan başka bir çalışmada, *T. asperallum*'un CMV enfekteli hıyar bitkilerinde virüs enfeksiyonunu engellediği bildirilmiştir. Aynı çalışmada, *T. asperallum* tarafından uyarılan aracılı direncin altında yatan moleküler mekanizmalar Q-PCR (quantitive polymerase chain reaction) ile araştırılmış ve fungal biyo-kontrol ajanının, CMV'ye karşı dayanımla ilgili *pr1*, *pal1*, *etr1*, *sod*, *rip* ve *lox1* genlerinin ifadesini transkripsiyon seviyesinde etkili bir şekilde arttırdığı tespit edilmiştir. Reaktif oksijen türevleri (ROS) ve ROS temizleyici enzimlerin (SOD, LOX1, POX ve CAT) bitkide ifade edilme seviyesi incelendiğinde ise tek başına veya *T. asperallum* uygulandıktan sonra CMV ile inokule edilen bitkilerde gözlenen

hidrojen peroksit (H_2O_2) artışının önemli ölçüde birbirinden farklı olduğu gözlenmiştir. Ayrıca, sözü edilen çalışmada, ROS'un bitki savunma tepkilerinden sorumlu olduğu doğrulanmıştır. Sonuç olarak, Q-PCR ve enzimatik test sonuçları, jasmonik asit (JA)/etilen (ET)/salisilik asit (SA) üretimi ile ilgili genlerde ve enzimlerde önemli bir artış olduğunu göstermiş olup *T. asperallum*'un JA/ET/SA sinyal yolunu aktive ederek CMV'ye karşı sistemik direnci uyardığı düşünülmüştür (Tamandegani et al., 2021).

Streptomyces türleri başta olmak üzere 80'den fazla aktinobakteri cinsi bitki korumada etkin olarak kullanılan sekonder metabolitleri yoğun olarak üretmektedir. Biyofungisit formülasyonlarının %50'si aktinobakteri veya onların sekonder metabolitlerinden oluşmaktadır (Magarvey et al., 2004). Aktinobakteri *Strepcomces noursei* var. *xichangensis*'ten ekstrakte edilen ve yeni bir sitozin nükleozit peptit bileşiği formundaki antibiyotik ningnanmisin, bitkisel üretimde kullanıldığında TMV enfeksiyonlarını engellemede en başarılı olan mikrobiyal biyofungisittir (Zhao et al., 2015). Ningnanmisin, bitkide birden fazla savunma mekanizmasını uyarmaktadır. Yapılan çalışmalarda bu antimikrobiyal metaboltin peroksidaz (POD), fenilalanin amonyak liyaz (PAL), süperoksit dismutaz (SOD) aktivitesinin uyarılması ve asidik PR (patojen related: patojenle ilişkili) proteinleri grubunun aktivasyonu yoluyla TMV ile enfekte olmuş bitkilerde virüse karşı artan dirençten sorumlu olabileceği ortaya koyulmuştur. Ayrıca, bitkide *NPR1* ve *Jaz3* genlerinin artan ifadesinin TMV'nin kılıf protein sentezlemesini engelleyici etkisi olduğu yapılan çalışmalarla kanıtlanmıştır (Han et al., 2014).

Uzun yıllardır antibiyotiklerin bitki patolojisinde, özellikle de bitki virolojisinde kullanımının kritik öneme sahip olduğu varsayılmaktadır. Galal (2006), *Streptomyces* türlerinin virüs enfeksiyonlarına karşı bitkilerde sistemik kazanılmış direnci (SAR) teşvik ettiğini; Li vd. (Li et al., 2018) ise *S. pactum* Act12'nin domates bitkilerinde TYLCV'ye karşı ISR mekanizmalarını aktive eden SA ve JA konsantrasyonlarını arttırdığını bildirmişlerdir. Endonükleazları ve çeşitli fitohormonları salgılayan *Bacillus subtilis* 26D ve *B. subtilis* Ttl2 bakteri suşlarının patates bitkilerinde *Potato virus* X (PVX) ve PVY'yi inhibe ettiği rapor edilmiştir. 26D ve Ttl2 suşlarının her ikisi de transkripsiyonel genleri aktive ederek bitkilerde ISR'yi tetiklemiş ve PVX veya PVY ile enfekteli bitkilerde büyüme düzenleyici hormonlardan stokininlerin miktarını arttırırken, indol asetik asit seviyesini azaltmıştır (Veselova et al., 2022).

4. MİKROBİYAL BİYOFUNGİSİTLERİN KULLANIMINDAKİ ZORLUKLAR VE GELECEKTEKİ ARAŞTIRMA YÖNELİMLERİ

Literatürden de anlaşılacağı üzere mikrobiyal biyofungisitler, virüsler de dahil bitki patojenlerinin kontrolünde gelecek vaat etmektedir. Öte yandan, mikrobiyal kaynaklı bu preperatların kullanımı ve etkililiği konusunda bazı zorluklar ve sınırlılıklar bulunmaktadır. Birçok araştırmacı, özellikle ticari olmayan biyolojik ajanlardan geliştirdikleri mikrobiyal biyofungisitleri kullanarak bitki hastalıklarının kontrolü açısından laboratuvarda ve sera gibi kontrollü koşullarda büyük başarılar elde etmiştir. Ancak bu başarı üretim alanlarına yani sahaya aktarılmak istendiğinde bitki hastalıklarının tutarlı bir şekilde kontrol altına alınamamasıyla sonuçlanmıştır (Nicot et al., 2016). Mikrobiyal biyofungisitlerin sahada tutarsız sonuçlar vermesi ve etkinliklerinin azalmasının bazı nedenleri bu bölümde ele alınmıştır.

4.1. Ürün Geliştirme ve Formülasyon

Mikrobiyal biyofungisitler başta olmak üzere genel olarak biyofungisitlerin sahaya aktarımı, çoğu kez zor olmuştur (Handelsman, 2002). Bu durum formülasyon ve dolayısıyla ürün geliştirmenin zor olmasından kaynaklanmaktadır. Biyo-kontrol ajanlarını canlı, etkililiğini kaybetmeden ve amacına uygun şekilde kullanılabilir özellikte tutmak için özel formülasyon ve depolama teknikleri gerekmektedir (Usta, 2013). Biyo-kontrol ajanlarını diğer kontrol tekniklerinden ayıran en önemli özellik, canlı olmalarıdır. Ortam koşullarının (mikro iklim) değişimine oldukça hassas olmalarından dolayı mikrobiyal biyofungisitler için özel formülasyonlara ihtiyaç duyulmasının yanında, bu biyofungisitlerin depolanması, sevkiyatı ve kullanımı sırasında da özel işlemler gerekebilmektedir (Elad and Stewart, 2007).

Mikrobiyal biyofungisitlerdeki biyo-kontrol ajanı veya onun ürettiği sekonder metabolitlerin konsantrasyonu, ürün formülasyonunda karşılaşılan bir diğer sorundur. Yapılan in vitro ve in vivo denemede, pek çok faktörün biyolojik kontrol ajanının veya ürettiği sekonder metabolitlerin konsantrasyonunu değiştirebileceği sonucuna varılmıştır (Fenta and Menkonnen, 2024). Örneğin, *Trichoderma pseudokoningii* SMP2'nin ürettiği trichokoninler, pürifiye edilerek TMV enfekteli tütün bitkilerine uygulanmıştır. Bu peptaibol bileşiklerinin 100 nM konsantrasyonda viral RNA'yı %60 oranında azaltarak belirti şiddetinde düşüşe sebep olduğu belirlenmiştir. Ancak bu dozun üretim alanlarında etkili olup olmadığı konusunda daha fazla araştırmaya ihtiyaç olduğu rapor edilmiştir (Mendoza-Figueroa et al., 2014). Ayrıca, yapılan pek çok çalışmada etkili virüs kontrolünün bakteriyel biyo-kontrol ajanının konsantrasyonu, uygulama zamanı ve uygulama yöntemine bağlı olduğu bildirilmiştir (Manjunatha et al., 2022).

Biyofungisit üretim proseslerinin ürün canlılığı ve etkinliği üzerinde etkisinin oldukça fazla olması da biyolojik kontrol ürünlerinin geliştirilmesinde karşılaşılan bir diğer zorluktur. Yapılan çalışmalarda, konidial yaş ve üretim sıcaklığı da dahil olmak üzere birçok faktörün, fungal biyo-kontrol ajanlarının çimlenmesi ve biyoaktivitesi üzerinde önemli etkisi olduğu tespit edilmiştir. Örneğin, *Trichoderma atroviride* 25°C'de maksimum gelişme potansiyeline ulaşırken, maksimum çimlenme ve biyoaktivite 30°C'de üretilen konidilerde gözlenmiştir (Fenta and Menkonnen, 2024). Bu durum kültür koşullarının mikrobiyal biyofungisitlerin formülasyonları üzerinde önemli bir etkiye sahip olduğu anlamına gelmektedir.

Mikroorganizmalardan elde edilen ve biyolojik kontrol etkinliği olan çeşitli sekonder metabolitler, genellikle düşük miktarlarda bulunmakta ve büyük ölçekte saflaştırılmaları ise oldukça zor olmaktadır (Jairo et al., 2012). Mikroorganizma bazlı metabolitlerin standartlaştırılmış ekstraksiyon yöntemlerinin olmaması ürün geliştirme konusunda yaşanan temel sorunlardan biridir. Farklı ekstraksiyon yöntemleri, hastalık kontrol ürünlerini farklı şekilde etkilemekte, dolayısıyla bu durum geliştirilen formülasyonun etkinliğini de değiştirmektedir. Örneğin, *T. harzianum*, *T. viride* ve *T. longisporum* gibi fungal biyo-kontrol ajanı hücresiz kültür özütlerinin domateste TMV'yi inhibe etmede etkili olduğu kanıtlanmıştır. Farklı çözücülerde ekstrakte edilen biyo-kontrol ajanlarının etkinlikleri de farklı olmuştur. Yapılan çalışmada benzen ve asetonda ekstrakte edilen *Trichoderma* türleri daha etkili olurken, bunu etil alkol ekstraktları izlemiştir. Çalışmanın diğer bölümünde ise asetonda ekstrakte edilen *T. harzianum* ve etil alkolde ekstrakte edilen *T. viride* kombinasyonunun domates bitkilerindeki TMV enfeksiyonlarının kontrolünde daha etkili olduğu sonucuna varılmıştır (Kolase and Sawant, 2007).

4.2. Birden Fazla Konukçuyu Etkileyen Bir Virüs İçin Ürün Geliştirilmesi

Fitopatojenlerin biyolojik olarak kontrol etmenin zorlukları arasında ürün geliştirme sorunu da yer almaktadır. Yaygın ve birden fazla konukçuyu etkileyen hastalıklarının kontrolü için geliştirilen ürünler, ancak tüm konukçulara ve farklı üretim sistemlerine entegre edilebildiğinde optimum başarı sağlamaktadır. Virüslerin karmaşık yapısı, bitkilerle ve diğer organizmalarla olan etkileşimleri, farklı konukçularda ve coğrafi koşullarda etkili çözümler oluşturmayı zorlaştırmaktadır (Nega, 2014). Ayrıca, yapılan pek çok araştırmada fungal endofitler tarafından bitkilerde tetiklenen savunma tepkilerinin aynı bitki türünü enfekte eden farklı virüslere karşı aynı olmadığı görülmüştür. Örneğin *Trichoderma harzianum* ve *Metarhizium anisopliae* uygulanmış mısır bitkileri, endofit uygulaması yapılmamış kontrol bitkilerine kıyasla *Sugarcane mosaic virus* (SCMV)'e daha fazla dayanım gösterirken, aynı bitkiler *Maize chlorotic mottle virus* (MCMV)'e daha hassas tepkiler vermiştir (Kiarie et al., 2020).

4.3. Çevresel Değişkenlerin Mikrobiyal Biyofungisitler Üzerindeki Etkileri

Biyolojik mücadele ajanlarının farklı iklim ve çevre koşullarına uyum sağlama yeteneği ve çeşitli senaryolarda hedef hastalığa karşı önemli bir etkinliğe sahip olup olmaması, sera ve tarla koşullarındaki etkinliğini belirleyen en temel faktördür. Özellikle sıcaklık, bağıl nem ve UV ışınlar biyo-kontrol ajanlarının ömrünü etkileyen başlıca unsurlardır (Nunes, 2012). Sözü edilen bu çevresel faktörler, sera ortamında kolay bir şekilde kontrol altında tutulabilirken tarlada biyo-kontrol ajanları ve onların antimikrobiyal özelliğe sahip sekonder metabolitleri, sürekli olarak sıcaklık ve bağıl neme maruz kalmaktadır.

Biyolojik mücadele teknikleri, patojenin enfeksiyon yapması için gerekli çevresel koşullar ile biyo-kontrol ajanlarının gelişmesi için ihtiyaç duyduğu ortam koşullarının uyumsuz olması nedeniyle çoğu kez başarısızlıkla sonuçlanmaktadır. Örneğin, yapılan bir çalışmada *N. benthamina* bitkilerinde PVY enfeksiyonlarının en iyi 10-20ºC'de geliştiği, 20ºC'nin üzerindeki sıcaklıklarda ise enfeksiyonda gerilemeler olduğu tespit edilmiştir (Chung et al., 2016). Bu virüsü kontrol eden *Trichoderma* türleri, 25-30ºC'de en iyi şekilde gelişim göstermektedir (Singh et al., 2014). Biyolojik kontrol ajanlarının en iyi geliştiği, dolayısıyla etkinliğinin en yüksek olduğu sıcaklık derecelerinde PVY bitkide zaten kolonize olmuş ve enfeksiyonları ciddi boyutlara ulaşmış olacaktır.

Çevresel faktörler, ayrıca fitopatojen virüslere karşı bitki savunma mekanizmalarının endofitlerle uyarılmasında da önemli rol oynamaktadır. Örneğin, domates bitkilerine *Piriformospora indica* uygulanması, daha yüksek ışık yoğunlukları altında sürgünlerdeki *Pepino mosaic virus* miktarını azaltırken, meyve biyokütlesini önemli ölçüde arttırmaktadır (Fakhro et al., 2010). Özetlediğimiz tüm bu nedenlerden dolayı, bitki virüs hastalıklarının etkili bir şekilde biyolojik kontrolü için farklı çevre koşullarında etkili olabilen farklı biyo-kontrol ajanlarının veya ürettikleri metabolitlerin bir arada yer aldığı formülasyonların geliştirilmesi gerekebilmektedir.

4.4. Uygulama Süresi ve Diğer Ürünlerle Karışabilirlik

Mikrobiyal fungisitlerin bitki virüs hastalıklarına etkisi koruyucu ve bitki savunmasını uyarıcı nitelikte olup tek başına herhangi bir virüs hastalığını tedavi etme durumu oldukça nadirdir (Hodgson et al., 2014). Bu nedenle, biyo-kontrol ajanlarının etkili şekilde kullanılmasını sağlamak için bilgi yoğun bir hastalık yöntemine ihtiyaç duyulmaktadır. Patojenin biyolojisinin ve konukçu virüs etkileşimlerinin bilinmesi, biyo-kontrol ajanının ne zaman ve nerede kullanılması gerektiğinin belirlenmesi ve en iyi hastalık yönetimi stratejisinin geliştirilmesinde yardımcı olabilmektedir. Bir biyo-kontrol ürününün en iyi uygulama süresinin, uygulamanın yapıldığı zaman dilimine bağlı olduğu tespit edilmiştir (Arnold et al., 2000).

Virüs hastalıklarının etkin bir şekilde kontrol edilmesi için birçok koruyucu önlemin bir arada kullanıldığı entegre mücadele stratejilerinin uygulanması önem taşımaktadır. Mikrobiyal fungisitlerin antiviral etkilerinden yararlanılırken, virüs hastalıklarının yayılmasını sağlayan vektörlerle ve virüs rezervuarı yabancı otlarla mücadele adımı çoğu kez göz ardı edilememektedir. Bu nedenle, üretim alanlarında hem biyolojik kontrol ajanı uygulaması hem de vektörlere veya virüs kaynağı yabancı otlara karşı sentetik pestisit uygulaması kaçınılmaz olmaktadır. Mikrobiyal biyofungisitler canlı organizma kaynaklı formülasyonlar olduğundan sentetik pestisitlerle veya bitki besin elementleriyle karışmaları durumunda nasıl bir senaryonun ortaya çıkacağı bilinmek zorundadır. Bu konuyla ilgili netlik sağlanabilmesi için de daha fazla araştırmanın yapılması gerekmektedir.

5. SONUÇ VE ÖNERİLER

Bu çalışmada, *Streptomyces* spp., *Bacillus* spp. ve *Trichoderma* spp. kaynaklı yaygın şekilde kullanılan mikrobiyal biyofungisitlerin önemli bitki virüs hastalıkları üzerindeki potansiyel etkileri mevcut literatür ışığında kapsamlı bir şekilde değerlendirilmiştir. İncelenen çalışmalar, *Streptomyces*, *Bacillus* ve *Trichoderma* kaynaklı bazı metabolitlerin bitki sistemik direncini teşvik ederek ve bazen doğrudan antival etki göstererek TMV, ToMV, CMV, TSWV ve PVY başta olmak üzere farklı bitki virüslerinin enfeksiyonlarını önemli ölçüde azalttığını göstermiştir. Bu bulgular, mikrobiyal fungisitlerin doğrudan kimyasal mücadelesi mümkün olmayan virüs hastalıklarına karşı alternatif kontrol yöntemi olabileceğinin altını çizmektedir.

Mikrobiyal biyofungisitlerin etkinliği uygulanan doz, uygulama zamanı ve süresi, çevresel koşullar ve diğer pestisitlerle veya farklı biyolojik kontrol ürünleriyle karışabilme durumuna göre değişkenlik gösterebilmektedir. Farklı biyofungisit gruplarının birlikte kullanılması durumunda, çeşitli virüs-bitki etkileşimlerine etkisi daha detaylı bir şekilde araştırılmalıdır. Ayrıca, mikrobiyal biyofungisitlerin tarla koşullarındaki uzun vadeli performansı ve ekonomik uygulanabilirliği konularında daha fazla araştırmaya ihtiyaç bulunmaktadır.

Konuyla ilgili gelecekte yapılacak araştırmalarda, farklı biyofungisit grubu karışımlarının ve kimyasal mücadele yöntemleriyle entegrasyonunun bitki virüs hastalıklarına potansiyel birleşik veya sinerjik etkileri üzerine yoğunlaşılmalıdır. Ayrıca, mikrobiyal biyofungisitlerin bitkiler ve virüsler üzerindeki etki mekanizmalarının moleküler düzeyde aydınlatılması, daha özgül ve yüksek etkili biyolojik kontrol stratejilerinin geliştirilmesinin önünü açacaktır. Sonuç olarak, mikrobiyal biyofungisitlerin bitki virüs hastalıklarına potansiyel etkileri umut vaat etmektedir. Bu çalışmalar, biyo-kontrol ajanlarının ve ürettikleri metabolitlerin fitopatojen virüslerin kontrolüne özgüleştirilmesi ve ileride virüsit formülasyonlarının geliştirilmesine ışık tutucu niteliktedir.

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EFFECT OF RAW PHOSPHATE AND ELEMENTAL SULFUR TREATMENTS ON AVAILABLE PHOSPHORUS CONTENT OF SOILS

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ABSTRACT

Phosphorus (P) is one of the most important macro plant nutrients for optimum growth and development of plants. Plants' P needs are met by the application of P fertilizers to soils. Phosphorus fertilizers are obtained from raw phosphate materials. Direct application of raw phosphate to basic soils does not provide a significant contribution to the P nutrition of plants.. The aim of this study was to determine the effect of applying raw phosphate materials and elemental sulphur to soils on available phosphorus content. Raw phosphate is a material obtained by grinding rock phosphate and is stable under natural conditions and does not turn into a form that plants can take up. In this study, soil taken from an area with low available P content, raw phosphate and elemental sulphur were used as materials. The experiment was carried out in the form of a pot experiment according to a randomized plot design with 3 replications. 0, 0.08 g, 0.16 g, 0.32 g powdered raw phosphate and 0, 0.08 g, 0.16 g, 0.32 g elemental sulphur were applied to the soils (1 kg) and mixed thoroughly. Samples were taken from the soils brought to field capacity on the 45th, 90th and 135th days and the soils were analysed. According to the obtained data, elemental S and raw phosphate application decreased the pH value of the soils at a statistically significant level ($p<0.01$) at the end of the experiment. In the application of elemental S and raw phosphate to the soils, the available P concentrations in the soils increased depending on the raw phosphate dose and this increase was found to be statistically significant ($p<0.01$). This situation shows that the application of raw phosphate

materials mixed with elemental S can be considered as an alternative for feeding plants with P. However, it would be beneficial to test the application with detailed field trials.

Keywords: Soil, Raw Phosphate, Elemental Sulfur, Available Phosphorus

TOPRAKLARA HAM FOSFAT VE ELEMENTEL KÜKÜRT UYGULAMALARININ ALINABİLİR FOSFOR İÇERİĞİNE ETKİSİ

ÖZET

Fosfor (P), bitkilerin optimum büyümesi ve gelişmesi için en önemli makro bitki besin elementlerinden birisidir. Bitkiler P ihtiyacı, fosforlu gübrelerin topraklara uygulaması ile karşılanmaktadır. Fosforlu gübreler ise ham fosfat materyallerinden elde edilmektedir. Ham fosfatın bazik topraklara direk uygulanması bitkilerin P ile beslenmesine önemli bir katkı sağlamamaktadır. Bu çalışmanın amacı; ham fosfat materyali ile elementel kükürdün (S) topraklara birlikte uygulanmasının bitkiler tarafından alınabilir P içeriği üzerine etkisini belirlemektir. Ham fosfat, fosfat kayasının öğütülmesi ile elde edilen bir materyal olup bazik koşullarda stabil kalmakta ve bitkilerin alınabileceği forma dönüşmemektedir. Bu çalışmada materyal olarak daha alınabilir P içeriği düşük alandan alınan toprak, ham fosfat ve elementel kükürt kullanılmıştır. Deneme tesadüf parselleri deneme desenine göre 3 tekerrürlü olarak saksı denemesi şeklinde yürütülmüştür. Topraklara (1 kg) 0, 0.08 g, 0.16 g, 0.32 g dozlarında toz haline getirilmiş ham fosfat ve 0, 0.08 g, 0.16 g, 0.32 g elementel kükürt uygulanıp iyice karıştırılmıştır. Tarla kapasitesine getirilen topraklardan 45., 90. ve 135. günlerde örnekler alınmıştır ve topraklarda alınabilir P analizleri yapılmıştır. Elde edilen verilere göre elementel S ve ham fosfat uygulaması deneme sonunda toprakların pH değerini istatistiksel olarak önemli ($p<0.01$) düzeyde azaltmıştır. Topraklara elementel S ve ham fosfat uygulamasında topraklarda alınabilir P içeriği ham fosfat dozuna bağlı olarak artış göstermiştir ve bu artış istatistiksel olarak önemli ($p<0.01$) bulunmuştur. Bu durum, ham fosfat materyallerinin elementel S ile karıştırılarak uygulanmasının, bitkilerin P ile beslenmesinde bir alternatif olarak değerlendirilebileceğini göstermektedir. Ancak, uygulama açısından detaylı tarla denemeleri ile arazi koşullarında test edilmesinde fayda vardır.

Anahtar Kelimeler: Toprak, Ham Fosfat, Elementel Kükürt, Alınabilir Fosfor

1.GİRİŞ

Türkiye topraklarının genel olarak organik madde içeriği az, % kireç içeriği ve pH'sı yüksek olduğu için topraklara gübreler ile uygulanan fosfor (P), bitkiler tarafından alınamaz forma dönüşür. Topraklara uygulanan fosforun ancak %10-30 bitkiler tarafından alınabilir (Korkmaz ve ark., 2009; Saltalı ve Nedirli, 2021). Fosfor bitki gelişimi için mutlaka gerekli makro bitki besin elementlerinden birisidir. Fosfor; bitkinin bünyesi, kök gelişimi, verim ve kalite, enerji dönüşümü ve taşınması, enzimatik reaksiyonlar, generatif üreme vb. alanlarda etkili bir elementtir (Korkmaz ve ark., 2004).

Yüksek pH'lı topraklarda P fiksasyonunu azaltmak ve alımını artırabilmek için bu toprakların pH'sının optimum seviyelere düşürülmesi gerekmektedir (Güneş ve ark., 2000). Kahramanmaraş topraklarının kireç miktarının yüksek olması pH seviyelerini yükseltmektedir. Bu durumda kükürt (S) uygulamasının bölgede etkili olabileceği tahmin edilmektedir. Kükürt uygulamalarının P yarayışlılığı üzerine etkisine dair farklı çalışmalar gerçekleştirilmiştir. Chouliaras ve Tsadilas (1996), kireçli topraklarda S uygulamalarının toprak pH'sını düşürmesi ile yarayışlı P, demir (Fe) ve mangan (Mn) konsantrasyonlarında önemli miktarda artışların olduğunu rapor etmişlerdir. Erdal ve ark., (2000) da benzer şekilde kireçli topraklarda S uygulamalarının pH seviyesini düşürdüğünü ve buna bağlı olarak mısır bitkisinde P alımının arttığını rapor etmişlerdir. Nour ve Elfaki (2019)'de, alkalin topraklara elementel S0 uygulamasının toprak reaksiyonun azalmasına ve topraklarda alınabilir P içeriğinin artmasına neden olduğunu, bu nedenle bazik topraklarda alınabilir P içeriğinin artırılması için elementel S0 uygulamasını önermişlerdir.

Kurak ve yarı kurak bölgelerde alkalin veya kireçli toprakların pH'nın düşürülmesi amacıyla elementel S0 kullanılabilmektedir. Bu uygulamalar sadece toprak pH'sını düşürmekle kalmayıp birçok besin elementinin yarayışlılığını da arttırmaktadır. (Mengel ve ark., 2001). Toprak pH'sının biyoaktiviteyi ve besin maddelerinin bitkiler için kullanılabilirliğini etkilediğini ileri sürmektedir. Alkalin topraklarda elementel S0 kullanımı toprak pH'sını düşürmekte, bu da bitki besin maddelerinin, özellikle de fosforun kullanılabilirliği için uygun koşullar yaratmaktadır (Deluca ve ark., 1989). Aynı zamanda, kireçli topraklara elementel S0 uygulanması Fe klorozunun düzeltilmesine de yardımcı olmaktadır (Saroha ve Singh 1980).

Kireçli ve alkalin topraklara uygulanan elementel S0, toprakta 3-4 ay içerisinde oksidasyona uğrayarak önce SO4 formuna oksitlenmekte daha sonra H2SO4'e dönüşmektedir. Kükürdün oksitlenerek H2SO4'i oluşturması toprak reaksiyonunun azalmasına ve topraklarda stabil besin elementlerinin çözünürlüklerinin artmasını sağlamaktadır (Mengel ve ark., 2001). Topraklarda kükürdü, kükürt oksitleyici bakteriler okside etmekte (Etesami ve Jeong, 2021) ve okside kükürt ile üretilen asitli bileşikler de topraklarda alınamaz formda bulunan fosforun çözünürlüğünü artırmaktadır (Khan ve ark., 2020).

Toprağa uygulanan elementel S0 etkinliği, parça iriliği, uygulama dozu, uygulama zamanı ve uygulama yapılan toprağın pH değeri gibi özelliklere bağlıdır (Ülgen ve Yurtsever, 1988; Aktaş, 1991). Bu konu ile ilgili yapılan çalışmalarda, Elementel S0' ün parça büyüklüğü azaldıkça oksidasyonunun hızlandığı ve alkalin toprağın S oksidasyonunun artırıldığı bildirilmiştir (Nor ve Tabatabai, 1977; Li ve Caldwell, 1966; Attoe ve Olsen,1966).

Orman ve Kaplan (2000), aşırı kireçli ve yüksek kireçli iki farklı topraklara, artan dozlarda uygulanan elementel S0 ve Keçiborlu Kükürt Fabrikası flotasyon atığını uygulamışlardır.

Deneme sonucunda 5. ve 10. haftalarda ölçülen pH değerlerinin 0.35– 1.05 birim düştüğünü görmüşler ve bu düşüşlerin istatistiksel açıdan önemli olduğunu bulmuşlardır. Elementel S0 uygulamasının toprak pH'sı üzerine yapılan başka bir çalışmada alkalin reaksiyonlu topraklara S0 uygulamalarında, %2'lik kükürt dozunun pH'yı 7.80'den 7.17'ye düşürerek en etkili doz olduğunu belirtilmiştir (Pınar, 1994).

Ham fosfat kaynaklarından elde edilen fosforlu gübreler, alkalin ve kireçli topraklara uygulandıklarında, Ca ve kireç ile reaksiyona girerek zaman içerisinde çözünemez formlarda kalsiyum fosfatlı bileşikleri oluşturmaktadır (Korkmaz ve ark., 2009). Türkiye topraklarının genellikle alkalin reaksiyon gösterdiği ve kireç içerdiği dikkate alındığında fosfor elementinin bu topraklarda yarayışlılığı düşük olan kalsiyum fosfatlar biçiminde çökelmesi kaçınılmazdır. Fosforun topraktaki optimum çözünürlüğünün pH 6.5-7.0 aralığında olduğu göz önünde bulundurulduğunda ülkemizde kurak ve yarı kurak bölgeler topraklarında da bu türden reaksiyonlar gelişmektedir.

Son yıllarda gübre fiyatlarının hızla artması fosforlu gübrelere göre maliyeti daha düşük kaynaklara yönelimi artırmıştır. Fosforlu kimyasal gübre uygulama maliyetini azaltmak için alternatif besin girdisi kaynaklarının kullanımı, bitkisel üretim maliyetini azaltacağı tahmin edilmektedir. Sentetik gübre kullanımını azaltmanın böyle bir yolu, bitkilere kullanılabilir fosfor sağlamak için sentetik fosfatlı gübrelerden daha ucuz olduğu düşünülen fosfat kayası (PR) kullanımıdır (Lorion, 2004). Kaya (ham) fosfatları fosforlu gübrelerin ham maddesini oluşturmaktadır. Bu mineralin asitlerle reaksiyonu sonucunda ise fosforlu kimyasal gübreler elde edilmektedir. Bu durum, endüstriyel işlemler gerektirdiğinden maliyetli bir işlemdir. Ham fosfatlar asit topraklara uygulandığında fosforlu gübrelerin yerine geçebilmekte ve maliyetin düşmesine neden olabilmektedir.

Ham fosfat, fosfat kayasının öğütülmesi ile elde edilen bir materyal olup bazik koşullarda stabil kalmakta ve bitkiler tarafından alınabilir forma dönüşmemektedir. Ham fosfatların bazik topraklara elementel S0 ile birlikte uygulandığında kükürdün oksitlenmesi ve asidik bileşiklerin oluşması ile toprak reaksiyonunun azalacağı ve toprakta alınabilir P içeriğini artıracağı tahmin edilebilmektedir. Bu durumda, fosforlu gübreler yerine elementel S0 ile ham fosfatların uygulaması mümkün olabilecek ve fosforlu gübre maliyeti de azalabilecektir. Bu tür çalışmaların farklı toprak ve iklim koşullarında araştırılmasına ihtiyaç vardır.

Bu çalışmanın amacı; topraklara farklı dozda ham fosfat ve elementel S0 uygulamalarının toprakların alınabilir P içeriğine etkisini araştırmaktır.

2.MATERYAL VE METOT2.1. MATERYAL

Bu çalışmada, alkalin ve kireçli toprak, Mısır'dan ithal edilen ham (kaya) fosfat ve elementel S0 materyal olarak kullanılmıştır.

2.2. METOT

Deneme tesadüf parselleri deneme desenine göre 3 tekerrürlü olarak saksı denemesi şeklinde yürütüldü. Ham fosfat toplam %25 P2O5 içermektedir. Topraklara öğütülmüş 0.08 g kg-1 (20 kg da-1 ham fosfat = 5 kg P2O5 da-1), 0.16 g kg-1 (40 kg da-1 ham fosfat = 10 kg P2O5 da-1)

ve 0.32 g kg-1 (80 kg da-1 ham fosfat = 20 kg P2O5 da-1) ham fosfat ile 0.08 g kg-1 (20 kg da-1), 0.16 g kg-1 (40 kg da-1), 0.32 g kg-1 (80 kg da-1) elementel kükürt (S0) karıştırılarak uygulandı. Ham fosfat ve elementel S0 topraklar ile homojen olacak şekilde karıştırıldı. Ardından topraklara 400 ml su uygulanarak tarla kapasitesine getirildi. İhtiyaca göre zaman içerisinde saksılara tarla kapasitesine getirilecek düzeyde su ilave edildi. Deneme yaklaşık 5 ay sürdü ve 45., 90. ve 135. günlerde toprak örnekleri alındı. Denemede saksı içerisindeki topraklardan 3 derinlikten (en üst kısım, orta ve alt kısım) olmak üzere örnekler alınmıştır. Alınan örnekler gölgede kurumaya bırakılmıştır. Kuruyan örnekler ağzı kilitli poşetlere koyularak serin bir ortamda muhafaza edilmiştir.

Toprak örneklerinde pH değeri 1/2.5 toprak su oranı kullanılarak oluşturulan çözeltilerde cam elektrotlu pH metre ile ölçülmüştür. Aynı çözeltide EC metre ile elektriksel iletkenlik değeri belirlenmiştir (Black, 1965). Toprak örneklerinden % kireç içeriği kalsimetre yöntemine göre bulunmuştur (Gülçur, 1974). Toprak örneklerinde P tayini) Olsen ve Sommers (1982) tarafından bildirilen 0.5 M NaHCO3 yöntemine göre yapılmıştır (Kuo,1996). Organik madde Nelson ve Sommers (1996), tekstür ise Gee ve Bouder (1986) tarafından geliştirilen yönteme göre yapılmıştır.

Araştırmada elde edilen verilerin karşılaştırılması için varyans analizi (ANOVA) yapıldı ve ortalamalar arasındaki farklılıkların belirlenmesinde Tukey Çoklu Karşılaştırma Testi kullanılmıştır.

3. BULGULAR ve TARTIŞMA

Deneme kullanılan topraklar ve ham fosfata ait özellikler Çizelge 1'de verilmiştir.

Çizelge 1. Denemede kullanılan toprakların ve ham fosfatın bazı özellikleri

Toprak ve Ham Fosfat Özellikleri	Birimler	Değeri	
Toprak			
Silt	%	11	
Kum	%	71	
Kil	%	18	
pH	1/2.5	7.80	
EC	µS cm^{-1}	330	
Organik Madde İçeriği	%	2.01	
Kireç	%	18.84	
Fosfor (P)	mg kg^{-1}	5.90	
Ham Fosfat			
pH*	-	2.43	18.10
EC*	dS m^{-1}		
Toplam P	%	25	

*Ham fosfat pH ve EC değerleri 1/12.5 oranında belirlenmiştir.

Denemede kullanılan topraklar alkalin ve fazla kireçli sınıfında yer almakta olup tekstürü kumlu killi tındır. Araştırma materyali olarak kullanılan ham fosfatın toplam P içeriği % 25,

elementel kükürdün (S0) toplam S ise % 98'dir. Toprağın organik madde içeriği orta düzeyde olup fosforu azdır.

3.1. Elementel Kükürt (S0) ve Ham Fosfat Uygulamasının Toprakların pH ve % Kireç İçeriğine Etkisi

Araştırmada 45. gün ham fosfat ve elementel S0 uygulamalarının ortalama toprak pH değerleri üzerine etkisi incelendiğinde çok azda olsa bir düşme söz konusudur (Çizelge 2). Ancak, ham fosfat ve elementel S0 uygulamalarının toprak pH değeri üzerine etkisi istatistiksel olarak önemli değildir. Çizelge 2'de görüldüğü gibi ortalamalar aynı grupta yer almaktadır. Elementel S0 ve ham fosfat uygulamalarının 90. günde toprak pH değerleri üzerine istatistiksel olarak önemli düzeyde bir etki göstermemiş olup aynı grupta yer almıştır. Denemenin 135. Gününde elementel S0 uygulama dozuna bağlı olarak toprak pH değerleri azalmıştır ve bu azalma istatistiksel olarak $p<0.01$ düzeyinde önemli bulunmuştur.

Çizelge 2. Elementel S0 ve ham fosfat uygulamalarının pH ortalama değerleri

		Ham fosfat dozları (kg da^{-1})				
45. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	7.99	8.01	8.02	8.04	8.02
	20	7.95	8	7.97	7.95	7.97
	40	7.92	7.98	7.94	7.92	7.94
	80	7.91	7.93	7.89	7.90	7.91
	Ort.	7.94	7.98	7.95	7.95	
		Ham fosfat dozları (kg da^{-1})				
90. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	7.95	7.9	8	7.93	7.94
	20	7.93	7.89	7.94	7.91	7.92
	40	7.92	7.86	7.91	7.90	7.90
	80	7.90	7.8	7.87	7.88	7.86
	Ort.	7.93	7.86	7.93	7.91	
		Ham fosfat dozları (kg da^{-1})				
135. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	8.01ab	8.28a	8.04ab	8.02ab	8.09A**
	20	8ab	8.03ab	7.93b	7.96ab	7.98AB
	40	7.96ab	8ab	7.92b	7.86b	7.94BC
	80	7.87b	7.94b	7.76b	7.74b	7.83C
	Ort.	7.96AB	8.06A*	7.91B	7.90B	

**:$p<0.01$, *:$p<0.05$

Elementel kükürdün farklı dozlarının uygulanmasında, ortalama değerler açısından en yüksek pH değeri 0 kg da-1 kükürt uygulama dozunda 8.09 olarak elde edilirken en düşük pH değeri 80 kg da-1 elementel S0 uygulamasında (pH: 7.83) elde edilmiştir. Elementel S0 uygulaması ile 135 günde alınan topraklarda toprak pH değerinin azalması, elementel kükürdün zamanla asit bileşikler oluşturacak şekilde oksitlenmesine ve asidik bileşiklerin ($2S+3O2+ 2H2O \rightarrow 2H2SO4$) toprak pH'sını düşürmesine bağlanabilir. Güneri ve ark. (2009), yüksek kireçli ve alkalin topraklara elementel S0 uygulamasının toprakların pH değerlerinin düşürülmesinde

etkili olduğunu ve bu nedenle bu tür topraklarda yetiştirilen portakalın verim ve kalitesinin artırılması için elementel S0 uygulamasını önermişlerdir. Cui ve ark. (2004), topraklara 200 mmol S uygulaması ile 7.7 olan toprak pH değerinin 54 gün sonra 0.30 birim düştüğünü rapor etmiştir. Okalebo ve ark. (2006), yaptığı bir çalışmada, S uygulamasının toprak pH'sını önemli düzeyde düşürdüğünü belirtmişlerdir. Yapılan diğer bir çalışmada ise kireçli topraklara uygulanan kükürt dozunun artmasına bağlı olarak toprak pH'sının 5. haftaya kadar düştüğü belirlenmiş olup ve sonraki haftalarda toprak pH'sında artış başladığı tespit edilmiştir (Parham ve ark., 2002). Yüksek kireçli topraklara asit bileşikler uygulamasının başlangıçta toprak pH değerini düşürdüğü ve zamanla bu düşüşün kalıcı olmadığı ileri sürülmektedir (Maltaş ve Kaplan, 2016).

Elementel S0 ve ham fosfat ve uygulamalarının 45., 90. ve 135. günde toprağın %kireç içeriği üzerine etkisi Çizelge 3'te verilmiştir. Çalışmada 45. gün elementel S0 uygulama dozlarında toprakların %kireç içeriği en yüksek kontrol grubunda 19.85, en düşük 40 kg da-1 dozunda 18.21 bulunmuştur. Ham fosfat x elementel S0 interaksiyonu $p<0.05$ düzeyinde önemli bulunmuştur. Ancak, elementel S0 dozlarından 0 ile 80 kg da-1 uygulama dozu aynı grupta yer almıştır. Bu nedenle bir etkisinin görüldüğünü söylemek mümkün değildir.

Elementel S0 ve ham fosfatın farklı dozlarının uygulanmasında toprakların % kireç içeriği üzerine 90. günde de önemli bir etki görülmeyip ortalamalar aynı grupta yer almıştır. Farklı dozda elementel S0 uygulamasına bağlı olarak toprakların % kireç içeriğinde istatistiksel olarak önemli bir farklılık olmasa da, çok azda olsa bir azalma eğiliminin olduğu görülmektedir.

Çizelge 3. Elementel S0 ve ham fosfat uygulamalarında toprak kireç içeriği ortalama değerleri

**:p<0.01, *:p<0.05

		Ham fosfat dozları (kg da^{-1})				
45. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	19.73a-d	19.31a-e	20.48ab	19.89abc	19.85A*
	20	18.31b-f	17.89c-f	20.65a*	18.72a-f	18.89BC
	40	20.06abc	16.93f	18.31b-f	17.55def	18.21C
	80	19.48a-e	17.43ef	19.22a-e	20.32ab	19.11AB
	Ort.	19.39A	17.89B	19.66A**	19.12A	
		Ham fosfat dozları (kg da^{-1})				
90. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	19.18	19.65	19.81	20.23	19.72
	20	21.57	17.3	20.06	19.56	19.62
	40	19.56	18.31	19.14	19.56	19.14
	80	20.06	19.56	19.39	16.68	18.92
	Ort.	20.09	18.70	19.60	19.0	
		Ham fosfat dozları (kg da^{-1})				
135. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	20.58	19.74	21.93	21.59	20.96
	20	23.69	20.67	21	18.65	21.00
	40	21.04	19.49	22.18	20.67	20.84
	80	19.66	20.83	21.09	22.05	20.91
	Ort.	21.24	20.18	21.55	20.74	

Elementel S0 ve ham fosfat uygulamalarının denemenin 135. gününde toprakların % kireç içerikleri üzerine istatistiksel olarak önemli bir etkisi gözlenmemiştir. Elementel S0 asidik karakterli bir toprak düzenleyici olmasına rağmen etkisinin gözlenmemesi toprakların yüksek kireçli olmasına bağlanabilir. Çünkü en fazla elementel S0 uygulama dozu 80 kg da-1 olup topraklarda yaklaşık 50 ton da-1 kireç bulunmaktadır.

3.2. Elementel S0 ve Ham Fosfat Uygulamasının Toprakların Alınabilir P İçeriğine Etkisi

Elementel S0 ve ham fosfat uygulamalarının 45. günde topraktaki ortalama P değerleri üzerine etkisi incelendiğinde, elementel S0 uygulamasının P üzerine önemli bir etkisi olmayıp ortalamalar aynı grupta yer almıştır (Çizelge 4). Ham fosfat uygulamalarında ise uygulama dozuna bağlı olarak, topraklarda alınabilir P miktarı istatistiksel olarak önemli ($p<0.01$) düzeyde artmıştır. Ham fosfatın kontrol grubunda ortalama 6.23 mg kg-1 olan alınabilir P içeriği en yüksek ham fosfat uygulama dozunda 23.22 mg kg-1 bulunmuştur. Çizelge 4'te görüldüğü gibi ham fosfat x elementel S0 interaksiyonu da önemli bulunmuştur. Bu durum, ham fosfat x elementel S0 uygulamasının birlikte etkili olduğu şeklinde değerlendirilebilir.

Çizelge 4. Elementel S0 ve ham fosfat uygulamalarında toprakta alınabilir P değerleri

		Ham fosfat dozları (kg da^{-1})				
45. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	5.86e	8.68c	11.76b	23.40a	12.43
	20	6.56de	8.54c	10.99b	22.62a	12.18
	40	6.37de	8.35c	12.35b	23.54a*	12.66
	80	6.14de	7.60cd	11.4.b	23.31a	12.12
	Ort.	6.23D	8.29C	11.63B	23.22A**	
		Ham fosfat dozları (kg da^{-1})				
90. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	4.73ı	7.69fg	11.22d	19.08a**	10.58AB
	20	5.48hı	8.54ef	11.08d	17.91ab	10.75AB
	40	6.37gh	8.02f	11.60d	15.60c	10.40B
	80	6hı	9.39e	11.60d	17.30b	11.07A*
	Ort.	5.64D	8.41C	11.38B	17.47A**	
		Ham fosfat dozları (kg da^{-1})				
135. Gün		**0**	**20**	**40**	**80**	**Ort.**
S^0 Dozları (kg da^{-1})	**0**	5.57ı	7.50gh	10.89de	16.73a	10.17B
	20	6.51hı	8.49fg	11.84cd	17.34a	11.05A
	40	6.14hı	8.54fg	12.78bc	17.95a*	11.35A
	80	6.05hı	9.53ef	14.00b	16.50a	11.52A**
	Ort.	6.07D	8.52C	12.39B	17.13A*	

**:$p<0.01$, *:$p<0.05$

Denemenin 90. Gününde, elementel S0 ve ham fosfat uygulamasının alınabilir P üzerine etkisi $p<0.05$ düzeyinde önemli bulunmuştur. Elementel S0 uygulaması ile 0 dozda ortalama 10.58 mg kg-1 olan alınabilir P miktarı, 80 kg da-1 uygulamasında 11.07 mg kg-1 yükselmiştir. Denemede 90. günde elde edilen alınabilir P miktarı 45. güne göre yaklaşık 2 mg kg-1 düzeyinde daha azdır. Bu durum, elementel S0 uygulaması ile ortaya çıkan bileşiklerin yeniden

topraklarda P ile çökelmesine bağlanabilir. Saltalı ve Nedirli (2021), topraklara P uygulaması sonrası topraklardan örnekler almışlar ve 10., 15. ve 30. günlerde topraklarda alınabilir P içeriği bakımından fark olmadığını, ancak zamana bağlı olarak topraklarda alınabilir P içeriğinin azaldığını rapor etmişlerdir. Ham fosfat ve elementel S0 uygulamalarının 90. günde topraktaki P üzerine etkisi incelendiğinde ham fosfat dozlarının artması ile alınabilir P miktarları önemli ($p<0.01$) düzeyde artmıştır. En yüksek P miktarı 20 kg da-1 dozunda 17.47 mg kg-1 elde edilirken en düşük P miktarı 5.64 mg kg-1 kontrol grubunda elde edilmiştir. Nour ve Elfaki (2019), bazik topraklara elementel kükürt uygulamasının toprak reaksiyonun azalmasına ve topraklarda alınabilir P içeriğinin artmasına neden olduğunu, bu nedenle bazik toprakların iyileştirilebilmesi ve P içeriğinin artırılması için elementel kükürt uygulamasını önermişlerdir. Topraklarda kükürdü, kükürt oksitleyici bakteriler okside etmekte (Etesami ve Jeong, 2021) ve okside kükürt ile üretilen asitli bileşikler de topraklarda alınamaz konumda bulunan fosforun çözünürlüğünü artırmaktadır (Khan ve ark., 2020).

Denemenin 135. gününde elementel S0 ve ham fosfat uygulamasında, elementel S0 uygulama dozlarında en yüksek alınabilir P miktarı 11.52 mg kg-1, en düşük 10.17 mg kg-1 elde edilmiştir. Elementel S0 uygulamasının alınabilir P üzerine etkisi $p<0.01$ düzeyinde önemli bulunmuştur. Elementel S0 uygulamasına bağlı olarak topraklarda alınabilir P konsantrasyonunun artması, kükürdün oksidasyonundan kaynaklı asit bileşiklerin toprakların pH değerini düşürmesine ve dolayısıyla P serbestlenmesine bağlanabilir. Khan ve ark. (2017), kaya fosfatı kompost ve elementel S0 ile karıştırarak kireçli ve alkalin bir toprakta yaptıkları çalışmada; uygulama dozlarına bağlı olarak topraklarda alınabilir P miktarının arttığını ve buna bağlı olarak bitkinin P alımında da artışlar olduğunu rapor etmiştir. Diğer yandan elementel S0 ve ham fosfat uygulaması ile ham fosfat uygulama dozu arttıkça topraklarda ortalama alınabilir P miktarını istatistiksel olarak önemli ($p<0.05$) düzeyde artırmıştır. Aynı zamanda, elementel S0 x ham fosfat interaksiyonu $p<0.05$ düzeyinde önemli bulunmuştur. Bu durum, ham fosfatın ve elementel S0 uygulamasında, zamanla ham fosfatın mineralizasyonundan kaynaklandığı düşünülmektedir. Ayrıca, elementel kükürdün zamanla oksidasyonu ve asitli bileşiklerin oluşması da topraklarda ham fosfattan P serbestlenmesine katkı sağlayabilir. Yüksek kireçli ve alkalin topraklara elementel S0 uygulamasının toprakların pH değerleri üzerine etkisinin de araştırıldığı bir çalışmada; elementel S0 uygulamasının toprak pH değerinin düşürülmesi konusunda etkili olduğunu ve portakal yetiştirilen yüksek kireçli ve alkalin topraklarda verim ve kalitesinin artırılması için elementel S0 uygulanması önermişlerdir (Güneri ve ark., 2009). Okalebo ve ark. (2006)'da, yaptığı bir çalışmada S0 uygulamasının toprak pH'sının düşürülmesinde elementel kükürdün etkili olduğunu vurgulamışlardır. Kaya fosfat, elementel S0 ve kompostun farklı dozları ile buğday bitkisinin verimi üzerine yapılan bir çalışmada; kaya fosfat + elementel S0 uygulamasının buğdayın P alımını ve verimi artırdığı rapor edilmiştir. Aynı çalışmada, kaya fosfat + elementel S0 + kompost karıştırılması durumunda bitki P alımının ve verimin daha da yükseldiği vurgulanmıştır (Khan ve ark., 2017).

4. SONUÇ VE ÖNERİLER

Bu çalışmada, kaya fosfatın öğütülmesi ile elde edilen ham fosfat materyalleri ile elementel kükürdün topraklara birlikte uygulanmasının alınabilir P içeriği üzerine etkisi araştırılmıştır. Çalışma saksı denemesi şeklinde yürütülmüştür. Elde edilen verilere göre, elementel S0

uygulaması ile toprakların pH değeri istatistiksel olarak önemli düzeyde azalmıştır. Elementel S0 ve ham fosfat uygulamasının toprakların % kireç içeriği üzerine herhangi bir etkisi gözlenmemiştir. Topraklara elementel S0 ve ham fosfat uygulamasında, toprakların alınabilir P konsantrasyonu ham fosfat dozuna bağlı olarak istatistiksel olarak önemli düzeyde ($p<0.01$) artmıştır. Benzer şekilde, elementel S0 uygulamalarının da denemenin 90. ve 135. Gününde alınabilir P içeriğini artırdığı belirlenmiştir. Fosforlu gübrelerin, ham fosfat ve elementel kükürdün ekonomik özellikleri değerlendirilerek, ham fosfat kaynaklarının elementel S0 ile karıştırılarak uygulanması, bitkilerin P ile beslenmesinde bir alternatif olarak değerlendirilebilir. Ancak, detaylı tarla denemeleri ile test edilmesinde fayda vardır.

Araştırmacıların Katkı Beyanı

Araştırma için fikir ve hipotezin oluşturulması: ŞNE, KS; deneme tasarımı ve yürütülmesi ŞNE, KS; örneklerin toplanması ve analizi: ŞNE, KS, ÖFD; verilerin elde edilmesi: ŞNE, KS, ÖFD, istatistik analizi: BB, KS, bildirinin sunulması ve yazılması; ŞNE, KS, BB.

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THE USE OF BLACK CUMIN SEED IN POULTRY NUTRITION

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ABSTRACT

Black cumin seed (*Nigella sativa L.*), one of the medicinal and aromatic plants, is used as a natural medicine due to the presence of antimicrobial, antioxidant and other pharmacological properties. After the ban of growth stimulant antibiotics in poultry nutrition, researchers have intensified their studies on natural alternative products that can be used to protect the health and improve the performance of animals. The presence of a large number of essential nutrients and various pharmacological active compounds in its composition makes black cumin seeds a potential alternative feed raw material for poultry rations. In studies on the use of black cumin seed in poultry nutrition, it has been reported that it increases growth performance, feed consumption and feed efficiency of animals, as well as positive effects on intestinal health, intestinal microbiota and some blood parameters. When the feeding studies on black cumin are examined, studies on the use of black cumin seed and oil obtained from black cumin seed are more intensively encountered.

In this review, the effects of the use of black cumin seed, black cumin oil and the remaining pulp of black cumin seed after the oil is extracted from black cumin seed on poultry are summarised in the light of the literature.

Keywords: Black cumin seeds, Broiler chickens, Laying hens, Quail

KANATLI HAYVANLARIN BESLENMESİNDE ÇÖREK OTU TOHUMU KULLANIMI

ÖZET

Tıbbi ve aromatik bitkilerden biri olan çörek otu tohumu (*Nigella sativa L.*), antimikrobiyal, antioksidan ve diğer farmakolojik özelliklerinin varlığı nedeniyle doğal bir ilaç olarak kullanılmaktadır. Kanatlı hayvanların beslenmesinde büyüme uyarıcı antibiyotiklerin yasaklanmasından sonra araştırmacılar hayvanların sağlığını korumak ve performansını artırmak için kullanılabilecek doğal alternatif ürünler üzerine çalışmalarını yoğunlaştırmıştır. Bileşiminde bulunan çok sayıda temel besin maddesinin ve çeşitli farmakolojik aktif bileşiklerin varlığı, çörek otu tohumlarını kanatlı hayvanlarının rasyonları için potansiyel bir alternatif yem hammaddesi haline getirmektedir. Çörek otu tohumunun kanatlı hayvanların beslenmesinde kullanımı ile ilgili çalışmalarda hayvanların büyüme performansını, yem tüketimini ve yem verimliliğini artırdığı, bununla birlikte bağırsak sağlığı, bağırsak mikrobiyotası ve bazı kan parametreleri üzerine olumlu etkilerinin olduğu bildirilmektedir. Çörek otu ile ilgili yapılan besleme çalışma irdelendiğinde, çörek otu tohumu ve çörek otu tohumundan elde edilen yağın kullanımı ile ilgili çalışmalara daha yoğun rastlanılmaktadır.

Bu derlemede özellikle çörek otu tohumu, çörek otu yağı ve çörek otu tohumundan yağı alındıktan sonra geri kalan küspesinin kanatlı hayvanlarda kullanımının hayvanlar üzerindeki etkileri literatür ışığı altında özetlenmiştir.

Anahtar Kelimeler: Çörek otu tohumu, Etlik piliç, Yumurta tavuğu, Bıldırcın

GİRİŞ

Kanatlı hayvan yetiştiriciliği hayvancılık sektörleri içerisinde, yüksek biyolojik değere sahip hayvansal protein sağlayan, dünya çapında en kazançlı üretim sektörlerinden biridir. 2006 yılına kadar kanatlı hayvan beslemede, antibiyotikler büyük bir yere sahipti ve piliçlerde büyüme destekleyicileri olarak yaygın olarak kullanılmaktaydı. Kanatlı rasyonlarında yoğun olarak antibiyotik kullanımına bağlı olarak özellikle insanlarda ortaya çıkan bakteriyel dirençle birlikte büyüme uyarıcı antibiyotiklerin kullanımı yasaklanmış ve araştırmacılar alternatif olabilecek doğal, güvenli ve gelişmeyi uyarıcı madde arayışları başlamışlardır (Asgar ve ark., 2022).

Doğal kaynaklarının hayvan beslemede tercih edilmesindeki temel etken bitkisel kökenli unsurların insan sağlığını olumsuz etkileyebilecek beklenmedik bir etkiye sahip olmaması ve güvenilir kaynak olmalarıdır. Doğal ürünler sentetik antioksidanlara alternatif olmaları nedeniyle tercih edilmektedirler (Yanishleva ve ark., 2001; Barreira ve ark. 2008; Bouaziz ve ark., 2008; Bulca, 2014). Bitkisel kökenli yem katkı maddelerinin; hücreye zarar veren molekülleri temizleyerek oluşabilecek hasarlardan korunmaya yardımcı olması ve gıdalarda mikrobiyal, fiziksel ve kimyasal özelliklerin korunması, gıdanın dış görünüşünü, tadını, kokusunu olumsuz yönde etkilememesi bu tip doğal ürünlere olan ilgiyi arttırmaktadır (Etherton ve ark., 2002).

Entansif besleme uygulamaları ile hayvanlardan kısa zamanda daha hızlı canlı ağırlık kazancı hedeflendiğinden, hayvanların genetik kapasitesi doğrultusunda uygun rasyonlarla beslenmeleri gerekmektedir. Bununla birlikte bu performans değerlerini yakalamak için rasyonlara büyümeyi uyarıcı maddeler de ilave edilmektedir. Antibiyotikler uzun yıllar kanatlı hayvanların beslenmesinde büyüme uyarıcı olarak kullanılmıştır. Büyüme uyarıcı maddelerin doğal kökenli olmaları ve etki mekanizmalarının ortaya konmasıyla birlikte hayvan beslemede ve hayvansal ürünlerin işlenmesinde antibiyotiklere alternatif olabileceği düşünülmektedir (İpçak ve ark., 2017). Yemlerin korunması ve besleme sonucu elde edilen ürünlerin raf ömrünün uzatılması için antioksidanlar; hayvanların sağlıklı gelişimi için de antimikrobiyal etkili hammaddeler kullanılmaktadır (Bilal ve ark., 2008). Gerek laboratuvar gerekse canlı hayvanlar üzerinde yapılan çalışmalar sonucunda bitki ve ekstraktlarının alternatif yem ham maddesi veya yem katkı maddesi olarak kullanılabileceği ortaya konmuştur (Bilal ve ark., 2008).

İçeriğinde bulunan çok fazla sekonder metabolitler ile antioksidan ve antimikrobiyal etkiye sahip tıbbi ve aromatik bitkilerden biri de çörek otu tohumudur. Yapılan çalışmalarda çörek otu tohumu, besin madde içeriğinin yüksek olmasının yanında vitamin-mineral bakımından da iyi bir kaynak olarak tanımlanmakta, bileşimindeki maddelerin farmakolojik özellikleri sayesinde destek ve tedavi amacı ile de yüzyıllardır kullanılan bir bitki olarak bilinmektedir.

Çörek Otu Tohumu

Çörek otu (*Nigella sativa* L.) bitkisi, *Ranunculaceae* familyasına ait olup adaptasyonu yüksek olması nedeniyle çoğu bölgede yetiştirilebilen, tek yıllık, otsu, ortalama 25- 55 cm boya sahip bir bitki olarak tanımlanmaktadır (Kılıç ve Arabacı, 2016; Çelik, 2022). Nigella kelimesi Lâtince siyahımsı anlamında kullanılan nigellus'tan türetilmiştir. Türkçe de Nigella sativa

bitkisinin karşılığı olarak çörek otu, ekilen çörek otu, kara çörek otu veya siyah kimyon isimleri gelmektedir (Shoshin, 2015).

Ranunculaceae bitki ailesinden Nigella cinsinin yirmi türünden biri olan ve kutsal tohum olarak bilinen çörek otunun, tıpta kullanılan bitkiler içinde zengin tarihsel ve mistik bir geçmişe sahip olduğu, uzun yıllar yiyecekleri koruyucu ve lezzeti arttırmak amacıyla kullanıldığı bilinmektedir (Ragaa, 2010; Kılıç ve Arabacı, 2016). Türkiye'de; ekmek, çörek ve peynir çeşitlerinde kullanımı yoğun olan çörek otu tohumları yüzyıllardır hekimler tarafından farklı hastalıkların (ağrı kesici, nefes açıcı, sindirim sistemi problemlerinde tedavi, menstürasyonu düzenleme) tedavisinde kullanılmaktadır (Yüncü ve ark., 2013). Bununla birlikte Orta Doğu ve Uzak Doğu ülkelerinde astım, bronşit, baş ağrısı, dizanteri, enfeksiyonlar, şişmanlık, sırt ağrısı, hipertansiyon, farenjit, grip, paralizi, karın ağrısı ve mide bağırsak yolları problemleri gibi birçok hastalık grubunun tedavisinde de kullanılmaktadır (Kanter ve ark., 2005; Salem ve ark., 2010; Ahmad ve ark., 2013; Yüncü ve ark., 2013). İçeriğinde bulunan çeşitli metabolitlerin göstermiş olduğu terapötik etkinliklerinin farklı olması nedeniyle pek çok farklı farmakolojik etkiye sahiptir.

Çörek otu tohumunun çok eski çağlardan beri kullanıldığının göstergeleri arasında, Tutankamon'un mezar buluntuları arasında ortaya çıkması, iyileştirici ve güzelleştirici etkilerinden dolayı Kleopatra tarafından da kullanılması bunlara örnek verilmektedir. Bununla birlikte; Dioskorides tarafından ağrı kesici ve antihelmentik etkisi, Hipokrat tarafından ise karaciğer hastalıklarında ve sindirim sistemi şikâyetlerini gidermesi amacıyla kullanılmıştır. İbni Sina'nın tıp tarihi açısından önemli bir kaynak olarak kabul gören eseri "Kanun" da çörek otunun metabolizmayı uyaran ve halsizlik-uyuşukluk giderici etkisi vurgulanmaktadır. Peygamberimiz Hz. Muhammed (SAV) "Çörek otunu kullanın, ölümden başka her şeye devadır" sözü çörek otunun inançlı bir biçimde ve kitlesel olarak kullanılmasını etkilemesi açısından anlamlıdır (Gün, 2012).

Çörek otunda farmakolojik anlamda etken maddeler olarak %0.5-1.6 arasında uçucu yağlar (timokinon, timohidrokuinon, nigellon, timol, karvakrol, α ve β pinen, d-limenonene, p-simen), alkoloidler, steroller (betaso- sterol, sykloeikolenol, sykloartenol, sterol esterler, sterol glukosidler), saponinler ve quinonlar bulunmaktadır. Yapılan çalışmalar çörek otu tohumunun antibakteriyel, antioksidan immun sistemi destekleyici, helmintleri öldürücü, antidiabetik ve antitümoral aktivite gösterdiğini ortaya koymuştur (Tufan ve ark., 2015). Çörek otu bu farmokolojik özellikleri sayesinde insan sağlığı üzerine etkisi ile ilgili çok sayıda çalışma bulunmaktadır. Çörekotu ve çörekotundan elde edilen maddeler birçok hastalığın tedavisinde kullanılmaktadır. Çörekotunun antioksidan etki yaptığı ve çörekotundan elde edilen timokinon adlı maddenin süper oksit, hidrojen peroksit, nitrik oksidi ve oksidatif stresi azalttığı bildirilmiştir (Ayaş, 2024).

Çörek otu tohumuna ait besin madde içerikleri Tablo 1'de, aminoasit, yağ asidi ve vitamin içeriklerine ait değerler ise Tablo 2'de verilmiştir.

Tablo 1. Çörek Otu Tohumu Besin Maddesi Bileşenleri (100 g kuru madde için)

Bileşen	**Miktar (g) / mg / %**
Nem	5.02 ± 0.01 g
Ham protein	21.07 ± 0.01 g
Ham yağ	39.02 ± 0.09 g
Ham lif	6.01 ± 0.06 g
Toplam karbonhidrat	25.86 ± 0.10 g
Toplam kül (mineral)	3.02 ± 0.02 g
Enerji değeri	644.88 kcal

Tablo 2. Çörek otu tohumunun aminoasit, yağ asidi ve vitamin içerikleri (Tetik, 2020)

Amino Asit	**Miktar (%)**	**Yağ Asidi**	**Miktar (%)**	**Vitamin**	**Miktar (mg/kg)**
Leusin	6.00	Linoleik Asit	57.71	**α-tokoferol**	25.59
Valin	4.77	Oleik Asit	24.46	**β-tokoferol**	14.21
Lizin	3.86	Palmitik Asit	12.17	**γ-tokoferol**	242.83
Treonin	3,86	Stearik Asit	2.31	**Toplam tokoferoller**	282.63
Fenilalanin	3,70	Arachidik Asit	0.33	**B1 (Tiamin)**	13–18
Metiyonin	1,88	Eikosadienoik Asit	2.52	**B6 (Piridoksin)**	4–15
Histidin	2,79	Myristik Asit	0.19	**Niasin (B3)**	33–97
İzolösin	3,69	Palmitoleik Asit	0.14	**Folat (B9)**	400–870
Tirozin	3,35	Linolenik Asit	0.12		
Sistin	1,17				

Çörek Otu Tohumunun Kanatlı Hayvanlarda Kullanımı

Dünyada ve ülkemizde hayvansal protein gereksiniminin karşılanmasında ilk sırada yer alan kanatlı hayvan sektöründe kullanılan katkı maddelerinin büyük miktarının ithal olması nedeniyle girdiler oldukça yüksektir. Bununla birlikte, hayvan beslemede yem katkı maddeleri hem yemden yararlanmayı artırmak hem de minimum giderle olası en yüksek miktar ve kalitede hayvansal ürün elde etmek amacıyla kullanılmaktadır (Gölcü ve Duru, 2023).

Özellikle kanatlı hayvanların beslenmesinde büyüme uyarıcı antibiyotiklerin yasaklanmasından sonra araştırmacılar hayvanların sağlığını korumak ve performansını artırmak için kullanılabilecek doğal alternatif ürünler üzerine çalışmalarını yoğunlaştırmıştır.

Bitkisel katkı maddelerinin doğal olmaları ve hem de hayvan sağlığını olumlu yönde etkilemeleri yem katkı maddesi olarak kullanılmasında önemli avantajlarıdır. Ayrıca bu bitkisel ürünlerin dolaylı yoldan hayvansal ürünlere geçerek tüketilmesi sağlık, ürün kalitesi ve lezzeti yönünden olumlu etkiler gösterebilmektedir.

Bu doğal tıbbi bitkilerden biri olan çörek otu tohumunun ve farklı bileşenlerinin kanatlı hayvanlar üzerindeki etkileri değerlendirildiğinde; yemin lezzetini, sindirilebilirliğini, hayvanlarda canlı ağırlığı, yumurta verimini ve yem değerlendirmeyi artırdığı belirlenmiştir. Bununla birlikte, içeriğinde bulunan sekonder metabolitler sayesinde bağışıklık sistemini güçlendirip patojen mikroorganizmaların baskılanmasını sağlamaktadır. Bununla birlikte antilipidemik etkisiyle düşük kolesterollü hayvansal ürün eldesi açısından önem arz etmektedir.

Tablo 3'de farklı kanatlı hayvan türlerinde çörek otu tohumu ve tohumundan elde edilen bileşenlerin kullanıldığı güncel çalışmalar özetlenmiştir.

Tablo 3. Farklı kanatlı hayvan türlerinde çörek otu tohumu ve bileşenlerinin kullanımı

Hayvan	Kullanım Şekli	Doz	Etkiler	Kaynak
Etlik piliç	Çörek otu tohumu	% 0, 0.5, 1 ve 1.5	Çörek otu tohumunun canlı ağrılık artışı ve yemden yararlanmayı olumlu yönde etkilediği, serum kolesterol değerini düşürdüğünü bildirmişlerdir.	Singh ve Kumar (2018)
Etlik piliç	Çörek otu tohumu ve çemen tohumu	0, 5 ve 10 g/kg	Çörek otu tohumunun ttlik piliçlerde performans, yem tüketimi ve kan bileşenlerini etkilemediği, abdominal yağ içreğini azalttığı, bağışıklık sistemini güçlendirdiği bildirilmiştir.	Laudadio ve ark. (2020)
Etlik piliç	Çörek otu yağı ve kekik yağı	0, 100 ve 250 mg/kg	Etlik piliç rasyonlarında kekik yağı ve çörek otu yağı kullanımı, performans parametrelerini ve sekum esansiyel yağ asitlerini etkilememiş, ancak bağırsak sağlığı üzerinde olumlu etkileri olmuştur.	Özlem ve Yıldız (2020)
Japon bıldırcını	Çörek otu tohumu	%0, 0.5, 1 ve 2	Erkek bıldırcın rasyonlarına çörek otu tohumu ilavesinin performans, testis özellikleri, serum parametreleri ve üreme hormonları üzerine istatistiki bir etkisinin olmadığı, ancak %0,5 ilavesinde testis ağırlığı/canlı ağırlık oranında artma	Sevim ve ark. (2021)

			ve serum FSH seviyesinin düşme eğiliminde olduğu bildirilmiştir.	
Japon bıldırcını	Çörek otu tohumu	% 0, 1, 2 ve 4	%2 ilaveli grubun diğer gruplara göre; canlı ağırlığı, canlı ağırlığı artışı ve yem dönüşüm oranını iyileştirdiği, et kalite özelliklerinin daha iyi olduğu ve raf ömrünü iyileştirdiğini bildirmişlerdir.	Asgar ve ark. (2022)
Etlik piliç	Çörek otu tohumu küspesi	0, 20, 40 ve 60 g/kg	Etlik piliç performans özelliklerini iyileştirmiş, antioksidan, bağışıklık ve et kalitesini artırmış ve patojenik bakteri papülasyonunu azaltmıştır.	Fathi ve ark. (2023)
Etlik piliç	Çörek otu tohumu küspesi ve Hindistan cevizi küspesi	%0, 5 ve 10	Her iki alternatif yem hammaddesinin etlik piliçlerin performansını iyileştirdiği, karkas randımanını artırdığı ve bağırsak sağlığını iyileştirmiştir.	Zazaa ve ark., (2023)
Japon bıldırcını	Çörek otu tohumu	%0, 0.5, 1 ve 2	Hayvanların performansını etkilemediği, kanda AST, laktat dehidrogenaz, üre, glutatyon peroksidaz düzeyleri, kolseterol ve LDL değerlerini azalttığı kan ve karaciğer parametrelerini olumlu yönde etkilediği bildirilmiştir.	Çimrin ve ark., (2023)
Yumurta tavuğu	Çörek otu tohumu	0, 10 20 ve 30 g/kg	Günlük canlı ağırlık artışı ve yumurta ağırlığını etkilemediği, en yüksek yumurta veriminin 30 g/kg ilaveli gruptan elde edildiği ve yumurta verimliliğini önemli derecede etkilediği bildirilmiştir.	Ali ve ark., (2023)
Etlik piliç	Çörek otu tohumu	0, 5, 10, 15 ve 20 g/kg	Etlik piliçlerin performansını etkilemediğini bağırsak histomorfolojik parametrelerini iyileştirdiği ve bağırsak mikrobiyatısını olumlu yönde etkilediğini bildirmişlerdir.	Abdollai ve ark. (2024)

Yapılan güncel çalışmalar ile ilgili Tablo 3 genel olarak değerlendirildiğinde; çörek otunun farklı bileşenlerinin (tohumu, yağı ve küspesi) farklı kanatlı hayvan türlerinin rasyonlarında kullanımı ile yemin lezzetini, sindirilebilirliğini, canlı ağırlığı, yumurta verimini, yemden yararlanmayı bağırsak sağlığı ve morfolojisi ile bağışıklık sistemi üzerinde olumlu etkilerinin olduğu görülmektedir.

Sonuç

Sağlıklı, dengeli ve sürdürülebilir bir yaşam için insanların tükettikleri besin maddelerinin güvenilir ve insan sağlığı açısından hiçbir risk taşımaması gerekmektedir. Bilinçli tüketici ve sağlıklı hayvansal ürünlere olan talep tıbbi ve aromatik bitkilerin önemini giderek artırmaktadır. Genel bir anlayış olarak, sağlıklı ve dengeli beslenmemizde tarladan ya da hayvancılık işletmesinden sofraya gelinceye kadar her türlü üretilen ürünün denetlenebilir ve güvenilebilir olması beklenmektedir.

İnsanların beslenmesinde temel bir protein kaynağı durumunda olan kanatlı hayvanların ürünleri de sağlık açısından herhangi bir risk taşımamalıdır. Antibiyotiklere alternatif olarak düşünülen ve tamamen doğal olan tıbbi ve aromatik bitkilerin antimikrobiyal, antibakteriyel, antifungal, antiviral, ve antioksidan etkilerine yönelik elde edilen sonuçlar olumlu yöndedir.

Bu tıbbi ve aromatik bitkilerden biri olan çörekotu ve çörekotundan elde edilen maddeler insanlarda tedavi edici ve koruyucu olarak kullanıldığı gibi hayvan beslemede özellikle de kanatlı beslemesinde yaygın olarak kullanılmaktadır. Kanatlı karma yemlerine çörek otu tohumu ve bileşenlerinin ilavesi yem tüketimini, yemin sindirimini, bağırsak villus gelişimini, günlük canlı ağırlık artışını, immün sistem aktivitesini, bazı kan parametrelerini ve et kompozisyonunu olumlu yönde etkileyebilmektedir. Sonuç olarak son dönemde popülerliği artan çörekotu ve çörekotundan elde edilen maddelerin kanatlı hayvanların beslenmesinde kullanılmasının birçok faydası bulunmaktadır.

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CHANGES IN SOME QUALITY CHARACTERISTICS OF SOYBEAN (*Glycine max.* L. Merr) UNDER FULL AND DEFICIT IRRIGATION

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ABSTRACT

In the Mediterranean climate, longer periods of heat and drought have been observed in spring and summer for recent years. Long high temperature periods and extreme hot conditions in semi-arid regions reveal water scarcity in crop production. Identifying the rapidly changing ecological conditions in the world in a short time and creating solutions and ensuring adequate and healthy nutrition of the increasing population due to this change is only possible by developing agricultural production systems suitable for this change. Evaluating the variability of drought stress on morphological, yield and quality parameters will lead to strategic measures to be taken in order to achieve optimal yield and quality characteristics depending on the stress conditions that will increase with climate change. A field experiment was conducted to determine the effects of four different irrigated and limited irrigation (based on water holding capacity (WHC)) treatments (water scarcity: 25%, 50% WHC, and irrigated: 75%, 100% WHC) on two different soybean varieties (Cinsoy and Altınay) on grain quality properties of soybean. For this reason, protein ratio (%), ash ratio (%), fiber ratio (%) and oil ratio (%) of soybean seed was analyzed by NIRS (Near Infrared Reflectance Spectroscopy). According to the variance analysis results of the experiment, it was observed that limited irrigation practices had significant effects especially on protein and oil ratio. In the study, year, water and year*water interactions were statistically significant at 0.01 level. In the experiment, protein ratio varied between 32.24-35.62%, oil ratio 18.68-20.45%, ash ratio 4.03-4.60% and fiber ratio 5.03-5.10%. These changes clearly show that water scarcity conditions not only affected yield and plant growth in soybean, but also caused significant changes in grain quality.

Keywords: Climate change, drought, soybean, water stress, protein, oil

TAM VE KISITLI SULAMA ŞARTLARI ALTINDA SOYA FASULYESİ (*Glycine max*. L. Merr) TANESİNDE BAZI KALİTE ÖZELLİKLERİNİN DEĞİŞİMİ

ÖZET

Akdeniz ikliminde, son yıllarda ilkbahar ve yaz aylarında daha uzun süreli sıcaklık ve kuraklık dönemleri gözlenmektedir. Yarı kurak bölgelerdeki uzun yüksek sıcaklık dönemleri ve aşırı sıcak koşullar, bitkisel üretimde su kıtlığını ortaya çıkarmaktadır. Dünyada hızla değişen ekolojik koşulların kısa sürede tespit edilerek çözüm üretilmesi ve bu değişime bağlı olarak artan nüfusun yeterli ve sağlıklı beslenmesinin sağlanması ancak bu değişime uygun tarımsal üretim sistemlerinin geliştirilmesi ile mümkündür. Kuraklık stresinin morfolojik, verim ve kalite parametreleri üzerindeki değişkenliğinin değerlendirilmesi, iklim değişikliği ile artacak stres koşullarına bağlı olarak optimum verim ve kalite özelliklerinin elde edilmesi için stratejik önlemlerin alınmasına yol açacaktır. İki farklı soya fasulyesi çeşidi (Cinsoy ve Altınay) üzerinde dört farklı sulu ve sınırlı sulama (su tutma kapasitesine (WHC) dayalı) uygulamasının (su kıtlığı: %25, %50 ve sulu: %75, %100 WHC) soya fasulyesinin tane kalite özellikleri üzerindeki etkilerini belirlemek için bir tarla denemesi yürütülmüştür. Bu nedenle soya fasulyesi tohumunun protein oranı (%), kül oranı (%), lif oranı (%) ve yağ oranı (%) NIRS (Near Infrared Reflectance Spectroscopy) ile analiz edilmiştir. Deneme varyans analiz sonuçlarına göre, kısıtlı sulama uygulamalarının özellikle protein ve yağ oranı üzerinde önemli etkileri olduğu görülmüştür. Çalışmada yıl, su ve yıl*su interaksiyonlarının 0.01 seviyesinde istatistiki olarak önemli farklar oluşturduğu görülmüştür. Denemede protein içeriği %32,24-35,62, yağ içeriği %18,68-20,45, kül içeriği %4,03-4,60 ve lif içeriği %5,03-5,10 arasında değişmiştir. Bu değişimler, su kıtlığı koşullarının soyada sadece verim ve bitki büyümesini etkilemediğini, aynı zamanda tane kalitesinde de önemli değişikliklere neden olduğunu açıkça göstermektedir.

Anahtar Kelimeler: İklim değişikliği, kuraklık, soya fasulyesi, su stresi, protein, yağ

INTRODUCTION

Soybean (Glycine max. L. Merr.) is one of the most widely cultivated legumes in the world due to its valuable seed composition. Soybean has an extremely important position in human and animal nutrition due to its fat (18-20%), protein (36-40%), carbohydrate (30%), mineral matter (5%) content (Shea et al., 2024). Soybean is one of the most important oilseed crops worldwide and contains high amounts of protein for human food and animal feed (Wysokinski et al., 2024). Soybean (Glycine max. (L.) Merr) is one of the field crops with the largest economic importance in the world. Annual production is around 370 million/ton. Soybean is a highly nutritious legume both for human consumption and as animal feed, with high protein and fat content (Statista, 2023). Since soybean is a legume plant, it has a special importance in increasing soil fertility with its ability to bind the free nitrogen of the air to the soil. For this reason, it is an important crop rotation plant. Soybean is a taprooted legume plant that can form nodules called nodules with Rhizobium bacteria and bind the free nitrogen of the air to the soil. The bacterial race that can form effective nodules in soybean is Bradyrhizobium japonicum bacteria group (Miransari, 2016).

Drought conditions are the most limiting factor for crop production in the world. Water resources available for crops are limited except for rainfall. Therefore, it is important to select plant species that can best adjust the water use efficiency of plants under drought stress. Water use efficiency is defined as the ratio of biomass production to plant transpiration, which is the amount of water used by the plant (Bacon, 2009). In the Mediterranean climate, the increase in temperature periods in recent years has exposed water scarcity in crop production (Parkes et al., 2022). Extreme weather events such as droughts reduce crop production, making it difficult to obtain and distribute crops worldwide. High temperatures during plant growth periods cause yield and quality losses in crops, posing a major threat to food. Temperature plays a critical role in plant growth and development. Average temperatures are projected to increase worldwide by an average of 0.3^0C every 10 years, increasing by 1.5^0C by 2050 and up to 4^0C by 2100. These temperature increases are one of the most important abiotic stress factors threatening plant growth and yield (Poudel et al., 2023).

Plants try to survive under the influence of different environmental factors. These environmental factors can be named as biotic and abiotic factors. In order to obtain an economic product, the optimum environmental demands that the plant species or variety grown must meet the optimum environmental demands that it can adapt to itself. Drought, which is one of the abiotic stress factors, is defined in different ways by many researchers and is defined as the presence of moisture in the soil at the wilting point of the plant (Lynch, 1995). Soybean is a plant with moderate water requirements (mesophyte). It has better drought tolerance than legumes such as broad bean (Vicia faba L.) and pea (Pisum sativum L.). This resistance mechanism is due to genetic adaptations such as leaf and stem hairiness, which reduces excessive transpiration at high temperatures, and a taproot system that spreads into deep layers of the soil (Staniak et al., 2023).

For high yield in soybean, total water requirement should be 450-700 mm. It has been reported that available water in the soil should reach 50-85% for germination of soybean seeds and that they are very sensitive to water deficiency during flowering and grain filling periods (Silva et al., 2020). Productivity under drought conditions varies depending on the intensity and duration

of the stress and the phenological stages of development. In soybean cultivation, there are 3 critical periods related to increased water demand. The first is the period from sowing to emergence, the second is the flowering period, and the third is the pod setting period (Lewandowska and Kotcchi, 2020). The most damaging periods of temperature and water stress during the generative period are flowering and pod development. Yield losses are related to photosynthetic performance during the generative period. In drought stress, stomata in leaves are closed and the production of assimilates such as starch is limited, which negatively affects photosynthetic performance. Inadequate assimilate delivery to flowers and pods, together with high temperatures, leads to smaller grains and thus lower yields. Water stress during the flowering period stresses the plant, causing flower and pollen losses and reducing seed yield (Soba et al., 2022).

Arıoğlu (2007) reported that soybean seeds contain 18-24% oil, depending on the variety, and that soybean oil contains important fatty acids such as 19-30% oleic acid, 44-62% linoleic acid, 4-11% linolenic acid, 7-14% palmitic and 1.4-5.5% stearic acid. It has been revealed that soybean oil ratio and fatty acid composition can be affected by many factors such as variety and the region where it is grown (Galao et al., 2014). Piper and Boote (1999) reported that the oil and protein content of the seed is closely related to environmental factors, especially with the increase in temperature during the growth period, the oil content increases and the protein content decreases. Under arid conditions, soybean seed protein content increases while crude oil content decreases and these ratios change linearly with increasing stress (Sobko et al., 2020). Ravelambola (2022) reported that drought can affect protein structure as well as protein synthesis and that the transfer of amino acids to the leaf is hampered by hydration of the decomposed proteins. In addition, Specht et al. (2014) reported that when soybean plants are subjected to water stress, the oil content increases while the protein content decreases. Since palmitic fatty acid belongs to the group of saturated fatty acids, it is desired to have a low ratio. When the water stress was increased from 20% to 40% in different developmental stages, it was observed that the dry matter content of soybean decreased by 25-34% and yield decreased by 18-30% (Vearela, 1998). There is a positive relationship between temperature and fat content. In addition, an increase in protein content was found with the increase in temperature. They also found an increase in methionine amino acid composition in protein (Shi et al., 2023). Wilson (2004) reported that the temperature during the growing period was effective on the oil content in soybean and the oleic acid content increased when the day and night temperatures increased together during the growing period.

In this study, it was aimed to investigate the effects of full and limited irrigation practices on some grain quality parameters in soybean varieties, which is one of the important plants for sustainable agriculture. In this study, it was aimed to develop soybean cultivation in sustainable agricultural systems under high temperature and water scarcity conditions in Aydın ecological conditions.

MATERIAL AND METHOD

The field studies of the experiment were carried out in Aydın ecological conditions (37o45' N, 27o45' E location) during the soybean vegetation period of 2020 and 2021. Two medium-early soybean varieties (Cinsoy and Altınay) were obtained from Izmir Aegean Agricultural Research

Institute as material to evaluate the quality characteristics of soybean in the experiment. The experiment was established according to a randomized block split-plot design. The experiment consisted of 2 soybean cultivars (Cinsoy and Altınay) and 4 different irrigation treatments (water scarcity: 25%, 50% and irrigated: 75% and 100%). The experiment was established as 24 plots in total. Each plot consisted of 4 rows, 70 cm between rows, 5.4 cm above rows, 5 m in length, 2.80 m in width and 14 m2 in total.

The soil characteristics of the land where the research was conducted are low in organic matter (1.7%) and has a sandy loam soil structure. Soil pH is alkaline (7,92) and has a salt-free structure. According to the soil analysis, it was determined that lime content was high (7,93%), sodium (89 ppm), potassium (224 ppm), calcium (2481 ppm) and phosphorus (11,53 ppm) levels were medium useful.

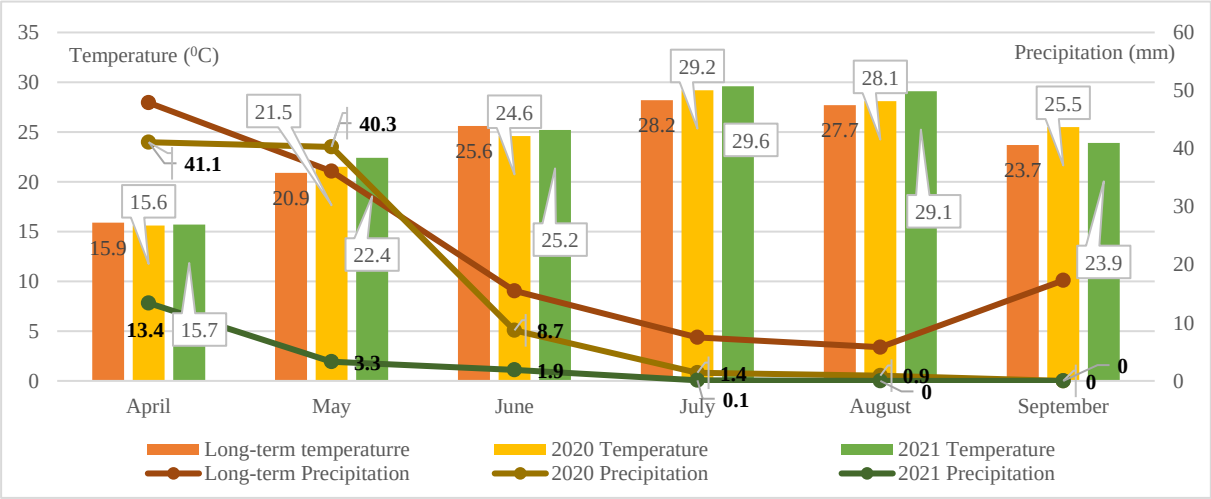

Figure 1. Monthly and long-term temperature and precipitation values (General Directorate of Meteorological Affairs, Station: Koçarlı/Aydın)

The comparison of temperature and precipitation values in Aydın province during the soybean growing period of 2020 and 2021, when the experiment was conducted, with the long-term average values is given in Figure 1. It is seen that the average monthly precipitation amounts in both trial years in April-September, which is the soybean growing period, are well below the long-term rainfall average. In general, when temperature comparisons are made on a yearly basis, temperature averages have been close to each other except for the high daily average temperatures experienced in different months.

It was observed that daily high temperature averages during the vegetative periods in both trial years caused significant differences. Although monthly temperature values during the phenological development periods were higher in the second year compared to the first year, daily temperature averages did not exceed 35^0C in the second year of the experiment. In 2020, temperatures hovered around 25^0C on sowing dates and temperatures hovered around 35^0C until the flowering period. In the 2021 experimental year, it was determined that the daily high temperature averages were above 35^0C throughout the vegetation period from the date of sowing.

Figure 2. General images of the soybean trial

In the experiment, controlled irrigation applications were carried out by making calculations for four different water treatments (Water scarcity: 25%, 50%, and Irrigated: 75% and 100%). The amounts of irrigation water to be applied to the plots were calculated with different coefficients according to the evaporation amounts obtained from the Class A evaporation pan (US Weather Bureau Class A Pan) (Kanber, 1984), and applications were made regularly every seven days with drip irrigation system according to the following equation.

I=Kpc.Ep.P.A [I:amount of irrigation to be applied to the plot, Kpc:evaporation contanier coefficient 100%, Ep:cumulative evaporation amount(mm), P:plant cover(%), A:plot area(m^2)]

In both years of the experiment, controlled irrigation was started when the first flowers (BBCH 61) appeared and controlled irrigation was gradually terminated according to the ripening periods. During the growth and development period in 2020, a total of 858.77 mm irrigation water was given to soybean in 100% water application, 644.05 mm in 75% water application, 399.37 mm in 50% water application and 199.67 mm in 25% water application. In the 2021 experimental year, 816.98 mm in 100% water application, 612.73 mm in 75% water application, 376.99 mm in 50% water application and 169.99 mm in 25% water application.

Figure 3. Analysis images of soybean trial

In this study, protein rate (%), ash rate (%), fiber rate (%) and oil rate (%) of soybean seeds were analyzed by NIRS (Near Infrared Reflectance Spectroscopy). The analysis of variance of the data obtained in both years of the field trials were evaluated in TARIST package program in accordance with the randomized block split plots experimental design. In the comparison of the means, the EKÖF comparison test was used (Açıkgöz et al., 1994).

RESULTS AND DISCUSSION

In this study, the effects of different restricted water applications on some quality characteristics of soybean varieties were investigated in order to ensure the continuity of soybean production in sustainable agriculture by taking into account the importance of climate change. According to the results of the analysis of variance, limited irrigation practices were found to be statistically significant at 0.01 level ($p \leq 0.01$) on protein, oil and ash ratios which are quality parameters (Table 1). The factors applied in the experiment did not make a statistical difference on the fiber ratio. In terms of variety factor, only the protein ratio was found to be statistically significant at 0.05 level ($p \leq 0.05$). In the experiment, Year*Water interaction was found statistically significant at 0.01 level ($p \leq 0.01$) in protein, fat and ash ratio, while Variety*Water interaction was found significant only in protein ratio at 0.05 level ($p \leq 0.05$).

Protein Ratio (%)

Limited irrigation conditions lead to water deficit in tissues and hinder various physiological processes such as photosynthesis, transpiration and stomatal conductance. This affects plant growth and development as well as seed yield and grain composition (Staniak et al., 2023). Under drought conditions, soybean seed protein content increases while crude oil content decreases and these ratios change linearly with increasing stress (Sobko et al., 2020). Ravelambola (2022) reported that drought can affect protein structure as well as protein synthesis and that the transfer of amino acids to the leaf is hindered by hydration of the proteins that are decomposed. In addition, in the study investigating the changes of limited irrigation and drought on protein, oil ratio and fatty acid content in soybean seeds, it was reported that 25% water application and drought increased the protein ratio by 4.4% and decreased the oil ratio by 2.9%.

Table 1. Mean values of soybean quality parameters for the combined trial years

Experimental Factor	Protein Ratio (%)	Oil Ratio (%)	Ash Ratio (%)	Fiber Ratio (%)
Mean Year (A)				
2020	35,62a	19,24	4,60a	5,10
2021	32,24b	19,87	4,22ab	4,82
Mean Variety (B)				
Cinsoy	34,41a	19,62	4,45	4,90
Altınay	33,44b	19,49	4,37	5,03
Mean Irrigation (C)				
%25	35,09a	18,29b	4,65a	4,94
%50	33,98ab	19,60ab	4,41ab	5,00
%75	33,91ab	19,60ab	4,35ab	4,85
%100	32,73b	20,74a	4,24b	5,03
LSD Values				
A	0,68**	ns	0,32**	ns
B	0,48**	ns	ns	ns
C	0,68**	0,67**	0,13**	ns
A*B	ns	ns	ns	ns
A*C	0,96**	0,95**	0,18**	ns
B*C	0,96*	ns	ns	ns
A*B*C	ns	ns	ns	ns

ns: non- significant; *: significant at 0.05 level; **: significant at 0.01level

In Table 1, year, water and variety factors were found to be statistically significant at p≤0.01 level (Table 1). While the average protein ratio was 35.62% in 2020, it was 32.24% in 2021. Among the average limited water treatments, the highest protein value was obtained in 25% water treatment (35.09%). Among the variety averages, Cinsoy variety (34.41%) stands out. Poeta vd. (2016) reported that the increase in protein content was positively and linearly correlated with water stress condition and negatively correlated with oil content. Unal and Onder (2008) obtained grain protein content as 34.40-38.61%, Devi (2013) obtained 34.40-36.71%, Cevheri and Yilmaz (2018) obtained 39.31-41.74% protein content in their study. In our study, the fact that the highest protein ratio was obtained in the 25% water restricted treatment and the highest oil ratio was obtained in the 100% water treatment shows that the data in the experiment are largely in agreement with important studies.

Oil Ratio (%)

Alsajri et al. (2020) reported that the oil and protein content of the seed is closely related to environmental factors, especially with the increase in temperature during the growth period, the oil content increases while the protein content decreases. In addition, Specht et al. (2001) reported that oil content increases and protein content decreases when soybean plants are subjected to water stress. High daily temperatures decrease oil content and increase protein content in soybean seeds (Gibson and Mullen, 1996; Dornbos, 2020). Borowski and Michalek (2014) reported that oil content decreased (13.8%) and grain protein content increased (6.2%) in soybean varieties with limited irrigation under drought conditions. Water factor ($p \leq 0.01$) and Year*Water interaction ($p \leq 0.01$) were found to be statistically significant on oil ratio (Table 1). There were no significant differences between the years of the experiment. The average values of oil in grain were 19.24% in 2020 and 19.87% in 2021. The treatments did not cause a statistical difference on variety averages. The average oil ratios of the varieties were 19.62% and 19.49% for Cinsoy and Altınay varieties, respectively. There was a statistically significant difference on the oil ratios of soybean in water restricted treatments. The average oil ratios in irrigation treatments were determined as 20.74% in 100% water application and 18.29% in 25% water application. When the previous studies on grain oil ratios were examined; Akınerdem et al. (2014) obtained the crude oil ratio value between 19.15-19.89%, Ay (2012) between 16.66-19.30%, Kılınç and Arıoğlu (2018) reported it as 18.65%, and Gaweda et al. (2017) reported that it varied between 7.20-18.60%. Poeta et al. (2016) reported that fatty acid components did not change proportionally, but high temperature and limited irrigation decreased polyunsaturated fatty acid ratios. The oil values obtained in our study were found to be compatible with previous studies (18.29-20.74%) and the oil contents were not affected by all the treatments in our study.

Ash Ratio (%)

In Table 1, the effects of years, water treatments and Year*Water interactions on ash ratio of grain were found significant at 0.01 ($p \leq 0.01$) level. There was no statistical difference between the varieties. In terms of limited water treatments, the highest ash content was obtained in 25% water treatment (4.65%). In 2020, the ash ratio was 4.60% and 4.22% in 2021. While the average ash rate was 4.45% in Cinsoy variety, it was 4.37% in Altınay variety. Sıulapwa and Mwambungu (2014) examined the changes in grain content of soybean seeds by applying different treatments and reported that the ash rate in grain varied between 4.4 and 7.3%. The averages of ash values obtained in our study were generally consistent with the literature.

Fiber Ratio (%)

In Table 1, it is seen that the factors applied in the experiment, years, water treatments and variety interactions did not make a statistical difference on grain fiber ratio. Among the limited water treatments, the fiber ratio was 4.94% in 25% water treatment and 5.00% in 100% water treatment. In 2020, the fiber rate was 5.10% and in 2021 it was 4.82%. While the average fiber ratio was 4.90% in Cinsoy variety, it was obtained as 5.03% in Altınay variety. Sıulapwa and Mwambungu (2014) examined the changes in grain content by applying different treatments on

soybean seeds and reported that the fiber ratio in grain varied between 5.4 and 7.5%. The averages of fiber values obtained in our study were generally below the literature values.

CONCLUSION

One of the most important issues in agricultural production is to determine the rate at which the applications made during plant growth and development periods affect yield and quality parameters. Limited irrigation is an important production alternative in reducing the water requirement in agricultural production, increasing the water use efficiency of plants and utilizing non-irrigated lands. It is important to investigate the responses of plants to restricted irrigation conditions under different climatic and soil conditions. In this study, the effects of restricted irrigation practices on soybean grain quality in soybean, which is one of the important crops for sustainable agriculture, were investigated. According to the results obtained from the experiment, it has important results in revealing the effects of irrigation practices and their interactions with high temperature values on grain quality potentials in soybean varieties. It was observed that limited water applications and soybean varieties had significant effects on the average values obtained. The fact that the highest protein content was obtained in the 25% limited water treatment and the highest oil content was obtained in the 100% full water treatment shows that the data in the experiment are largely in agreement with important studies. These effects clearly show that water scarcity conditions not only affect yield and plant growth in soybean, but also cause significant changes in grain quality. In general, it was concluded that soybean grain quality traits are dependent on environmental and genetic factors, but the results obtained should be supported by more comprehensive studies in the future.

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UNMANNED GROUND VEHICLES IN SMART FARMING: APPLICATIONS, CHALLENGES AND SOLUTIONS

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ABSTRACT

Smart agricultural applications have initiated a significant transformation process towards increasing the efficiency, sustainability and quality level of agricultural production. In this transformation, unmanned ground vehicles have the potential to autonomously perform many agricultural activities such as soil analysis, plant monitoring, planting, spraying and harvesting. This study aims to examine the application areas, technological requirements and technical difficulties encountered in agricultural production of unmanned ground vehicles in Turkey and internationally. Open access academic publications published in recent years were examined with a comprehensive literature review method. Within the scope of the reviewed literature, the effectiveness of unmanned ground vehicles in tasks such as mission planning, Global Positioning System-based navigation, artificial intelligence-supported image processing, multi-sensor integration, crop harvesting, weed control, material transportation and environmental data collection were evaluated. The findings showed that unmanned ground vehicles reduce the dependence on manpower in agricultural activities, optimize resource use, make production processes more planned and measurable and feed decision support systems by continuously collecting data. On the other hand, technical limitations such as adaptation of systems to field conditions, battery type and life, global positioning system and sensor accuracy are still waiting to be solved. In addition, field tests of many prototype systems remain limited, they do not provide universal ease of use, and low-cost production models cannot be developed for commercial use. Recent studies have highlighted new battery technologies such as lithium iron phosphate, artificial intelligence-supported image processing, multi-sensor fusion, modular structure and multi-functionality, real-time kinematic positioning using Global Positioning Systems, and new approaches such as end-to-end data processing. For these technologies to become widespread in Turkey, it is of great importance to encourage university-industry collaborations, support local research and development and prototyping studies, conduct academic studies supported by field applications, and increase digital education content for farmers.

Keywords: unmanned ground vehicles, smart farming, agricultural automation, farm robotics, autonomous systems

AKILLI TARIMDA İNSANSIZ KARA ARAÇLARI: UYGULAMALAR, ZORLUKLAR VE ÇÖZÜMLER

ÖZET

Akıllı tarım uygulamaları, tarımsal üretimin verimliliğini, sürdürülebilirliğini ve kalite düzeyini artırma yönünde önemli bir dönüşüm süreci başlatmıştır. Bu dönüşümde insansız kara araçları, toprak analizi, bitki takibi, ekim, ilaçlama ve hasat gibi birçok tarımsal faaliyeti otonom olarak gerçekleştirme potansiyeline sahiptir. Bu çalışma, insansız kara araçlarının Türkiye'de ve uluslararası alanda tarımsal üretimdeki uygulama alanlarını, teknolojik gereksinimlerini ve karşılaşılan teknik zorlukları incelemeyi amaçlamaktadır. Son yıllarda yayımlanmış açık erişimli akademik yayınlar kapsamlı bir literatür taraması yöntemiyle incelenmiştir. İncelenen literatür kapsamında insansız kara araçlarının görev planlama, Küresel Konumlama Sistemleri tabanlı navigasyon, yapay zekâ destekli görüntü işleme, çoklu sensör entegrasyonu, ürün hasadı, yabancı otla mücadele, malzeme taşıma ve çevresel veri toplama gibi görevlerdeki etkinliği değerlendirilmiştir. Bulgular, insansız kara araçlarının tarımsal faaliyetlerde insan gücüne olan bağımlılığı azalttığını, kaynak kullanımını optimize ettiğini, üretim süreçlerini daha planlı ve ölçülebilir hale getirdiğini ve sürekli veri toplayarak karar destek sistemleri beslediğini göstermiştir. Öte yandan, sistemlerin arazi koşullarına adaptasyonu, batarya tipi ve ömrü, küresel konumlandırma sistemi ve sensör doğruluğu gibi teknik sınırlılıklar hâlâ çözülmeyi beklemektedir. Ayrıca, birçok prototip sistemin tarla testleri sınırlı kalmakta, evrensel bir kullanım kolaylığı sunamamakta ve ticari kullanıma geçişte düşük maliyetli üretim modelleri geliştirilememektedir. Son dönem çalışmalarda lityum demir fosfat gibi yeni batarya teknolojileri, yapay zekâ destekli görüntü işleme, çoklu sensör füzyonu, modüler yapı ile çoklu işlevsellik, Küresel Konumlama Sistemleri kullanarak gerçek zamanlı kinematik konumlandırma ve uçtan uca veri işleme gibi yeni yaklaşımların öne çıktığı görülmektedir. Türkiye'de bu teknolojilerin yaygınlaşması için üniversite-sanayi iş birliklerinin teşvik edilmesi, yerli araştırma-geliştirme ve prototipleme çalışmalarının desteklenmesi, saha uygulamalarıyla desteklenen akademik çalışmaların yapılması ve çiftçilere yönelik dijital eğitim içeriklerinin artırılması büyük önem taşımaktadır.

Anahtar Kelimeler: insansız kara aracı, akıllı tarım, tarımsal otomasyon, tarım robotları, otonom sistemler

1. GİRİŞ

Akıllı tarım, tarımsal verimliliği artırmak, maliyetleri azaltmak ve çevresel sürdürülebilirliği sağlamak amacıyla bilgi teknolojilerinin tarım süreçlerine entegre edilmesidir. Bu yaklaşım, tarla ve ürün yönetiminde doğru zamanda doğru müdahalelerin yapılmasını sağlamaktadır (Özlüoymak, 2024). Son yıllarda sensörler ve kameralar gibi donanımların makine öğrenmesiyle uyumlu hale gelmesi, tarımda gerçek zamanlı veri toplama ve karar destek sistemlerinin kullanımını kolaylaştırmaktadır (Özgüven, Eminoğlu, & Çolak, 2024). Bu dijital dönüşümün bir parçası olarak İnsansız Kara Araçları (İKA) tarımsal üretimde giderek önemli bir rol oynamaya başlamıştır. Tarımsal mekanizasyondan otonom sistemlere geçiş, Tarım 4.0 kavramı ile ivme kazanmıştır. Tarım 4.0 ile beraber bilgisayar kontrollü makineler, sensör teknolojileriyle entegre ekipmanlar ve otonom araçlar gibi ortaya çıkan birçok yenilik tarım sektörünün geleceğini şekillendirmektedir (Özlüoymak, 2024). Günümüzde sürücüsüz traktörler, otonom tarım makineleri ve tarım robotları gibi ticari ürünler tarımsal üretim süreçlerinde kullanılmak üzere piyasaya sunulmaya başlamıştır (Özgüven, Eminoğlu, & Çolak, 2024). Örneğin, büyük üreticiler otonom olarak operasyon yapan traktörlerin prototiplerini tanıtmıştır.

Özel amaçlı tarım robotlar meyve toplama, yabancı ot temizleme gibi işlemleri gerçekleştirebilir duruma gelmiştir. Bu gelişmeler, tarımda insan gücüne olan bağımlılığı azaltarak verimliliği yükseltme potansiyeli olduğunu göstermektedir (Gossett, 2025).

İKA'lar, entegre edilen sensörler ve yapay zekâ algoritmaları ile çevresini algılayıp otonom karar verebilen sistemlerdir. Akıllı tarım kapsamında İKA'lar, sahada önceden belirlenmiş rotalarda hareket ederek veya gerçek zamanlı çeşitli görevleri yerine getirebilmektedir. Tarımsal insansız kara araçları, genellikle elektrikle çalışan ve tarımsal görevleri otonom şekilde yerine getirebilen robotlardır. Bu araçlar, çeşitli kontrol sistemleri, konumlandırma, ölçüm birimleri ve bazı durumlarda robotik kollar gibi çeşitli sensör ve donanımlarla donatılmıştır. Bu sayede çevresel verileri toplamakta, işler ve fiziksel müdahale gerektiren işlemleri insan kontrolü olmadan gerçekleştirmektedir (Agelli, Caglayan, 2024).

Bu bildiride, akıllı tarımda İKA kullanımının mevcut durumunu kapsamlı biçimde ele alınmaktadır. İKA Uygulamaları bölümünde toprak analizi, bitki sağlığı izleme, ekim, ilaçlama ve hasat gibi görevlerde bu araçların nasıl kullanıldığı örneklerle açıklanacaktır. Teknolojik gereksinimler kısmında bir İKA'nın etkin çalışması için gereken Küresel Navigasyon Uydu Sistemleri (GNSS) tabanlı navigasyon, yapay zekâ destekli görüntü işleme, çoklu sensör entegrasyonu ve batarya sistemleri incelenecektir. Karşılaşılan Zorluklar başlığı altında arazi şartlarına uyum, konumlandırma hassasiyeti, sensör kalibrasyonu, maliyet ve test sorunları ele alınacaktır. Son olarak Mevcut Çözümler ve Öneriler kısmında, literatürde önerilen yeni batarya teknolojileri, Yüksek hassasiyetli konumlama, modüler tasarım yaklaşımları, yapay zekâ algoritmaları ile performans iyileştirmeleri ve Türkiye'de üniversite-sanayi iş birliği gibi konular tartışılarak geleceğe yönelik öneriler sunulacaktır.

2. İKA UYGULAMALARI

Toprak Analizi ve Örnekleme

İnsansız kara araçları, tarla üzerinde önceden tanımlanmış konumlara otomatik olarak yönlenerek, sondaj mekanizması aracılığıyla fiziksel toprak örnekleri alabilmektedir. Aracın üzerinde bulunan sensörler sayesinde nem, sıcaklık ve elektriksel iletkenlik gibi temel toprak verilerini eş zamanlı olarak ölçmektedir. Böylece hem fiziksel örnekleme hem de dijital sensör verisi toplanarak tarımsal analiz için zengin bir veri seti oluşturulmaktadır (Kitić, 2022). Bu sistemler sayesinde çiftçiler, gübreleme uygulamalarını daha etkin şekilde yaparak toprak verimini artırmaktadır (Fountas vd., 2020).

Bitki Sağlığı İzleme ve Ürün Takibi

Bitkilerin sağlık durumlarını sürekli izlemek, ürün kayıplarını önlemede önemlidir. İnsansız kara araçlarının üzerine entegre edilen kamera sistemleri ile bitkilerin renk değişimleri ve yapıları yüksek çözünürlükte izlenmektedir. Derin öğrenme algoritmaları sayesinde yaprak, gövde ve meyve gibi bitki organlarında ortaya çıkan hastalık belirtileri ve zararlı etkileri erken tespit etmekte, böylece müdahale zamanında ve etkili şekilde yapılmaktadır (Çetin & Aydın, 2024; Bajraktari & Toylan, 2025). Bu yaklaşım, özellikle geniş tarım arazilerinde insan gözleminin yetersiz kaldığı durumlarda bitki sağlığı izlemesine olanak sağlamaktadır.

Ekim ve Dikim

Ekim ve dikim işlemlerinde insansız kara araçları, konumlandırma ve yönlendirme sistemleri ile tohumları belirlenen sıra ve aralıklarla toprağa yerleştirmektedir. Örneğin, FarmDroid isimli proje, tohumun konumunu hafızaya alarak ileride yapılabilecek işlemlere (örneğin yabancı ot temizliği) zemin hazırlarken, aynı zamanda tohumun ideal derinlik ve aralıkta ekilmesini sağlayarak son ürünün homojenliğini sağlamaktadır (Gossett, 2025).

İlaçlama ve Hassas Püskürtme

Görüntü işleme algoritmalarıyla insansız kara araçları, tarımsal uygulamalarda hassasiyet kazandırarak çevresel etkilerin azaltılmasını sağlamaktadır. Bu sistemler, tüm alana kimyasal uygulamak yerine yalnızca zararlı otların tespit edildiği bölgelere ilaç sıkarak gereksiz ilaç kullanımının önüne geçmektedir. İKA üzerinde bulunan görüntü işleme sistemi sayesinde zararlı otlar yüksek doğrulukla tanımlanmakta, hedefli noktalara otomatik olarak ilaç püskürtülmektedir. Bu sayede hem kimyasal tüketimi azaltılmakta hem de ekonomik verimlilik sağlanmaktadır. Böyle uygulama İKA teknolojisinin sadece mekanik hareket kabiliyetiyle değil, yazılım ve algılama sistemleriyle de modern tarımda önemli bir etkiye sahip olduğunu göstermektedir (Akdan vd., 2023).

Hasat ve Ürün Toplama

Hasat ve ürün toplama, tarımın en fazla emek gerektiren süreçlerinden biri olup, bu alanda otomasyon sistemlerinin kullanımı giderek yaygınlaşmaktadır. Özellikle meyve ve sebze gibi hassas ürünlerin toplanmasında kullanılan insansız kara araçları ve robotik sistemler, insan iş gücüne olan ihtiyacı azaltmakta ve ürün hasadını daha hızlı, verimli ve düzenli hâle getirmektedir. Kamera ve robotik kollarla donatılmış bu sistemler, meyve olgunluğunu tespit edebilen sensörlerle, ürüne zarar vermeden hasat yapabilmektedir (Gossett, 2025).

3. TEKNOLOJİK GEREKSİNİMLER

Konumlandırma Sistemleri

İKA'ların arazide istenen şekilde hareket edebilmesi için hassas konumlandırma sistemlerine ihtiyaçları vardır. İstenen hassasiyete ulaşılması için RTK-GNSS teknolojileri kullanılır. GNSS (Küresel Konumlama Uydu Sistemleri), uydular aracılığıyla dünya üzerindeki konumları kesin olarak belirleyen sistemlerdir. RTK (Gerçek Zamanlı Kinematik Doğrulama) ise GNSS uydu sinyallerini yerel bir baz istasyonu referansı kullanarak hassas şekilde sağlayan bir sistemdir (Fredeluces, Ozeki, Kubo & El-Mowafy, 2024). İKA'ların üzerine yerleştirilen GPS veya GNSS sensörleri aracın anlık konumunu görebilmesini ve görev güzergahını takip etmesini sağlamaktadır. Yer istasyonundaki ikinci bir sensör, araç ile sürekli iletişim kurar ve gerçek zamanlı kinematik doğrulama yaparak aracın konum hassasiyetini santimetre düzeyine indirmektedir. GPS sinyali kesildiğinde ise atalet ölçüm birimi (IMU) ve pusula gibi yardımcı sensörler ile konumlandırma doğruluğu korunmalıdır (Özlüoymak, 2024).

Yapay Zekâ Destekli Görüntü İşleme

İKA'ların çevrelerini algılayabilmeleri için üzerlerinde çeşitli kameralar bulunmaktadır. Bu kameralar tarafından elde edilen görüntüler, derin öğrenme algoritmalarıyla analiz edilerek bitki sağlığı, zararlı ot varlığı ve çevresel engelleri tespit etmektedir. Özellikle YOLO gibi nesne tanıma modelleri, görüntüleri anında işleyerek aracın anlık kararlar verebilmesini sağlamaktadır. Kameralar ve sensörler, değişken ışık ve hava koşullarına karşı dayanıklı hâle getirilmelidir (Agelli & Caglayan, 2024).

Çoklu Sensör Entegrasyonu

İKA'ların üzerinde birçok sensör bulunmaktadır. Konumlandırma, ivmeölçer, jiroskop, LiDAR (ışık algılama ve mesafe ölçüm sistemi), radar, ultrasonik ve kamera gibi farklı sensörler bir arada kullanılmaktadır. Bu çoklu sensör sistemi, farklı verileri birleştirilerek güvenilir bir karar mekanizması oluşturmasını sağlamaktadır. Örneğin, konumlandırma sinyali kesildiğinde ivme, jiroskop ve LiDAR verileri ile aracın konumu tahmin etmektedir. Sensör füzyonu, çevresel algılamanın yanı sıra haritalama, engel tanıma ve yön bulma gibi işlevleri de desteklemektedir (Ušinskis vd., 2025). Ancak bu sistemlerin verimli çalışabilmesi için düzenli kalibrasyon ve çevresel dayanıklılık gereklidir.

Batarya ve Enerji Sistemleri

İKA'lar çoğunlukla elektrik depolayan ve elektrikli motorlarla çalışan sistemlerdir. Bu nedenle enerji yönetimi önemli bir konudur. Genellikle Lityum iyon veya Lityum Demir Fosfat (LiFePO4) tipi bataryalar tercih edilmektedir. Ağır yük taşıyan İKA'larda dizel motor kullanımı da yaygındır, fakat bu İKA'lar daha çok askeri amaçlarda kullanılmaktadır. Arazi koşullarında enerji tüketimini azaltmak için sistemler verimli çalışacak şekilde yapılandırılmalı, gerektiğinde uyku moduna geçebilmeli ve güneş panelleri gibi destekleyici sistemlerle çalışabilmelidir. Enerji sistemi arazi koşullarına, hava durumuna ve iş yoğunluğuna göre hesaplanmalı ve tasarlanmalıdır.

4. KARŞILAŞILAN ZORLUKLAR

İnsansız kara araçlarının tarımda yaygınlaşmasında çözülmesi gereken zorluklar bulunmaktadır. Bu zorluklar, sistemin araziye uyumu, konumlandırma doğruluğu, sensörlerin güvenilirliği, enerji kısıtları, maliyet faktörü ve kullanıcı deneyiminin sınırlılığı gibi alanlarda yoğunlaşmaktadır.

Zorlu Arazi Koşullarına Uyum

Tarım arazileri çoğu zaman düzensiz, eğimli, çamurlu veya tozludur. Bu tür zemin koşullarında İKA'ların operasyonu için çekiş gücü, süspansiyon sistemleri ve yerden yüksekliği önemli faktörlerdir. Arazi yapısına uygun olarak tasarlanmayan sistemlerde aracın patinaj yapma veya devrilme riski artmaktadır (Gossett, 2025). Bu nedenle İKA'ların mekanik tasarımlarının, özellikle bağımsız süspansiyon sistemlerinin ve tahrik düzeneklerinin engebeli araziye uyum sağlayacak şekilde modüler şasi yapısı ile geliştirilmesi gereklidir (Grimstad & From, 2017).

Konumlandırma Hassasiyeti ve Sürekliliği

İKA'ların verimli çalışması için yüksek doğrulukta konum verisi gereklidir. Ancak bitki örtüsü, atmosferik koşullar veya fiziksel engeller konumlandırma sinyallerini zayıflatmaktadır. RTK-GNSS sistemleri iki noktadan referans aldığı için bu sorunu kısmen çözse de sinyal kaybı yaşanan anlarda konum doğruluğu düşmektedir (Fredeluces vd., 2024). Bu kayıplar sırasında ivmeölçer, jiroskop, LiDAR ve diğer sensörlerin desteği ile görev istikametinin korunması gerekmektedir (Saleem vd., 2015).

Sensör Kalibrasyonu ve Güvenilirliği

Tarımda kullanılan sensörler, toz, nem, çamur ve darbe gibi dış etkenlere maruz kalmaktadır. Bu koşullar sensör ölçümlerinde sapmalara veya veri kaybına yol açmaktadır. Çoklu sensör sistemlerinde her bileşenin düzenli kalibrasyonu gereklidir. Bu, özellikle kamera ile püskürtme memesi gibi entegre sistemlerde hassasiyet açısından büyük önem taşımaktadır (Ušinskis vd., 2025). Sensör tiplerine ve ortam koşullarına bağlı olarak günlük veya haftalık olarak temizlenmelidir. Hassas sensörlerin temizlikleri izopropil alkol ve yumuşak fırça ile yapılmalı, kamera ve lidar gibi objektifi olan sensörler ise çizilmeye neden olmayacak mikrofiber bezler ile temizlenmelidir (Zhou vd., 2023). Kullanıcıların temizlik konusunda teknik bilgi eksikliği, uygun temizlik malzemelerine erişimin zorluğu ve rutin temizliğin aksatılması aracın operasyonuna engel olmaktadır.

Enerji ve Batarya Kısıtları

Batarya ile çalışan İKA'ların sınırlı çalışma süresi, büyük alanlarda kesintisiz operasyonu zorlaştırmaktadır. Benzinli veya dizel araçların aksine, bataryalı araçların operasyon süresi 45 dakika ile 2 saat arasındadır. Gün boyu sürecek bir görevde defalarca kez şarj edilmesi gerekmektedir. Güneş enerjisi desteği ve hızlı batarya değiştirme sistemleri bu soruna çözüm olabilir fakat bu sistemler ağırlığı ve karmaşıklığı artırmaktadır. Batarya performansı, yüksek sıcaklık veya aşırı soğuk gibi çevresel koşullardan doğrudan etkilenmekte olup, operasyon süresini belirgin şekilde azaltmaktadır (Loukatos vd., 2024).

Yüksek Maliyet

Sensör, motor, batarya ve kontrol sistemlerinin maliyetleri, İKA'ların seri üretime geçmemesi nedeniyle oldukça yüksektir. Orta ve küçük ölçekteki çiftçiler için bu yatırımı karşılamak zordur. Bu durum, teknolojinin yaygınlaşmasını yavaşlatmaktadır (Özlüoymak,2024).

Saha Testlerinin Sınırlılığı

Birçok sistem sadece laboratuvar ortamında test edilmekte, tarla koşullarında uzun soluklu kullanım, güvenilirlik ve bakım süreçlerine dair yeterli veri bulunmamaktadır. Bu durum, üretici ve kullanıcılar arasında güven problemi yaratmaktadır.

5. MEVCUT ÇÖZÜMLER VE ÖNERİLER

Gelişmiş Batarya Teknolojileri

LiFePO4 gibi yeni nesil batarya teknolojileri, yüksek çevrim ömrü ve ısıl kararlılığı ile tarımsal uygulamalarda güvenli ve uzun süreli kullanım sağlamaktadır. Ayrıca hızlı şarj desteği ve değiştirilebilir modüler sistemler, operasyon süresini artırmak için etkili çözümler sunmaktadır (Loukatos vd., 2024). LiFePO4 bataryalar, kurşun-asit akülere göre çok daha hafiftir ve daha az yer kaplamaktadır. Lityum iyon bataryalara kıyasla daha uzun ömürlüdür, daha hızlı şarj olur ve yanma-patlama riski yoktur. Ayrıca diğer bataryaların aksine 0 ila 45 °C arasındaki hava sıcaklıklarında güvenli şekilde çalışabilmektedir (Loukatos vd., 2024). Bazı İKA modellerinde, batarya bittiğinde hızlı şekilde değiştirilebilen modüler batarya sistemleri uygulanarak duraksız görev yürütülmesi amaçlanmaktadır.

RTK-GNSS Tabanlı Konumlama

RTK destekli GNSS sistemleri ile santimetre düzeyinde konum hassasiyeti sağlamaktadır. NTRIP ağları ve mobil referans istasyonları, açık alanlarda sinyal gücünü artırarak konum doğruluğunu iyileştirmektedir (Fredeluces vd., 2024). GNSS kayıplarını azaltmak amacıyla jiroskop, ivmeeölçer, pusula, LiDAR ve kamera gibi sensörlerin verileri entegre edilerek konum takibi kesintisiz hâle getirilmektedir (Saleem vd., 2015).

Modüler Yapı

Tarımsal İKA'lar için geliştirilen modüler sistemler, farklı görevler için kolayca değiştirilebilen şasi ve sensörler ile esneklik sağlamaktadır (Kemeshi vd., 2025; Gadekar vd., 2023). Örneğin Thorvald II projesindeki İKA, tek bir hareket sistemi üstünde değiştirilebilir üst gövdeleri ile seralarda, açık tarlalarda ve bağlarda uyarlanabilir şekilde değiştirilebilmektedir (Grimstad & From, 2017).

Yapay Zekâ Tabanlı Algoritmalar

İKA'ların üzerilerindeki bilgisayarlarda YOLO, R-CNN, ByteTrack gibi yapay zeka tabanlı algoritmalar çalıştırılarak, gerçek zamanlı zararlı ot ve hastalık tespiti yapılmaktadır. Pekiştirmeli öğrenme ve yol planlama algoritmaları ile İKA'ların çevresel koşullara uyumu ve görevlerindeki başarı oranları artırılmaktadır (Bajraktari & Toylan, 2025). Potansiyel alan ve görsel sıra takibi gibi algoritmalar ile İKA'ların karmaşık bahçelerde, ağaç sıraları arasında ya da dar geçitlerde güvenle gezinmeleri sağlanmaktadır (Ye vd., 2024; Zhang vd., 2023; Shi vd., 2023).

Üniversite-Sanayi İş Birlikleri

TÜBİTAK ve Teknofest gibi oluşumlarla desteklenen Ar-Ge projeleri, yerli üretimin artmasına ve sahada test edilen prototiplerin geliştirilebilmesine olanak sağlamaktadır (Özgüven, Eminoğlu & Çolak, 2024).

Standartlar ve Eğitim

Çiftçilere yönelik dijital eğitimler, uzaktan kontrol ve güvenlik üzerine kılavuzlar hazırlanmalıdır. Sanal çit, acil durdurma sistemleri gibi güvenlik önlemlerinin standartları belirlenmelidir (Yang vd., 2023). Ayrıca sahadan elde edilen verilerin açık kaynak olarak paylaşılması hem akademik çalışmalar hem de endüstriyel Ar-Ge açısından veri havuzu oluşturulmasına katkı sağlayacaktır.

6. SONUÇ

İnsansız kara araçları, tarımda otomasyonun önemli aktörlerinden biri hâline gelmiş, çeşitli uygulama alanlarında somut faydalar sağlamaya başlamıştır. Bu çalışmada elde edilen bulgular, İKA'ların tarla operasyonlarında insan gücüne olan bağımlılığı azalttığını, veri temelli karar alma süreçlerini desteklediğini ve üretim verimliliğini artırdığını göstermektedir. Toprak analizi, bitki sağlığı takibi, hassas ekim, ilaçlama ve hasat gibi temel işlemlerde kullanılan İKA'lar, zaman ve kaynak kullanımı verimli, düzenli ve tekrarlanabilir hale getirmiştir. Türkiye üzerinde değerlendirildiğinde, tarımda teknolojik dönüşümün hızlandırılması için İKA'ların daha erişilebilir hâle gelmesi, yerli üretimin teşvik edilmesi ve saha odaklı araştırmalara ağırlık verilmesi gerekmektedir. Özellikle genç nüfusa yönelik teknoloji tabanlı tarım modelleri, uzun vadede bu alana ilginin artmasını, bahsi geçen teknolojilerin geliştirilmesini, en önemlisi de yerli olarak prototiplerin üretilmesini sağlayacaktır.

Çalışmada vurgulanan teknik zorluklar, hâlihazırda İKA sistemlerinin yaygınlaşmasının önünde önemli engeller oluşturmaktadır. Ancak batarya teknolojilerindeki gelişmeler, hassas konumlama çözümleri, modüler sistemler ve yapay zekâ algoritmalarının sahaya entegre edilmesi gibi yenilikçi yaklaşımlar, bu engellerin aşılmasına yönelik çözümler sunmaktadır. Gelecekte, akıllı tarım sistemlerinde İKA'lar, yalnızca büyük ölçekli işletmelere değil, küçük ve orta ölçekli çiftçilere de hitap edeceği düşünülmektedir. Bunun için devlet destekli teşvik modelleri, kiralama sistemleri ve bölgesel eğitim programları gibi çok yönlü stratejiler gerekmektedir.

Bu bildiride aktarılan içerik ve bulgular, İKA teknolojilerinin tarımsal üretimdeki rolünü daha iyi anlamaya katkı sağlamayı ve gelecekteki araştırmalara yön vermeyi amaçlamaktadır.

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EFFECTS OF BEE POLLEN AND PROPOLIS AS ALTERNATIVE FEED ADDITIVES IN SUSTAINABLE SHEEP NUTRITION

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ABSTRACT

From past to present, products derived from beekeeping activities such as honey, pollen, propolis, royal jelly, and bee venom have been utilized as fundamental food sources in healthy diets due to their content of primary and secondary nutrients. In addition to promoting general health, these products have been increasingly used in apitherapy practices for the supportive treatment of various diseases among the public. Scientific studies have demonstrated that these bee products possess a range of biological effects, including antibacterial, antiviral, anticancer, antioxidant, and antirheumatic properties. In recent years, they have also attracted growing interest in the field of animal nutrition. Following the prohibition of antibiotic use as feed additives in animal husbandry, there has been a rising demand for natural alternatives. Scientific research on propolis and pollen has shown that these products can positively influence animal performance by enhancing feed intake, body weight gain, and feed conversion efficiency. With their growth-promoting characteristics, bee products are considered promising natural alternatives for use in animal feeding practices.

This review aims to compile studies investigating the effects of dietary supplementation with bee pollen and propolis on sheep performance parameters, such as body weight gain, feed efficiency, and reproductive traits, within the framework of sustainable sheep farming. The objective is to provide a valuable resource for researchers and producers interested in this area.

Keywords: Sheep, lamb, animalnutrition, beepollen, propolis,

SÜRDÜRÜLEBİLİR KOYUN BESLEMEDE ALTERNATİF YEM KATKI MADDESİ OLARAK ARI POLENİ VE PROPOLİSİN ETKİLERİ

ÖZET

Geçmişten günümüze, arıcılık faaliyetleri sonucunda elde edilen bal, polen, propolis, arı sütü ve arı zehri gibi arı ürünleri, içeriklerindeki birincil ve ikincil besin maddeleri sayesinde sağlıklı beslenmede temel gıda maddeleri olarak kullanılmaktadır. Sağlıklı beslenmenin yanı sıra, bu ürünler halk arasında apiterapi uygulamaları kapsamında çeşitli hastalıkların destekleyici tedavisinde de yaygın şekilde kullanılmaktadır. Antibakteriyel, antiviral, antikanserojen, antioksidan, antiromatizmal gibi birçok biyolojik etkisi bilimsel çalışmalarla ortaya konan arı ürünleri, son yıllarda hayvan besleme alanında da ilgi görmeye başlamıştır. Hayvan beslemede antibiyotiklerin yem katkı maddesi olarak kullanımının yasaklanmasıyla birlikte, antibiyotiklere alternatif doğal ürünlerin kullanımına yönelik arayışlar artış göstermiştir. Bu bağlamda, propolis ve polen gibi arı ürünleri üzerine yapılan bilimsel araştırmalar, bu ürünlerin hayvanların yem tüketimi, canlı ağırlık artışı ve yemden yararlanma oranı gibi performans kriterleri üzerinde olumlu etkiler oluşturabileceğini göstermektedir. Arı ürünleri, gelişmeyi teşvik edici bu özellikleri sayesinde, hayvan beslemede kullanılabilecek alternatif doğal ürünler olarak değerlendirilmektedir. Bu derlemede, sürdürülebilir koyunculuk uygulamalarına katkı sağlamak amacıyla, koyunların günlük diyetine eklenen arı poleni ve propolisin canlı ağırlık kazanımı, yemden yararlanma performansı ve üreme gibi verimlilik parametreleri üzerindeki etkilerini araştıran çalışmalar derlenmiş ve bu alanda araştırma yapmayı planlayan akademisyenlere ve üreticilere yol göstermek hedeflenmiştir.

Anahtar Kelimeler: Koyun, kuzu, hayvan besleme, arı poleni, propolis,

1. GİRİŞ

Arıcılık faaliyetleri sonucunda elde edilen propolis, polen, arı sütü ve arı zehri gibi ürünler; antibakteriyel, antioksidan, antikarsinojenik, immün sistemi uyarıcı, antifungal gibi birçok biyolojik özelliğe sahip, çok yönlü doğal bileşiklerdir (Premratanachai ve Chanchao, 2014). İnsanlar binlerce yıldır bal arıları (*Apis mellifera*) tarafından üretilen ve primer ile sekonder metabolitler bakımından zengin olan bal, propolis, polen, arı ekmeği, arı zehri ve arı sütü gibi arı ürünlerini sağlıklı beslenme, bağışıklık sisteminin güçlendirilmesi ve çeşitli hastalıkların tedavisinde kullanmaktadır. Bu ürünler arasında özellikle arı poleni ve propolis ön plana çıkmaktadır. Arı poleni, çiçekli bitkilerden bal arıları tarafından çiçek nektarı ve sindirim enzimleri ile karıştırılarak toplanan doğal bir protein kaynağıdır. Polenler, çiçeklerin erkek üreme hücrelerini oluşturmakla birlikte, yüksek düzeyde besin öğeleri ve fitokimyasal bileşikler içerir ve sekonder metabolitler açısından oldukça zengindir. Arı poleninin başlıca biyolojik bileşenleri; polifenolik bileşikler, fenolik asit türevleri, hidroksisinnamik asitler ve flavonoid glikozitlerdir. Flavonoid bileşikleri ise antioksidan, antiinflamatuar, antikarsinojenik, antiaterosklerotik ve kardiyoprotektif etkiler başta olmak üzere pek çok farmakolojik ve fizyolojik fayda sağlamakta; ayrıca yaşlanma karşıtı etkiler göstererek endotel fonksiyonlarını iyileştirmektedir (Martín-Muñoz ve ark., 2010). Propolis (arı tutkalı), bal arıları (*Apis mellifera*) tarafından çeşitli ağaç ve bitki türlerinin salgılarından ve tomurcuklarından toplanan maddelerin, balmumu ve polenle karıştırılıp enzimatik değişime uğratılmasıyla elde edilen doğal bir reçineli üründür (Seven ve ark., 2010; Yücel ve ark., 2014). Propolis, kimyasal yapısında yer alan flavonoidler, fenolik asitler, yağ asitleri, steroidler, alkoller ve ketonlar gibi sekonder metabolitler ve biyoaktif bileşenler sayesinde antioksidan, antibakteriyel, antifungal, antiviral, antiinflamatuar, antiparaziter, antimetanojenik, immünmodülatör ve antikanser özellikler göstermektedir (Rufatto ve ark., 2018; da Silva ve ark., 2019). Ayrıca, propolisin antibakteriyel, antifungal, antiviral, antiparaziter, antiinflamatuar, immün stimülatör, antitümör, lokal anestezik ve antioksidan aktiviteleri bilimsel çalışmalarla da desteklenmiştir (Bogdanov, 2017; González-Búrquezz ve ark., 2017). Son yıllarda, çiftlik hayvanlarının besin madde ihtiyaçlarının karşılanması, performanslarının artırılması ve bağışıklık sistemlerinin güçlendirilmesi amacıyla antibiyotiklerin yerine, primer ve sekonder metabolitler bakımından zengin doğal ürünlerin (bal, propolis, polen, arı ekmeği, arı zehri ve arı sütü) kullanımı teşvik edilmektedir. Arı poleninin koyun, koç ve kuzuların diyetlerine yem katkı maddesi olarak eklenmesinin; döl verimi, besi performansı, yem dönüşüm oranı, canlı ağırlık artışı, sperm ve yumurta kalitesi ile sütten kesim ağırlığı gibi birçok verimlilik parametresi üzerinde olumlu etkiler sağladığı çeşitli bilimsel çalışmalarla gösterilmiştir (Gaafar, 2024; Ayman ve ark., 2024; Liang-zhong ve ark., 2023; Kaabi ve ark., 2022; Banana, 2020; Fodail ve ark., 2018).

Benzer şekilde, çiftlik hayvanlarının yemlerine propolis ilavesinin, rumen mikrobiyal fermantasyonunu dengeleyerek patojen bakteri sayısını azaltabileceği ve besin maddelerinin daha verimli kullanımını sağlayarak geviş getiren hayvanların performansını artırabileceği bilimsel araştırmalarla desteklenmiştir (Cécere ve ark., 2021; Abd-Allah ve Daghash, 2019; Yılmaz ve ark., 2004; Kupczyński ve ark., 2012; Zawadzki ve ark., 2011; De Melo Garcia ve ark., 2023).

Bu derleme çalışmasında, sürdürülebilir koyun beslemede günlük diyete arı poleni ve propolis eklenmesinin, koyunların canlı ağırlık artışı, yemden yararlanma performansı, sütten kesim ve üreme gibi verimlilik özelliklerine etkilerini inceleyen çalışmaları bilimsel bir çerçevede bir

araya getirerek, konu hakkında araştırma yapmak isteyen akademisyenlere ve üreticilere yol gösterilmesi amaçlanmıştır.

2. YÖNTEM

Bu derleme makalesinin hazırlanmasında literatür taraması amacıyla Google Scholar ve Web of Science gibi uluslararası veri tabanları kullanılmıştır. Literatür taraması, sırasıyla "Arı Poleni", "Arı Poleni ve Koyun Besleme", "Propolis" ve "Propolis ve Koyun Besleme" anahtar kelimeleri kullanılarak gerçekleştirilmiştir. Tarama sonucunda elde edilen çalışmalar arasından, makalenin kapsamı ve amacıyla uyumlu olan literatürler seçilmiş, ilgili bilgiler özetlenmiş ve bilimsel bütünlük içerisinde derlenerek bu makale tamamlanmıştır.

3. ARI POLENİ VE KİMYASAL BİLEŞİMİ

Arı poleni, çiçekli bitkiler tarafından üretilen erkek üreme hücrelerinin sporlarından oluşmakta olup, bal arıları (Apis mellifera) tarafından kendi sindirim enzim salgıları ve çiçek nektarı ile karıştırılarak toplanan doğal bir protein kaynağıdır. Polenler, arıların temel besin kaynağını oluşturmalarının yanı sıra, yüksek düzeyde besin ve fitokimyasal bileşikler içermekte ve sekonder metabolitler bakımından oldukça zengin bir yapıya sahiptir. Arı poleni; primer ve sekonder metabolitlerin pek çoğunu içermekte olup, başlıca biyolojik bileşenleri arasında polifenolik bileşikler, fenolik asit türevleri, hidroksisinnamik asitler ve flavonoid glikozitler yer almaktadır. Flavonoid bileşikleri, yaşlanma karşıtı, antioksidan, antiinflamatuar, antikarsinojenik, antiaterosklerotik ve kardiyoprotektif gibi çeşitli farmakolojik ve fizyolojik etkiler göstermekte, ayrıca endotel fonksiyonlarını desteklemektedir (Martín-Muñoz ve ark., 2010). Çiçek polenleri, arıların yaşam döngüsü içerisinde hayatta kalmalarını ve üremelerini destekleyen lipitler, yağ asitleri, proteinler, esansiyel amino asitler (EAA), karbonhidratlar, mineraller, vitaminler ve karotenoidler gibi temel besin ögelerinin önemli bir kaynağı olarak kabul edilmektedir (Carpes ve ark., 2008). Arı poleni üzerine yapılan araştırmalar, bu ürünün fonksiyonel gıda takviyesi olarak kullanılabileceğini ve sahip olduğu biyoaktif bileşikler ile antioksidan özellikler sayesinde çeşitli terapötik faydalar sunabileceğini göstermektedir. Arı poleni, protein (%25), esansiyel amino asitler, yağ (%6) gibi birçok önemli bileşen bakımından zengin olup, yaklaşık %51'den fazlası çoklu doymamış yağ asitlerinden (PUFA) oluşmaktadır (%13 linoleik asit, %20 palmitik asit ve %39 linolenik asit). Ayrıca, 28'den fazla mineral, 12 vitamin, 11 enzim veya koenzim, karbonhidratlar (%35–%61; ağırlıklı olarak sakkaroz, glikoz ve fruktoz olmak üzere 11 farklı şeker türü), karotenoidler, flavonoidler ve fitosteroller içermektedir (Xu, Sun, Dong ve Zhang, 2009).

4. ARI POLENİ VE KOYUN BESLEME

Gaafar (2024), arı poleninin emziren Rahmani kuzuların diyetlerine yem katkı maddesi olarak eklenmesinin bağışıklık tepkisi, hastalık enfeksiyonu, ölüm oranı, büyüme performansı ve sütten kesim ağırlığı üzerine etkilerini araştırmıştır. Çalışmada, emziren kuzulara 1 g/kuzu/gün düzeyinde arı poleni verilmesinin bağışıklık tepkisini iyileştirdiği, hastalık enfeksiyonu ve ölüm oranını azalttığı, ayrıca sütten kesim ağırlığı ile toplam ve ortalama günlük canlı ağırlık artışını

artırdığı bildirilmiştir. Ayman ve ark. (2024), Ossimi kuzularının diyetlerine farklı seviyelerde hurma poleni (DPP) ilavesinin büyüme performansı, besin sindirilebilirliği, besin değerleri, yem dönüşüm oranı ve kan parametreleri üzerindeki etkilerini incelemiştir. Araştırma sonucunda, özellikle daha yüksek hurma poleni takviyesi düzeylerinde günlük büyüme oranlarında, besin sindirilebilirliğinde ve bazı kan parametrelerinde anlamlı iyileşmeler sağlandığı belirtilmiştir. Liang-zhong ve ark. (2023), Hu koyunlarının bozulmamış arı poleni ile beslenmesinin büyüme performansı, bağışıklık fonksiyonları ve ekonomik verimlilik üzerine etkilerini değerlendirmiştir. Çalışmada, arı poleni ile uygun düzeyde yapılan yem takviyesinin yem maliyetlerini azaltabileceği, büyüme performansını ve serum bağışıklık fonksiyonlarını iyileştirdiği ve ekonomik kazançları artırdığı ortaya konmuştur. Hu koyunları için günlük 2 g bozulmamış arı poleni takviyesi önerilmiştir. Kaabi ve ark. (2022), koyun yumurtalarının (oosit) in vitro olgunlaşma (IVM) ortamına uygulanan Nigella sativa balı, doğal Suudi Sider balı ve bal arısı poleninin olası etkilerini araştırmıştır. Çalışmada, IVM ortamına düşük yoğunluklarda doğal bal ve arı poleni eklenmesinin in vitro olgunlaşma oranlarını artırdığı, glutatyon seviyesini yükselttiği ve olgunlaşan oositlerde gen ekspresyonunu iyileştirdiği rapor edilmiştir. Al-Amery ve Banana (2020), farklı seviyelerde sulu ve alkollü arı poleni ekstraktlarının 5 °C'de farklı saklama süreleri boyunca Awassi koçlarının semen özellikleri üzerindeki etkilerini değerlendirmiştir. Araştırma sonucunda, arı poleni ekstraktlarının tüm uygulamalarda sperm hareketliliği ve canlılığında anlamlı artış sağladığı, sperm anormalliği ve malondialdehit (MDA) konsantrasyonunda ise anlamlı azalma görüldüğü belirtilmiştir. Fodail ve ark. (2018), doğum öncesi ve sonrası dönemde Rahmani koyunlarının temel diyetine farklı dozlarda (3, 6 ve 9 g) oral yolla verilen arı poleninin süt verimi, süt kompozisyonu, kan parametreleri, kolostrum içeriği ve yeni doğan kuzuların büyüme performansı üzerindeki etkilerini araştırmıştır. Sonuç olarak, 9 g arı poleni ilavesinin süt verimini ve kompozisyonunu, kan parametrelerini ve kolostrum kalitesini iyileştirdiği, ayrıca kuzuların büyüme performansını olumlu yönde etkilediği bildirilmiştir. Taghian ve ark. (2017) ise hurma poleni, arı poleni ve arı ekmeğinin büyüme faktörü olarak rasyona ilave edilmesinin Saidi koçlarının vücut ağırlığı, günlük canlı ağırlık artışı, yem alımı ve yem dönüşüm oranı üzerindeki etkilerini değerlendirmiştir. Çalışma, bu doğal ürünlerin söz konusu performans parametrelerinde iyileşmelere yol açtığını ortaya koymuştur.

5. PROPOLİS VE KİMYASAL BİLEŞİMİ

Propolis, ya da diğer adıyla arı tutkalı, bal arıları (Apis mellifera) tarafından çeşitli ağaç ve bitki türlerinin salgılarından ve tomurcuklarından toplanarak, balmumu ve polenle karıştırılıp kendi enzimleri aracılığıyla kimyasal olarak değişime uğratılmasıyla elde edilen doğal, reçineli bir maddedir (Seven ve ark., 2010; Yücel ve ark., 2014). Propolis; flavonoidler, fenolik asitler, yağ asitleri, steroidler, alkoller ve ketonlar gibi sekonder metabolitler veya biyoaktif bileşenler içermesi nedeniyle antioksidan, antibakteriyel, antifungal, antiviral, antiinflamatuar, antiparaziter, antimetanojenik, immünmodülatör ve antikanser özellikler göstermektedir (Rufatto ve ark., 2018; da Silva ve ark., 2019).

Bu biyoaktif özellikler, propolisin bileşiminde bulunan bileşenlerin çoğunun bitkilerde doğal olarak bulunması ile ilişkilidir ve propolisi insan ve hayvan tüketimi için güvenli bir gıda maddesi haline getirmektedir. Bu doğrultuda, son yıllarda propolisin, hayvan ve insan

beslenmesinde antibiyotiklere alternatif bir yem katkı maddesi olarak kullanımı üzerine yoğun bilimsel araştırmalar yapılmaktadır (Morsy ve ark., 2015). Propolis bileşiminin, arıların toplama yaptığı alanlardaki bitki örtüsünün floristik ve ekolojik özelliklerine bağlı olarak doğal bir değişkenlik gösterdiği bildirilmektedir (Alencar ve ark., 2007; Toreti ve ark., 2013). Kimyasal olarak propolis; yaklaşık %50 oranında reçineler, %30 oranında balmumu, %5 oranında polen, %10 oranında uçucu yağlar ve %5 oranında vitaminler (B1, B2, B3, B6), steroidler, benzoik asit, ketonlar, yağ asitleri, kinonlar, esterler, laktonlar ve şekerler gibi diğer organik bileşenlerden oluşmaktadır (Abdulkhani ve ark., 2017).

6. PROPOLİS VE KOYUN BESLEME

Kısıtlanmış erkek kuzuların günlük rasyonlarına farklı seviyelerde kırmızı propolis özütü (RPE) ilave edilmesinin rumen ve bağırsak performansı ile histomorfometrik parametreleri, ayrıca karaciğer ve böbreklerin histopatolojik özellikleri üzerindeki etkilerini değerlendirmek amacıyla yürütülen bir çalışmada, günlük 21 mL RPE takviyesinin rumen ve bağırsakta emilim yüzey alanını artırarak bağırsak sağlığını iyileştirdiği, glikojen hepatik indeksini geliştirdiği ve böbrek ya da karaciğer hasarına yol açmadan kapalı sistemde yetiştirilen erkek kuzularda toplam ağırlık artışını artırabildiği bildirilmiştir (De Melo Garcia ve ark., 2023). Kurak koşullarda yetiştirilen ve geç gebelik ile laktasyon dönemlerinde bulunan Barki koyunlarına uygulanan propolisin biyo-hematolojik parametreler, antioksidan enzim aktiviteleri ve üretkenlik üzerine etkilerini araştıran bir diğer çalışmada ise, doğum öncesi dönemde Çin propolisi takviyesinin süperoksit dismutaz (SOD), haptoglobin (HP), nitrik oksit (NO) konsantrasyonları ve malondialdehit (MDA) düzeylerini iyileştirdiği, bağışıklık sistemi fonksiyonlarını geliştirdiği, ayrıca süt verimi ile kuzuların sütten kesim ağırlığını artırdığı ve antioksidan durumu olumlu yönde etkilediği rapor edilmiştir (Shedeed ve ark., 2019). Propolis tozu veya tutkal özütünün farklı konsantrasyonlarda kullanılarak, sentetik antibiyotiklerle karşılaştırıldığı ve koçların semen kalitesi, bakteriyel kontaminasyona karşı dirençleri ile doğurganlık oranları üzerindeki etkilerinin değerlendirildiği bir çalışmada ise, doğal propolis kullanımının uzatılmış koç spermasında antimikrobiyal etki göstererek sperm kalitesini, bakteriyel inhibisyon bölgelerini ve doğurganlık oranını artırdığı belirlenmiştir (Mohamed, 2017). Brezilya propolisinin Santaines koyunlarında kuzulama performansı, süt üretimi ve kan metabolitleri üzerine etkilerini inceleyen bir çalışmada, propolis uygulamasının toplam lökosit sayısını, protein, globülin ve glikoz konsantrasyonlarını artırdığı, somatik hücre sayısını azalttığı, süt verimi ile süt yağ, protein ve laktoz oranlarını iyileştirdiği tespit edilmiştir. Ayrıca, propolis uygulaması ortalama canlı ağırlık artışı ve yemden süte dönüşüm oranını artırırken, kuzuların doğum ve sütten kesim ağırlıkları üzerinde anlamlı bir etki göstermemiştir. Doğum öncesi dönemde uygulanan propolis ekstraktının, hem kuzular hem de koyunlar açısından gebelikten laktasyona geçiş dönemini olumlu etkilediği bildirilmiştir (Morsy ve ark., 2016). Yeşil propolis, kahverengi propolis ve monensin sodyumun kuzuların davranışları ve besi performansları üzerindeki etkilerini karşılaştırmak amacıyla yapılan bir başka çalışmada, yeşil propolis ile günlük 67,0 mg flavonoid sağlanan diyetin, besi kuzularında canlı ağırlık artışını ve yem dönüşümünü azalttığı; buna karşılık kahverengi propolis ile sağlanan 20,2 mg flavonoid uygulamasının ise, monensin sodyuma benzer şekilde yem dönüşümünü ve besi performansını iyileştirdiği rapor edilmiştir. Araştırmacılar, propolis özütünün besi kuzularının günlük rasyonlarında monensin sodyuma alternatif potansiyel bir gıda takviyesi olabileceğini, ancak

biyoekonomik olarak verimli optimum takviye düzeylerinin belirlenebilmesi için daha fazla çalışmaya ihtiyaç duyulduğunu vurgulamışlardır (İtavo ve ark., 2011).

7. SONUÇ VE ÖNERİLER

Mevcut bilimsel çalışmalar doğrultusunda, arı poleni ve propolisin belirli düzeylerde koyun, koç ve kuzuların diyetlerine eklenmesinin, bu hayvanların üretkenlik, verimlilik ve bağışıklık durumlarını iyileştirdiği sonucuna varılmıştır. Ancak, elde edilen bulguların doğruluğunun artırılması ve genellenebilirliğinin sağlanabilmesi için daha fazla araştırmaya ihtiyaç duyulmaktadır. Arı poleni ve propolisin bileşimlerinin, arıların ziyaret ettiği toplama alanlarındaki bitki örtüsünün floristik ve ekolojik özelliklerine bağlı olarak değişkenlik göstermesi nedeniyle, bu doğal ürünlerin etkilerini daha kapsamlı şekilde değerlendirebilmek adına, kontrollü laboratuvar çalışmaları ve farklı koşullarda gerçekleştirilecek hayvan denemeleri ile desteklenen ilave bilimsel araştırmalar yapılması önerilmektedir.

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THE ROLE OF RURAL DEVELOPMENT IN ACHIEVING THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

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My academic journey, which encompasses an Honorary Doctor of Philosophy in Generic Education from Abide University and Institute and a Doctor of Divinity from North Central Theological Seminary, has been deeply influenced by the Arthurian legend. This collection of tales about King Arthur, his knights, and their quests holds significant cultural and historical importance. It has been a central theme in my exploration of cross-cultural communication, offering a unique perspective to understand the relationship between myth, culture, and science. I believe this perspective, which emphasizes the importance of noble ideals and heroism, can provide insights into the study of rural development. The Arthurian legend, focusing on noble ideals and heroism, can be a compelling lens through which to understand the challenges and opportunities in rural development. The legend's emphasis on noble ideals and heroism can be seen as a metaphor for the dedication and courage required to pursue sustainable rural development. It also serves as a persuasive avenue to investigate how sound influences the artistic and architectural features of the medieval era, symbolizing the shaping of societal norms and values.

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My international experiences have significantly broadened my academic perspective, particularly in understanding how the Arthurian legend resonates across cultures with its universal themes of heroism and noble ideals. This exposure has enriched my understanding of global issues, including rural development and gender inequality. It has connected me with a broader educational network and prompted me to examine our shared cultural heritage through the lens of the Arthurian legend. This cultural phenomenon transcends national borders, and our collective inquiry can lead to a deeper understanding of shared human experiences, including the diverse interpretations and applications of the Arthurian legend regarding gender and empowerment issues in rural development.

Public Affairs, August 1-15, 2022, Online
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During my time as a Book Pecker Fellow at Peace X, India, I was honoured to be named the top fellow in the social science department. In this capacity, I researched the cultural significance of the Arthurian legend, which motivated me to continue my academic endeavours. Additionally, I earned a computer literacy certificate in Migration Studies from GRFDT, New Delhi, India. My research on the cultural significance of the Arthurian legend has provided unique insights into the field of rural development, particularly in the context of India.

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ABSTRACT

Rural development is crucial and urgent for achieving the United Nations' Sustainable Development Goals (SDGs). It plays a significant role in reducing poverty (SDG 1), ending hunger (SDG 2), providing access to clean water and sanitation (SDG 6), and creating sustainable communities (SDG 11). The urgency and importance of these issues are underscored by the fact that many people live in rural areas, which is vital for agriculture and food security. Focusing on rural development supports SDG 2, which aims to end hunger and ensure everyone can access safe and nutritious food throughout the year. This involves promoting sustainable farming practices, increasing the productivity and income of small farmers, and improving their working and living conditions. Rural development also plays a crucial role in tackling poverty (SDG 1), as about 75% of the world's poor live in rural regions. We must improve access to essential services, build infrastructure, and strengthen social protection systems to combat this rural poverty. Supporting sustainable farming can secure food and increase family incomes. Another key part of rural development is providing clean water and sanitation (SDG 6). Many rural communities still lack safe drinking water and proper sanitation.

Investing in these facilities is essential for health and can also reduce poverty by lowering healthcare costs and increasing productivity. SDG 11 aims to make cities and human settlements inclusive and sustainable, which is also relevant for rural areas. We should promote sustainable development in rural communities by ensuring access to essential services, improving transport, and respecting cultural and natural heritage. Rural development is not isolated; it connects to other goals, such as SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), and SDG 10 (Reduced Inequalities). Addressing the challenges in rural areas is crucial for creating a fairer and more sustainable world. To achieve effective rural development, we need to use approaches that consider social, economic, and environmental factors. Linking rural and urban areas, promoting cooperation, investing in infrastructure, and providing access to markets, technology, and education are all essential strategies. The need for these practical strategies in rural development is a call for action. They are paramount as they ensure the successful planning and implementation of initiatives. A question arises: How does rural development help achieve the United Nations Sustainable Development Goals (SDGs) related to reducing poverty and hunger, providing access to clean water, and promoting community sustainability? This essay will review existing research and publications on rural development and its impact on the SDGs. This will highlight key themes, challenges, and successful strategies in rural areas.

Keywords: Rural Development, Sustainable Development Goals (SDGs), Gender Equality.

Introduction

The rural environment is a complex system where differences in development are visible both within countries and between them. Analyzing these rural areas is challenging because of their diversity and the lack of comparable indicators (Mihai, F.-C., & Aitu, C., 2020). This makes it hard to create objectives and indicators that meet both national and international needs. Although the common goal should make harmonization easier, policies and strategies often lack coherence. [1]Documents like Agenda 2030 outline ways to achieve good practices and reliable results, even if they do not provide universal answers. Political decisions at all levels are crucial but do not always support the best outcomes for rural areas. There are many different situations, and applying the same models everywhere may not work due to the unique conditions at the regional and local levels. Still, more mechanisms must be developed to align international sustainable development goals with local needs, especially in rural regions.

[2]Agenda 2030 has 17 sustainable development goals and 169 targets supported by the United Nations (Mihai, F.-C., & Aitu, C., 2020). This global effort addresses poverty, climate change, environmental pollution, and social inequality. It builds on the previous Millennium Development Goals, which started in 2000 (Mihai, F.-C., & Aitu, C., 2020). It focused on issues like poverty, hunger, disease, and education, promoting gender equality and environmental sustainability until 2015[3]. The Paris Agreement[4] seeks to tackle climate change and help developed and developing countries adapt. It aims to create clean, climate-resilient communities. The Paris Agreement (Mihai, F.-C., & Aitu, C., 2020) and Agenda 2030 are the most ambitious international initiatives to address economic development while considering social and environmental sustainability. These actions must reduce the significant gaps between rural and urban areas, especially concerning social and economic conditions. Even with [5]rural-urban migration, many people still live in rural areas, facing dangers from climate change, poverty, and a lack of infrastructure, particularly in developing countries. Reducing inequalities (Mihai, F.-C., & Aitu, C., 2020) in access to basic needs should be a priority at the international level. Rural areas provide urban regions with essential resources like food, energy, and raw materials while protecting natural habitats, flora and fauna, and cultural heritage (Mihai, F.-C., & Aitu, C., 2020). Therefore, sustainable rural development is a complex issue that combines environmental, economic, and social factors. It requires the same level of attention from academics, international organizations, national and local authorities, professionals, and community members as urban development does.

Literature Review

The Role of Rural Development in Achieving the United Nations Sustainable Development Goals. Rural development is a multifaceted approach integral to achieving the United Nations Sustainable Development Goals (SDGs). Multiple studies have explored the impact of rural

[1] Sustainable Rural Development under Agenda 2030. Introduction. Paragraph 2nd.
[2] Sustainable Rural Development under Agenda 2030. Introduction. Paragraph 3rd.
[3] Sustainable Rural Development under Agenda 2030. Introduction. Paragraph 3rd.
[4] Sustainable Rural Development under Agenda 2030. Introduction. Paragraph 4th.
[5] Sustainable Rural Development under Agenda 2030. Introduction. Paragraph 4th.

development on poverty alleviation, food security, and sustainable community building, highlighting its importance in addressing global challenges. Poverty remains a pressing issue in rural areas, where limited access to resources and markets exacerbates socioeconomic disparities. According to the Food and Agriculture Organization (2017), rural development initiatives that enhance agricultural productivity and provide access to basic services can significantly reduce poverty. The United Nations Development Programme (2019) also emphasizes that targeted rural development strategies can uplift rural communities by providing income-generating activities and promoting local entrepreneurship. Food security is intricately linked to rural development. The 2019 Food and Agriculture Organization Report indicates that investments in rural infrastructure, such as roads and storage facilities, are crucial for reducing food waste and improving market access for farmers.

An FAO (2020) study reveals that enhancing agricultural practices and supporting smallholder farmers can increase food production and improve nutrition in rural populations, thus addressing global hunger challenges. Access to clean water and sanitation is essential for sustainable rural communities. A report by UNICEF (2020) highlights that rural areas often face challenges accessing safe drinking water and sanitation facilities. Effective rural development programs focusing on water resource management and sanitation infrastructure can significantly improve rural residents' health outcomes and quality of life. A case study in India demonstrated that community-led initiatives in water management improved access to safe water for over a million people (Pandey et al., 2021). Creating sustainable communities is fundamental to rural development. Research suggests that integrating environmental sustainability into rural development strategies promotes resilience against climate change. The International Fund for Agricultural Development (2018) discusses how sustainable agricultural practices, such as agroecology, contribute to environmental sustainability and socioeconomic stability in rural communities. Moreover, a longitudinal study by Smith et al. (2021) identifies that rural communities adopting sustainable practices benefit from improved ecosystem services and increased biodiversity. Gender inequality remains a critical issue in rural development contexts. Schreiber et al. (2019) emphasize that empowering women through education and resource access is crucial for sustainable rural development. Their study found that the success rates of rural development projects significantly improved.

Methodology

This research's methodology on rural development's role in achieving the United Nations Sustainable Development Goals (SDGs) involves qualitative and quantitative approaches to provide a comprehensive understanding of the interplay between rural development and the SDGs. A thorough review of the existing literature has been conducted to identify key themes, challenges, and successes in rural development related to the SDGs. This has included analyzing academic journals, books, and reports from international organizations such as the United Nations, World Bank, and non-governmental organizations (NGOs). Selected case studies of rural development projects that align with specific SDGS have been analyzed. This approach has provided a deeper understanding of successful strategies and practices that can be replicated in other rural contexts. Surveys have been distributed to individuals and communities in various rural settings. Questions will focus on access to resources, perceptions of

development initiatives, and the impact of these initiatives on their lives. Data from surveys and existing databases have been analyzed quantitatively to identify patterns, correlations, and trends related to rural development and achieving specific SDGs. This analysis aims to quantify the impact of rural development initiatives on poverty reduction, hunger alleviation, and access to clean water and sanitation. To ensure the research is grounded in the realities of rural communities, participatory methods have been employed. Community workshops and focus groups will be organized to engage residents and solicit their feedback on development initiatives. This approach has promoted inclusivity and empowered communities to voice their concerns and aspirations. The findings from both qualitative and quantitative research will be synthesized to develop a set of recommendations for policymakers and practitioners. These recommendations focus on improving the effectiveness of rural development strategies in achieving the SDGs, emphasizing collaboration, sustainability, and community engagement. The study results have been disseminated through academic publications, policy briefs, and community reports.

Efforts have been made to present the findings at relevant conferences and workshops to reach a broader audience and encourage dialogue around rural development and the SDGs. This multifaceted methodology aims to comprehensively understand rural development's critical role in achieving the United Nations Sustainable Development Goals, highlighting challenges and opportunities for sustainable progress. Women participate in decision-making processes. Women's empowerment is essential for achieving SDG 5 and enhancing community resilience and food security (World Bank, 2020). Rural development is central to achieving several interlinked Sustainable Development Goals. Comprehensive strategies addressing poverty, food security, clean water access, sustainable community building, and gender equality can create holistic and sustainable solutions to the challenges faced by rural populations. This review contextualizes rural development within the framework of the Sustainable Development Goals and summarizes key findings from existing literature.

Discussion: [6]The Paris Agreement aims to take decisive action to fight climate change and adapt to its impacts in developed and developing countries. It seeks to create clean and climate-resilient communities. Along with the Agenda 2030, it is one of the most ambitious global efforts to tackle critical issues related to future economic growth, social well-being, and environmental sustainability (Mihai, F.-C., & Aitu, C., 2020). These actions must address the significant differences in socioeconomic conditions between urban and rural areas and highlight rural communities' risks from climate change, poverty, and lack of necessary infrastructure, especially in developing and transition countries. It is crucial to prioritize reducing these geographical and social inequalities at the international level. (Mihai, F.-C., & Aitu, C., 2020) On the other hand, rural areas provide essential resources for urban areas, including raw materials, energy, food, and water. They also contribute labour and help protect the natural habitats of unique plants and animals and essential landscapes. Rural communities are vital for preserving cultural and historical heritage. Therefore, sustainable rural development is a complex issue that combines environmental, economic, and social factors. It needs to receive as much attention from researchers, international organizations, government agencies, professionals, and civil society as urban development does (Mihai, F.-C., & Aitu, C., 2020).

[6] Sustainable Rural Development under Agenda 2030. Introduction. Paragraph 4th.

7Rural communities face many challenges due to climate change, land degradation, deforestation, loss of biodiversity, and fragmented natural habitats. In developing countries in Africa, Asia, and Latin America, the rural population suffers more from extreme poverty, famine, social exclusion, and environmental injustice (Mihai, F.-C., & Aitu, C., 2020). 8These communities rely on their local environment, such as climate, natural resources, landscape, socioeconomic conditions, and demographics, for economic development through agriculture, industry, or tourism. (Mihai, F.-C., & Aitu, C., 2020) Many rural areas still depend on subsistence agriculture, which makes them vulnerable to natural disasters like extreme weather, floods, landslides, erosion, and drought. This can lead to low agricultural productivity, famine, extreme poverty, land abandonment, and large-scale migration. 9Poverty and poor infrastructure are the main reasons for underdevelopment and environmental damage. Rural areas need access to basic public services to ensure a decent quality of life, especially in places without major geographical barriers. [10]Globally, there are significant gaps between rural and urban areas regarding access to essential services like drinking water, sanitation, electricity, and waste management. This is especially true in low- and middle-income countries (Mihai, F.-C., & Aitu, C., 2020). Rapid urban growth in these countries causes many poor people to move to cities, often ending up in crowded slums without access to basic urban services. This situation threatens public health and the local environment. Uncontrolled urban growth spreads into surrounding rural lands, creating informal settlements. [11]Currently, 1.9 billion rural people lack proper waste management services, with coverage rates below 50% in 105 countries. This critical situation leads to millions of tons of household waste generated each year that goes uncollected. Waste often ends in nature through illegal dumping, disposal in water bodies, or burning. Freshwater ecosystems are harmed by this uncontrolled waste disposal, which can contaminate water bodies downstream, especially during heavy rains and floods, and eventually reach the ocean (Mihai, F.-C., & Aitu, C., 2020). [12]Plastic pollution severely affects wildlife, and rural communities contribute to this problem directly through fishing and indirectly through poor waste management practices. [13]A study looks at rural infrastructure in China. [14]It divides it into three main areas: facilities for living and work (such as drinking water, irrigation, electricity, roads, wastewater treatment, and waste management), development infrastructure (like education and healthcare), and environmental infrastructure (including clean energy, green housing, and environmental protection systems). Improving public transport is vital to help

[7] Sustainable Rural Development under Agenda 2030. Societal and environmental threats in rural areas. Paragraph 1st.
[8] Sustainable Rural Development under Agenda 2030. Societal and environmental threats in rural areas. Paragraph 1st.
[9] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 1st.
[10] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 2nd.
[11] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 2nd.
[12] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 2nd.
[13] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 3rd.
[14] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 3rd.

people reach education (like high schools and universities), healthcare services, justice, and social programs (Mihai, F.-C., & Aitu, C., 2020). [15]In developed countries, many people move from cities to nearby rural areas to escape noise and air pollution. [16]There is a lot of rural land development for housing, transportation, and commercial or industrial uses near these "peri-urban" (Mihai, F.-C., & Aitu, C., 2020) areas, including tourism and recreation. As a result, farming in these areas is being replaced by manufacturing and various services close to big cities. This contrasts with remote rural communities focusing primarily on farming and using natural resources. [17]Small and medium-sized businesses in rural areas use local resources, support the local economy, create jobs, develop infrastructure, and engage with the community. Small-scale farmers who use eco-friendly practices (Mihai, F.-C., & Aitu, C., 2020) can provide diverse and nutritious food while protecting the environment. Long-term growth policies should support small farmers instead of large agribusinesses to ensure food security and social fairness in tropical regions. [18]New relationships between urban and rural areas can encourage nearby farmers to adopt better management practices and engage in non-farming activities, such as tourism, environmental conservation, and forest restoration or urban-rural migration. Rural households often face challenges when trying to sell their products. They are usually limited to local markets or must sell to mediators at low prices. This issue is common in [19]Eastern European countries, where dispersed villages, poor roads, and limited urban services make it hard for local farmers to connect directly with city customers. [20]Creating farmer associations can help these producers access regional or national markets, shorten supply chains, and reduce reliance on food imports, particularly in agricultural countries like Romania (Mihai, F.-C., & Aitu, C., 2020). These countries should shift from being cheap raw material providers for exports to developing manufactured products and services, such as furniture, food products, organic farming, renewable energy, and agritourism. [21]Digital technologies can change how farmers find price and market information. They can help coordinate resources like transport, logistics, finance, and production techniques, benefiting the agriculture sector in developing countries. [22]To support sustainable development, improvements in water harvesting, growing drought-resistant crops, and better local governance are necessary. This can include integrated resource management and accessible public services. Better connections between urban and

[15] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 8th.
[16] Sustainable Rural Development under Agenda 2030. Rural population access to basic public utilities. Paragraph 8th.
[17] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 3rd.
[18] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 3rd.
[19] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 3rd.
[20] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 3rd.
[21] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 4th.
[22] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 5th.

rural areas can also help. [23]The "Smart Village" initiative is one positive step. It aims to provide energy access to remote villages and improve related areas like clean water, sanitation, education, healthcare, and gender equity, which align with the Sustainable Development Goals (SDGs). [24]In poorer rural areas of developing countries like Bangladesh, where energy comes from wood or dried cattle dung, household bioenergy systems, such as anaerobic digestion of waste, could help achieve several SDGs. Despite facing challenges like poverty, low education, and cultural barriers, these systems offer societal and environmental benefits. [25]Training and awareness programs can help address these issues. [26]Fortunately, domestic biogas projects are emerging in countries like Pakistan, India, China, Vietnam, and others in Asia, Africa, and South America. Rural tourism, agritourism, religious tourism, and ecotourism (Mihai, F.-C., & Aitu, C., 2020) are alternatives or complementary economic activities that could further stimulate rural entrepreneurship while decreasing rural community dependency on one primary economic sector (agriculture, forestry, energy, mining, or fishing). Rural communities face many challenges, including natural disasters, policy changes, economic issues, and security problems. Managing these risks helps strengthen the community's resilience. Sustainable development relies on three key social, financial, and environmental areas (Mihai, F.-C., & Aitu, C., 2020).

Conclusion

This study highlights the importance of addressing the issues we found while also recognizing the positive results that emerged. We must consider how these findings will affect future strategies and practices to promote sustainable progress and practical solutions. Building a teamwork culture and encouraging open conversations among all stakeholders is vital. This approach will help us face challenges and achieve common goals. By working together, we can make meaningful progress towards our shared objectives.

[23] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 7th.
[24] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 8th.
[25] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 8th.
[26] Sustainable Rural Development under Agenda 2030. Pathways towards sustainable development goals(SDG's). Paragraph 8th.

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PLANT PRODUCTION PLANNING AND SUPPORT IN TURKİYE

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ABSTRACT

In recent years, global climate changes, water restrictions, rapid population growth, pandemics, geopolitical risks and conflicts in our nearby geography have increased the importance of food supply security. In order to minimize the impact of these negativities and ensure food supply security, an effective planning process that adopts the most appropriate use of natural resources has become mandatory.

The purpose of the Agricultural Production Planning implemented in Turkey is to prevent excess or deficiency in production and to ensure supply security in strategic products. In this direction, minimum and maximum production quantities will be determined according to the country's needs, and the product or product groups to be produced on the basis of the agricultural basin will be determined by taking into account the supply and demand amounts of the products.

With the amendment to the Agricultural Law published in the Official Gazette on April 5, 2023, and the Regulation on Agricultural Production Planning published on September 14, 2023, production planning in plant production has been started as of September 01, 2024. In the planning, the planning of the technical committee established in each province is taken into account and the decision is made by the Planning Board located in the center.

With plant production planning, 13+1 products were included in the planning scope. While selecting these products; their importance in human and animal nutrition, foreign trade status, sufficiency rates within the country, raw material status used in industry, food safety and food security and rotation were taken into consideration.

With plant production planning, which product will be produced in which quantity and in which basin, and products that can be produced in regions with water restrictions were determined. One of the most important incentives of production planning has been the new support policy. Planning is guided by supports, but in cases where the production of products subject to planning is not complied with, there are sanctions.

With the supports to be given in planning, supports can be provided from 25% to the full coverage of fertilizer and fuel oil expenses. In regions with water restrictions, the entire fertilizer and fuel oil expense for production will be covered by the Ministry of Agriculture.

Keywords: Plant Production, Planning, Sufficiency, Food Supply Security, Water Shortage

TÜRKİYE'DE BİTKİSEL ÜRETİM PLANLAMASI VE DESTEKLEMELER

ÖZET

Son yıllarda yaşanan küresel iklim değişiklikleri, su kısıtı, hızlı nüfus artışı, pandemi, jeopolitik riskler ve yakın coğrafyamızda yaşanan çatışmalar gıda arz güvenliğinin önemini artırmıştır. Yaşanan bu olumsuzlukların etkisini en aza indirerek gıda arz güvenliğini sağlayabilmek için doğal kaynakların en uygun kullanımını ilke edinen etkin bir planlama süreci zorunlu hâle gelmiştir.

Türkiye'de uygulamaya konulan Tarımsal Üretim Planlamasının amacı; üretimde arz fazlası veya eksikliğinin oluşmasının önüne geçmek ve stratejik ürünlerde arz güvenliğinin korunmasını sağlamaktır. Bu doğrultuda ülke ihtiyacına göre asgari ve azami üretim miktarları tespit edilecek, ürünlerin arz ve talep miktarı dikkate alınarak tarım havzası bazında hangi ürün veya ürün gruplarının üretileceği belirlenecektir.

5 Nisan 2023 tarihinde Resmi gazetede yayınlaann Tarım kanunu değişikliği, 14 Eylül 2023 te yayınlanan Tarımsal Üretimin Planlanması hakkındaki Yönetmelik ile 01.09.2024 tarihi itibariyle bitkisel üretimde üretim planlamasına başlanılmıştır. Planlamalarda her ilde kurulu teknik Komitenin planlaması dikkate alınarak merkezde bulunan Planlama kurulu tarafından karara bağlanmaktadır.

Bitkisel üretim planlaması ile 13+1 ürün planlama kapsamına alınmıştır. Bu ürünler seçilirken; insan ve hayvan beslenmesindeki önemleri, dış ticaret durumları, ülke içerisinde yeterlilik oranları, sanayide kullanılam hammadde durumu, gıda güvenliği ve gıda güvencesi ve münavebe dikkate alınmıştır.

Bitkisel üretim planlaması ile hangi ürünün ne miktarda hangi havzada üretileceği, su kısıtı olan bölgelerde üretilebilecek ürünler belirlenmiştir. Üretim planlamasının en önemli teşviklerinden birisi yeni destekleme politikası olmuştur. Planlama destekler ile yönlendirilmektedir ancak planlamaya tabi ürünlerin üretimine uyulmadığı durumlarda yaptırımda sözkonusudur.

Planlamada verilecek destekler ile gübre ve mazot giderlerinin % 25'inden tamamının karşılanmasına kadar destekler verilebilecektir. Su kısıtı uygulanan bölgelerde üretim için yapılan gübre ve mazot giderinin tamamı tarım bakanlığı tarafından karşılanacaktır.

Anahtar Kelimeler: Bitkisel Üretim, Planlama, Yeterlilik, Gıda Arz Güvenliği, Su Kısıtı

1. GİRİŞ

Dünyada son 50 yıl içerisinde dünya nüfusu katına, kentleşme oranı % 37'den % 57'ye, doğal afetler ise 5 katına çıkmıştır. Doğal afetlerin ekonomik zararı 250 milyar $, bu ekonomik kaybın % 50 si ise tarım sektöründe gerçekleşmiştir (Dünya Bankası, 2023).

Yapılan projeksiyonlarda 2050 yılında dünya nüfusunun 10 milyar, Türkiye nüfusunun 105 milyon olacağı, 2050 yılında gıda talebine bağlı olarak bugünkü üretimin % 70 oranında artması, gıda üretimi için ise fazla su tüketiminin % 15 artabileceği tahmin edilmektedir (FAO, 2023).

Türkiyenin mevcut su potansiyeli 2024 yılı itibariyle 112 milyar m^3 iken 2030 yılı için 93.3 milyon nüfusa karşılık 91 milyar m^3 su potansiyeli tahmin edilmektedir. Bu süreç içerisinde nüfus artışının % 9.5 olacağı, su potansiyeli azalışının ise % 18.7 olacağı, mevcutta kişi başı yıllık su miktarının 1313 m3 iken 2030 yılında su putansiyeli azalışı ve nüfus artışına göre yapılan hesaplamalar ile kişi başı su tüketim miktarının 975 m3'e düşeceği, Türkiyenin su stresi çeken bir ülke konumundan su fakiri bir ülke konumuna düşebileceği hesaplanmaktadır (TOB, 2024a)

Türkiyede bitkisel üretim alanları son yıllarda artan nüfus ve tarım dışına çıkarılan arazilerin artışından dolayı 1990 yılında 4.9 da/kişi iken 2022 yılı verilerine göre bu alanın 2.8 da/kişi'a düştüğü belirlenmiştir.

Türkiye'de son 21 yılda arazi kullanımındaki değişiklikler Çizelge 1'de görülmektedir.

Çizelge 1. Türkiye arazi valığındaki değişim (bin ha)

Yıl	Tarla	Nadas	Meyve	Sebze	Süs Bitkileri	Toplam
2001	17.917	4.914	2.610	909	0	26.350
2016	15.575	3.998	3.329	804	5	23.711
2017	15.498	3.697	3.348	798	5	23.346
2018	15.421	3.513	3.457	784	5	23.180
2019	15.398	3.387	3.519	790	5	23.099
2020	15.628	3.173	3.559	779	5	23.144
2021	16.062	3.059	3.591	755	5	23.472
2022	16.510	2.960	3.671	718	6	23.865

Türkiye'de son 21 yılda tarla bitkileri ekim alanının % 8, sebze üretim alanlarının % 21, nadas alanlarının % 40 azaldığını buna mukabil meyve bahçelerinin alanlarının % 41 arttığını, toplam ekili dikili alanın ise 2022 yılında 2002 yılına göre % 9 azaldığı Çizelge 1'de görülmektedir.

Son yıllarda yaşanan küresel iklim değişiklikleri, su kısıtı, hızlı nüfus artışı, pandemi, jeopolitik riskler ve yakın coğrafyamızda yaşanan çatışmalar gıda arz güvenliğinin önemini artırmıştır.

Yaşanan bu olumsuzlukların etkisini en aza indirerek gıda arz güvenliğini sağlayabilmek için doğal kaynakların en uygun kullanımını ilke edinen etkin bir planlama süreci zorunlu hâle gelmiştir.

Artan nüfusa karşılık azalan tarım alanları, iklim değişikliği, gıda güvenliği ve güvencesinin ön plana çıkmış olması tarımda planlamayı zorunlu hale getirmiştir.

2. BITKISEL ÜRETIM PLANLAMASI

Bitkisel Üretim Planlamasının amacı; üretimde arz fazlası veya eksikliğinin oluşmasının önüne geçmek ve stratejik ürünlerde arz güvenliğinin korunmasını sağlamaktır. Bu doğrultuda ülke ihtiyacına göre asgari ve azami üretim miktarları tespit edilerek, ürünlerin arz ve talep miktarı dikkate alınarak tarım havzası veya işletme bazında hangi ürün veya ürün gruplarının üretileceği belirlenmektedir (TOB, 2024b).

Tarımda bitkisel üretim planlaması ile;

- Suyu merkeze alarak iklim değişikliğine uyumlu üretim yapılması,
- Stratejik ürünlerin en uygun yerde yetiştirilmesi,
- Üretimde verim ve kalitenin artırılması,
- Kaynakların etkili kullanılması,
- Verimlilik ve tarımsal üretimde artış sağlanması,
- Üreticilerin yaşadığı pazarlama sorunlarının önüne geçilmesi,
- Üreticilerin refah düzeyinde artış sağlanması,
- Sanayinin ihtiyaç duyduğu hammadde tedarikinin sağlanması,

amaçlanmaktadır.

2.1. Yasal Değişiklik

23 Mart 2023 tarihinde TBMM'de Kabul edilen değişiklik ile Tarım Kanununun 7. Maddesinde yapılan değişiklik ile tarımsal üretim planlaması ile Tarım ve Orman Bakanlığı yetkili kılınmıştır. Değişiklik 5 Nisan 2023 tarihli Resmi Gazete ile yayınlanarak yürürlüğe girmiştir. Yine 14 Eylül 2023 tarihli Resmi Gazetede yayımlanan *Tarımsal Üretimin Planlanması Hakkında Yönetmelik* yayımlanarak üretim planlaması mevzuatı oluşturulmuştur.

2.2. Bitkisel Üretim Planlaması Kapsamı

Bitkisel üretim planlaması çalışmaları sürecinde öncelikle planlama kapsamına alınacak ürünler, bu ürünlerin yetiştirilebileceği azami ve asgari miktarları ve bu ürünlerin yetiştirilebileceği havzalar belirlenmektedir.

Planlama kapsamına alınacak ürünler belirlenirken; stratejik ürünlerde yeterlilik, gıda güvenliği ve güvencesi, hayvan beslenmesi, münavebe, tarıma dayalı sanayi ve dış ticaret durumu dikkate alınmaktadır.

Türkiye'de sebze, meyve ve bazı tarla bitkilerinde yeterlilik oranları Şekil 1'de görülmektedir.

Şekil 1. Türkiye'de bazı ürünlerin yeterlilik oranları (2022)

Şekil 1'de görüldüğü üzere Türkiye'de sebze ve meyve grubunda yeterlilik oranları % 100'ün üzerinde iken tarla bitkileri grubunda bazı ürünlerde yeterlilik oranı % 100'ün altındadır. Bunları buğday, mısır, pirinç, arpa, ayçiçeği, k.mercimek ve soya olarak sayabiliriz.

Gıda arz güvenliği, stratejik önemi, hammadde temini, insan ve hayvan beslenmesi gözönüne alındığında bitkisel üretim planlamasına esas olmak üzere 13+1 ürün belirlenmiştir. Bunlar; hububat (buğday, arpa, dane mısır) baklagil (mercimek, nohut, kuru fasulye), yağlı tohumlar (ayçiçeği, soya, pamuk, kanola, aspir), tüm yem bitkileri ve kuur soğan ve patatestir.

Bir kanuna tabi olan bazı ürünler (çay, çeltik, şeker pancarı, fındık, zeytin) ile stratejik olarak değerlendirilmeyen bazı ürünler (triticale, çavdar, yulaf) olarak planlama kapsamına alınmamıştır.

Her bir üründe azami asgari üretim miktarları hesaplanırken krtiter olarak; nüfus, turist sayısı, ithalat, ihracat, yurtiçi tüketimi, tohumluk, sanayide kullanım miktarı ve iklimsel faktörler gözönüne alınmaktadır.

Ürün-havza eşleştirmelerinde; mevcut durum analiz edilmekte, uzman görüşleri dikkate alınarak ürün uygunluk haritalarına göre eşleştirmeler yapılmaktadır. Ürün uygunluk haritaları; iklim, toprak, topoğrafya ve sulama durumuna göre belirlenmiştir.

Tarımsal üretim planlamasının yönetimi, merkezde Tarımsal Üretim Planlama Kurulu, illerde ise çeşitli sivil oplum kuruluşları ve ilgili paydaşları içerisine alan Teknik Komite tarafından yapılmaktadır.

11 ilde bulunan 52 ilçe, tarımsal yer altı su kısıtı olan alan konumundadır. Bu ilçelerde yeni bir hayvancılık işletmesinin açılması ve sulu ürün yetiştirilmesi izne tabidir. Bu alanlarda özellikle şekerpancarında olduğu gibi bir münavebe uygulanacak ve 4 yılda bir ancak sulanabilen ürün yetiştirilebilecektir (Şekil 2).

Şekil 2. Su kısıtı olan il, ilçe ve havzalar

Bitkisel üretim planlaması kapsamında; % 6 eğimin üzerindeki tarım alanlarında meyve bahçesi tesisi bakanlığın iznine tabidir. Bir alanın % 80 ve üzeri alanı meyvecilik alanı ise kalan alanda izne gerek olmayıp bu kalan alanda da meyve bahçesi kurulabilecektir. Kendine yeterlilik oranı % 150'nin üzerinde olan ürünler Bakanlık iznine tabidir.

Bitkisel üretim planlaması 3 yıllık yapılmaktadır ancak her bir yıl değişiklik yapılabilmektedir.

Kuruda ikili, suluda ise üçlü münavebe uygulaması esas olup ÇKS başvurusu üzerinden ve gerektiğinde atrazide yerinden controller yapılabilecektir.

2.3.Bitkisel Üretim Planlaması Kapsamında Yaptırımlar

Tarımsal Üretim Planlaması kapsamında Bakanlığın belirlediği kurallara uymayan çiftçilere aşağıdaki yaptırımlar uygulanacaktır:

- Bakanlıkça belirlenen ürün veya ürün gruplarının üretimine başlanmadan önce planlamaya uymadığı tespit edilen çiftçiler, İl/İlçe Müdürlükleri tarafından 12 ay içinde planlamaya uygun üretim yapmaları konusunda yazılı olarak (Tebligat Formu ile) uyarılacaktır.

- Uyarıldığı tarihi takip eden 12'nci ayın sonunda uygun olmayan faaliyete devam eden çiftçiler, 5 yıl süre ile Bakanlığın hiçbir destekleme programından yararlanamayacaktır. Bu kararla ilgili gerekli bilgi ve belgeler İl/ İlçe Müdürlüğü tarafından düzenlenerek mahallî mülki amire sunulacaktır.

- Yazılı olarak uyarılan, 5 yıl süreyle destekleme programından yararlanamaz kararı verilen ancak bir sonraki takvim yılında da planlamaya aykırı faaliyetine devam eden çiftçilere, üretimini yaptığı ürün veya ürün grubuna göre elde edeceği yıllık brüt hasılasının %1'inden

5'ine kadar idari para cezası uygulanacaktır. İl/İlçe Müdürlüğü tarafından idari para cezası uygulanması için gerekli bilgi ve belgeler düzenlenerek mahallî mülki amire sunulacaktır.

- Eğer söz konusu üretim faaliyeti çok yıllık ise yazılı uyarı ve destekleme programından yararlandırılmama işlemleri tesis edilmesine rağmen çiftçi bu üretimine devam ediyorsa aykırı faaliyette bulunduğu tespit edilen her yıl için bu faaliyetten elde edeceği yıllık brüt hasılasının %1'inden 5'ine kadar idari para cezası uygulanacaktır.

- 5488 sayılı Tarım Kanunu kapsamındaki idari yaptırımlar, kabahate konu ürünün yetiştirildiği işletmenin bulunduğu mahallî mülki amir tarafından uygulanacaktır.

- İdari para cezası tutarının hesaplanmasında çiftçinin üretim yaptığı ürün veya ürün grubuna ait TÜİK tarafından yayımlanan il geneline ait o yılın ortalama verimi ile üretici satış fiyatı dikkate alınarak brüt hâsıla hesaplanacaktır. TÜİK tarafından verim ve fiyatı yayımlanmayan ürünlerin verim miktarı ile üretici satış fiyatı İl Müdürlüğü tarafından havza bazında belirlenecektir.

3.DESTEKLEMELER

Bitkisel üretim planlamasında kullanılacak araçlar, destekleme modeli, tarımsal krediler, hibeler, sözleşmeli üretim, kayıtlılık-tarım sayımı, işlenmeyen arazilerin üretime kazandırılmasıdır.

Özellikle yeni destekleme modeli, bitkisel üretimde yönlendirici bir araç olarak kullanılacaktır.

Bitkisel üretimde 2027 sonunda halen ortalama 35 milyon ton olan hububat üretiminin % 13 artışla 39.5 milyon tona, 1.2 milyon ton olan baklagil üretiminin % 17 artışla 1.4 milyon tona, 4.6 milyon ton olan yağlı tohumlar üretim miktarının ise % 22 artışla 5.6 milyon tona çıkarılması hedeflenmektedir.

Yeni destekleme modeli ile tüm bitkisel üretime temel destek olarak ifade edilen destekleme ile alan bazlı olmak üzere üretimde kullanılan mazotun % 50'si, gübrenin ise % 25'i destek olarak üreticiye ödenecektir. Planlamaya tabi ürünleri bakanlık tarafından belirtilen alanlarda belirtilen ürünlerin üretilmesi halinde üretimde kullanılan mazotun tamamı, gübrenin ise yarısı, bu ürünlerin su kısıtı olarak ilan edilen havzalarda (ilçe) üretilmesi halinde gübre ve mazotun tamamı bakanlık tarafından üreticiye ödenecektir. Her yıl desteğin miktarı ürünün ekim zamanında ilan edilecektir.

4.SONUÇ

Türkiye nüfusu, ziyarete gelen turist sayısı, misafir göçmenler ile birlikte yılda ortalama 100 milyon nüfusu beslemek ve yıllık belirli bir tarımsal ihracatı yapmak durumundadır. Diğer taraftan bunu su kısıtını gözeterek yapmak durumundadır. Bundan dolayı bitkisel üretimini, tarımsal üretimini planlamak amacıyla 2023 yılında mevzuat değişikliğine gidilmiştir.

Planlamanın esas amacı stratejik ürünlerde kendine yeterlilik, gıda güvenliği ve güvencesinin sağlanması, hangi ürünün nerede ne miktarda üretileceğinin belirlenmesidir. Planlamanın yaptırımdan daha ziyade teşvikler ile yönlendirme yapılarak yapılması esas alınmıştır.

Türkiye'de mevcut ekili dikili tarımsal alana bakıldığında meyve bahçeleri lehine bir genişleme tarla tarımı ürünlerine karşılık bir daralma sözkonusudur.

Bitkisel üretim planlaması bir anlamda insan ve hayvan beslenmesinde kullanılan tarla tarımı ürünlerinin yetiştiriciliğinin güvence altına alınmasıdır denilebilir.

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FORAGE CROP BREEDING STUDIES IN TURKEY

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ABSTRACT

Considering that feed costs constitute 70% of the total inputs of livestock enterprises, the supply of affordable and high-quality roughage is critically important for livestock activities. Roughage sources are primarily obtained from pastures, meadows, and forage crop cultivation within agricultural fields. However, the misuse of pastures and meadows, overgrazing, and the effects of climate factors have decreased the quantity and quality of these areas. This situation has emphasized the necessity of forage crop farming.

Despite the importance of forage crops for both animal nutrition and soil improvement, breeding efforts targeting these crops have historically lagged behind compared to other plants. Significant advancements in plant breeding have been achieved with the development of modern molecular genetic methods, enabling the creation of more productive forage crop varieties. Turkey, located at the crossroads of the Mediterranean and Near East, is rich in genetic diversity for forage crops, providing an ideal environment for breeding activities.

In Turkey, forage crop breeding gained momentum with the establishment of the Pasture, Meadow, and Forage Crops Branch in 1952. Today, among the 3,834 registered field crop varieties in the country, 290 belong to forage crops. Alfalfa, Italian ryegrass, vetch, and forage pea are the most registered forage crops, with a prominent role played by the private sector in breeding activities for these species. Following 2010, the use of biotechnological methods in breeding has led to a significant increase in breeding activities.

The development of forage crop breeding in Turkey is crucial for sustainable agriculture. Supporting these studies and integrating biotechnological innovations will contribute significantly to the agricultural and livestock sectors in the future.

Keywords: Forage Crops, Forage Crop Breeding, Forage Crop Breeding in Turkey

TÜRKİYE'DE YEM BİTKİLERİ ISLAH ÇALIŞMALARI

ÖZET

Türkiye'de yem maliyetlerinin hayvancılık işletmelerinin toplam girdilerinin %70'ini oluşturduğu göz önünde bulundurulduğunda, ucuz ve kaliteli kaba yem temini hayvancılık faaliyetleri için kritik öneme sahiptir. Kaba yem kaynakları temel olarak çayır, mera ve tarla tarımı içerisindeki yem bitkileri yetiştiriciliğinden elde edilmektedir. Ancak, çayır ve mera alanlarının tekniğine uygun kullanılmaması, ağır otlatma ve iklim faktörlerinin etkisiyle bu alanlardan elde edilen ot miktarı ve ot kalitesinü düşürmektedir. Bu durum, tarla tarımı içerisinde yem bitkileri tarımının gerekliliğini artırmaktadır.

Yem bitkilerinin hayvan beslenmesi ve toprak ıslahı açısından önemli olmasına rağmen, tarih boyunca bu bitkilere yönelik ıslah çalışmaları diğer bitkilere göre daha geç başlamıştır. Modern moleküler genetik yöntemlerin gelişmesiyle birlikte, bitki ıslahında önemli ilerlemeler kaydedilmiş ve yem bitkilerinde yeni çeşitler geliştirilmiştir. Türkiye, Akdeniz ve Yakındoğu geçiş bölgesinde bulunması nedeniyle yem bitkileri genetik çeşitliliği açısından zengin bir kaynaktır ve bu bitkilerin ıslahı için ideal bir ortam sunmaktadır.

Ülkemizde yem bitkileri ıslah çalışmaları, tarım Bakanlığı bünyesinde 1952 yılında Çayır, Mera ve Yem Bitkileri Şubesinin kurulmasıyla hız kazanmıştır. Günümüzde 3834 tescilli tarla bitkisi çeşidi arasında 290 yem bitkisi çeşidi yer almaktadır. Yonca, tek yıllık çim, fiğ ve yem bezelyesi en fazla tescil edilen yem bitkileri olup, bu türlerde özel sektörün ıslah çalışmaları daha belirgindir. 2010 sonrası dönemde biyoteknolojik yöntemlerin kullanımıyla ıslah faaliyetlerinde önemli bir artış gözlenmiştir.

Türkiye'de yem bitkileri ıslahının geliştirilmesi, sürdürülebilir tarım için hayati öneme sahiptir. Bu alandaki çalışmaları desteklemek ve biyoteknolojik yenilikleri uygulamak, gelecekte tarımsal üretime katkı sağlayacaktır.

Anahtar Kelimeler: Yem Bitkileri, Yem Bitkileri Islahı, Türkiye'de Yem Bitkileri Islahı

1. GİRİŞ

Yerleşik hayatla birlikte başlayan tarım faaliyetleri, insanların temel besin kaynaklarının üretimini sağlamaktadır. Tarım, insanların ihtiyaç duyduğu besin maddelerini üretme sürecidir ve bu süreç, taze meyve ve sebzeler, tahıllar, baklagiller, et ve süt ürünleri gibi çeşitli gıda kaynaklarının elde edilmesini sağlar. Bu gıdalar, vücudun günlük enerji ihtiyacını karşılamanın yanı sıra, protein, vitamin, mineral ve lif gibi hayati besin maddelerini de sağlar. Dengeli ve sağlıklı bir beslenme, doğrudan tarım faaliyetleri ile ilişkilidir. Dengeli ve sağlıklı bir beslenme için, insanların hem bitkisel hem de hayvansal kaynaklı gıdaları yeterli miktarda tüketmeleri gerekmektedir. Gelişmiş ülkelerde insanların sağlıklı ve dengeli olarak beslenmesinde hayvansal proteinlerin payının artırılması, temel bir hedef haline gelmiştir. Yapılan araştırmalarda yetişkin bir insanın günlük 70 gr protein tüketmesi ve bunun %40'ının hayvansal kaynaklı proteinlerden oluşması gerektiği belirtilmektedir (Yeditepe Hastaneleri, 2025). Hayvansal proteinler, insan beslenmesinde hayati öneme sahip makro besin maddeleridir. Vücut fonksiyonlarının düzgün çalışması, hücrelerin yenilenmesi ve genel sağlığın sürdürülmesi için gereklidir. Bu protein kaynakları, yüksek biyoyararlanım oranlarına sahiptir ve vücudun ihtiyaç duyduğu tüm esansiyel amino asitleri içerirler. Hayvansal proteinler, bitkisel proteinlerle karşılaştırıldığında, daha yüksek kaliteli proteinler olarak kabul edilir. Hayvansal protein kaynakları arasında et, balık, yumurta ve süt ürünleri gibi gıdalar yer alır ve bu gıdaları elde etmenin yolu hayvancılık faaliyetleridir.

Tarımsal faaliyetler içerisinde yer alan hayvancılık; çeşitli evcil hayvanları besleme, onların ürünlerinden ve gücünden yararlanma işlerini kapsamaktadır (Şahin ve Doğanay, 2000 s.256). İnsanlığın en eski ekonomik faaliyetlerinden biri olan hayvancılık, günümüz dünyasında çok yönlü bir ekonomik sektöre dönüşmüştür. Nüfusun gıda ihtiyacı ve istihdamını sağlayan hayvansal üretim maddeleri; aynı zamanda sanayinin birçok alanında hammadde olarak kullanılmaktadır. Ayrıca, hayvansal üretim maddeleri, ihracat potansiyeli bakımından ülkelerin ekonomik kaynakları arasında önemli bir yer tutmaktadır. Hayvancılık, ülke ekonomisini geliştiren, birim yatırıma en yüksek katma değer oluşturan ve en düşük maliyetle istihdam imkânı sağlayan bir sektördür (Demir, 2012). Günümüzde hayvancılık bütün dünyada özellikle de gelişmiş ülkelerde önemli bir endüstri haline gelmiş ve ekonominin ayrılmaz bir parçası olmuştur.

Bununla birlikte hayvancılığı etkileyen ıslah, pazarlama, araştırma, bakım ve idare, besleme gibi birçok faktör bulunmaktadır. Ancak bunların en önemlisini yem üretimi oluşturmaktadır. Bir hayvancılık işletmesinin toplam girdilerinin %70'ini yem maliyeti oluşturduğu düşünüldüğünde hayvancılık faaliyetleri için yem teminin önemi ortaya çıkmaktadır (Tarım ve Orman Bakanlığı (TOB), 2025). Bu konuda hem nispi olarak ucuz olan hem de ruminantların sindirim faaliyetlerini olumlu yönde etkileyen kaba yemler, bu yemlerin kaynakları ve alternatif kaba yem kaynakları ön plana çıkmaktadır (Özkan ve Şahin Demirbağ, 2016). Kaba yem; doğal halde %14'ten daha fazla su içeriğine ya da kuru maddede %16-18'den daha yüksek ham selüloz içeriğine sahip olan her tür materyaldir. Hayvancılık için en önemli ve en ucuz yem kaynağı kaba yemler otçul hayvanların rasyonlarının ana kısmını oluşturan doğal şartlarda yetişen düşük enerjili yemlerdir. Aynı zamanda kaba yemler; geviş getiren hayvanların beslenme fizyolojilerine uygun olup hayvanlarda mekanik tokluk sağlaması tarafıyla büyük öneme sahiptir.

Kaliteli kaba yem, çayır ve meralar ile tarla tarımı içerisindeki yem bitkileri yetiştiriciliği olmak üzere iki önemli kaynaktan sağlanmaktadır. Çayır ve meralar hayvan beslenmesinde çok önemli kaba yem kaynaklarıdır. Aynı zamanda flora ve fauna çeşitliliğinin ve gen kaynaklarımızın gelecek nesiller için korunması, tarımsal faaliyetlerin ve hayvancılığın etkili bir şekilde sürdürülmesi için, korunması ve geliştirilmesi mutlak suretle gerekli olan alanlardır. Fakat çayır ve mera alanlarının amaç dışı kullanımı, ağır otlatma, iklim faktörleri gibi sebeplerle günden güne bu alanların yeterliliği ve kalitesi azaltmaktadır. Hem çayır ve mera alanlarının yetersiz gelmesi hem de bu alanlardan yıl boyu üretim yapılamaması yem bitkileri tarımını zorunlu kılmıştır.

2.YEM BİTKİLERİNİN ÖNEMİ VE KÜLTÜRE ALINMASI

Yem bitkisi, hayvan yemi olarak yetiştirilen, ancak bunun yanında toprak ve suyu muhafaza etme, ekim nöbeti içerisinde kendinden sonra gelen ürünlerin verimini artırma özellikleri taşıyan, doğrudan doğruya veya sonradan yedirilmek üzere hasat edilerek kurutulan veya silajı yapılan bitkilerdir (Bilgili, 2018). Kaba yem olarak tanımlanan yem bitkileri en ucuz besin kaynağıdır. Hayvanların mide mikroflorası için lüzumlu besin maddelerini içermektedir. Mineral ve vitamin kaynağı olmaları nedeniyle hayvanların verim ve üreme performanslarını etkilerler. Yem bitkilerinin yem olma niteliğinin yanında daha birçok faydalı yönleri vardır. Tarımsal üretimin esas kaynağı olan toprağın yerinde tutulmasında yani toprak ve su erozyonlarının önlenmesinde en etken silahtır. Özellikle baklagiller ailesinden olan yonca, korunga ve fiğ gibi yem bitkileri, azot fiksasyonu vasıtasıyla, havanın serbest azotunu toprağa aktararak hiçbir zararlı yan etkisi bulunmayan tabii bir gübreleme yaparlar. Aynı zamanda toprağın derin tabakalarında çözünmez halde bulunan bazı besin elementlerini (fosfor gibi) çözündürüp, toprağın üst tabakalarına taşıyarak kendinden sonra gelecek ürün için hazır hale getirirler. Başka yabancı otların gelişmesine müsaade etmezler. Böylece girmiş oldukları ekim nöbeti sistemi (münavebe) içerisinde toprak verimliliğini artırarak kendinden sonra gelen ürünün hem veriminin artmasına hem de kaliteli ve lezzetli ürünlerin üretilmesine imkân sağlarlar. Buğdaygil ve baklagil yem bitkileri ekildikleri toprakları yalnız verimli hale getirmekle kalmazlar. Aynı zamanda bol miktarda bırakmış oldukları kök ve toprak üstü artıkları ile toprağın organik madde miktarını artırarak yapısını düzeltirler. Toprağın organik madde yönünden zenginleşmesi ise, özellikle yağışı az olan yerlerde çok önemli husus olan toprağın su tutma ve besin maddeleri kapasitesini artırır (Şeker, 2002).

Gerek hayvan beslenmesi açısından gerekse de toprak ıslahı açısından bu denli önemli olmasına rağmen, yem bitkilerinin önemi oldukça geç fark edilmiştir. İnsanoğlunun kendi beslenmesi için kullandığı bitkiler üzerindeki ıslah çalışmaları oldukça eskiye dayanmasına karşılık, günümüzde insanlar tarafından ekimi dikimi yapılarak hayvanların beslenmesinde kullanılan ve yem bitkisi olarak adlandırılan bitkilerin ıslahına ise gıda olarak kullanılan bitkilerin ıslahından çok daha sonra başlanılmıştır. Çünkü, günümüzde yem bitkisi olarak kullanılan bitkiler gıda olarak kullanılan bitkilere göre insanoğlu tarafından çok daha sonra kültüre alınmıştır. İnsanoğlunun göçebe yaşam tarzında yüzyıllarca daha çok doğal çayır meralara dayalı olarak beslediği hayvanlarını göçebe hayatını bırakıp yerleşik hayata geçmesiyle yerleşim yerindeki doğal meraların hayvanlar için yıl boyu yem üretememeleri nedeniyle yem bitkileri tarımı yaygınlaşmaya başlamıştır (Hatipoğlu ve ark., 2023).

Her ne kadar yem bitkileri gıda olarak kullanılan bitkilere göre daha geç kültüre alınmışlarsa da bazı yem bitkilerinin kültürü tarihin eski devirlerine kadar uzanmaktadır. Örneğin yoncanın 3000 yıl kadar önce Ön Asya'da tarımının yapıldığı bilinmektedir. MÖ 1400-1200 yıllarına ait Hitit tabletlerinde hayvanlara yonca yedirildiği kayıtlıdır. Arkeolojik bulgulara göre adi fiğ, burçak ve bezelye tarımı MÖ 6000-5000 yıllarına kadar inmektedir. Korunganın 1000 yıldan bu yana tarımı yapılmaktadır. Yunanlı yazarlar MÖ 500-250 yıllarında şalgam, acıbakla, çayır üçgülü ve fiğ türlerinin yeşil gübre ve toprak ıslah edici özelliklerinden bahsetmişlerdir (Hatipoğlu ve ark., 2023).

Yem bitkilerinin geniş olarak kültüre alınması Avrupa medeniyetinin bir ürünüdür. İngiltere'de kuru ot üretimi MÖ 750 yıllarına dayanmaktadır (Açıkgöz, 2021). Ancak, İngiltere'de kapalı meraların MS 800'lerde kurulmaya başlanması, daha sonra 1400'lerde "ley farming" in temeli olan 2 yıl buğday-5 yıl mera ekim nöbetinin başlaması ile yem bitkilerine özellikle buğdaygillere talebi artırmıştır. Büyük bir olasılıkla bu meralarda ilk kez İngiliz çimi ekimi yapılmıştır. Avrupa'da başta çayır üçgülü ve çim türleri olmak üzere yem bitkilerinin tarımı 16. yüzyılda yayılmıştır. Çayır üçgülü gerçek anlamda ilk kez 1550 yıllarında İtalya'da kültüre alınmış, 1650'lerde İngiltere'de tanınmıştır. Ardından ak üçgül ve gazal boynuzu tarımına başlanmıştır. Avrupa'da tarımına başlanan serin mevsim baklagil ve buğdaygil yem bitkileri 19. yüzyılda Amerika kıtasına götürülmüştür. Rodos otu ilk kez Güney Afrika'da 1895 yılında kültüre alınmış, 1900'lü yıllarda Avustralya ve ABD'ye götürülmüştür. ABD'de Sudan otu tarımına 1909 yıllarında Sudan'dan gelen tohumlarla başlanmıştır. Ayrık ve brom türlerinin tohumları 1900'lü yıllarda Doğu Avrupa ülkelerinden getirilmiştir. Nohut geveni, alaca taç otu gibi bazı bitkiler ise son yıllarda kültüre alınmışlardır (Hatipoğlu ve ark., 2023).

3.ISLAH ÇALIŞMALARININ TARİHSEL GELİŞİMİ VE MODERN YEM BİTKİLERİ ISLAH YÖNTEMLERİ

İstenilen amaca yönelik ve bir hedef doğrultusunda bitki cins, tür ve çeşitlerinin genomik bilgisini, genetik ve sitogenetik yöntemlerden yararlanarak planlı şekilde değiştirme ve geliştirmeye bitki ıslahı denir (Tosun, 2015). Kromozom sayısı, kromozomların morfolojisi ve benzerlikleri türler arasındaki ilişkiyi açıklamada, bitkilerin taksonomisini belirlemede, karyotiplerinin incelenmesinde ve genetik sisteminin fiziksel olarak gösteriminin sağlanmasında bilgi vermektedir (Öz, 1995).

Bitkilerin kültüre alınması ile başlayan bitki ıslahı, başlangıçta, gıda ve giyinme amaçlı hedef bitkilerin seçimine yönelik faaliyetleri kapsarken; zamanla daha fazla verim, süsleme, boyama ve beğeni gibi çoğalan ve farklılaşan ihtiyaçlara yönelik olarak çeşitlenmiş ve genetik yanında daha önce kullanılmayan çok farklı bilim dallarının da dahil edildiği faaliyetler haline dönüşmüştür (Oğlakçı ve Tiryaki, 2014).

Islahçı ve araştırmacılar, çalışmalarında kullanım amacına bağlı olarak, kültürü yapılan bitki genotiplerinde gördükleri eksik ya da fazla bitkisel karakterleri tamamlama ya da elemine etme yoluna gitmişlerdir. Islahçılar, bu süreç içerisinde karşılaştıkları sorunları çözümleme yanında, mevcut bitkisel ürünleri çeşitlendirme ya da günümüz ihtiyaçlarına yönelik yeni bitkilerin kültüre alınması imkân ve olanaklarını da bulmak zorunda kalmışlardır (Oğlakçı ve Tiryaki, 2014).

Başlangıçta sanatsal veya eksperlik yönleri daha etkin olan bitki ıslahı çalışmalarında, hücre yapısı ve bitki fizyolojisi alanında ortaya konulan yeni bilgiler, gen ve kalıtıma yönelik genetik ilkelerin ortaya konması, ıslah çalışmalarının bilimsel yönünü kuvvetlendirmiştir. Modern teknolojilerin canlı organizmalara uygulanabilir hale gelmesi ile birlikte biyoteknolojik yöntemler geliştirilmiş ve bunlar ilgili ıslah programlarına entegre edilmeye başlanmıştır (Oğlakçı ve Tiryaki, 2014).

Geçen yüzyılın sonları ve bu yüzyılın başlarında moleküler genetik alanında kaydedilen ilerlemeler, bitki ıslahçılarının inceledikleri bitkisel karakterleri daha önceden hayal edemeyecekleri seviyelerde inceleme ve saptama olanağı tanımıştır. Bu nedenle, günümüz bitki ıslahçıları, kendilerinden önce bu alanda çalışan bilim insanlarının sahip olmadığı yeni yöntemler ve teknikleri, yürüttükleri ıslah programlarına uyumlu hale getirmek ve ilgili bilim dallarından yararlanmak durumundadırlar (Begley ve Hill, 2010).

Bu kapsamda, bu uygulamaların başında bitki biyoteknolojisi gelmektedir. Genetik mühendisliği ve rekombinant DNA teknolojisi, geliştirilecek yeni bitki çeşitlerinin daha etkin ve kısa bir sürede elde edilmesine imkân tanırken, birçok farklı bilim dalını da bitki ıslahçısının çalışmalarına entegre etmeleri ve bu bilim dallarında da uzmanlaşmaları gerekmektedir (Begley ve Hill, 2010).

Son yıllarda büyük bir hızla üretilen moleküler verilerdeki artışlar günümüzde devasa boyutlara ulaşmıştır. Bitki ıslahı açısından, üretilen bu moleküler bilginin var olan ya da geliştirilecek yeni teknoloji ve bilim dalları ile ıslah programlarına adaptasyonu gerekmektedir (Oğlakçı ve Tiryaki, 2014).

Hücre doku ve organelleri ve tüm canlı organizmanın moleküler seviyedeki davranışlarının bilimsel temellerini anlamaya çalışan yeni Omiks (omics) teknolojilerinden: Genomiks (genomics) (organizmaların genomik yapısını inceleyen bilim kolu) (gen ve gen fonksiyonlarının çalışıldığı), Proteomiks (Proteomics) (protein ve genom terimlerinin birlikte ifadesi) (organizmanın yaşamsal faaliyetlerinde rol alan proteinlerle ilgili) ve Sistem Biyolojisi (System Biology), Biyoinformatik (Bioinformatik) ve bilgisayar araçlarının etkin kullanılabilirliği, bitki ıslahçılarının yakın zamanda fazlaca karşılaşacakları yeni teknolojiler ve bilim dalları olarak karşımızda durmaktadır (Begley ve Hill, 2010).

4.TÜRKİYE YEM BİTKİLERİ GENETİK KAYNAKLARI

Genetik kaynaklar bitkilerde performansların artırılması ve yeni çeşitlerin geliştirilmesi amacıyla yabani ve modernize olmuş çeşitleri de içeren temel canlı kaynaklar olarak tanımlanmaktadır (Şakiroğlu, 2010). Bu kaynaklar özellikle ülkelerin tarımsal anlamda geliştirilmesinde önemli bir role sahiptirler.

Dünyanın çok farklı yerlerine dağılan bitkiler değişik iklim ve toprak koşullarına adaptasyon sağlayarak çok geniş bir varyasyon ve çeşitliliğin meydana gelmesine neden olmuştur. Böylelikle oluşan yerel popülasyonlar ile doğal florada bulunan türler ve yabani akrabalarından oluşan bitki kaynakları biotik ve abiotik streslere dayanımın kaynaklarını sağlamaktadır (Harlan, 1965). Bitki ıslahının yegâne kaynağı olan bitki genetik kaynaklarının korunması, değerlendirilmesi ve kullanılması önem arz etmektedir (Şehirali ve Özgen, 1987; Özgen ve ark., 2000; Tan, 2009; Tan, 2010).

Bitki ıslahı için geniş bir genetik tabana ihtiyaç olduğuna ilk kez Rus genetikçi N.I. Vavilov değinmiştir. Vavilov ve arkadaşları dünyanın tüm bölgelerinden kültürü yapılan bitkileri ve bunların yabani akrabalarını toplamışlardır. Bunlar üzerinde yapılan çalışmalardan sonra Vavilov 8 ana, 3 yan gen merkezi belirlemiştir. Bunlar üzerinde bazı değişiklikler yapılmakla birlikte, Vavilov'un teorisi halen geçerliliğini sürdürmektedir. Yem bitkisi türlerinin gen merkezleri oldukça çeşitli olmakla beraber, çoğu eski dünya kökenlidir (Yem Bitkileri Islahı, 2025).

Akdeniz ile Yakındoğu arasında bir geçit olan ülkemiz birçok yem bitkisinin doğal yetişme alanı içerisinde yer almaktadır. Ilıman bölge yem bitkilerinin hemen hemen tamamı ülkemizde doğal olarak yetişmektedir. Bu nedenle bu yem bitkilerinin ıslahı için Türkiye iyi bir kaynak durumundadır (Yem Bitkileri Islahı, 2025). Türkiye, çeşitli araştırıcılar tarafından tanımlanan gen merkezleri ve orijin merkezlerinin hepsinde yer almaktadır (Harlan, 1951; Zohary, 1970; Harlan, 1971; Paroda ve Arora, 1991). Bunun yanında bir çok bitki türü için ilk ya da ikincil farklılaşma merkezi olması Türkiye'nin doğal florasının bitki genetik kaynakları açısından zengin kaynaklara ve potansiyele sahip olduğunu göstermektedir. Harlan (1971), ülkemizi buğday, nohut, bezelye, mercimek, fiğ gibi birçok bitkinin ilk kültüre alındığı yer olarak bildirmiştir. Davis (1970), Türkiye'de yalnızca baklagillere ait 900 türün var olduğunu belirtirken, bunlardan 6 adet fiğ, 11 adet üçgül, 3 adet mürdümük ve 1 adet yonca türünün de Türkiye için endemik bitkiler arasında yer aldığını saptamıştır. Cocks (1999), 372 tür geven (Astragalus), 94 tür üçgül (Trifolium), 59 tür fiğ (Vicia), 58 tür mürdümük (Lathyrus), 46 tür korunga (Onobrychis) ve 30 tür yoncanın (Medicago) Türkiye florasında tespit edildiğini belirtmiştir. Bitki genetik kaynakları konusunda ülke çapında çalışmaların yürütülmesinden sorumlu olan Ege Tarımsal Araştırma Enstitüsü (ETAE)'nde 1964-1997 yılları arasında 8364 adet baklagil ve buğdaygil yem bitkisi toplanmıştır. Miktar bakımından uzun süreli saklama için yeterli olmayanlar ile generatif muhafaza ünitesinde miktarı azalan ya da çimlenme güçleri düşen tohum örneklerinde üretim-yenileme çalışmaları yapılmıştır (Sabancı ve ark., 1999).ETAE tarafından tescil ettirilen adi fiğ (Vicia sativa), tüylü fiğ (Vicia villosa) ve macar fiği (Vicia pannonica) çeşitleri, Türkiye'nin değişik yörelerinden toplanan materyal kullanılarak seleksiyon yöntemi ile geliştirilmişlerdir (Ürem, 1985; Sabancı, 1994; Sabancı ve ark., 1995). Kurt ve ark. (1990) mera ıslahında kullanılabilecek potansiyele sahip tek veya iki yıllık yonca türleri olan Medicago rigidula, M. turbinata, M. lupulina üzerinde çalışmışlardır. Fırıncıoğlu ve ark. (1996) Orta Anadolu Bölgesinde yazlık olarak yetiştirilen çiftçi popülasyonlarının kullanıldığı denemelerde fiğ (Vicia sativa), burçak (Vicia ervilia), koca fiğ (Vicia narbonensis) ile mürdümük (Lathyrus sativus), nohut mürdümüğü (Lathyrus cicera) türlerinin değişik özelliklerini incelemişlerdir. Türkiye'de doğal floradan topladıkları domuz ayrığı (Dactylis glomerata) popülasyonları üzerinde çalışan araştırıcılar değişik özelliklerini belirledikleri bitkilerin seleksiyon çalışması yapılarak kültüre alınmalarını önermişlerdir (Tükel ve Hatipoğlu, 1994; Tosun ve Sağsöz, 1994; Sağsöz ve ark., 1996).

Bununla birlikte ülkemizde iki adet gen bankası bulunmaktadır. Bunlardan ilki Ege Tarımsal Araştırma Enstitüsü (ETAE) `nde uluslararası standartlarda Ulusal Tohum Gen Bankası'dır. Burada ıslah edilmemiş kültür bitkileri çeşitleri (köy çeşitleri), bunların yabani akrabaları, ekonomik önemi olan yabani bitkiler ve doğal florada mevcut diğer bitki türlerinin (endemik türler dahil) kaybolma tehlikelerine karşı takibi, gözlem altında tutulmaları ve toplanması; uzun süreli muhafazası (exsitu ve insitu), karakterizasyonu, değerlendirilmesi ve bunlara ilişkin tüm

bilgilerin dokümantasyonu yapılmaktadır. Değişik bitki gruplarından 55 bini aşkın tohum örneği burada saklanmakta, bu bitkilerin birçoğunun herbaryum örnekleri de mevcut bulunmaktadır. 5000`in üzerinde vejetatif materyal ise muhafaza bahçeleri şeklinde oluşturulan arazi gen bankalarında muhafaza edilmektedir. Ayrıca yerinde muhafaza (insitu) çalışmaları da yürütülmektedir. Bu merkez, tohum bankası bakımından dünya genelinde 12. sırada yer almakta olup, bu bitkisel ürünler açısından bir garanti görevi üstlenmektedir. Diğer gen bankamız 30 Mart 2010 tarihinde Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğüne bağlı Tarla Bitkileri Merkez Araştırma Enstitüsü Müdürlüğü bünyesinde açılışı yapılan Türkiye Tohum Gen Bankası'dır. Bu merkez kapasite bakımından dünyada 2. en büyük gen bankasıdır. Bankanın faaliyetlerine 10 bin adet tohum örneğiyle başlanmış olup, toplam kapasitesi 300 bin adettir. Öncelikle bitki tohumlarının burada kayıtları yapılmakta, ayrıca kısa, uzun ve orta dönemde kullanımını sağlamak üzere değişik sıcaklıklarda koruma altına alınmaktadır. Ancak her iki gen bankamızda şu an itibariyle kapasitelerinin çok altında hizmet vermektedirler. Çok değişik destek kaynaklarıyla yapılan toplama projeleri ile ülkemizde bulunan bitki türleri toplanmaya devam etmektedir. Bu çalışmalar sonucunda toplanan tüm örneklerin yukarıdaki gen bankalarımıza gönderilerek koruma altına alınması çok büyük önem taşımaktadır. Bu konuda gerekli yasal altyapının oluşturulması gen kaynaklarımızın korunması konusunda büyük önem arz etmektedir (Yem Bitkileri Islahı, 2025).

5.DÜNYA'DA VE TÜRKİYE'DE YEM BİTKİLERİ ISLAH ÇALIŞMALARININ TARİHSEL GELİŞİMİ

Yem bitkilerinde modern ıslah yöntemleri ilk kez 20. yüzyılın başlarında İngiltere'de uygulanmıştır (Açıkgöz, 2021). Welsh Bitki Islah istasyonunda çok geniş buğdaygil koleksiyonu ile ıslah çalışmalarına başlanmıştır. 1930-40 yılları arasında S26 domuz ayrığı, S23 ve S24 İngiliz çimi, S100 ak üçgül ve S123 çayır üçgülü çeşitleri ıslah edilmiştir. Bu çeşitler 50 yıl süre ile üretimde kalmışlardır. Benzer çalışmalar, aynı yıllarda, Svalöf Araştırma Enstitüsünde (İsveç) uygulanmıştır. ABD'de ilk kez Minnesota Üniversitesinde Çayır Kelp Kuyruğu ıslahı başlamış, daha sonra, Cornell ve Minnesota Üniversiteleri (ABD), Saskatchewan Üniversitesi ve Swift Current Araştırma Enstitüsü (Kanada)'nde yem bitkileri ıslahına özellikle 1950'lerden sonra hız verilmiştir. ABD ve Kanada'nın kışları çok sert ve kurak geçen kuzey bölgelerinde serin mevsim baklagil ve buğdaygil yem bitkilerinin ıslahı ön plana alınmıştır. Örneğin, *Agropyron* türleri üzerinde çalışmalar 1920'li yıllarda başlamış, 1932 yılında Kanada'da diploid Fairway ve ABD'de 1953 yılında tetraploid Nordan çeşitleri ıslah edilmiştir. Bu iki çeşit ABD ve Kanada'da halen üretimde kullanılmaktadır. Daha sonra yapılan ıslah çalışmalarında kurak ve soğuk bölgeler için serin mevsim yem bitkilerinden birçok yeni çeşit ıslah edilmiş ve tarıma kazandırılmıştır. ABD'nin güney eyaletlerinde ise sıcak mevsim yem bitkilerine ağırlık verilmiştir. Örneğin, Köpekdişi ayrığı ABD'nin güney eyaletlerinde pamuk ve mısır tarımında yabancı ot olarak nitelenirken, 1943 yılında Coastal F1 çeşidi ıslah edilmiştir. Rizom ile kolayca üretilen bu çeşit tüm Güney ABD eyaletlerine yayılmıştır. Daha sonraki yıllarda; verim, hastalık ve zararlılara dayanıklılık ve kalite özellikleri yönünden üstün birçok yeni Köpekdişi Ayrığı çeşidi ıslah edilmiştir. Bugün bu çeşitler çok geniş alanlarda özellikle otlatma amacı ile yetiştirilmektedir (Hatipoğlu ve ark. 2023).

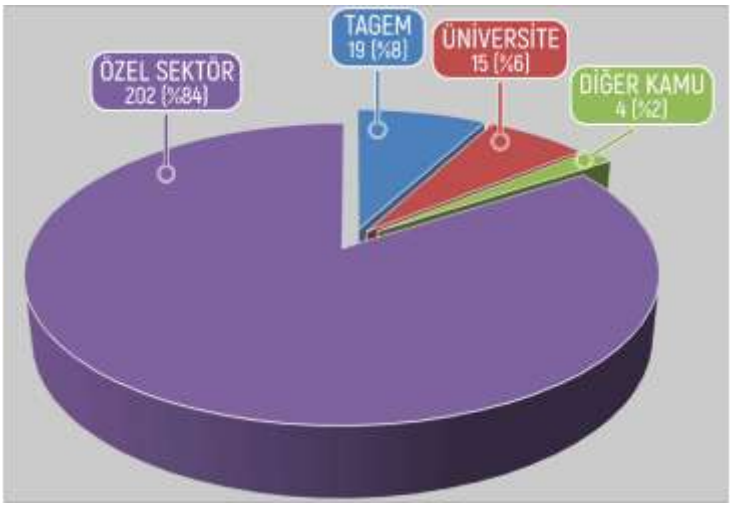
2021 yılı verilerine göre dünyada 731.8 milyon dolar tutarında yem bitkileri tohumu ihracatı ve 706.2 milyon dolar tutarında yem bitkileri tohum ithalatı yapılmıştır. Dünyada en fazla yem bitkisi tohumu ihraç eden ülkeler ABD, Danimarka ve Hollanda, en fazla yem bitkisi tohumu ithal eden ülkeler ise Hollanda, Fransa ve Almanya olmuştur (Hatipoğlu ve ark. 2023).

Türkiye'de bitki ıslahı çalışmaları 1926 yılında Ankara ve Eskişehir'de tohum ıslah istasyonlarının kurulmasıyla başlamıştır. Bu istasyonlarda 1950'li yıllara kadar daha çok tahıllarda çeşit geliştirme çalışmaları yapılmıştır. Yem bitkileri ıslahı çalışmaları ise 1952 yılında Tarım Bakanlığı bünyesinde Çayır, Mera ve Yem Bitkileri Şubesinin kurulması ile hızlanmıştır (Avcı, 2013). 1961 yılında Adana'da Çayır, Mera ve Yem Nebatları Tohum Üretme Merkezi Müdürlüğü kurulmuş ve bu kuruluş 1964 yılında Yem Bitkileri Üretme ve Zootekni Deneme İstasyonu Müdürlüğü adını almıştır. Söz konusu kuruluş ve Eskişehir Tohum Islah İstasyonu'nda yerli ve yabancı kaynaklardan temin edilen yem bitkisi tür ve çeşitlerine ait tohumlarla adaptasyon denemelerine başlanmıştır. 1964 yılında bugünkü adıyla Geçit Kuşağı Tarımsal Araştırma Enstitüsünde yapılan seleksiyon çalışmaları sonucu Sazova adıyla bir yonca çeşidi tescil ettirilmiştir. 1965 yılında kurulan Çayır, Mera Zootekni Araştırma Enstitüsü başta olmak üzere, 1963 yılında kurulan Ege Tarımsal Araştırma Enstitüsü, 1969 yılında kurulan Doğu Anadolu Tarımsal Araştırma Enstitüsü ve Merkez Tarla Bitkileri Araştırma Enstitüsünde yapılan seleksiyon çalışmaları sonucu bir yıllık baklagil yem bitkilerinde çok sayıda çeşit geliştirilmiştir.

6.TÜRKİYE TOHUM TESCİL VE ISLAH MERKEZLERİ

Ülkemizde, tohumluk sertifikasyonu ile ilgili faaliyetlere ilk olarak Ankara Üniversitesi Ziraat Fakültesi'nde başlanmıştır. Daha sonra, aynı amaçla 1959 yılında "Tohumluk Kontrol ve Sertifikasyon Enstitüsü" kurulmuş ve bu tarihten itibaren tohumluk sertifikasyonu ile ilgili hizmetler bu enstitü tarafından yürütülmüştür. Ülkemizde araştırma ve geliştirme faaliyetlerinin bir sonucu olarak yeni çeşitlerin ortaya konulması ve bu çeşitlerin tarafsız bir kuruluşça tescil edilmesi gereği üzerine 1960 yılında "Bölge Çeşit Deneme Enstitüsü" kurulmuştur. Aynı yıllarda ülkemizde tohumluk sertifikasyon hizmetlerini yaygınlaştırmak amacıyla Samsun, İstanbul, İzmir, Antalya ve Mersin'de tohumluk sertifikasyon laboratuvarları kurulmuştur. 21.08.1963 tarihinde 308 Sayılı "Tohumlukların Tescil, Kontrol ve Sertifikasyonu Hakkında Kanun" kabul edilmiş ve tohumlukların sertifikasyonuna ilişkin faaliyetler bu Kanun hükümlerine göre yürütülmüştür. Aynı yıl Ülkemiz ISTA'ya (Uluslararası Tohum Test Birliği) üye olmuştur. 1966 yılında ise sırasıyla şekerpancarı, hububat, mısır, ayçiçeği, soya, pamuk ve çayır, mera ve yem bitkilerinde OECD (Ekonomik Kalkınma ve İşbirliği Teşkilatı) tohumluk sertifikasyon sistemine dahil olmuş, 18 Kasım 2007 tarihi itibariyle de UPOV'a (Uluslararası Yeni Bitki Çeşitlerini Koruma Birliği) üye olmuştur. Tarım ve Köy İşleri Bakanlığı'nın teşkilat ve görevleri hakkındaki 3161 sayılı Kanun çerçevesinde 01.08.1986 tarihinde yapılan reorganizasyon sonucunda "Tohumluk Kontrol ve Sertifikasyon Enstitüsü" ve "Bölge Çeşit Deneme Enstitüsü" birleştirilmiştir. 01.01.1987 tarihinde yapılan yeni düzenleme ile Kuruluş "Tohumluk Tescil ve Sertifikasyon Merkez Müdürlüğü" olarak bugünkü adını almıştır (Tarım ve Orman Bakanlığı, 2025). Günümüzde Tarım ve Orman Bakanlığına bağlı olarak Tohumluk Tescil ve Sertifikasyon Merkez Müdürlüğü tarafından tohum ıslah çalışması yürüten kurum ve kuruluşlar yetkilendirilmekte ve kayıt altına alınmaktadır. Hali hazırda ıslah ve çeşit geliştirme

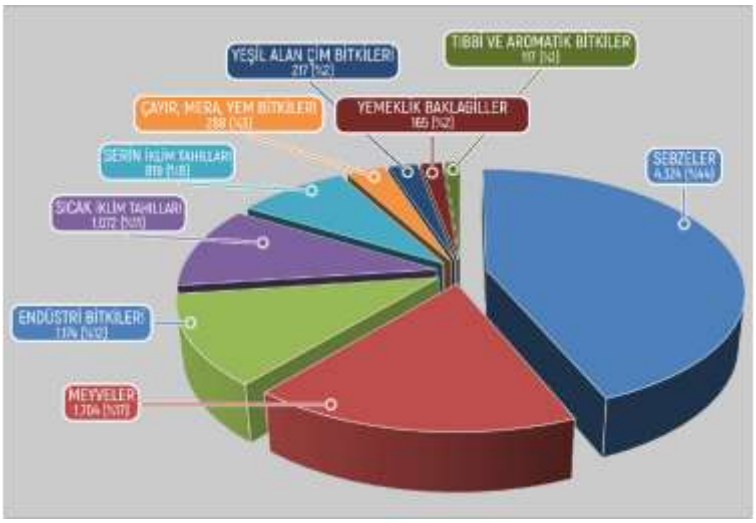
faaliyetleri yürütebilecek statüde yetkilendirilmiş ve kayıt altına alınmış 240 kurum ve kuruluş bulunmaktadır. Bu kuruluşlardan 202 tanesi özel sektör kuruluşu olmakla birlikte 15 tanesi üniversite kuruluşu, 19 tanesi Tarım ve Orman Bakanlığı Tarımsal Araştırmalar Genel Müdürlüğü'ne bağlı enstitü ve araştırma istasyonu ve 4 tanesi de diğer kamu kurumlarına bağlı kuruluşlardır (Şekil 1).



Şekil 1. Çeşit Geliştirme Faaliyetleri İçin Yetkilendirilmiş Kuruluşlar (TTSM, 2025)

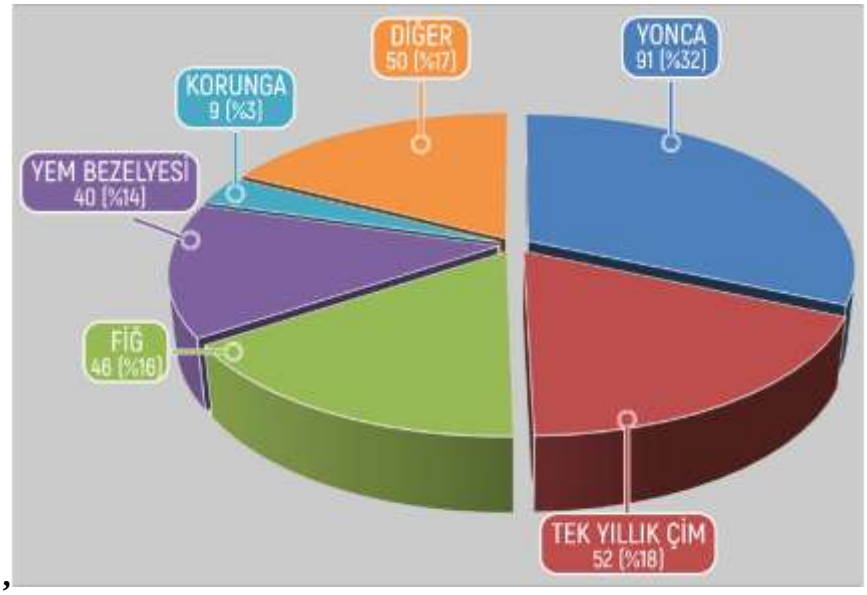
7.YEM BİTKİLERİNDE TESCİLLİ ÇEŞİTLER

Tarım ve Orman Bakanlığı, Tohum Tescil ve Sertifikasyon Müdürlüğü (TTSM) tarafından yayımlanan Milli Çeşit Listesinde ülkemizde tescil edilmiş 9880 adet çeşitten 3852 adedi tarla bitkilerine ait olup bunlardan 288 adedi çayır, mera ve yem bitkileridir (Şekil 2).



Şekil 2. Ürün Gruplarına Göre Çeşit Sayıları (TTSM, 2025)

Çayır, mera, yem bitkilerinde türlere göre 91 adet tescilli çeşit sayısı ile yonca, 52 adet tescilli çeşit sayısı ile Tek Yıllık Çim, 46 adet tescilli çeşit sayısı ile Fiğ ve 40 adet tescilli çeşit sayısı ile Yem Bezelyesi en çok tescil edilen çeşitlerdir (Şekil 3). Yonca, tek yıllık çim, fiğ ve yem bezelyesi haricindeki diğer çayır, mera, yem bitkilerinde geliştirilen çeşit sayıları oldukça azdır. İklim değişikliğinin de etkisiyle su kaynaklarına ilişkin sorunlar, küresel anlamda ekonomik, sosyal ve çevresel boyutlarda problemlere neden olmaktadır. İklim değişikliği yanında, büyüme hızı ve su tüketim alışkanlıklarının değişmesiyle su kaynakları üzerindeki baskılar daha da artmaktadır. Bu sebeple, gelecek nesillere sağlıklı ve yeterli su bırakabilmesi için ülkemizde de kaynakların çok iyi korunup, akılcı kullanılması gerekmektedir. Yem bitkileri özellikle abiyotik stres faktörlerine karşı alternatif olabilecek birçok yem bitkisini türüne sahiptir. Ancak görüldüğü üzere alternatif yem bitkilerinin ıslah çalışmalarında yetersiz kalınmıştır.



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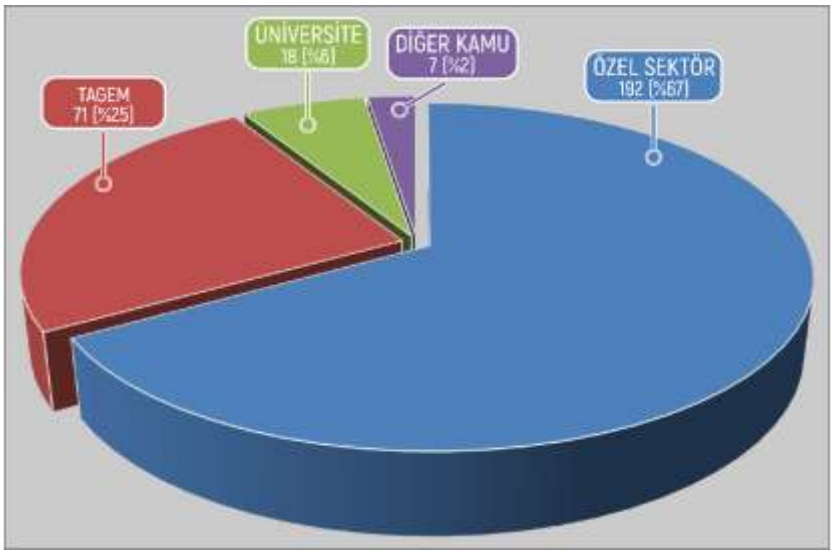
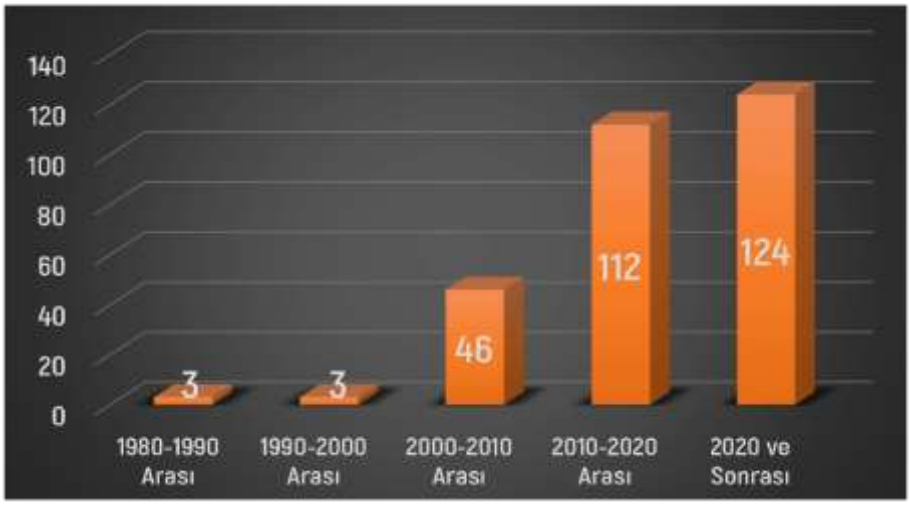
Şekil 3. Yem Bitkilerinde Türlere Göre Çeşit Sayıları (TTSM, 2025)

Bununla birlikte kurum ve kuruluş türüne göre tescil edilmiş çayır, mera, yem bitkileri grubundan çeşit sayılarına göre özel sektör 192 çeşit sayısına sahipken kamuya ait ıslah kuruluşlarının bunun oldukça gerisinde kaldığı görülmektedir. Kamuya ait ıslah kuruluşlarına ait tescil edilmiş 96 adet çeşidin 18 tanesi Üniversitelere bağlı kuruluşlar tarafından tescil ettirilmiştir (Şekil 4). Tüm dünyada olduğu gibi ülkemizde de üniversiteler eğitim, araştırma ve topluma katkı boyutlarını bir araya getirir. Bu yüzden üniversiteler ve üniversitelerde kurulan araştırma ve uygulama merkezlerinin kuruluş amaçları, toplumsal ihtiyaçları ve sorunları belirleme ve bu doğrultuda çözümler üretmektir. Ancak ıslah çalışmalarının ciddi bir altyapı ve kaynak gerektirmesi nedeniyle üniversiteler ıslah çalışmalarında gerektiği noktaya ulaşamamıştır. Kâr amacı gütmeyen kamu kurumları ve üniversitelere bağlı ıslah kuruluşlarının amaca ve konjonktüre uygun çeşit ıslahı noktasında desteklenmesinin stratejik öneme sahip olduğu düşünülmektedir.



Şekil 4. Tescil Sahibi Kurum Tipine Göre Tescil Sayıları (TTSM, 2025)

Çayır, mera, yem bitkilerinde tescil edilen çeşit sayılarının tarihsel gelişimine bakıldığında 2010 yılına kadar tescil edilmiş çeşit sayısının sadece 52 olduğu ancak 2010 sonrasında ciddi bir gelişme kat ederek yaklaşık 15 yıllık süreçte 200'den fazla yem bitkisi çeşidinin tescil edildiği görülmektedir (Şekil 5). Bu durumun ana nedeninin biyoteknolojik yöntemlerin yem bitkileri ıslahında geleneksel ıslah yöntemlerini tamamlayıcı araçlar olarak kullanılması ve moleküler tekniklerin yem bitkileri ıslahında kullanılmaya başlaması olarak değerlendirilmektedir.



Şekil 5. Yıllara Göre Yem Bitleri Çeşit Tescil Sayıları (TTSM, 2025)

8. SONUÇ

Türkiye, sahip olduğu coğrafi ve iklimsel çeşitlilik sayesinde yem bitkileri açısından yüksek potansiyele sahiptir. Ancak, bu zenginliğe rağmen ülkemizde işlenebilen tarım alanlarının yalnızca %11'inde yem bitkisi tarımı yapılmaktadır.

Ülkemizde yem bitkileri ıslah çalışmaları, Tarım Bakanlığı bünyesinde 1952 yılında Çayır, Mera ve Yem Bitkileri Şubesinin kurulmasıyla sistematik hale gelmiş ve zamanla ivme kazanmıştır. 2025 yılı itibarıyla Tarım ve Orman Bakanlığı Tohum Tescil ve Sertifikasyon Müdürlüğü (TTSM) verilerine göre, toplam 9880 tescilli bitki çeşidinden 3852'si tarla bitkisi, bunların 288'i ise çayır, mera ve yem bitkileri grubuna aittir. Bu çeşitler arasında 91 adet yonca, 52 adet tek yıllık çim, 46 adet fiğ ve 40 adet yem bezelyesi öne çıkmaktadır. Tescil edilen çeşitlerin %33'ü kamu kurumları tarafından geliştirilmiştir.

2010 sonrası dönemde modern ıslah tekniklerinin kullanımının yaygınlaşmasıyla birlikte tescilli çeşit sayısında belirgin bir artış yaşanmış; yalnızca 15 yıl içinde 200'den fazla yeni yem bitkisi çeşidi tescil edilmiştir. Bu gelişme olumlu bir tablo ortaya koymakla birlikte, ıslah çalışmalarının daha geniş bir tür yelpazesine yayılması gerekmektedir. Çayır, mera ve yem bitkileri ıslah çalışmaları özellikle kuraklığa toleranslı ve toprak ıslah edici özellikleri yüksek türler üzerine yoğunlaştırılmalıdır.

Yem bitkilerinin tohumlarının küçük olması, mekanizasyonunun tam gelişmemesi ve yeterli sayıda araştırmacının bulunmaması, bu alandaki ıslah çalışmalarının istenilen düzeye ulaşamamasına neden olmaktadır.

Tescil edilen çeşitlerin ticari haklarını alan firmaların yeterli düzeyde tohum üretmelerini sağlamak amacıyla yasal düzenlemelere ihtiyaç vardır. Tescilin ötesine geçerek tohum üretimi ve yaygınlaştırılması konusunda kamu-özel sektör iş birliği geliştirilmelidir.

Sonuç olarak, yem bitkileri ıslahına yönelik araştırma ve geliştirme altyapısının güçlendirilmesi, genetik kaynakların korunması ve değerlendirilmesi, üniversite ve kamu araştırma kuruluşlarının desteklenmesi ile birlikte; ülkemizde yem bitkileri tohumluk ithalatının azaltılması, yem bitkileri ekim alanlarının artırılması, sürdürülebilir hayvancılık ve tarım sistemine katkı sağlayacaktır.

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THE EFFECTS OF IBA AND OSTIOL STIMULATION TREATMENTS ON PARTHENOCARPIC FRUIT FORMATION IN "SARILOP" AND "BURSA SİYAHI" FIG (*Ficus carica*) CULTIVARS

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ABSTRACT

Sarılop is the most important dried fig cultivar of Türkiye, and *Bursa Siyahı* is the most important table cultivar, and these two cultivars hold significant importance in the country's export. These cultivars are *Smyrna* type, and pollination is essential for fruit formation. Fertilization is achieved through a special process called caprification, which involves the transfer of caprific synconiums to female fig trees. However, the caprification process has several disadvantages, such as time sensitivity, difficulties in obtaining caprifig fruits, the risk of disease transmission, and the labor requirement. In many fruit species, plant growth regulators in the auxin group can be used to induce parthenocarpic fruit formation without fertilization.

This study primarily aimed to reveal the effects of two different doses (1000 ppm and 2000 ppm) of IBA (Indole-3-butyric acid), a plant growth regulator from the auxin group, on parthenocarpic fruit formation for competing for the disadvantages of the caprification process. Additionally, it aimed to test the validity of the common claims among fig growers that physical stimulation of ostiol and application of olive oil to ostiole may induce parthenocarpic fruit formation. For these aims, a randomized plots experimental trial with three replications was established at the central experimental orchard of the Fig Research Institute, located in İncirliova district of Aydın province. A total of 10 trees were used. Synconiums on selected branches from different orientations on trees were isolated on May 25 using a special tulle that prevents the passage of fig wasps (*Blastophaga psenes*). Four different treatments were carried out: (1) 1000 ppm IBA spray, (2) 2000 ppm IBA spray, (3) physical stimulation of the ostiole using a stiff brush, (4) physical stimulation combined with an olive oil application to the ostiole. All treatments were carried out by two repetitions on 25 and 31 May. The fruit set was monitored regularly after applications, and the final fruit counts were made 20 days after the region's current caprification date.

None of the treatments induced parthenocarpic fruit formation, and all synconiums dropped in *Bursa Siyahı* cultivar. In *Sarılop* cultivar, only the 2000-ppm IBA treatment resulted in parthenocarpic fruit formation with a percentage of 28.5%, similar to the specific fruit characteristics of the cultivar. However, since the high synconium drop rate due to this treatment, it is concluded that it is unsuitable for commercial use and cannot be an alternative to caprification. Furthermore, parthenocarpic fruits obtained from this treatment were compared with naturally pollinated fruits in terms of quality and drying characteristics. The study also revealed that neither physical stimulation of the ostiole nor the combination of stimulation with olive oil application had affected parthenocarpic fruit formation. Thus, the results of our study

concluded that the claims of growers regarding these ostiole stimulations are not scientifically correct.

Keywords: *Ficus carica* L., caprification, parthenocarpy, IBA, ostiol situmulation

IBA VE OSTİOL UYARIMI UYGULAMALARININ "SARILOP" VE "BURSA SİYAHI" İNCİR (*Ficus carica*) ÇEŞİTLERİNDE PARTENOKARPİK MEYVE OLUŞUMU ÜZERİNE ETKİLERİ

ÖZET

Türkiye'nin en önemli kurutmalık incir çeşidi olan *Sarılop* ile en önemli sofralık çeşidi olan *Bursa Siyahı*, ülke ihracatında büyük paya sahiptir. Bu çeşitler, "*Smyrna"* tipi incir grubuna dâhildir ve meyve tutumu için kesin döllenmeye ihtiyaç duyarlar. Döllenme, "ilekleme" adı verilen, erkek incir synconiumlarının dişi ağaçlara taşınması yoluyla sağlanmaktadır. Ancak ilekleme işlemi, ilek meyvelerinin temin zorlukları, hastalık taşıma riski ve işgücü gerektirmesi gibi çeşitli dezavantajlara sahiptir. Oksin grubu bitki gelişim düzenleyiciler birçok meyve türünde döllenme olmadan partenokarpik meyve oluşumunu sağlamak için kullanılabilmektedir.

Bu çalışmada öncelikli olarak ilekleme işleminin dezavantajlarını azaltmaya yönelik olarak, oksin grubundan bir bitki gelişim düzenleyicisi olan IBA'nın (Indol-3 bütirik asit) iki farklı dozunun (*1000 ppm* ve *2000 ppm*) partenokarpik meyve tutumuna etkisini ortaya koymak amaçlanmıştır. Ayrıca, incir üreticileri arasında yaygın olan ostiolün fiziksel uyarılması ve ostiole zeytinyağı uygulanmasının partenokarpik meyve oluşumunu teşvik ettiği iddialarının geçerliliğinin test edilmesi amaçlanmıştır. Aydın İli İncirliova İlçesinde bulunan İncir Araştırma Enstitüsü Müdürlüğü merkez üretim parselinde, *Sarılop* ve *Bursa Siyahı* çeşitlerinde Tesadüf Parsellerinde faktöriyel deneme desenine göre 3 tekerrürlü bir deneme kurulmuştur. Her iki çeşitte toplam 10 ağaç kullanılmış, ağaçların farklı yönlerinden seçilen dallar üzerindeki tüm synconiumlar 25 Mayıs tarihinde, ilek arıcığı (*Blastophaga psenes*) geçişini engelleyen özel tüllerle izole edilmiştir. Deneme kapsamında dört farklı uygulama gerçekleştirilmiştir; 1000 ppm IBA, (2) 2000 ppm IBA, (3) Ostiole sert fırça ile fiziksel uyarım, (4) Fiziksel uyarım + ostiole zeytinyağı uygulaması. Tüm uygulamalar 25 ve 31 Mayıs tarihlerinde olmak üzere iki defa yapılmıştır. Uygulamalar sonrasında meyve tutumları düzenli olarak takip edilmiş ve bölgedeki ilekleme işleminin üzerinden 20 gün geçtikten sonra nihai meyve sayımı yapılmıştır.

Bursa Siyahı çeşidinde hiçbir uygulamanın partenokarpik meyve oluşumunu sağlamadığı ve tüm synconiumların döküldüğü görülmüştür. Sarılop çeşidinde ise yalnızca 2000 ppm IBA uygulamasında, %28,5 oranında çekirdeksiz, çeşide özgü özellikleri taşıyan partenokarpik meyveler oluşmuştur. Ancak bu uygulama sonucunda meyve döküm oranının oldukça yüksek olması nedeniyle, yöntemin ticari üretim açısından ekonomik olmadığı ve ileklemeye alternatif teşkil edemeyeceği belirlenmiştir. Sarılop çeşidinden elde edilen partenokarpik meyvelerin doğal döllenme yoluyla elde edilen meyvelerle kalite ve kuruma özellikleri bakımından karşılaştırılması yapılmıştır. Ostiolün fiziksel yollarla uyarılması ve fiziksel uyarı ile birlikte zeytinyağı uygulamalarının da partenokarpik meyve oluşumu üzerinde herhangi bir etkisinin bulunmadığı ve bu uygulamalara yönelik üretici kaynaklı söylentilerin bilimsel olarak doğru olmadığı sonucuna varılmıştır.

Anahtar Kelimeler: *Ficus carica* L., ilekleme, partenokarpi, IBA, ostiol uyarımı

1. GİRİŞ

İncir (*Ficus carica* L.) ülkemizde yaygın olarak yetiştirilen çok özel bir meyve türüdür. Türkiye incir üretiminde, üretim miktarı ve çeşitlilik bakımından dünyada önemli ülkelerden biridir. Dünyada 2022 yılı itibarı ile 296.753 ha alanda, 1.242.449 ton incir üretimi gerçekleşmiştir . Türkiye'de ise 57.459 hektar alandan yaklaşık 350.000 ton incir üretimi yapılmaktadır. Hem Türkiye hem de dünya incir üretim alanlarında ve üretim miktarında artış trendi bulunmaktadır (FAOSTAT, 2024; TUİK, 2024). Türkiye incir üretimi ve ihracatındaki en önemli çeşitler Sarılop ve Bursa Siyahı çeşitleridir. Sarılop incir çeşidi, üstün kuru meyve kalitesi ile Bursa Siyahı çeşidi ise taze sofralık kalitesiyle ön plana çıkmaktadır (Aksoy ve ark., 2007; Çalışkan, 2012). Kuru incir ihracatı Sarılop, Sofralık incir ihracatı da büyük ölçüde 'Bursa Siyahı' çeşidiyle yapılmakta ve bu çeşide ait bahçelerin sayısı son yıllarda giderek artmaktadır (Arpaci, 2017; Çalışkan, 2012; Koşar, 2023).

Üretim ve ihracatımızdaki önemli bu iki çeşit, "Smyrna" tipi incir grubuna dahildir ve karakteristik meyve gelişimleri için zorunlu olarak döllenmeye ihtiyaç duyarlar. Sarılop incir çeşidi, Türkiye'de özellikle Aydın yöresinde yoğun olarak yetiştirilir en yüksek ekonomik öneme sahip çeşidimizdir (Arpaci, 2017). Sarılop meyveleri ostiol kısmı kapalıya yakın, çatlamaya ve bozulmaya karşı dayanıklıdır. Meyvelerinin iç kısmı dolgun ve homojen olup, düşük çekirdek oranına sahiptir. Ortalama meyve ağırlığı 40–60 gram arasında, toplam çözünür kuru madde miktarı %20–25 arasındadır ve yüksek şeker oranına sahiptir (Ayar ve ark., 2019). Sarılop çeşidinde ikinci ürün meyveleri (iyilop) esas önemli olan üründür ve mutlaka döllenmesi gerekmektedir (Aksoy ve Şahin, 2001; Aksoy ve ark., 2007; Özbek, 1949). Bursa Siyahı çeşidi ise önemli sofralık incir çeşitlerinden biri olup meyveleri iri yapılı (ortalama 50–70 g), uzunca armudi formda ve olgunluk döneminde koyu mor-siyaha yakın kabuk rengine sahiptir. Kabuk yüzeyi parlak olup tüketici açısından görsel çekicilik taşır. Meyve eti açık kırmızıdan bordo renge kadar değişmekte, sulu, yumuşak ve yoğun aromalıdır (Çalişkan ve Polat, 2008; Kaynas ve ark., 1997; Koşar, 2023). Şeker ve toplam kuru madde içeriklerinin yüksek olması, düşük asit oranı, Bursa Siyahı'nı sofralık tüketim için uygun hale getirmektedir. Ostiol kısmı orta açıklıkta olup, dikkatli hasat yapılmadığında meyve çürüklüğü riski taşıyabilir. Yüksek pazar değeri, özgün lezzeti ve üstün dış görünüm özellikleri nedeniyle hem iç hem dış pazarda büyük talep görmektedir (Çalişkan ve Polat, 2008; Çalışkan ve Polat, 2012; Koşar, 2023; Polat ve Calışkan, 2008). Avrupa Birliği tarafından "coğrafi işaret" tescili almış olması, Bursa Siyahı'nın uluslararası düzeyde tanınırlığını ve ticari değerini daha da artırmıştır (ci.turkpatent.gov.tr, 2025).

İncir üretiminde döllenmenin sağlanabilmesi için, kaprifikasyon (ilekleme) adı verilen biyolojik bir uygulama gerekmektedir (Condit, 1920; Tribolet, 1912). Bu yöntemle erkek incir ağaçlarından elde edilen ilek meyveleri, dişi ağaçlardaki çiçeklerin tozlanmasını sağlamak amacıyla kullanılır. İlekleme ilek arıcığı (*Blastophaga psenes*) denilen ve erkek incir meyvelerinde simbiyotik halde yaşayan bir arıcık vasıtasıyla meydana gelmektedir (Çalışkan ve Bayazit, 2012). Sarılop çeşidi için tam olarak olmasa da Bursa Siyahı'nın yetiştirildiği ekolojilerde, tozlanmadan (kaprifikasyon) kaynaklanan sorunlar nedeniyle meyve veriminde dalgalanmalar görülebilmektedir (Çalışkan, 2012). Tozlayıcı olarak kullanılan erkek incirlerin (*Ficus carica* L. var. caprificus) özellikle ilek tarafından taşınan hastalıklardan ari olması, başarılı ve sağlıklı bir ileklemenin temel koşullarından biri olarak kabul edilmektedir (Ferguson ve ark., 1990). Dişi incir meyvelerinde karşılaşılan iç kararması (endopsis) problemi, genellikle

erkek incirlerden dişi meyvelere ilek arıcığı aracılığıyla *Fusarium moniliforme* gibi fungal patojenlerin taşınması sonucunda ortaya çıkmaktadır. Aynı zamanda kuru incir üretiminde kaliteyi ve pazarlanabilirliği olumsuz yönde etkileyen aflatoksin kontaminasyonunun, meyveye ilk bulaşmasının da ilek arıcıkları ile gerçekleşebileceği bildirilmektedir (Aksoy ve ark., 2001; Aksoy ve Şahin, 2001). Bunun yanında ilekleme işleminin ilekleme zamanlamasının hassasiyeti, ilek meyvelerinin temin zorlukları, işgücü gerektirmesi gibi birçok dezavantajlara sahiptir.

Oksin grubu bitki gelişim düzenleyiciler, özellikle tozlanma ya da döllenmenin yetersiz olduğu koşullarda meyve tutumunun artırılmasında önemli bir tarımsal araç olarak değerlendirilmektedir. Oksin grubu bileşikler, hücre bölünmesi ve uzaması, kök oluşumu, apikal dominansi ve meyve gelişimi gibi bitkisel süreçlerde kritik rol oynayan doğal veya sentetik bileşiklerdir (Taiz ve ark., 2015). Birçok meyve türünde, özellikle çekirdeksiz meyve üretimi hedeflendiğinde, oksinlerin partenokarpik meyve oluşumunu başarıyla sağladığı bilimsel çalışmalarla kanıtlanmıştır (Srivastava ve Handa, 2005). Oksin grubu bitki büyüme düzenleyicilerin, domates (*Solanum lycopersicum*), elma (*Malus domestica*), hıyar (*Cucumis sativus*) gibi birçok kültür bitkisinde, partenokarpiyi teşvik ettiği bilinmektedir (De Jong ve ark., 2009). Çekirdeksiz üzüm çeşitlerinde ise sitokinin ve oksinlerin birlikte kullanımıyla partenokarp meyve oluşumunun anlamlı düzeyde artırılabildiği belirlenmiştir (Güleryüz, 1982). Öte yandan, ayvalarda oksin türevi olan giberellik asit uygulamalarının (Mesejo ve ark., 2010), kirazlarda (*Prunus avium* L.) giberellik asit ve oksin karışımlarının (Özgüven, 1994), siyah mersin bitkisinde (Myrtus communis L.) gibberellik asit (GA_3) uygulamalarının partenokarpik meyve tutumu sağlayarak yetiştiricilikte bazı avantajlar sağladığı bildirilmektedir. Bunun dışında IAA, IBA, NAA, GA, 2,4-D gibi gelişim düzenleyicilerin meyve türlerinde meyve tutumu ve partenokarpik meyve oluşumu için kullanılabilmesi söz konusudur (Çimen, 1988).

Diğer meyve türlerine benzer şekilde incirlerde de döllenme olmadan meyve tutumunun oluşması istenen bir durum olmuştur (Crane ve Blondeau, 1949). San Pedro ve Adriyatik tipi incirlerde de hem döllenmeye ihtiyaç olmayan ve hem ihtiyaç duyulan çiçeklenme evrelerinde partenokarpik meyve tutumunun artırılması istenen bir durumdur. Ülkemizde de üreticiler ileklemenin zorluğu ve yıldan yıla farklı düzeylerde gerçekleşen meyve tutum oranları nedeniyle partenokarp meyve elde edilmesine ilgi duymuşlardır. İncirin ostiol kısmına fiziksel uyartıların yapılmasının ve ostiole zeytinyağı sürmenin meyve tutumunu artıracağı hatta döllenme olmadan meyve oluşumunu sağlayacağı yönünde inanışlar ve söylentiler ortaya çıkmıştır. Araştırmacılar, incirlerde kaprifikasyonun standartlaştırılması veya tamamen ortadan kaldırılmasına, partenokarpik meyve tutumunun artırılmasına yönelik olarak çok sayıda araştırma yürütmüşlerdir. Bu konudaki ilk ve öncü çalışmaların Kaliforniya'da Calymrna incirleri üzerinde Crane ve Blondeau (1949) başta olmak üzere Baskaya ve Crane (1950); Blondeau ve Crane (1948) tarafından yürütüldüğü görülmektedir. Bu çalışmalara ilerleyen yıllarda başka araştırmacılar tarafından devam edilmiştir (Lodhi ve ark., 1969). İncirde partenokarpiyi sağlamak üzere en fazla denenen bitki gelişim düzenleyicileri 2-4 D, 2-3-4 T, Naftoksi Asetik Asit (NA), Beta Naftoksi Asetik Asit (NOA), Giberellik Asit (GA_3), Kristal benzotiyazol-2-oksi-asetik asit ve Para-klorofenoksiasetik asit (PCPA), Indol-3 Bütirik Asit (IBA) ile NA+IBA ve NA+PCPA karışımlarıdır (Crane, 1952; Crane ve Blondeau, 1949; Crane ve Blondeau, 1951; Lodhi ve ark., 1969; Stewart ve Condit, 1949).

Günümüz şartlarında da geleneksel ilekleme yöntemine alternatif olabilecek, döllenme gerektirmeyen (partenokarpik) meyve oluşumunu teşvik eden yöntemlerin araştırılması incir üretiminin geleceği açısından önemlidir. Bu nedenle, bu çalışmada, incir üretiminde karşılaşılan ilekleme kaynaklı sorunlara çözüm arayışının bir parçası olarak, öncelikle oksin grubundan sentetik bir bitki gelişim düzenleyicisi olan Indol-3 Bütirik Asit'in (IBA) iki farklı konsantrasyonunun (1000 ppm ve 2000 ppm) Sarılop ve Bursa Siyahı çeşitlerinde partenokarpik meyve tutumuna olan etkilerinin incelenmesi amaçlanmıştır. Çalışmanın bir diğer amacı da incir üreticileri arasında yaygın olarak dile getirilen ve bilimsel bir dayanağı henüz tam olarak kanıtlanmamış olan ostiolün fiziksel olarak uyarılması ve bu uyarımın zeytinyağı uygulamasıyla desteklenmesinin partenokarpik meyve oluşumuna yol açtığı yönündeki iddiaların bilimsel geçerliliğini test etmektir. Elde edilen bulgularla incir üretiminde ileklemeye alternatif olabilecek potansiyel yöntemlerin belirlenmesi için literatüre katkı ve üreticiler için kontrollü bir deneme sonucunda elde edilmiş güvenilir bilgiler kazandırılmaya çalışılmıştır.

2. MATERYAL VE METOT

2.1. MATERYAL

Çalışma, İncir Araştırma Enstitüsü Müdürlüğü'ne ait Aydın İli İncirliova İlçesi Erbeyli Mahallesi, Merkez Yerleşkesinde yer alan Sarılop ve Bursa Siyahı çeşitlerine ait ağaçlar üzerindeki iyilop syconiumların üzerinde yürütülmüştür. Deneme yerinin deniz seviyesinden yüksekliği 60 m civarında olup; 37051ı50.72ıı K ve 27039ı50.39ıı D koordinatlarında yer almaktadır.

2.2. METOT

Deneme tesadüf parsellerinde faktöriyel deneme desenine göre, her bir uygulama için 3 tekerrür olacak şekilde planlanmıştır. Deneyde, her iki incir çeşidinden sağlıklı ve benzer gelişime sahip toplam 10 adet olgun ağaç kullanılmıştır. Denemede çeşitlere ait ağaçlarının farklı yönlerindeki dallar üzerinde bulunan aynı gelişim evresindeki synconiumlar 25 Mayıs tarihinde, ilek arıcığının içeriye girişini ve dolayısıyla doğal döllenmeyi engelleyecek ince gözenekli, özel tüllerle izole edilmiştir. Şekil 1'de deneme başlangıcında dallardaki syconiumların izole edildiği evreye ait fotoğraflar verilmiştir.

Şekil 1: İlek arıcığı (*Blastophaga psenes* L.) geçişini engellemek için kullanılan tüller (orijinal)

Deneme kapsamında toplam dört farklı uygulama (kontrol dışında) gerçekleştirilmiştir. Bunlar;

1-1000 ppm IBA Uygulaması: İzole edilen synconiumlara 1000 ppm konsantrasyonunda IBA çözeltisinin püskürtülerek uygulanması,

2-2000 ppm IBA Uygulaması: İzole edilen synconiumlara 2000 ppm konsantrasyonunda IBA çözeltisinin püskürtülerek uygulanması,

3-Ostiolün Fiziksel Uyarılması: İzole edilen synconiumlara, ostiol kısımlarından, steril ve yumuşak kıllı bir fırça yardımıyla nazikçe ve standart bir şekilde fiziksel uyarı yapılması,

4-Fiziksel Uyarım + Ostiole Zeytinyağı Uygulaması: İzole edilen synconiumların ostiol kısımlarına öncelikle yukarıda belirtildiği gibi fiziksel uyarının yapılması ve ardından sızma zeytinyağının ince bir tabaka halinde sürülmesi uygulamalarıdır.

Bunun dışında uygulamaların etkisini karşılaştırmak için Kontrol parseli oluşturulmuştur. Kontrol grubundaki syconiumlara herhangi bir uygulama yapılmamış sadece tül ile izole edilmişlerdir. Tüm uygulamalar (1-2-3-4), partenokarpik meyve gelişimini uyarmak amacıyla, çiçeklenme döneminin başlangıcına yakın iki farklı tarihte, 25 ve 31 Mayıs günlerinde olmak üzere iki kez tekrarlanmıştır. Uygulamaların tamamlanmasının ardından, dallardaki meyve tutumları düzenli aralıklarla gözlemlenmiş ve kayıt edilmiştir. Bölgedeki geleneksel ilekleme işleminin tamamlanmasından yaklaşık 20 gün sonra, muamele gören dallardaki nihai meyve sayısı belirlenerek meyve tutum oranları hesaplanmıştır. Ayrıca, Sarılop çeşidinde partenokarpik olarak elde edilen sınırlı sayıdaki meyvenin, aynı bahçedeki doğal döllenme yoluyla oluşmuş olgun meyvelerle bazı temel kalite parametreleri (meyve ağırlığı, ostiol genişliği, asitlik, suda çözünür kuru madde miktarı vb.) özellikleri bakımından karşılaştırmaları yapılmıştır.

3.BULGULAR VE TARTIŞMA

Sarılop ve Bursa Siyahı çeşitlerine ait ağaçlarda gerçekleştirilen IBA 1000 ve 2000 ppm uygulamaları ile fiziksel uyartı ve fiziksel uyartı+zeytinyağı uygulamaları ve kontrol grubunda kullanılan meyve sayıları (n), ara sayımda gözlemlenen meyve sayıları ve nihai olarak elde edilen partenokarp meyvelerin sayıları Tablo 1'de verilmiştir. Elde edilen verilerin deneme desenine uygun olarak gerçekleştirilen varyans analiz özeti sonuçları da Tablo 2'de verilmiştir. Denemenin uygulamalarında kullanılan meyve sayıları (n), dallar üzerinde eşit miktarda meyve bulamamaktan kaynaklı olarak 49 ile 65 adet arasında değişmiştir. Bu nedenle, ara sayımlarda dalda kalan elde edilen meyvelerin miktarı ve partenokarp meyve tutumları daha iyi bir karşılaştırma yapmak için yüzde (%) olarak ifade edilmiştir. İstatistiki analiz sonucunda; Ara sayımda dalda bulunan meyve sayısı üzerine herhangi bir faktörün etkili olmadığı belirlenirken, partenokarpik meyve tutumu üzerine çeşit faktörünün ve çeşit x uygulama interaksiyonun etkisi istatistiki olarak önemli bulunmuştur. İzole edilen dallardaki, ara sayımda meyve sayıları yüzde olarak %11,5 ile %36,8 arasında değişiklik göstermiştir ancak bu farklılık istatistiki olarak önemli bulunmamıştır (Tablo 2).

Tablo 1: Sarılop ve Bursa Siyahı çeşitlerinde IBA ve diğer uygulamaların partenokarpik meyve tutumu oranları (%)

Çeşitler *	Uygulamalar	Uygulamada kullanılan meyve sayısı (n)	Ara sayımdaki syconium yüzdesi (%) (25 Temmuz)	** Elde edilen partenokarp syconium yüzdesi (%) (8 Ağustos)
Sarılop	IBA - 1000	62	12,4 ± 6,9	0,0 ± 0,0 b
	IBA-2000	59	36,8 ± 3,9	28,5 ± 2,8 a
	Fiziksel Uyarı	57	19,5 ± 6,4	0,0 ± 0,0 b
	Fiziksel Uyarı + Zeytinyağı	65	15,0 ± 3,0	0,0 ± 0,0 b
	Kontrol (İzolasyon)	53	11,5 ± 1,1	0,0 ± 0,0 b
Sarılop ort.		59,2 ±2,1	19,1 ± 3,1	5,7 ± 3,1 **A**
Bursa Siyahı	IBA - 1000	54	14,5 ± 4,5	0,0 ± 0,0 b
	IBA-2000	57	16,2 ± 4,5	0,0 ± 0,0 b
	Fiziksel Uyarı	53	20,5 ± 8,4	0,0 ± 0,0 b
	Fiziksel Uyarı + Zeytinyağı	62	17,5 ± 3,9	0,0 ± 0,0 b
	Kontrol (İzolasyon)	49	16,4 ± 2,2	0,0 ± 0,0 b
Bursa Siyahı ort.		55,0 ±2,2	17,0 ± 2,0	0,0 ± 0,0 **B**
Genel ortalama		57,1 ±1,6	18,0 ± 1,8	2,9 ± 1,6

Aynı sütunda farklı harfle gösterilen ortalamalar arasındaki fark **çok önemlidir ($p<0.01$), * önemlidir ($p<0.05$)

Tablo 2: Sarılop ve Bursa Siyahı çeşitlerinde IBA ve diğer uygulamaların partenokarpik meyve tutumu oranlarına ilişkin varyans analiz özeti.

Bursa Siyahı çeşidinde uygulanan hiçbir yöntemin partenokarpik meyve oluşumuna yol açmadığı gözlemlenmiştir (Tablo 2). Sonuçlar, Bursa Siyahı çeşidinin partenokarpik meyve gelişimi için test edilen IBA konsantrasyonlarına ve diğer uyartı uygulamalarına tepki vermediğini göstermekte ve genetik olarak partenokarpik meyve verme eğiliminin de olmadığına işaret etmektedir. IBA dışındaki diğer bitki gelişim düzenleyicilerin partenokarpik meyve oluşumunu sağlama ihtimali bulunmakta olup bu durum yürütülecek başka çalışmalarla belirlenmelidir. Diğer gelişim düzenleyicilerin olası etkileri ortaya konuluncaya kadar Bursa Siyahı çeşidinde döllenmeyi sağlayan ilekleme işleminin meyve tutumu için mutlak bir gereklilik olduğunu söylemek mümkündür.

Sarılop çeşidi incelendiğinde, partenokarpik meyve oluşumu açısından sadece 2000 ppm IBA uygulamasının sınırlı bir başarı sağladığı görülmektedir (Tablo 2). Şekil 2'de 2000 ppm IBA uygulaması sonucu elde edilmiş partenokarp Sarılop incirlerine ait fotoğraflar verilmiştir. Tablo

2'de de görüleceği üzere 2000 ppm IBA uygulamasında, %28,5 oranında ortalama partenokarpik meyve tutumu elde edilmiştir. Diğer uygulamalar (1000 ppm IBA, fiziksel uyarım tek başına ve fiziksel uyarım + zeytinyağı uygulaması) Sarılop çeşidinde de partenokarpik meyve oluşumu sağlamamıştır (% 0.00). Bu durum, ostiolün fiziksel olarak uyarılmasının veya bu uyarımın zeytinyağı ile desteklenmesinin Sarılop çeşidinde partenokarpik meyve gelişimine neden olmadığını açıkça ortaya koymaktadır. Ayrıca, daha düşük konsantrasyondaki IBA (1000 ppm) uygulamasının da partenokarpiyi oluşturmada etkisiz olduğu görülmektedir.

Ayrıca, her iki çeşitte de kontrol grubunda partenokarpik meyve oluşumu gözlemlenmemiştir. Bu durum, izolasyon işleminin etkili olduğunu göstermesi yanında, çeşitlerin doğal partenokarpik meyve verme eğilimlerinin düşük ya da olmadığına işaret etmektedir. İzole edilen syconiumlarda yapılan ara sayımlarda Sarılop çeşidinde istatistiki olarak önemli olmasa da daha fazla oranda syconiumun dallar üzerinde bulunduğu belirlenmiştir. Açıkça görülmektedir ki çeşit faktörü partenokarpik meyve oluşumu üzerinde önemli bir etkiye sahiptir (Tablo 2). Crane ve Blondeau (1949) tarafından yürütülen çalışmada da Calmyrna incirlerinde izole edilmiş ve herhangi bir gelişim düzenleyicinin kullanılmadığı kontrol grubunda meyve tutumunun gerçekleşmediği bildirilmiştir.

Deneme alanındaki izolasyon ve herhangi bir uygulama yapılmamış ağaçlardan alınan Sarılop meyveleri ile IBA uygulaması sonucunda oluşan partenokarpik meyvelerin bazı özellikleri karşılaştırmalı olarak Tablo 3'te verilmiştir. Yapılan pomolojik ölçümlerde partenokarpik Sarılop meyvelerinin ağırlıklarının 55-60 gr arasında olduğu ve normal döllenmeyle oluşan meyvelere göre %15 düzeyinde daha hafif olduğu belirlenmiştir. Ayrıca, partenokarp meyvelerde ostiol açıklığının normal meyvelerdekinden daha küçük olduğu ve 5,12-5,21 mm arasında değiştiği belirlenmiştir. Gerçekleştirilen analizlerde ise partenokarpik Sarılop meyvelerinin SÇKM değerlerinin % 2 düzeyinde düşük olduğu ve asitlik değerlerinin normal döllenmeyle oluşmuş meyvelerinkine çok yakın değerlerde olduğu belirlenmiştir. Crane ve Blondeau (1949) tarafından yapılan çalışmada da benzer sonuçlar bildirilmiştir. Araştırmacılar Caliymrna incirlerinde, partekonarpik meyvelerde döllenme ile oluşan normal meyvelere göre % 7 ağırlık azalması olduğunu, büzüşmelerin olduğunu ve dış kabuk renginin daha açık olduğunu belirlemişlerdir.

Şekil 2: Olgunlaşan partenokarp Sarılop meyve örnekleri (orijinal)

Tablo 3: İlekleme ve IBA uygulaması sonucunda oluşan partenokarp Sarılop meyvelerinin karşılaştırmalı bazı özellikleri

İçerik	Sarılop (İlekleme ile oluşan)	Sarılop (IBA 2000 ppm uygulaması sonucu oluşan)
SÇKM (%)	22-23	20-21
Asitlik (%)	0,134-0,138	0,136-0,138
Ostiol (mm)	6,03-6,09	5,12-5,21
Meyve Ağırlığı (gr)	65-70	55-60

4.SONUÇ

Bu çalışma ile "Sarılop" incir çeşidinde IBA (2000 ppm) uygulaması ile sınırlı oranda partenokarpik meyve oluşumu sağlanabileceği belirlenmiştir. Ancak, meyve tutum oranlarının düşük, meyve döküm oranlarının yüksek olması nedeniyle uyarıcı kimyasal uygulamaların ticari üretim açısından ekonomik olamayacağı ve ileklemeye (caprification) alternatif teşkil edemeyeceği sonucuna varılmıştır. Bursa Siyahı çeşidinde hiçbir uygulamanın partenokarpik meyve oluşumunu sağlamadığı ve tüm synconiumların döküldüğü görülmüştür. Bu durum, bu çeşidin partenokarpik meyve gelişimine karşı genetik olarak dirençli olduğunu düşündürmektedir. Ayrıca, Bursa Siyahı'nın meyve bağlaması için dölleyici arıcığın varlığına mutlak ihtiyaç duyduğu bir kez daha doğrulanmıştır. Ostiolün fiziksel yollarla uyarılması ve fiziksel uyarı ile birlikte zeytinyağı uygulamalarının da partenokarpik meyve oluşumu üzerinde

herhangi bir etkisinin bulunmadığı ve bu uygulamalara yönelik üretici kaynaklı söylentilerin bilimsel olarak doğru olmadığı sonucuna varılmıştır.

Çalışma sonuçları, incirde partenokarpik meyve oluşumunun karmaşık bir süreç olduğunu ve mevcut oksin uygulamalarının özellikle Bursa Siyahı çeşidi için yetersiz kaldığını ortaya koymaktadır. Sarılop çeşidi için elde edilen sınırlı başarı ise, farklı oksin türlerinin, uygulama zamanlarının, dozlarının ve uygulama yöntemlerinin detaylı bir şekilde araştırılması gerektiğini göstermektedir. Gelecekteki araştırmalar, sadece kimyasal uyarıcıları değil, aynı zamanda genetik yaklaşımları ve farklı kültürel uygulamaları da içeren multidisipliner bir bakış açısıyla yürütülmelidir. İleklemeye alternatif olabilecek sürdürülebilir, ekonomik ve çevre dostu uygulamaların geliştirilmesi incirdeki kültürel işlemlerin kolaylaştırılması açısından öneme sahiptir. Bu bağlamda, partenokarpiye yatkın incir çeşitlerinin ıslahı ve biostimulantlar gibi farklı yaklaşımların da incelenmesi, gelecek araştırmalar için önemsenmesi gereken konular olduğunu düşünmekteyiz.

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GEOGRAPHICALLY INDICATED FIGS OF TÜRKİYE

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ABSTRACT

Throughout history, significant genetic diversity has emerged in figs (*Ficus carica* L.) grown in Anatolia due to diverse geographical conditions and interactions. Many local fig varieties from this diversity have gained national and international importance, leaving significant marks on global fig cultivation. Currently, Turkey hosts considerable fig populations primarily in the Aegean Region, as well as coastal areas of Marmara, Black Sea, and Mediterranean regions, as well as river valleys in Central Anatolia and Southeastern Anatolia. Apart from well-known varieties, these regions feature fig varieties with substantial variations in pollination characteristics, fruit morphology, peel and pulp color, seediness, maturation period, consumption methods, taste, aroma, and texture. Some fig varieties, notable for their distinctive characteristics, cultural significance, and historical value, have been registered with Geographical Indications (GI). Geographical indications are primarily important as quality marks that indicate and guarantee to consumers the origin of the product, its distinctive characteristics, and the relationship between these characteristics and the geographic area. However, consumers and experts do not know the descriptive, distinctive, and prominent quality characteristics of these registered GI figs. This study aims to introduce GI fig varieties in Turkiye, to reveal their characteristics, assess their current status, and provide future-oriented evaluations. The information obtained from the Turkish Patent Institute database, registration-holding institutions, research findings, and existing literature was analyzed in the study.

The first applications for geographical indication registrations of figs in Turkey were initiated in 2003 from İzmir and Aydın from the Aegean Region. Applications gained momentum after 2018, resulting in registrations for six different geographical regions. Currently, there are eight GI-registered figs in Turkey, namely Aydın Fig, Bursa Black Fig (Bursa Black, Black Bursa Fig), Ege Fig, Fethiye Kaya Fig, Havran Black Fig, Melli Fig, Midyat Fig, and Silopi Behnat Fig. In addition, five fig varieties, Buharkent Fresh Fig, Dalaman Fig, Hasankeyf Benati Fig, Payamlı Bardacık Fig, and Tekkeköy Patlıcan Fig are in the application stage of registration. Aydın Fig and Bursa Black Fig are the most important Geographical Indicated figs, have also been registered in the European Union, and are the most recognized varieties globally and the most produced varieties in Turkey. The production of the Aydın Fig and the Ege Fig is based on the “Sarılop” variety, Bursa Black Fig on the “Dürdane” variety, and the Fethiye Kaya Fig on the “Kaya” variety. Other figs are cultivated using local varieties as indicated in their

registered names. Their production and consumption quantities are limited and newly gaining national recognition. To fully realize the benefits expected from the GI system for figs, crucial measures must be undertaken to ensure consumer confidence and sustainability. Recommendations include correcting inadequacies and errors in product descriptions, scientifically defining and enhancing distinguishing characteristics, conducting detailed studies on product quality and nutritional properties, accelerating the registration for other valuable local fig varieties, conserving genetic resources, and strengthening cooperation with relevant expert institutions.

Keywords: Geographical indications, Fig, *Ficus carica* L., rural development

TÜRKİYE'NİN COĞRAFİ İŞARETLİ İNCİRLERİ

ÖZET

Anadolu'da çağlar boyunca yetiştirilen incirlerde (*Ficus carica* L.), coğrafi koşullar ve etkileşim sayesinde, önemli bir genetik zenginlik oluşmuştur. Bu çeşitlilik içerisinden birçok yerel incir varyetesi, ulusal ve uluslararası düzeyde önem kazanarak dünya incir yetiştiriciliğinde izler bırakmıştır. Günümüzde Türkiye'de, Ege Bölgesi başta olmak üzere Marmara, Karadeniz ve Akdeniz Bölgelerinin kıyı kesimlerinde, İç Anadolu ve Güneydoğu Anadolu bölgelerinde nehir vadilerinde hatırı sayılır incir varlığı bulunmaktadır. Bu bölgelerde, tanınan çeşitlerin dışında, döllenme özelliği, meyve morfolojisi, kabuk ve iç rengi, çekirdeklilik, olgunlaşma tarihi, değerlendirme şekli, tat, aroma ve tekstür bakımından önemli derecede varyasyon gösteren incir varyetelerine rastlanmaktadır. Kendine özgü karakteristiklere sahip, kültürel ve tarihi değerleri ile öne çıkan bazı incir varyetelerinin Coğrafi İşaret (Cİ) tescilleri yapılmıştır. Coğrafi İşaretler temel olarak, tüketiciler açısından ürünün kaynağını, karakteristik özelliklerini ve bu özellikler ile coğrafi alan arasındaki bağlantıyı gösteren ve garanti eden kalite işareti olması açısından önemlidir. Mevcut Coğrafi İşaretli incirlerimizin tanımlayıcı, ayırt edici ve ön plana çıkan kalite özellikleri, tüketiciler ve uzmanlar tarafından yeterince bilinmemektedir. Bu çalışmada, Türkiye'deki Coğrafi İşaretli incir çeşitlerinin tanıtılması, özelliklerinin ortaya konulması, mevcut durumlarını değerlendirmek ve geleceklerine yönelik değerlendirmenin yapılması amaçlanmıştır. Çalışmada, Türk Patent Enstitüsü veri tabanı, tescil sahibi kurumlardan alınan bilgiler, araştırma sonuçları ve literatür bilgileri kullanılarak elde edilen bilgiler analiz edilmiştir.

Türkiye'de incirlerin coğrafi işaretine yönelik ilk başvurular, 2003 yılında Ege Bölgesinde İzmir ve Aydın illerinden yapılmıştır. 2018 yılından sonra başvurular hız kazanmış ve 6 farklı coğrafi bölge için tesciller gerçekleştirilmiştir. Mevcut durumda, Türkiye'de, *Aydın İnciri, Bursa Siyah İnciri, Ege İnciri, Fethiye Kaya İnciri, Havran Siyah İnciri, Melli İnciri, Midyat İnciri ve Silopi Behnat İnciri* olmak üzere 8 farklı coğrafi işaret tescili olan incir bulunmaktadır. Bunların dışında, *Buharkent Taze İnciri, Dalaman İnciri, Hasankeyf Benati İnciri, Payamlı Bardacık ve Tekkeköy Patlıcan İnciri* adları ile henüz tescili gerçekleşmemiş, 5 farklı coğrafi işaret başvurusu aşamasındadır. *Aydın İnciri* ve *Bursa Siyah İnciri* Avrupa Birliği nezdinde tescillenmiş, dünyada da en fazla tanınırlığa sahip, ülke çapında en fazla üretimi yapılan en önemli Coğrafi İşaretli incirlerimizdir. *Aydın İnciri* ve *Ege İnciri*'nin üretimi "Sarılop", *Bursa Siyah İnciri*'nin "Dürdane" çeşidi ile yapılmaktadır. Diğerlerinin tamamında ise üretim, tescil adlarında belirtilen yerel incir varyeteleri ile gerçekleşmektedir. Üretim ve tüketim miktarları sınırlıdır ve ülke çapında yeni tanınmaya başlamışlardır. İncirlerde, Coğrafi İşaret sisteminden beklenen faydaların tam olarak elde edilebilmesi, tüketici güveninin ve sürdürülebilirliğin sağlanması için yapılması gereken önemli işler bulunmaktadır. Ürün tanımlamalarındaki eksiklik ve hataların giderilmesi, ayırt edici özelliklerin bilimsel yöntemler kullanılarak belirlenmesi ve geliştirilmesi, ürün kalite özelliklerinin besin içerikleri yönünden detaylı incelenmesi, diğer kıymetli yerel incir varyetelerinin tescil çalışmalarına hız verilmesi ve genetik kaynak olarak korunmaya alınması, konuyla ilgili uzman kurumlarla iş birliğinin güçlendirilmesi önerilmektedir.

Anahtar Kelimeler: Coğrafi işaret, İncir, *Ficus carica* L., Kırsal kalkınma

1. GİRİŞ

İncir (*Ficus carica* L.), insanlık tarihi boyunca özellikle Akdeniz ve Orta Doğu coğrafyasında hem önemli bir besin kaynağı hem de kültürel miras unsuru olmuştur (Ayar, 2023; Kislev ve ark., 2006). Antik dönemlerden bu yana sağlık ve refahın simgesi olarak kabul edilen bu meyve (Flaishman ve Aksoy, 2022), Latince adını, antik çağda "Caria" olarak bilinen ve günümüzde Aydın, Denizli ve Muğla illerinin bir bölümünü kapsayan bölgeden alır (Boyd, 1974; Ghazanfar ve Kogan, 2022; Starr ve ark., 2003). Anadolu günümüzde incirin sekiz gen merkezinden biri olarak kabul edilir ve binlerce yıllık yetiştiricilik geçmişi sayesinde zengin bir genetik çeşitlilik barındırmaktadır (Ayar, 2022; Ergül ve ark., 2021; Ikten ve ark., 2010; Simsek ve ark., 2020). Bu çeşitlilik içerisinden, kendine özgü morfolojik ve pomolojik özelliklere sahip çok sayıda yerel incir varyetesi ortaya çıkmıştır (Condit ve Başkaya, 1948; Çalişkan ve Polat, 2011). Bir zamanlar yerel olan bu varyetelerimiz arasından bazıları, üstün nitelikleri sayesinde ulusal ve uluslararası düzeyde önem kazanarak dünya incir yetiştiriciliğinde önemli izler bırakmıştır (Condit, 1920; Condit, 1955; Condit, 1957; Stover ve ark., 2007).

Günümüzde Türkiye, dünya incir üretiminin %25-27'sini yaparak ve tüm dünyaya incir satan en önemli üretici ülke konumundadır (FAOSTAT, 2025; Polat, 2024). İncir yetiştiriciliği, Türkiye'de tarım kültürünün önemli bir parçasıdır (Aksoy, 2019). Doğal olarak, incir yetiştirilen bölgelerde insanlar ve ürün arasında farklı şekillerde etkileşimler meydana gelmiş ve bazı bölgelerimiz incirleri ile tanınır olmuştur (Günal, 1999). İncir üretiminin Türkiye genelinde en yoğun olarak gerçekleştirildiği bölge Ege Bölgesidir, bunu Akdeniz ve Güneydoğu Anadolu Bölgeleri izlemektedir. Kurutmalık incir üretiminden en yüksek gelir Ege Bölgesi'nde sağlanırken, taze incir üretimi açısından Akdeniz Bölgesi öne çıkmaktadır (Aksoy, 2019; Çalışkan, 2012). Bununla birlikte, birçok bölgede yerel düzeyde incir üretimi geleneksel bilgi birikimi ve kültürel tercihlerle sürdürülmektedir. Ege Bölgesinde incir hem doğal hem de beşerî faktörlerle yoğun bir etkileşim içerisindedir (Çiftçi, 2019; Çobanoğlu, 2013; Günal, 1999). İncirlerdeki genetik çeşitlilik gibi, tüketim şekilleri de oldukça çeşitlidir. Anadolu'da incir esas olarak taze ve kurutularak tüketilmekle birlikte geleneksel gıda ürünlerinin üretimine ve çeşitli etnobotanik kullanım örneklerine de rastlamak mümkündür (Fujita ve ark., 1995; Lansky ve Paavilainen, 2011).

Türkiye'nin son yıllardaki Avrupa Birliğine uyum çabalarına paralel olarak, Coğrafi İşaret (Cİ) uygulamaları ulusal ve uluslararası düzeyde önem kazanmaya başlamış ve birçok ürünün tescili gerçekleştirilmiştir (İbiş, 2025; Kan ve ark., 2019). Eski çağlardan günümüze, Anadolu'da üretilen ve dış pazarlara gönderilen en özgün tarımsal ürünlerimizden birisi olan incir de bu süreçte çok geçmeden ilk coğrafi işaretlemenin yapıldığı ürünler arasında yerini almıştır (İbiş, 2025; TÜRKPATENT, 2025b). Coğrafi işaretler, belirli karakteristik özellikleri, nitelikleri veya ünleri, üretildikleri bölgeyle doğrudan ilişkili olan ürünleri tanımlamak ve benzerlerinden ayırmak için kullanılan önemli etiketlerdir. Bu işaretler, ürünleri doğal ve beşeri unsurların ortak etkileşiminden kaynaklanan özgün, ayırt edici özellikler ve tarihsel derinlik temelinde farklılaştırır (Vandecandelaere ve ark., 2018). Bu nedenle, ülkemiz incirlerinin coğrafi işaret sürecine dâhil edilmesi şaşırtıcı değildir. Bu bağlamda, incirin coğrafi işaretleme sürecine dâhil edilmesi, ürünün yüksek kalitesi ve tarihsel derinliği dikkate alındığında anlamlı ve doğal bir sonuçtur

"Coğrafi işaretler" terimi, geniş anlamıyla, uluslararası antlaşmalarda ve ulusal/bölgesel hukuk sistemlerinde kullanılan çeşitli kavramları kapsamaktadır Bunlar, Menşe Adı (AO), Menşe Adı Koruması (PDO) ve Coğrafi İşaret Koruması (PGI) gibi kavramlardır (WIPO, 2025). Avrupa Birliğindeki uygulanmasında ise Menşe Adı (PDO: Protected Designation of Origin), Mahreç İşareti (Coğrafi İşaret) (PGI: Protected Geographical Indication) ve İçkilerin Coğrafi İşareti (GI: Geographical Indication of Spirit Drinks) olmak üzere üç farklı şekilde işaretleme gerçekleştirilmektedir. Menşe Adı, ürünün tüm üretim süreçlerinin belirli bir coğrafi bölgede gerçekleşmesini zorunlu kılarken, Mahreç İşareti ürünün belirgin bir niteliğinin, ününün veya diğer özelliklerinin bir coğrafi bölge ile özdeşleşmesi durumunu ve korunmasını tanımlar. Mahreç işaretli ürünlerin, tanımlanmış özelliklerden en az birini bulundurması şartıyla adını aldıkları bölgenin dışında da üretilebilmeleri mümkündür. Avrupa Birliğinde son yıllarda coğrafi işaret dışında, geleneksel ürünlerin kalitesini garantileyen Traditional Speciality Quaranteed (TSG) ve dağ ürünü (Mountain Product) gibi zor doğal koşullarda üretilen ürünleri etiketleme yaklaşımı da geliştirilmiştir. Bu işaretler, fikrî mülkiyet hakları (IPR: Intellectual Property Rights) kapsamındadır ve sahipleri için hukuki bir koruma oluştururlar (eAmbrosia, 2025). Bir coğrafi işaret hakkı, bu işareti kullanma hakkına sahip kişilere, ürünleri ilgili standartlara uymayan üçüncü tarafların bu işareti kullanmasını engelleme imkânı tanır (WIPO, 2025). Türkiye'de coğrafi işaret tescil ve takibi Türk Patent ve Marka Kurumu (TÜRKPATENT) tarafından yürütülmektedir. Kurum coğrafi işaret uygulamalarını Avrupa Birliği normlarını referans alan ulusal mevzuat çerçevesinde gerçekleştirmektedir. Bununla birlikte, Türkiye'deki mevzuat Avrupa Birliğinde tanımlı coğrafi işaretleme kategorilerinden hepsini değil sadece Menşe Adı (PDO), Mahreç İşareti (PGI) ve Geleneksel Ürün (TSG) kategorilerini desteklemektedir (TÜRKPATENT, 2025a)

Türkiye'de özellikle Ege Bölgesi başta olmak üzere, farklı iklim ve topoğrafik koşullara sahip pek çok bölge, çeşitli incir varyetelerine dayalı olarak coğrafi işaret tescili almıştır. Güncel olarak 7'si Menşe Adı (PDO), 1'i Mahreç İşareti (PGI) kapsamında olmak üzere toplam 8 farklı Coğrafi İşaretli incir bulunmaktadır (TÜRKPATENT, 2025b). Bu ürünler arasında, "Aydın İnciri" ve "Ege İnciri" ile "Bursa Siyah İnciri", üretim miktarı, ekonomik büyüklük ve ilgilendirdiği üretici kitlesi açısından öne çıkmaktadır. Her ne kadar tüm coğrafi işaretli incir ürünleri yaygın olarak pazarda yer almasa da bazılarına market raflarında rastlamak mümkündür. Ayrıca, henüz mevzuat kapsamında yer almamakla birlikte "Dağ İnciri" etiketiyle satılan ürünler de bulunmaktadır (daginciri.com, 2025). Bu etiket, Türkiye'deki sınıflandırmalarda resmi olarak tanımlanmamış olsa da Avrupa Birliği'nin "Dağ Ürünü (Mountain Product)" kategorisine benzer bir anlam taşımakta ve yeni bir sınıflandırma ihtiyacını gündeme getirmektedir. Coğrafi işaret tescilli incirlerimiz arasında öne çıkan "Aydın İnciri" ve "Bursa Siyah İnciri", son yıllardaki çabalarla Avrupa Birliği nezdinde de tescil edilmiştir (eAmbrosia, 2025). Ayrıca, Fethiye Kaya İnciri için de AB başvuru süreci devam etmektedir (ftso.org.tr, 2023a; ftso.org.tr, 2023b). "Aydın İnciri" ve "Ege İnciri" kurutmalık incir üretim ve ihracatımızdaki en önemli varyetemiz olan "Sarılop" (Aksoy, 2019; Arpaci, 2017), "Bursa Siyah İnciri" ise taze incir üretim ve ihracatımızın en önemli çeşidi olan "Dürdane" varyetesine (yaygın bilinen adıyla "Bursa Siyahı") (Çalışkan, 2012) dayanmaktadır. Bu çeşitlerin kalitelerinin yüksek olması ve geleneksel anlamda ticari hacimlerinin yüksek olmasından dolayı en fazla tanınırlığa sahip coğrafi işaretli incirlerimiz olduğunu söylemek mümkündür. Diğer coğrafi işaretli incirler ise daha sınırlı üretim alanlarına ve düşük tanınırlığa sahiptir.

Coğrafi işaretler, yerel ürünlerin tanıtımı, katma değerlerinin artırılması ve iç-dış pazarlarda etkin şekilde yer bulmaları açısından stratejik öneme sahip araçlardır (Demir, 2020; Pektaş ve ark., 2018). Bu bağlamda, coğrafi işaretli incirler yalnızca ekonomik getirisi yüksek tarım ürünleri değil, aynı zamanda Türkiye'nin kültürel kimliğini yansıtan, ulusal ve uluslararası tanınırlığına katkı sağlayan değerlerdir. Ülkemizdeki yeri ve potansiyeli göz önünde bulundurulduğunda incir, diğer yerel ürünler için hem öncü hem de model olabilecek nitelikte bir üründür. Bu çalışma, Türkiye'deki coğrafi işaretli incirlerimizin önemlerinin vurgulanması, değerlerinin anlaşılması ve tanıtımlarına katkı sağlamak amacıyla tescil süreçleri, üretimleri ve organizasyon yapıları, yetiştirilen varyeteler ve bunların özelliklerinin bilimsel bir bakış açısı ile incelenmesi ve mevcut durumlarının ve potansiyellerinin değerlendirilmesi için yapılmıştır.

2. MATERYAL VE METOT

Bu çalışmada esas veri kaynağı olarak, Türk Patent ve Marka Kurumu (TÜRKPATENT) tarafından yayımlanan çevrimiçi veri tabanındaki güncel coğrafi işaret tescil listeleri, başvuru belgeleri ve bu listeye dayalı raporlar kullanılmıştır (TÜRKPATENT, 2025b). Buna ek olarak, Avrupa Birliği Coğrafi İşaret Tescil Sistemi aracılığıyla Türkiye menşeli incir ürünlerinin uluslararası tescil durumları kontrol edilmiştir (eAmbrosia, 2025). Ayrıca tescil sahibi kurum ve kuruluşlarla doğrudan iletişime geçilerek ürün tanımlamaları, ayırt edici özellikleri ve üretim süreçlerine ilişkin bilgiler temin edilmiştir. Ulusal ve uluslararası literatürde yer alan bilimsel makaleler, raporlar ve istatistiksel veriler de destekleyici bilgi kaynakları olarak kullanılmıştır.

Tüm kaynaklardan elde edilen verilerden; Coğrafi işaretli incirlerin sınırları, tarihçeleri, üretim miktarları, üretim ve pazarlama organizasyonları, yetiştirilen incir varyetelerinin tanımlayıcı meyve özellikleri, tüketim şekilleri, yerel ve kültürel bağlamda öne çıkan özellikleri derlenmiştir. Derlenen bu veriler, ürünlerin tanınmasına katkı sağlama amacı yanında, tüketiciler başta olmak üzere, üreticilerin, konu uzmanlarının, politika yapıcıların ve karar vericilerin bilgilendirilmesine yönelik olarak düzenlenmiş ve tablolar halinde sunulmuştur. Coğrafi işaretli incirlerin güçlü ve zayıf yönleri ile eksiklikleri değerlendirilmeye çalışılmış ve coğrafi işaretlemeden beklenen faydaların sağlanabilmesi için önerilerde bulunulmuştur.

3. BULGULAR VE TARTIŞMA

Türkiye'de incirlerin coğrafi işaretlenmesine yönelik ilk başvurular, üretimin en yoğun olarak gerçekleştiği Ege Bölgesi'nden, İzmir ve Aydın illerinden başlamıştır. Bu başvurular, 2003 yılı itibarı ile yapılmış olup, "Ege İnciri" 2006, "Aydın İnciri" ise 2007 yılında tescil edilmiştir. İncire ilişkin coğrafi işaret başvuruları, uzun bir aradan sonra, 2017 yılında Burdur ilinden "Melli İnciri" başvurusu ile yeniden başlamış ve 2024 yılına kadar toplam 12 farklı başvuru yapılmıştır. Bu dönemde yapılan başvuruların 4'ü yine Ege, 3'ü Güneydoğu Anadolu, 2'si Marmara, 1'er tanesi ise Akdeniz ve Karadeniz Bölgelerinden gelmiştir. Sonraki dönemde yapılan başvuruların 6'sı tescille sonuçlanmış olup 5'inin değerlendirme süreci devam etmektedir. Güncel olarak, toplam tescil edilmiş Coğrafi İşaretli İncir sayısı 8 olup, bunlar (alfabetik sıra ile) *Aydın İnciri, Bursa Siyah İnciri, Ege İnciri, Fethiye Kaya İnciri, Havran Siyah İnciri, Melli İnciri, Midyat İnciri ve Silopi Behnat İnciri*'dir. Tescillenmiş coğrafi işaretli incirlerimizin adları, kullanılan logoları ve tescili yapan kuruluş tarafından yayınlanmış

fotoğrafları Tablo 1'de verilmiştir (TÜRKPATENT, 2025c). *Buharkent Taze İnciri, Dalaman İnciri*, *Hasankeyf Benati İnciri, Payamlı Bardacık ve Tekkeköy Patlıcan İnciri* adları ile yapılan başvurular halen değerlendirme aşamasındadır (Tablo 5). Tescillenmiş ve başvuru aşamasındaki incirlerimize ilişkin bilgiler, Tablo 2 ve Tablo 3'te ayrı ayrı gösterilmiştir. Tablo 2'den de görüleceği üzere, bunlardan 7'si "Menşe Adı" (PDO) kapsamında tescillenmiş olup, yalnızca Silopi Behnat İnciri "Mahreç İşareti" (PGI) kapsamındadır. Benzer şekilde, başvuru aşamasındaki incirler arasında yalnızca *Hasankeyf Benati İnciri* için Mahreç İşareti başvurusunda bulunulmuş, diğer başvurular ise Menşe Adı kapsamında gerçekleştirilmiştir (TÜRKPATENT, 2025b).

"Ege İnciri" dışında tüm coğrafi işaretli incirlerin coğrafi sınırları, isminin de işaret ettiği il ve ilçe idari birimleri ile sınırlıdır. Ege İnciri ise diğerlerinden farklı olarak, İzmir'in belirli ilçeleri ile Aydın İlinin tüm ilçelerini de içine alan daha geniş bir alanı kapsamakta, aynı zamanda Aydın İnciri ile ortak Sarılop varyetesi ile tescillenmiş durumdadır (Tablo 2). Coğrafi işaretlerin dünyadaki uygulama örneklerinde de geniş alanları kapsayan örnekler bulunmakta olup, sağlayabileceği bazı avantajlar nedeniyle tercih bile edilebilmektedir. Sınırların geniş tutulmasının ürünlerin üretim miktarının artırılması ve dolayısıyla daha geniş bir tüketici kitlesine ulaştırılabilmesi açısından avantaj sağlaması mümkündür. Bununla birlikte, ürünlerde belirli bir kalite düzeyinin yakalanmasının, denetim ve pazarlama organizasyonun zorlaşması gibi sakıncaları bulunmaktadır (Demir, 2020). Ege İnciri, ülkemizin ilk coğrafi işaret başvurusu ve tescilli inciridir. Bu, ülkemiz koşulları için tesadüfi bir durum değildir ve tarihsel süreçte incirle ilgili belirli bir tanınırlığının olmasından kaynaklanmaktadır (Özbek, 1949). Diğer yandan, Aydın ili sınırlarında yetiştirilen Sarılop incirlerinin teorik olarak iki işareti kullanma imkânı bulunmaktadır. Bu tescile ilişkin özel durumun, gerçekleştirilecek etki analizi sonuçlarına göre ya da ülkemizin dış ticaretindeki menfaatleri, iç pazar koşulları, tüketicilere sağlayacağı faydalar, ürünlerin pazarlanması ve yönetim organizasyonu anlamında yeniden değerlendirilmesinin faydalı olacağı düşünülmektedir.

Başvuru aşamasındaki incirlere bakıldığında ürün için tanımlanan coğrafi alanların hepsinin ilçe ölçeğinde daha dar alanlar olduğu ve Hasankeyf Benati İnciri dışında diğerlerinin başvurularının milli çeşit listesinde kayıtlı ulusal çeşitlere dayandığı görülmektedir (Tablo 4) (TÜRKPATENT, 2025b). Bununla birlikte, tek yerel çeşitli başvuru olan Hasankeyf Benati İnciri'nin de Silopi Behnat İnciri'nin bir sinonimi ya da genetik ve morfolojik olarak çok yakın incir tipleri olabileceği akla gelmektedir. Bu ihtimalin güçlü olmasına ilişkin fazlasıyla kanıt bulunmaktadır. Nitekim coğrafi işaret Tescili almış olan Silopi Behnat İnciri'nin tescil öncesinde, "Benat" adı ile mahalli çeşit olarak özellikleri bir araştırma ile belirlenmiş ve kayıt başvurusu yapılmıştır. "Benat" ismi ile Hasankeyf'in "Benati" inciri arasındaki ses benzerliği çok yüksektir. Ayrıca, bu mahalli varyeteye ilişkin tanımlamalar ve internette paylaşılan görseller yüksek düzeyde benzerlik göstermektedir. Bununla ilgili tam bir sonuca varılabilmesi için dünyadaki diğer uygulama örneklerinde olduğu gibi DNA temelli moleküler teşhis tekniklerin kullanılması gerekmektedir (Ciarmiello ve ark., 2015; Ganopoulos ve ark., 2015). Ülkemizde de buna ilişkin laboratuvar imkânları ve yetkinlik düzeyi yüksek uzmanlar bulunmaktadır (Akin ve ark., 2021; Ergül ve ark., 2021).

Türkiye'deki coğrafi işaret tescil bilgileri incelendiğinde, ürünlerin büyük çoğunluğunun belediyeler, ticaret/ticaret-sanayi odaları, ticaret borsaları, valilik ve kaymakamlıklar gibi kamu veya yarı-kamu niteliğindeki kurumlar tarafından tescil ettirildiği görülmektedir. Benzer bir

eğilim incir özelinde de geçerlidir. Şu an için tescilli 8 incir ürününden 3'ünün tescil sahibi belediyeler, 2'sinin ticaret veya ticaret ve sanayi odaları, 2'sinin Tarım ve Orman Bakanlığı İlçe Müdürlükleri, 1'inin ki ise üretici kooperatif birliğidir. Türkiye'nin iki en bilinen coğrafi işaretli incirinden Aydın İnciri, ilin Ticaret Odası adına tescilli iken, Bursa Siyah İnciri, S.S. Bursa Bölgesi Tarım Kooperatifleri Birliği adına tescillidir (TÜRKPATENT, 2025b). Bu örnekler, ürünün ekonomik potansiyeliyle tescil sahibinin yapısı arasında bir ilişki kurulabileceğini işaret etmektedir Özellikle, üretici birliklerinin tescil sahibi olduğu coğrafi işaretlerin, üretim gücü, ürünün pazarlanması ve sağlayacağı ekonomik katkı bakımından daha işlevsel olacağı düşünülmektedir (Kan ve ark., 2019). Buna karşılık, Tarım ve Orman Bakanlığı'nın taşra teşkilatları olan ilçe müdürlüklerinin tescil sahibi olduğu durumların da olması dikkat çekicidir. Özellikle, Güneydoğu Anadolu Bölgesi'nde bu durum yaygındır. İlçe müdürlükleri, çoğu zaman mülki amirlerin desteğiyle başvuru sürecini yürütmektedir. Ticari potansiyeli ve üretim hacmi yüksek olan coğrafi işaretli incirlerde ise tescil sahibi kurumun üretici örgütü/birliği olması hem sahiplenmeyi hem de uygulama etkinliğini artıran bir unsurdur. Bu olumlu örnek, Bursa Siyah İnciri özelinde net biçimde gözlemlenmektedir.

TÜRKPATENT'in çevrimiçi veri tabanında yer alan "Faaliyet gösterenler" kısmı incelendiğinde, coğrafi işaretli incirlerin ekonomik büyüklüğü, işlerliği, üretim ve pazarlama organizasyonunun yapısı ve işleyişi hakkında önemli çıkarımlar yapmak mümkündür (TÜRKPATENT, 2025b). Örneğin, Aydın İnciri'nde pazarlamacı sıfatı ile kayıtlı 6 adet tarım satış kooperatifi, 6 adet limited şirket, 2 anonim şirket ve 2 gerçek kişi yer almaktadır. Buna karşın "üretici" sıfatı ile yalnızca 3 limited şirketin kayıtlı olduğu görülmektedir (ci.turkpatent.gov.tr, 2025f). Bu yapı, üretimin büyük ölçüde küçük üreticiler tarafından yapıldığını, daha çok yerel üretici kooperatifler ve özel şirketler aracılığıyla pazara sunulduğunu yansıtmaktadır. Bursa Siyah İnciri ile karşılaştırıldığında, Aydın İnciri'nin organizasyon yapısının daha fazla aktör içerdiği, ne var ki üretici temsiliyetinin nispeten düşük kaldığı anlaşılmaktadır. Ege İnciri örneğinde ise yalnızca bir üretici ve bir pazarlamacı anonim şirketin kayıtlı olması, sınırlı kapasite ve şirket temelli bir yapıya işaret etmektedir (ci.turkpatent.gov.tr, 2025h). Fethiye Kaya İnciri örneğinde ise üretim ve pazarlamanın, tek bir kooperatif aracılığıyla kollektif biçimde yürütüldüğü gözlemlenmektedir (ci.turkpatent.gov.tr, 2025i). Buna karşılık, Melli İnciri'nde üretim ve pazarlamanın çoğunlukla şahıslar üzerinden yürütüldüğü ve doğrudan yerel pazarlarda tüketiciye sunulduğu anlaşılmaktadır (ci.turkpatent.gov.tr, 2025k). Havran İnciri'nde ise faaliyet gösterenlere ilişkin herhangi bir bilgi bulunmamaktadır (ci.turkpatent.gov.tr, 2025j). Bu durum, işlerliğin henüz sağlanamadığını ve organizasyon yapısının tam anlamıyla fonksiyonel hale gelmediğini düşündürmektedir. Güneydoğu Anadolu Bölgesi'ne ait incirlerde ise faaliyet gösterenlere dair veri tabanında herhangi bir kayıt bulunmamaktadır (ci.turkpatent.gov.tr, 2025l; ci.turkpatent.gov.tr, 2025m). Bu konudaki eksikliğin mevcut üretim ve pazarlama şartlarını dikkate alarak giderilmesinin yerinde olacağı düşünülmektedir.

Aydın İnciri, Ege İnciri ve Bursa Siyah İnciri, diğer coğrafi işaretli incirlerden farklı olarak, 5553 Sayılı Tohumculuk Kanunu kapsamında ulusal çeşit listesine kayıtlı olan tescilli çeşitlerle (sırasıyla "Sarılop" ve "Dürdane") üretilmektedir. Bu durum, söz konusu ürünlerin coğrafi işaret tescili ve uygulama süreçleri açısından bir engel teşkil etmemektedir. Bununla birlikte, çeşitlerin resmi olarak tescillenmiş olması, bu çeşitlerin coğrafi işaret sınırları dışında, benzer ekolojik koşullara sahip farklı bölgelerde de yetiştirilebilmesine imkân tanımaktadır. Özellikle

bu çeşitlerin adları kullanılarak, coğrafi işaret alanı dışında üretilen ve fiziksel-morfolojik açıdan büyük ölçüde benzerlik gösteren ürünlerin iç piyasada dolaşıma girmesi mümkündür. Bu durum, coğrafi işaret sisteminin temel amacı olan ürünün menşeiyle bağlantılı ayrıştırma, farklılaştırma ve pazarda koruma sağlama işlevini zayıflatabilir (Gökovalı, 2007). Dolayısıyla, tescilli çeşitlerin farklı bölgelerde yetiştirilebilmesi, coğrafi işaretin ekonomik etkisini azaltabilecek ve tüketici nezdinde kafa karışıklığı yaratabilecek bir risk faktörü olarak değerlendirilmelidir.

Türkiye'deki tescilli coğrafi işarete sahip incirler ile başvuru aşamasındaki incirlerin tanımlayıcı meyve özellikleri, döllenme tipleri, tüketim uygunlukları ve öne çıkan özelliklerine ilişkin bilgiler, sırası ile Tablo 4 ve Tablo 5'te sunulmuştur. Başvurusu devam eden ve tescillenmiş incirlerimizin tamamının "Smyrna" tipi meyve verme özelliğine sahip olduğu görülmektedir. Bu tip incirlerde döllenme zorunludur ve meyveleri birçok özellik yönünden diğer tiplerden üstün özelliklere sahiptir (Çalışkan ve Bayazit, 2012; Eisikowitch ve Ghara, 2015). Bursa Siyah İnciri dışındaki tüm incirlerin taze tüketim ile birlikte kurutularak tüketilme durumu söz konusudur. Coğrafi işaret tescili yapılmış 8 incirin dayandığı varyetelerin sarı, sarı yeşil, yeşil tonlarda kabuk rengine sahip olanların daha fazla olduğu, daha koyu mor renkte (koyu mor, siyah-mor) olanların ise daha az olduğu görülebilmektedir. Meyve iç renkleri ise genellikle pembe renkte, daha az sayıdakinin de kırmızı renkte olduğu ve bazılarının pembe ve kırmızı arası geçiş renklerinde olduğu görülmektedir. Bu renk aralıkları itibarı ile incirlerin hepsinin tüketici tercihlerinde görsel cazibe ve kalite açısından olumlu karşılanabilecek özelliklere sahip olduğu söylenebilir. Nitekim iç özelliği beğenildiği için özellikle tercih edilen ve klonal olarak çoğaltılan genotipler olmasından dolayı günümüze kadar ulaşıp coğrafi işaret tesciline konu olmuşlardır. Meyve şekli bakımından incirlerin genel olarak yuvarlak ve yuvarlağa yakın basık formlarda olduğu, sadece birinin uzun oval formda olduğu görülebilmektedir. Coğrafi işaretli incirlerimizin meyve şekil tanımlamalarına bakıldığında, uluslararası incir tanımlayıcı kriterlerinde belirtilen grupların ve ölçüm şekillerinin dikkate alınmadığı görülmektedir (IPGRI, 2003).

Öte yandan, tanımlayıcı ve ayırıcı özellik olarak bahsedilen içerik bilgilerinin sınırlı ve basit analiz sonuçlarına dayalı olarak verildiği, yine benzer şekilde tat ve aroma özelliklerinin de büyük ölçüde birbirine benzeyen ve yüzeysel tanımlarla ifade edildiği görülmektedir (Tablo 4 ve 5). Bu durum, ürünün pazarlama potansiyelin ve tüketici farkındalığını sınırlandıran bir etkide bulunabilir. Dünyadaki coğrafi işaretli zeytinyağı örneklerine bakıldığında, özel içerik bilgilerinin ürünlerin kalitesini ve farklılıklarını ortaya koymak için oldukça detaylı olarak incelendiği ve bu bilgilerin ürünlerin pazarlamasında kullanıldığı görülmektedir (Inarejos-García ve ark., 2010). İncir meyveleri, insan beslenmesinde temel besin öğelerini içermesi yanında sağlığa olumlu etkilerde bulunan özel biyokimyasal bileşikler de içerdiği için fonksiyonel gıda olarak kabul edilmektedir (Caliskan, 2015). Bu nedenle, özel içerik bilgilerinin, zeytinyağı örneklerinde olduğu gibi, nitelikli kimyasal analizler yoluyla belirlenerek incirlerin kalitesiyle ilgili ayrıştırıcı ve farklılaştırıcı bilgiye dönüştürülmesi ve bu bilgilerin ürünlerin iç ve dış pazardaki kalite algısında kullanılmasına özel önem verilmelidir (Caliskan, 2015; Hosseini ve ark., 2025; Kiralan ve ark., 2023; Vinson, 1999). Özellikle aroma profillerinin daha detaylı şekilde tanımlanması, tüketici tercihlerinin yönlendirilmesi açısından büyük önem taşımaktadır. Nitekim dünyadaki diğer meyve türlerine ilişkin coğrafi işaret uygulamalarında olduğu gibi, duyusal analizler ve içerik analizleri (örneğin şeker-asit dengesi,

fenolik bileşikler, organik asitler vb.) ile desteklenen detaylı kalite profilleri oluşturmak, incir meyvelerinin özgünlüğünü daha açık biçimde ortaya koyacaktır (Aljane ve ark., 2020; Çalişkan ve Polat, 2011; Veberic ve ark., 2008). Ayrıca, yerel ürünlerin geleneksel tüketim biçimlerine ilişkin ifadeler de çoğu zaman sınırlı ve genelleyici düzeyde kalmaktadır. Oysa ürünün bölgesel kültürdeki yeri, tüketim alışkanlıkları ve bu meyveden elde edilen geleneksel gıda ürünleri (örneğin incir ezmesi, reçel, pestil gibi) dikkatle belgelenmeli ve gerekirse üretim yöntemleriyle birlikte sunulmalıdır (Günal, 1999; Kantaroğlu ve Demirbaş, 2018; Trichopoulou ve ark., 2006) .

4. SONUÇ VE ÖNERİLER

Coğrafi İşaretler, üreticilere sağladığı koruma, pazarlama olanaklarını artırması ve ekonomik ve kırsal kalkınmayı desteklemesi yönüyle önemlidirler. Bununla birlikte en önemli fonksiyonları belirli bir coğrafyada üretilmiş ürünlerin diğerlerinde üretilenlerden kalite yönüyle olumlu yönde ayrıştığını göstermesidir. Coğrafi işaret koruması (PDO) sadece ekonomik kazanç boyutu ile değil geleneksel bilgi ve üretim şekillerinin, kültürel mirasın korunmasına katkı sağlar. Aynı zamanda korunan ürünleri üreten işletmelerin ürünlerini daha yüksek fiyattan satmalarına imkân sağlayarak gelirlerini artırır. Kırsal bölgelerde turizmi ve diğer coğrafi faaliyetleri olumlu yönde etkileyerek kalkınmaya destek olur. Bununla birlikte, bu durum sadece tescil ile sağlanabilecek bir sonuç değildir. Bunun dışında, ürünlerin kaliteli biçimde üretilmesini sağlayacak organizasyon yapısının kurulması, kullanıcıların belirlenmesi, ürünlerin kalitesini denetleyecek sistemin kurumlar ve altyapı anlamında oluşturulması gerekmektedir. Ayrıca tanıtımının yapılarak, tüketicilerin bilgilendirilmesi ve ürünün piyasada tanınırlığının arttırılması gerekir (Gökovalı, 2007; WIPO, 2025).

Türkiye, incir üretiminde dünyanın en önemli ülkelerinden biridir ve bu nispette fırsatlara sahiptir (Ana ve ark., 2022; Tırkaz ve ark., 2022). Önemli fırsatlarından birisi de tarihi ve kültürel derinliğinin, genetik zenginliğinin bir yansıması olarak ortaya çıkmış coğrafi işaretli incirleridir. Son yıllarda, coğrafi işaretli ürünlerin tesciline yönelik artan ilginin bir sonucu olarak, 2016 yılından sonra, tescilli ürün sayımızda ciddi bir artış meydana gelmiş ve bu süreçte, coğrafi işaretli incirlerimizin sayısı 2'den 8'e çıkmıştır (Kan ve Kan, 2020). Ülkemizdeki coğrafi işaret tescilli incir ve başvuru sayısı incir üretim kültürünün ve incirden ürün elde etme kültürünün ne kadar önemli olduğunu göstermektedir. Mevcut durumda, iç pazar ve dış pazarlar için ayrı düzeyde öneme sahip, farklı üretim miktarları ve kalite özelliklerinde çeşitli coğrafi işaretli incirlerimiz bulunmaktadır. Aydın İnciri ve Bursa Siyah İnciri coğrafi işaretleri, üretim miktarı, ticaret hacmi ve uluslararasılaşmaları itibarı ile en önemlileridir. Düşük miktarlarda üretime sahip coğrafi işaretli incirlerin daha çok sosyo ekonomik etkileri olduğunu söylemek mümkündür. Sağlanan faydalar arasında yörenin ve yöre insanının tanınması olduğu gibi, yöredeki insanların aidiyet duygularını artması da sayılabilir. Ayrıca bölgede işbirliği düzeyinin kültürünün gelişmesine katkı sağlama gibi olumlu sosyokültürel etkiler oluşturabilirler (Demir, 2020).

Coğrafi işaret sisteminden beklenen faydaların tam olarak elde edilebilmesi, tüketici güveninin ve sürdürülebilirliğin sağlanması için yapılması gereken önemli işler bulunmaktadır. Özellikle üretim miktarı düşük olan tescilli incirlerimizde, ürün tanımlamalarındaki eksiklik ve hataların giderilmesi, ayırt edici ve ürünlerin farklılaştırmasında işe yarayacak özelliklerin bilimsel yöntemler kullanılarak geliştirilmesi yerinde olacaktır. Coğrafi işaretli incirlerde, ayırt edici

özgün özelliklerin ortaya konulmasında ülkemizin bilimsel potansiyelinden ve uzmanlarından daha fazla istifade edilmesi gerekmektedir. Bu süreçlerin etkin bir şekilde yürütülebilmesi için ilgili uzman kurum ve kuruluşlar arasındaki işbirliğinin güçlendirilmesi de kritik bir öneme sahiptir. Üniversiteler ve araştırma kuruluşları işbirliğiyle, Coğrafi İşaretli incirlerin kendine özgü tat, aroma, tekstür gibi duyusal özellikleri ile besin içerikleri detaylı olarak analiz edilmelidir. İncirlerin besin içerikleri ve kalitesini artıran özel biyokimyasal içeriklerinin detaylı bir şekilde incelenmesi ve sonuçların tüketicilerle paylaşılması ürünlerin kalite algısı ve tercih edilmeleri açısından önemlidir (Hosseini ve ark., 2025).

Ülkemizin farklı yörelerindeki diğer kıymetli yerel incir varyetelerinin de sistemli bir biçimde kayıt altına alınarak, coğrafi işaret tescil süreçlerine dahil edilmesi önemsenmelidir (Ayar, 2023; Ayar ve ark., 2021; Çalışkan ve Polat, 2012; Gündeşli, 2020). Bunun sağlayacağı çok boyutlu faydalardan birisi de genetik kaynakların korunması olacaktır. İyi özelliklere sahip incir varyetelerinin gen kaynağı olarak kullanılması ve ıslah çalışmalarında kullanılma potansiyeli vardır. Unutulmamalıdır ki Anadolu toprakları "Brown Turkey" ve "Calmyrna" incirlerinin orijinidir. Ayrıca, yeni yapılacak başvurularda, ürün karakteristikleri ile üretildiği coğrafya arasındaki bağın daha güçlü kurulmasına ve bunun bilimsel verilerle desteklenmesine dikkat edilmeli, mevcutlarda ise zaman içerisinde ilişkinin güçlendirilmesi için çabalanmalıdır. Bir başka önemli konu da mevcut ve gelecekteki coğrafi işaretli incirlerimizde ürün güvenliği ile ilgili izlenebilirlik sisteminin oluşturulmasıdır. Coğrafi İşaretlerin, Organik Tarım, GLOBALGAP, İyi Tarım Uygulamaları ve HACCP gibi çevreye duyarlı gıda üretim, kontrol ve sertifikasyon sistemleri ile yürütülmesi düşünülmelidir (Kan ve Gülçubuk, 2008). Zira bu, güvenli ürünlerin üretilmesine, doğal kaynakların korunmasına, uzun vadede müşteri memnuniyetinin oluşmasına ve her yönüyle üretimin sürdürülebilirliğine katkı sağlayacaktır.

Öte yandan, coğrafi işaret tescil belgesinin alınmasının son değil, bir başlangıç noktası olduğu unutulmamalıdır. Geliştirme yönünde çabalara devam edilmeli ve üründen elde edilecek gelirlerin artırılmasına yönelik olarak başka faaliyetlerde gerçekleştirilmelidir. Coğrafi incirlerde marka yönetimi yaklaşımı benimsenerek, pazarlama iletişimi ve halkla ilişkiler geliştirilmeli ve böylece yeni pazarların açılması sağlanmalıdır (Çiftçi, 2019). İncirden yapılan geleneksel ürünlere sahip olan ve ürün işleme potansiyeli bulunan yörelerin, bu ürünleri coğrafi işaret kapsamında pazara sunarak gelirlerini artırmaları ve ilave istihdam oluşturmaları mümkündür. Ayrıca hem uluslararası hem de ulusal tescilli coğrafi işaretli incirlerimizin turizm ve gastronomi ile birleştirilmesi için çabalar sarf edilmelidir (Armesto López ve Martin, 2006; Denk, 2025; Kan ve ark., 2012). Nitekim bunun yakın vadede incirde gerçekleşebileceğine dair göstergeler oluşmaya başlamıştır (Şahin ve Girgin, 2024). Mevcut ve gelecekteki tescil sahiplerinin, ürünlerinin yurt içi ve yurtdışı pazarların taleplerine ne kadar uyduğunu belirlemeleri yerinde bir iş olacaktır. Ayrıca ulusal tescillerini devam ettirecek olanların ve uluslararası tescile başvuracakların öncelikle kararlarını tescil maliyetlerine ve etki analizi sonuçlarına göre vermeleri yerinde olacaktır. İncir yetiştiriciliğimizdeki mevcut pozisyonumuz ve avantajlarımızla yerel incirlerimizi ve coğrafi işaretli incirlerimizi anlamlı çabalarla daha iyi noktalara taşımamız mümkün görünmektedir.

Tablo 1: Türkiye'deki Coğrafi İşaretli İncirlerin Logoları (TÜRKPATENT, 2025c).

Coğrafi İşaret Adı	Fotoğrafı	Logosu
Aydın İnciri	-	
Bursa Siyah İnciri	-	
Ege İnciri	-	
Fethiye Kaya İnciri	-	
Havran Siyah İnciri		Logosu yok
Melli İnciri		Logosu yok
Midyat İnciri		Logosu yok
Silopi Behnat İnciri	-	

Tablo 2: Türkiye'deki Coğrafi İşaretli İncirlere İlişkin Bilgiler

Coğrafi İşaret Adı	Coğrafi bölgesi	Coğrafi işaretin türü	İşaretin coğrafi sınırları	Coğrafi işaretin başvuru tarihi	Coğrafi işaretin tescil tarihi	Tescil sahibi	İncir çeşidinin adı – Tescil durumu	Kaynak
Aydın İnciri	Ege Bölgesi	Menşe adı	Aydın İli, Tüm İlçeler	09.12.2003	20.08.2007	Aydın Ticaret Odası	Sarılop – Ulusal Tescilli	(ci.turkpatent.gov.tr, 2025f)
Bursa Siyah İnciri	Marmara Bölgesi	Menşe adı	Bursa İli	12.04.2018	14.11.2018	S.S. Bursa Bölgesi Tarım Kooperatifleri Birliği	Dördane – Ulusal tescilli	(ci.turkpatent.gov.tr, 2025g)
Ege İnciri	Ege Bölgesi	Menşe adı	İzmir İli: Torbalı, Bayındır, Kiraz, Ödemiş, Tire, Beydağ, Selçuk İlçeleri ile Aydın İlinin tüm ilçeleri	06.02.2003	12.06.2006	İzmir Ticaret Borsası	Sarılop – Ulusal tescilli	(ci.turkpatent.gov.tr, 2025h)
Fethiye Kaya İnciri	Ege Bölgesi	Menşe adı	Muğla İli – Fethiye İlçesi	05.06.2020	11.08.2021	Fethiye Ticaret ve Sanayi Odası	Kaya - Yerel çeşit	(ci.turkpatent.gov.tr, 2025i)
Havran Siyah İnciri	Marmara Bölgesi	Menşe adı	Balıkesir İli, Havran İlçesi	11.10.2022	08.06.2023	Balıkesir Büyükşehir Belediyesi	Havran – Yerel çeşit	(ci.turkpatent.gov.tr, 2025j)
Melli İnciri	Akdeniz Bölgesi	Menşe adı	Burdur İli, Bucak İlçesi	09.08.2017	30.07.2018	1-Bucak Belediye Başkanlığı 2-Tarım ve Orman Bakanlığı Bucak İlçe Müdürlüğü	Melli - Yerel çeşit	(ci.turkpatent.gov.tr, 2025k)
Midyat İnciri	Güneydoğu Anadolu	Menşe adı	Mardin İli- Midyat İlçesi	04.11.2019	10.03.2021	Midyat Belediyesi	Yerel çeşit	(ci.turkpatent.gov.tr, 2025l)
Silopi Behnat İnciri	Güneydoğu Anadolu	Mahreç İşareti	Şırnak İli – Silopi İlçesi	04.10.2022	09.05.2024	Silopi İlçe Tarım ve Orman Müdürlüğü	Behnat (Benati) - Yerel çeşit (kayıtlı)	(ci.turkpatent.gov.tr, 2025m)

Tablo 3: Coğrafi İşaret Başvuru Aşamasındaki İncirlere İlişkin bilgiler

Coğrafi İşaret Adı	Coğrafi bölgesi	Coğrafi işaretin türü	İşaretin coğrafi sınırları	Coğrafi işaretin başvuru tarihi	Başvuru sahibi	İncir çeşidinin adı – tescil durumu	Kaynak
Buharkent Taze İnciri	Ege Bölgesi	Menşe adı	Aydın İli, Buharkent İlçesi	17.01.2024	Nazilli Ticaret Odası	Sarılop-Ulusal Tescilli	(ci.turkpatent.gov.tr, 2025a)
Dalaman İnciri	Ege Bölgesi	Menşe adı	Muğla İli - Dalaman İlçesi	14.04.2023	Muğla Ticaret ve Sanayi Odası	Bardacık – Ulusal Tescilli	(ci.turkpatent.gov.tr, 2025b)
Hasankeyf Benati İnciri	Güneydoğu Anadolu	Mahreç İşareti	Batman-Hasankeyf İlçesi	23.09.2024	Hasankeyf İlçe Tarım ve Orman Müdürlüğü	Benati – Yerel Çeşit	(ci.turkpatent.gov.tr, 2025c)
Payamlı Bardacık İnciri	Ege Bölgesi	Menşe adı	İzmir-Güzelbahçe	11.08.2022	Güzelbahçe Belediye Başkanlığı	Bardacık – Ulusal tescilli	(ci.turkpatent.gov.tr, 2025d)
Tekkeköy Patlıcan İnciri	Karadeniz Bölgesi	Menşe adı	Samsun İli-Merkez-Tekkeköy	10.07.2023	Tekkeköy Belediye Başkanlığı	Patlıcan – Ulusal Tescilli	(ci.turkpatent.gov.tr, 2025e)

Tablo 4: Coğrafi İşaretli İncirlerin Meyve Özellikleri (TÜRKPATENT, 2025b)

Coğrafi işaret adı	Kabuk rengi	İç rengi	Meyve şekli	Meyve ağırlığı (aralık ve ortalama)	Meyve verme tipi	Tüketim uygunluğu (/Yöreye özgü özel ürün ya da tüketim şekli)	İncirin kalite ve kullanım yönünden ayırıcı - öne çıkan özelliği
Aydın İnciri	Açık sarı	Pembe	Oval-basık	64,77-67,84 g	Smyrna	Taze sofralık ve kurutmalık	İçinin yoğun balı ve kıvamlı olması, aroması
Bursa Siyah İnciri	Koyu mor	Koyu kırmızı	Uzun oval	76,92- 90,90 g	Smyrna	Taze sofralık	İri meyveli olması, tat ve aroması, taze tüketime uygunluk
Ege İnciri	Yeşilimsi sarı	Pembe	Oval	67,5-68,05	Smyrna	Taze sofralık ve kurutmalık	Aroması ve kuru kalitesinin yüksek olması
Fethiye Kaya İnciri	Siyah-mor	Kırmızımsı	Oval-basık	21,66 – 31,68 g	Smyrna	Taze sofralık ve kurutmalık	Tadının çok tatlı olması, hem taze hem sofralık tüketilebilmesi
Havran Siyah İnciri	Siyah-mor	Kırmızımsı	Uzun-oval	55 gr	Smyrna	Taze sofralık ve kurutmalık	İri meyveli ve tatlı olması
Melli İnciri	Açık yeşil ile sarımtırak	Koyu pembe	Basık	38,4 gr	Smyrna	Taze sofralık ve kurutmalık	Çekirdeğinin fazla olması, ince pürtüsüz kabuğa sahip olması
Midyat İnciri	Sarı-yeşilimsi	Açık pembe	Basık	33,55 – 54,82 g	Smyrna	Taze sofralık ve kurutmalık	Kuraklığa dayanıklı olması
Silopi Behnat İnciri	Sarı	Pembemsı kırmızı	Oval-basık	33,56-52,07gr	Smyrna	Taze sofralık ve kurutmalık (Seyfi: Özel incir pestili)	Kuru incirinin (Seyfi) pestil kıvamında olması

Tablo 5: Başvuru Aşamasındaki İncirlerin Meyve Özellikleri (TÜRKPATENT, 2025b)

Coğrafi işaret adı	Kabuk rengi	İç rengi	Meyve şekli	Meyve ağırlığı / Meyve iriliği	Meyve verme tipi	Tüketim uygunluğu (/Yöreye özgü özel ürün ya da tüketim şekli)	İncirin kalite ve kullanım yönünden ayırıcı - öne çıkan özelliği
Buharkent Taze İnciri	Sarı	Pembe	Basık	66,8-67,85 gr	Smyrna	Taze sofralık ve kurutmalık	Üretim yeri itibarı ile sezon içindeki erkencilği
Dalaman İnciri	Açık yeşil	Koyu pembe	Basık	45-60 gr	Smyrna	Taze sofralık	Benzoik asit ve mevalonik lakton içeriği
Hasankeyf Benati İnciri	Sarı-yeşil alacalı	Açık pembe	Yassı-basık	33,56-52,07 gr	Smyrna	Taze sofralık ve kurutmalık	Güneşe tutulduğunda yarı saydam özelliğe sahip olması İncir cipsi üretimine uygunluk
Payamlı Bardacık İnciri	Açık yeşil-boyuna çatlak	Koyu pembe	Uzun-oval	Orta	Smyrna	Taze sofralık	Uzun boyunlu-kabuk rengi boyuna çatlak
Tekkeköy Patlıcan İnciri	Siyah-mor	Kırmızımsı	Uzun-oval	50-70 gr	Smyrna	Taze sofralık ve kurutmalık (/Ezme olarak tüketilmesi)	Tat ve aroması

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DROUGHT TOLERANCE MECHANISM IN COMMONLY USED GRAPEVINE ROOTSTOCKS

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ABSTRACT

Vitis vinifera L. is one of the most important species within the *Vitis* genus in terms of cultivated area, production, and economic output. Although *V. vinifera* has a broad genetic diversity, modern grapevine cultivation is carried out by grafting *V. vinifera* varieties onto American rootstocks resistant to the phylloxera (*Daktulosphaira vitifoliae*: Fitch) or hybrids derived from them. In recent years, countries such as China and Peru, alongside Mediterranean nations with traditional viticulture, have quickly expanded their modern vineyards, emerging as important actors in the global grape market. Along with the rising market competition, these developments have highlighted the importance of ensuring the sustainability of production against the environmental stress factors that restrict viticulture. In this context, the selection of rootstocks is not only based on their resistance to phylloxera and the affinity between the rootstock and scion, but also on their tolerance to biotic and abiotic stress factors, particularly drought stress, which has become a key criterion. With the effects of global climate change, drought is progressively becoming a growing threat to viticulture. Even though rootstocks adapted to different environmental conditions were developed in the past, their genetic diversity remains insufficient, as most of these rootstocks were derived from the hybridization of a small number of species. Extended dry seasons and changing rainfall patterns are resulting in yield and quality reductions in vineyards, thus requiring the development of new rootstocks with improved drought tolerance. This study focuses on the physiological, biochemical, and molecular responses of some grapevine rootstocks commonly used worldwide and in Turkey to drought stress, as discussed in the current literature, and evaluates the mechanisms of drought tolerance. The presented information will support efforts to breed new drought-resistant grapevine rootstocks and determine graft combinations that show high adaptability to dry conditions.

Keywords: *Vitis* ssp., Abiotic stress, Osmoregulation, Metabolic response, Water limitation

YAYGIN KULLANILAN ASMA ANAÇLARINDA KURAKLIĞA TOLERANS MEKANİZMASI

ÖZET

Vitis vinifera L. türü, *Vitis* cinsi içerisinde yetiştiricilik alanı, üretim miktarı ve ekonomik getirisi açısından öne çıkan bir türdür. Geniş bir genetik varyasyona sahip olmasına rağmen, modern bağcılıkta *V. vinifera* çeşitlerinin yetiştiriciliği, filoksera zararlısına (*Daktulosphaira vitifoliae*: Fitch) karşı dayanıklı Amerikan türleri ya da bu türlerden geliştirilen hibrit anaçlar üzerine aşılanarak gerçekleştirilmektedir. Günümüzde yalnızca geleneksel bağcılık yapılan Akdeniz ülkeleri değil, aynı zamanda Çin ve Peru gibi ülkeler de modern bağ alanlarını hızla genişleterek küresel üzüm pazarında önemli aktörler hâline gelmiştir. Bu gelişmeler, artan pazar rekabetiyle birlikte, bağcılığı sınırlayan çevresel stres faktörlerine karşı üretimin sürdürülebilirliğini daha da önemli hâle getirmiştir. Bu bağlamda anaç seçiminde yalnızca filokseraya dayanıklılık ve anacın kalem ile gösterdiği afinite değil; aynı zamanda biyotik ve abiyotik stres faktörlerine, özellikle de kuraklık stresine karşı tolerans düzeyi de temel bir kriter olarak ön plana çıkmaktadır. Küresel iklim değişikliğinin etkisiyle kuraklık, bağcılık açısından giderek artan bir tehdit oluşturmaktadır. Geçmişte farklı çevresel koşullara uyum sağlayabilen anaçlar geliştirilmiş olsa da bu anaçların çoğu sınırlı sayıda türün melezlenmesiyle elde edildiğinden genetik çeşitlilik açısından yeterli değildir. Uzayan kurak sezonlar ve azalan yağış rejimleri, bağlarda verim ve kalite kayıplarına yol açmakta, bu da kuraklığa daha toleranslı yeni anaçların geliştirilmesini zorunlu kılmaktadır. Bu çalışmada, dünyada ve Türkiye'de yaygın olarak kullanılan bazı asma anaçlarının kuraklık stresine karşı gösterdikleri fizyolojik, biyokimyasal ve moleküler tepkiler güncel literatür ışığında ele alınmış, kuraklık toleransına ilişkin mekanizmalar değerlendirilmiştir. Sunulan bilgiler, kuraklığa dayanıklı yeni asma anaçlarının ıslahı ile kurak koşullara yüksek adaptasyon kabiliyeti gösteren aşı kombinasyonlarının belirlenmesi yönünde yürütülen çalışmalara katkı sunacaktır.

Anahtar Kelimeler: *Vitis* ssp., Abiyotik stres, Osmoregülasyon, Metabolik tepki, Su kısıtı

1. GİRİŞ

Küresel iklim değişiminin olumsuz etkilerinin tarımsal alanlarda artması ve su kaynaklarına erişimin zorlaşması ile beraber tarımsal üretim maliyetleri de artış göstermiştir. Bu sebeple; daha ekonomik ve sürdürülebilir bir yöntem olan kuraklığa toleranslı bitkilerin ıslahına yönelik araştırmalar ve yatırımlar giderek hızlanmıştır (Ceccarelli ve ark., 2010). Bu bitkilerden biri olan asma, üretimi oldukça yaygın olan ve ürünü çok çeşitli sektörlerde ham madde olarak değerlendirilen, ticari öneme sahip bir bitki türüdür (Odabaşıoğlu ve ark., 2022). Her ne kadar bağcılık her iki yarım kürede de 10-20°C izotermlerinde yer alan ılıman iklim kuşağında yoğun olarak yapılmaktaysa da sıcak iklim bölgelerinde de azımsanmayacak bir ölçüde yetiştiriciliği sürdürülmektedir (Jackson ve Cherry, 1988). Kültüre alınmış birçok bitkinin aksine; asmanın göreceli olarak kuraklığa toleransı yüksektir. Ürün verimine olumsuz bir etkisi olmasına rağmen orta derecede kuraklığın, şarap üretiminde kullanılan üzüm çeşitlerinde tanelerin fitokimyasal bileşimini etkileyerek şarap kalitesine olumlu bir yansımasının olduğu bildirilmektedir (Savoi ve ark., 2020; Tsegay ve ark., 2014). Filoksera zararlısının (*Daktulosphaira vitifoliae*: Fitch) bağlara yayılımı ve *Vitis vinifera* L. türüne ait çeşitlere verdiği zararlar nedeniyle günümüzde bağcılık; Amerikan asma anaçları üzerine *Vitis vinifera* L. çeşitlerinin aşılanması yöntemiyle sürdürülmektedir (Gökbayrak, 2006). Bu nedenle asma fidanı üretimi dünya genelinde büyük ölçüde aşılı olarak yapılmaktadır (Smith, 2004). Filokseraya dayanımın yüksek olması Amerikan asma anaçlarında elzem bir özellik olsa da günümüzde tek başına aranan bir özellik olmaktan çıkmıştır. Son yıllarda asma anaçlarında; çeşitlerle oluşturulan aşı kombinasyonlarında yüksek afinite göstermenin, patojenlere ve diğer zararlılara karşı dayanıklı olmanın yanı sıra toprak tuzluluğu, kuraklık ve benzeri abiyotik stres faktörlerine karşı toleransın yüksek olması gibi özellikler de aranmaya başlanmıştır.

Vitis vinifera L. türüne ait üzüm çeşitlerinin yetiştiriciliğinde kullanılan Amerikan asma anaçlarının büyük bir bölümü, filokseraya toleranslı olmaları hedeflenerek ıslah edildiklerinden dolayı üç farklı *Vitis* türünden (*V. rupestris, V. berlandieri, V. riperia)* en az birinin kullanılmasıyla elde edilmiştir (Cousins, 2005; Odabaşıoğlu, 2021; Atak, 2025). *Vitis riparia* yüzlek kök sistemiyle göreceli olarak sulak alanlara iyi adapte olurken, *Vitis rupestris* ve *Vitis berlandieri* daha derine gidebilen kök sistemine sahip oldukları için kuraklığa toleransları bu türe göre daha yüksektir. Türkiye'de *Vitis vinifera* L. türüne ait çeşitlerin kendi kökleri üzerinde yetiştiriciliği; sınırlı alanlarda da olsa (filokseradan ari bazı bölgelerde) devam etmektedir.

Abiyotik stres faktörleri arasında kuraklığın (su kısıtı); doğrudan verim kaybına ve üründe kalitenin azalmasına neden olduğu bilinmektedir. Bu nedenle suyun etkin kullanımını sağlayan tarımsal sistemlerin geliştirilmesi; tarım işletmeleri için anahtar bir stratejidir. Küresel iklim değişikliği etkilerinin giderek artacağı varsayılmakta ve hatta gelecekte kuraklığın etkisinin günümüz yarı kurak-kurak alanlarında etkisini daha da göstereceği öngörülmektedir (Feng ve ark., 2014). Bu bağlamda anaçlar; su kullanımın etkinliği, potansiyel yaşam gücünün ve büyüme kapasitesinin yüksek olması ve kalemin stres koşullarına adaptasyonunu geliştirerek ürün kayıplarının sınırlandırılmasında önemli bir rol oynayabilirler (Marguerit ve ark., 2012).

İklim değişimi nedeniyle tatlı su kaynaklarına erişim giderek zorlaşmaktadır. Bu nedenle bağcılık için kuraklığa dayanımı yüksek anaçların geliştirilmesi amacı ile yapılan ıslah çalışmaları giderek hız kazanmıştır (Schachtman ve Goodger, 2008). Anaçların genetik çeşitliliği özellikle kuraklık açısından küresel iklim değişimine adaptasyonunda önemli bir rol

oynamaktadır (Vincent ve ark., 2007). Ancak anaçlar arasında kuraklığa dayanımda standart bir metodolojinin bulunmaması nedeniyle çalışmalar arasında farklılıklar bulunabilmektedir (Ollat ve ark., 2016). Nitekim Çizelge 1 incelendiğinde, farklı araştırıcıların belirli bir asma anacının kuraklığa tolerans düzeyi için farklı değerlendirmelerde bulundukları görülebilmektedir.

Çizelge 1. Bazı Amerikan asma anaçlarının kuraklığa tolerans düzeyleri (Zhang ve ark., 2016)

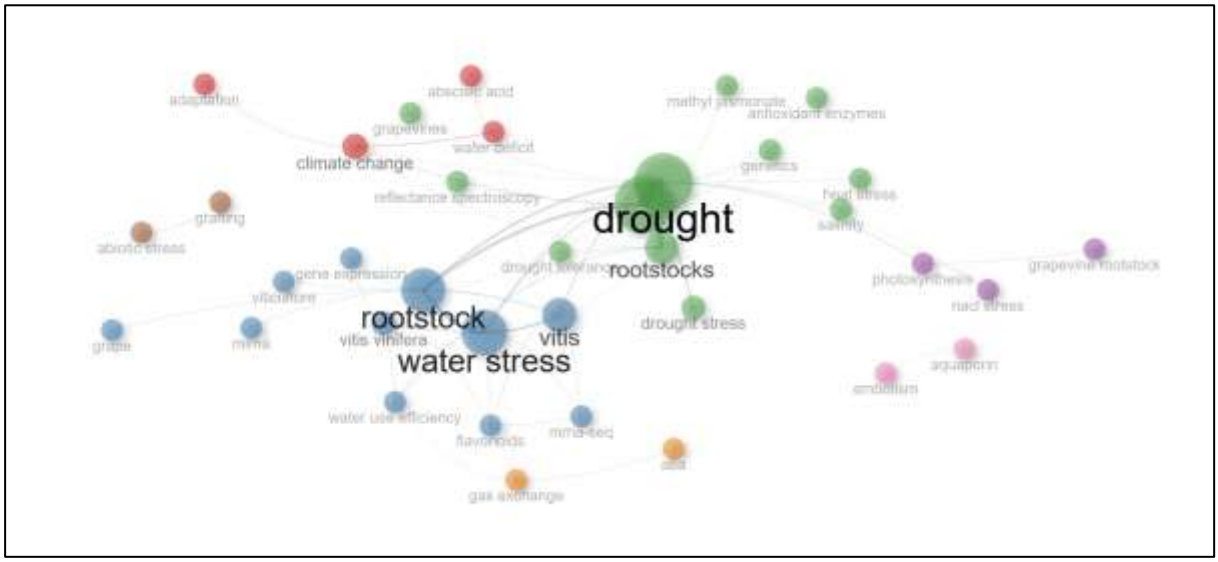
Anaç	Kuraklığa Tolerans Düzeyi*			
	Samson ve Casteran (1971)	Fregoni ve ark. (1978)	Carbonneau (1985)	Corso ve Bonghi, 2014
99R	3	3	3	-
110R	4	4	4	3
140Ru	3	4	4	3
1103P	4	4	3	3
SO4	1	1	3	1
420A	1	1	2	1
5BB	1	1	2	2
333EM	4	3	1	-
101-14 MGt	1	1	1	2
41B	3	4	2	2
420A	1	1	2	1
3309C	4	1	2	1
Fercal	3	-	2	-
Rup. du Lot	1	1	1	-

*(4: Yüksek, 1: Düşük)

2. ANAÇLARIN KURAKLIĞA TOLERANS MEKANİZMALARI

İklim değişiminin etkileri nedeniyle, özellikle Akdeniz havzasında yoğun olarak yetiştiriciliği yapılan asma bitkisini etkileyen en önemli sorunların başında kuraklık gelmektedir. Kısmi kuraklık şarap içeriğinde istenilen bir unsur olmasına rağmen kuraklığın şiddeti ve süreci önemli verim kayıplarına ve hatta bitki ölümlerine neden olmaktadır (Gambetta ve ark., 2020). Bu nedenle araştırmacılar son dönemde, asmalarda kuraklık stresinin fizyolojisi üzerine çalışmalarını yoğunlaştırmışlardır. “Grapevine”, “drought stress” ve “rootstock” anahtar kelimeleri ile Scopus veri tabanında dizinlenen makalelerde kullanılan anahtar kelimeler ile oluşturulan ağ haritası aşağıdaki şekilde sunulmuştur (Şekil 1). Bu çalışmalar derlendiğinde 7 farklı alt kümenin oluştuğu görülmektedir. En büyük alana sahip olan yeşil kümede sadece kuraklık değil kuraklık stresi ile birlikte tuz ve yüksek sıcaklık ile kombine çalışmaların da yapıldığı görünürken ikinci büyük alana sahip olan mavi kümede ise moleküler çalışmaların

toplandığı görülmektedir. Bu da günümüzde çalışmaların bu doğrultuda yoğunlaştığını göstermektedir.



Şekil 1. Scopus veri tabanında konu ile ilgili yapılmış çalışmaların dağılımı

Bitkilerde kuraklık koşulları altında gözlemlenen dehidrasyon, kökler vasıtasıyla alınan su ile terleme yoluyla kaybedilen su arasındaki dengenin bozulduğu durumlarda ortaya çıkar (Aroca ve ark., 2012). Bu nedenle, asma (*Vitis vinifera* L.) gibi rutin olarak bir anaç üzerine aşılanarak çoğaltılan bitkilerde, stres koşullarına adaptasyon sağlamaya yönelik çalışmalar, anaçlar üzerinde yoğunlaşmaktadır. Asma anaçları, üzerlerine aşılanan üzüm çeşitlerinin eko-fizyolojik davranışını ve meyve kalitesini etkilerken, biyotik (toprak kaynaklı zararlılar vb.) ve abiyotik (tuzluluk, su veya oksijen eksikliği vb.) gibi dışsal sınırlayıcı faktörlere karşı da tolerans sağlar (Tramontini ve ark., 2013a).

Asma anaçları, kuraklık durumunda kalemlerin transpirasyonunun kontrolünde kaleme önemli katkılar sağlamaktadır (Smart ve ark., 2006). Anaçlar kuraklığa toleransta etkin bir rol oynamasına rağmen; kök fizyolojisi ve morfolojisine yönelik çalışmalar, genellikle yaprak gibi toprak üstü organlara kıyasla ikincil düzeyde kalmaktadır. Bunun başlıca nedeni, köklerin doğal ortamda doğrudan gözlemlenmesinin zor olmasıdır. Toprak altında gelişen köklerin zarar vermeyecek yöntemlerle zaman içinde izlenmesi ve örneklenmesi oldukça güçtür. Ayrıca kök dokularında hormon, gen ekspresyonu ya da metabolit düzeylerinin ölçümü için gereken örnekleme işlemleri çoğunlukla bitkiye zarar verecek şekilde olabilmektedir. Bu da zamana bağlı analizlerin güvenilirliğini sınırlandırmaktadır (Zheng ve ark., 2023). Köklerin su alım kapasitesinin stres altında değiştiğini ve bu değişimlerin zamansal olarak izlenmesinin deneysel olarak zor olduğunu vurgulamıştır. Javaux ve ark. (2013) ise kök-toprak etkileşimlerinin karmaşık yapısı ve bu ilişkinin modellenmesindeki belirsizliklerin, kök çalışmalarını daha da karmaşık hale getirdiğini belirtmiştir. Tüm bu metodolojik zorluklar, köklerin kuraklık stresine verdiği yanıtların tam olarak anlaşılmasını güçleştirmiş ve araştırma odağının çoğunlukla

yaprak fizyolojisi ve stoma yanıtları üzerine yoğunlaşmasına neden olmuştur. Oysa stresin ilk algılandığı ve sistemik yanıtların başladığı organ olarak köklerin daha fazla dikkate alınması, bitkilerin kuraklığa tolerans mekanizmalarının bütüncül olarak anlaşılması açısından büyük önem taşımaktadır.

Kök sisteminin gelişimi oldukça esnektir. Kök sisteminin yapısı; kaynaklara erişim, abiyotik-biyotik dışsal etmenlere tepkide ve değişen çevre koşullarına en iyi şekilde adapte olacak şekilde düzenlenmektedir (Zhang ve Kirkham, 1996). Aşılanmış bitkilerde anaç ve kalem arasında etkileşim vardır. Bu etkileşim ve aralarındaki iletişim halen tam olarak açıklanabilmiş değildir. Farklı anaçların kök sistemleri; hormon üretimlerinin yanı sıra bitki besin elementleri ve su alımı kapasiteleri açısından da birbirlerinden farklılık göstermektedir (Satisha ve ark., 2007; Zhang ve ark., 2016). Bu farklılığı; değişik anaçlar üzerine aşılanmış belirli bir üzüm çeşidinin aynı bölgede farklı zamanlarda tanelerini olgunlaştırması veya vejetatif gelişiminde gözle görülür değişikliklerin olması gibi ölçütleri inceleyerek tespit etmek mümkündür (Keller, 2020; Odabaşıoğlu, 2020). Bununla birlikte kuraklığa farklı tepkiler gösteren anaçlar üzerine aşılanmış üzüm çeşitlerinde; kullanılan anaca bağlı olarak büyüme ve gelişme farklılıkları, mahsuldardık değişimleri, tanelerin fitokimyasal kompozisyonlarının değişmesi vb. durumlar, kuraklığa dayanıklı anaçların önemini ortaya koymuştur (Cakir ve ark., 2022; Ezzahouani ve Williams, 1995; Köse ve ark., 2014; Zhang ve ark., 2016). Genel olarak kuraklık, kültürü yapılan üzüm çeşitlerinin büyüme, verimlilik ve ürün kalitesi vb. üzerinde olumsuz bir etkiye sahiptir (Kamiloğlu ve ark., 2014). Öte yandan asmalar, büyüme ve gelişimini devam ettirebilmek için hem yapısal hem de fizyolojik değişimler sayesinde kuraklığa adaptasyon sağlama eğilimindedir.

Stomalar, asmaların kuraklık stresine maruz kaldıkları süre boyunca su kaybının düzenlenmesinde önemli bir role sahiptir (Damour ve ark., 2010; Flexas ve ark., 2009; Tombesi ve ark., 2015). Günümüze değin, kuraklık stresi altında stomaların kontrol mekanizması üzerine pek çok çalışma yapılmıştır. Stomaların düzenlenmesi, su kullanım etkinliğini ve dolayısıyla fotosentetik aktiviteyi etkiler. Asmalar, bitki su durumunda ki azalmaya bağlı olarak stomalarının hassasiyetlerine göre isohidrik ve anisohidrik olmak üzere sınıflandırılmaktadır (Van Leeuwen ve ark., 2009). Sıkı bir stoma kontrolü sağlayanlar isohidrik olarak tanımlanmakta ve bu farklı stoma davranışlarının altında genetik kontrolün olabileceğine dair kanıtlar bulunmaktadır. (Coupel-Ledru ve ark., 2014).

Stomaların kapanmasının düzenlenmesi hidrolik, kimyasal, fiziksel ve hatta elektriksel sinyallerle ilişkilendirilmektedir (Beis ve Patakas, 2010). Kuraklık stresine karşı bitkilerde gelişen temel savunma mekanizmalarından biri, köklerin toprakta azalan su potansiyelini algılaması ve bu duruma yanıt olarak yapraklara sinyaller iletmesidir. Son araştırmalar, bu süreçte yalnızca aktif absisik asit (ABA) üretiminin değil, aynı zamanda ABA'nın biyosentetik öncü maddelerinin de önemli bir rol oynadığını ortaya koymuştur. Kuraklık koşullarında kökler, ABA'nın doğrudan kendisini üretmek yerine, xanthoxin gibi öncü bileşikleri sentezleyerek bunları ksilem yoluyla yapraklara taşır. Böylece ABA biyosentez yolunun bazı basamaklarının farklı dokularda gerçekleştiğini ve bu dağılımın bitkisel yanıtları daha esnek hale getirdiğini bildirmiştir (Seo ve Koshiba, 2002). Bu öncüller yaprak hücrelerinde ABA'ya dönüştürülerek bekçi hücrelerde sinyal iletimini başlatır ve stomaların kapanmasına neden olur. Böylece transpirasyon azalır, su kaybı kontrol altına alınır ve bitkinin kuraklık koşullarına adaptasyonu sağlanır (Davies ve Zhang, 1991). Sauter ve ark. (2001), kökten yaprağa taşınan

ABA ve öncüllerinin bitkisel dokularda farklı şekillerde metabolize edilerek uzun mesafeli sinyal iletimini sağladığını ifade etmiştir. Bu bulgular, köklerin yalnızca su eksikliğini algılamakla kalmayıp, bu bilgiye dayalı olarak sistemik kimyasal sinyal üretimiyle bitki genelinde etkili ve hedefe yönelik kuraklık yanıtlarını başlattığını ortaya koymaktadır.

Kuraklığa toleransı yüksek olan asma anaçlarının yapraklarında stoma yoğunluğunun, kuraklığa hassas olan anaçlara göre daha düşük olduğu rapor edilmiştir (Bekişli ve Gürsöz, 2016). Kara ve Özeker (1999) kuraklığa toleranslı anaçların, hassas olan anaçlara kıyasla üzerlerine aşılanan kalemlerin (çeşitlerin) yapraklarında stoma sayısını arttırma eğiliminde olduğunu bildirmiştir. Odabaşıoğlu (2020) ise kuraklığa toleransı yüksek olan asma anaçlarına aşılı olarak yetiştirilen üzüm çeşitlerinin yapraklarındaki stoma yoğunluğunun, daha kurak geçen sezonlarda arttığını saptamıştır. Bu bulgular; kurak şartlara omcanın tepkisi açısından anaçların, kalemin su durumu ve gaz değişimi üzerine etkiye sahip olduğunu gösterir niteliktedir. Anaçlar, kalemlerdeki stomaların yalnızca hareketlerini değil aynı zamanda yapraklardaki ve diğer yeşil aksamlardaki yoğunluğunu da etkileyebilmektedir. Öte yandan kuraklığa toleransı yüksek anaçların ıslahı için yapılan çalışmalar, kalemin transpirasyon ve hormon sinyal iletişiminin şekillenmesinde anaçların genetik bir katkısı olduğunu kanıtlamıştır (Richards, 1983; Soar ve ark., 2006).

Asma anaçları kuraklığa farklı derecelerde tolerans gösterebilmektedirler. Örneğin, 101-14 ve Schwarzmann daha az tolerans gösterirken, Lider 116-60, Ramsey, 140 Ruggeri, Kober 5BB ve 110R kuraklığa göreceli olarak daha toleranslıdır (Corso ve Bonghi, 2014). Bu farklılığın temelinde, anaçlar ıslah edilirken seçilen *Vitis* türlerinin kuraklığa tolerans düzeylerinin birbirlerinden farklı olması yatmaktadır (Çizelge 2). Nitekim, Lovisolo ve ark. (2008b) *Vitis berlandieri* x *Vitis rupestris* melezlerinin, *Vitis berlandieri* x *Vitis riperia* melezlerine göre kurak koşullara daha iyi adaptasyon gösterdiğini savunmuştur. Sürgün büyümesi, klorofil kapsamı ve bitkinin zararlanma semptomları dikkate alınarak yapılan bir çalışmada, *Vitis cinerea* türünün kuraklığa direnci yüksek anaçların ıslahında kullanılabilecek uygun bir genetik kaynak olabileceği bildirilmiştir (Pavlousek, 2011). Oysaki Padgett-Johnson ve ark. (2003) ve Rustioni ve ark. (2016), bu türün kuraklığa duyarlı olduğunu savunmuşlardır. Araştırmacılar, asma anaçları ıslah edilirken heterosis (melez azmanlığı) etkisinin ortaya çıkabildiğini ve bu nedenle kuraklığa tolerans düzeyi bakımından bazı melez anaçların ebeveynlerinden daha iyi performans sergilediklerini savunmuşlardır. Nitekim bu duruma verilebilecek en güzel örnekler 110R, 140Ruggeri ve 1103Paulsen anaçlarıdır. Her üç anaç da *Vitis berlandieri* x *Vitis rupestris* melezidir ve ebeveynlerine göre kuraklığa toleransları daha yüksektir.

Çizelge 2. Bazı *Vitis* türlerinin kuraklığa tolerans düzeyleri (Padgett-Johnson ve ark., 2003)

Duyarlı	Kısmen Toleranslı	Toleranslı	Çok Toleranslı
V. solonis >	*V. cordifolia* >	*V. longii* >	
V. riperia >	*V. treleasei* >	*V. girdiana* >	*V. champinii* >
V. berlandieri >	*V. monticola* >	*V. arizonica* >	*V. doaniana*
V. lincecumii >	*V. candicans* >	*V. californica* >	
V. cinerea	*V. rupestris*	*V. vinifera*	

Çeşitli bitki türlerinde kuraklık stresine toleransta, oksidatif zararın azalması ile antioksidan sistem arasında yakın bir ilişki bulunmuştur (Aganchich ve ark., 2009; Lima ve ark., 2002; Ozkur ve ark., 2009; Reddy ve ark., 2004; Sofo ve ark., 2005; Zhang ve Kirkham,1996). Kuraklık stresine karşı geliştirilen savunma tepkilerinden biri, reaktif oksijen türlerinin (ROS) neden olduğu hücresel hasarı önlemek amacıyla enzimatik antioksidan savunma sistemlerinin aktive edilmesidir (Beis ve Patakas, 2012). Kuraklık stresinin erken dönemlerinde süperoksit dismutaz (SOD), katalaz (CAT), askorbat peroksidaz (APX) ve glutatyon redüktaz (GR) gibi enzimlerin aktivitesinde anlamlı artışlar gözlemlenmiştir. Bu enzimler, ROS'un toksik etkilerini azaltarak hücre zarlarının bütünlüğünü ve metabolik dengeyi korumaya yardımcı olur. Ancak stresin şiddetinin artması ve sürenin uzaması durumunda bu enzimatik aktivitelerde bir düşüş görülmektedir. Bu azalma, bitkinin antioksidan kapasitesinin yetersiz kalması ve oksidatif hasarın kontrolsüz biçimde artmasıyla ilişkilendirilir. Weidner ve ark. (2009) kuraklık stresinin asma köklerinde bazı fenolik asitlerin (*p*-kumarik asit, ferulik asit) miktarını arttırdığını bildirmiştir. Patakas ve ark. (2002), kuraklık uygulanan asmalarda yapraklardaki SOD ve CAT aktivitelerinin başlangıçta yükseldiğini ancak uzun süreli su kesintisinde bu aktivitelerin azaldığını raporlamıştır. Benzer şekilde, Flexas ve ark. (2002), kuraklık stresine karşı fotosentetik aparatın korunmasında antioksidan sistemin önemli olduğunu, fakat uzun süren stresin bu savunma sistemini zayıflattığını ortaya koymuştur. Koç (2020) tarafından yapılan bir çalışmada ise Türkiye'ye özgü asma çeşitlerinde kuraklık stresinin başlangıcında artan APX ve CAT aktivitelerinin ilerleyen günlerde azaldığı ve bunun hücresel zar hasarıyla ilişkili olduğu bildirilmiştir. Bu bulgular, asmalarda kuraklık stresine karşı geliştirilen antioksidan savunmanın geçici ve strese bağlı olarak sınırlı etkinliğe sahip olduğunu göstermektedir.

3. KİMYASAL TEPKİLER

Anaçlar, kaleme topraktan su ve besin elementleri tedariki sağlamasının yanı sıra pek çok bitki hormonunun da bir kaynağıdır (Keller, 2020; Richards, 1983). Hormon seviyesinde ve sinyal iletimindeki değişim yoluyla anaçların, kalemin büyümesi üzerine bir etkisi olduğu açıktır. Kök-sürgün büyümesinin kontrolünde en merkezi olan hormonlar sitokinin ve oksin, bitkilerde uzun mesafe taşınan hormonlardır (El-Showk ve ark., 2013). Skene ve Antcliff (1972), farklı anaçlar üzerine aşılı Sultana üzüm çeşidinin yaş üzüm verimi ile kanama suyundaki sitokinin seviyesi arasındaki ilişkiyi incelemişler ve sitokinin seviyesi düşük olan omcaların aynı zamanda daha düşük üzüm verimi elde edilen anaç üzerine aşılı olanlar olduğunu saptamışlardır. Benzer bulgulara ulaşan Nikolaou ve ark. (2000) farklı anaçlar (420A, 110R, 99R, 41B, 5BB, 8B, 1103P, 31R ve 3309C) üzerine aşılanmış Thompson Seedless üzüm çeşidine ait omcaların büyüme parametreleri ile sitokinin içerikleri arasında pozitif korelasyon olduğunu ayrıca yüksek sitokinin içeren anaçların, ksilem eksüdatlarında ve yaprak ayasında yüksek azot içerdiğini bildirmiştir.

Kökten gelen kimyasal tepkilerin; özellikle kuraklık stresinin ilk aşaması boyunca asmaların kısa süreli adaptasyonu için önemi büyüktür (Rossdeutsch ve ark., 2016). Bu sinyaller ksilem sayesinde yapraklara kadar taşınabilmektedir. Bu sayede yaprakların büyümesi ve kalemin su kaybının düzenlenmesi sağlanmış olur. Kurak şartlar boyunca köklerden etilenin öncü maddeleri, malat, sitokinin, pH değişimi ve ABA gibi pek çoğunun kimyasal iletişimde rolleri

bulunmaktadır. Özellikle sitokininler köklerde sentezlendikleri için, besin eksikliğinde de olduğu üzere, kuraklık stresi altındaki asmalarda kökler ile kalem arasındaki iletişimde önemli bir role sahip olabilir (Schachtman ve Goodger, 2008). Bu açıdan, ksilem özsuyundaki ABA:Sitokinin oranlarının kuraklık stresinin sinyalizasyonu açısından önem bir işlevinin olması muhtemeldir (Stoll ve ark., 2000). Öte yandan asmalarda, sitokinin ve ABA arasında stomaların kapanması açısından antagonistik bir etki tanımlanmıştır (Montanaro ve ark., 2022). Sharp ve LeNoble (2002), kuraklık stresi altındaki bitkilerde kök-sürgün arasındaki sinyalizasyonda ABA-Etilen ilişkisinin önemli bir rol oynadığını bildirmişlerdir. Ayrıca köklerde yeterli düzeyde ABA sentezlenmediğinde, etilen veya etilenin öncüsü olan ACC hormonunun, köklerden sürgünlere taşındığını bildirmişlerdir. Kurak koşullara asma anaçlarının tepkileri ve adaptasyonu bakımından söz konusu ilişki ile ilgili önemli bir bulgu henüz rapor edilmemiştir.

Yeterli miktarda su bulunmayan toprak şartları altında, köklerdeki sitokinin hormon seviyesinin azalmasıyla beraber kalemlerin vejetatif gelişmesinde azalmaya neden olan, kalemde daha düşük konsantrasyon ile sonuçlanır. Kalem/anaç etkileşimi, taç yapısını ve boyutunu etkileyerek kuraklığa toleransta asmalarda su kullanımını etkileyecek önemli bir etkiye sahiptir (Whiting, 2004). Bunların yanında kimyasal sinyaller, ABA ve akuaporin ifadesi su taşınımını bitkilerde önemli şekilde etkilemektedir. Rehidre olmuş asmalarda transpirasyonal kontrolde ABA'nın önemli bir role sahip olduğu, ksilem embolizmi ve absisik asit hormonunun streslenmiş bitkilerde arttığı bildirilmiştir (Lovisolo ve ark., 2008a; 2008b).

4. HİDROLİK İLETKENLİK

Angiospermlerde ksilem aracılığıyla suyun taşınması, damar çapı, dağılımı, yoğunluğu, hidrolik iletkenlik ve ksilem ağı topolojisi gibi anatomik özellikler tarafından belirlenmektedir. Ksilem anatomisi ile anaçlardan sürgünlere su taşınım verimliliği arasında doğrudan bir ilişki bulunmaktadır (de Herralde ve ark., 2006). Bu durum, anaçların topraktan su alıp kaleme iletme kapasitelerinin birbirinden farklı olduğunu ortaya koymaktadır (Koundouras ve ark., 2008). Asmalar ise, diğer birçok bitki türüyle karşılaştırıldığında daha geniş ksilem damarlarına sahip olmaları sayesinde, su kısıtı koşullarına karşı nispeten daha toleranslı olarak değerlendirilmektedir (Comas ve ark., 2010). Ayrıca kendi organları arasında ksilem genişliği bakımından farklılıklar (kökler > gövde dokuları) mevcuttur (Lovisolo ve ark., 2008a; Serra ve ark., 2014). Hidrolik sistem sadece genetik mekanizma tarafından değil aynı zamanda ksilem dokusunun gelişimi üzerine bir etkiye sahip olan toprak tipi tarafından da etkilenmektedir (Tramontini ve ark., 2013b). Etkili bir kök sistemine sahip asma anaçlarının, topraktan aldığı su ve besin maddelerini en az kayıpla ve hızlı bir şekilde kaleme iletebilmesi üreticilerin avantajınadır.

Uygun sulama şartları altında anaçların kök hidrolik iletkenlikleri farklıdır ve kuraklık stresi ile hidrolik iletkenliklerinde azalma söz konusudur (Lovisolo ve ark., 2008b; Vandeleur ve ark., 2009). Kuraklık stresi altında iletkenlikteki bu azalmaya, muhtemelen akuaporin gen ifade ve aktivesindeki değişim katkı sağlamaktadır (Vandeleur ve ark., 2009). Ayrıca ABA, akuaporin aktivitesi ve kök hidrolik iletkenliği arasında bir ilişki bulunmaktadır (Maurel ve ark., 2010). Kök hidrolik iletkenliğindeki değişimler potansiyel olarak yaprak su potansiyelini de etkileyebilir ve bu nedenle kök hidrolik iletkenliğindeki azalma yaprak su potansiyelinde de bir

azalmaya neden olabilir (Brodribb ve Hill, 2000; Else ve ark., 1995).

Kuraklık stresi, kök hidrolik iletkenliğindeki sürekli azalmaya muhtemel katkı sağlayan bilhassa apoplast kök dokularında ki suberin tabakasının değişimi vasıtasıyla yapısal değişime de neden olabilir (Steudle, 2000). Asmalarda kılcal kök uçlarındaki olgunlaşan bölgelerde ekzodermis ve endodermis bir suberinleşme bulunabilir (Gambetta ve ark., 2013) ve kuraklık stresinin artmasıyla beraber bu suberinleşmeye daha sık rastlanılmaktadır (Lovisolo ve ark., 2010; Vandeleur ve ark., 2009). Kuraklığa 110R anacından göreceli olarak daha hassas olan 101-14MGt anacında kuraklık stresiyle birlikte daha erken ve daha büyük suberinleşme olduğu gözlemlenmiştir (Barrios-Masias ve ark., 2015). Yeni nesil dizileme yöntemi ile asmada yapılan bir çalışma da VriMYB41 transkripsiyonel faktörünün kuraklık stresi ile birlikte suberin birikiminde aktif bir rol oynadığı ortaya konmuştur (Zhang ve ark., 2020).

5. ABSİSİK ASİT (ABA)

Bitkiler kuraklık stresine karşı genellikle dört tür tepki mekanizması gösterirler: kuraklıktan kaçınma, kuraklıktan sakınma, kuraklığa tolerans ve kuraklıktan kurtulma (Fang ve Xiong, 2015). ABA, kuraklık stresine karşı bitkilerin geliştirdiği tolerans mekanizmalarında aktif rol almaktadır. Bu nedenle ABA, stres hormonu olarak da bilinmektedir. ABA, bitkilerin çevresel strese karşı tepkisi bakımından oldukça kritik bir öneme sahiptir (Dalal ve Chinnusamy, 2015). ABA, özellikle kuraklık altında sürgün fizyolojisini etkilemesi üzerine anaçların düzenlemesi için güçlü bir adaydır. Yedi farklı asma anacı üzerine aşılanmış Şiraz üzüm çeşidinin stoma davranışları ile sürgün ksilem özsuyundaki ABA konsantrasyonu arasında güçlü bir ilişki bulunmuştur (Soar ve ark., 2004).

Kurağa görece olarak toleransı yüksek olan bitkiler kuraklık stresi ile başa çıkmak için üç yol izlemektedirler. Bunlar; su tüketiminin azaltılması, su alımını arttırılması ve stres genlerinin ifadelerindeki değişimler ile stomaların kapanarak su kısıtının olumsuz etkilerinin azaltılmasıdır (Surbanovski ve Grant, 2014). ABA bu süreçlerde düzenleyici bir hormon olarak yer almaktadır. Köklerde ABA'nın üretilerek yapraklara taşınması, topraktaki su durumunun rapor edilmesi için kullanılan bitkinin ana mekanizması olarak düşünülmektedir. Bununla birlikte, köklerdeki ABA üretiminin lokasyonu tam olarak bilinmemekte ve ayrıca bu iletişim mekanizması ile etkileşebilen yapraklarda da ABA sentezinin mevcut olduğu düşünülmektedir (Rossdeutsch ve ark., 2016). Kök bölgesinde sentezlenen ABA hormonunun etilen ile antigonistik etkileşime girerek etilen üretimini sınırladığı ve kök uçlarının uzamasının devam etmesi için elzem bir rol oynadığı vurgulanmıştır (Serra ve ark., 2014). ABA'nın ana köklerin uzamasını teşvik ettiği ve lateral köklerin kuraklığa tepki olarak ortaya çıktığı, bir başka çalışma ile doğrulanmıştır (De Smet ve ark., 2006). Bu yüzden ABA kök sisteminin yapısı ve boyutları üzerine önemli bir etkiye sahiptir.

6. AKUAPORİNLER

Akuaporinler farklı fizyolojik süreçlerde yaşayan organizmaların çoğunda bulunan su kanal proteinleridir. Asma genomunda yapılan filogenetik analizler sonucu 28 adet akuaporin geni sınıflandırılmıştır (Koç ve ark., 2024). Asmalarda akuaporinler, değişen çevre şartlarında bitkilerin iyon-su dengesini devam ettirerek kuraklığa adaptasyonda temel bir rol oynarlar.

Kuraklığa daha toleranslı anaçlar, ilerlemiş ksilem gelişimi ve daha düşük damar embolizasyonu ile ilişkilendirilen daha yüksek hidrolik iletkenliğe sahiptirler (Lovisolo ve ark., 2008b). Anaçlar arasındaki bu farklılıkları açıklayabilen yaygın bir görüş; bitkilerdeki özel proteinler olan ve su kısıtında harekete geçen akuaporinlerin varlığıdır (Vandeleur ve ark., 2009). Farklı bitki türlerinde yapılan çalışmalarda kuraklık stresi uygulanmamış bitkilerde *PIP1-1* akuaporin geninin yapraklarla kıyaslandığında köklerde çok daha fazla ifade olduğu görülmüştür (Galmes ve ark., 2007; Jang ve ark., 2004; Weig ve ark., 1997).

Bazı çok yıllık bitki türlerinde, kalem gücünün değişimi ile kök sisteminin hidrolik parametrelerindeki değişimler ilişkilendirilmiştir. Kuraklık boyunca kalemlerde su kullanımının kontrolünde, asma anaçları ile bağlantılı olarak akuaporin proteinlerinin büyük bir rol oynadığını ileri sürülmüştür. Gambetta ve ark. (2012), *Vv*PIPs ifadesinin yaşam gücü yüksek anaçlarda daha yüksek ifade edildiğini saptamıştır. Dahası bir başka çalışmada, 110R anacında akuaporin geninin ifadesinde yaprak ve kökler arasında farklılık tespit edilmiştir. Araştırmacılar bu farklılığı; yapraklarda transpirasyon vasıtasıyla oluşan su kaybının azaltılması için gen ifadesinin azaldığı, kökler yoluyla suyun topraktan alımının arttırılması içinse gen ifadesinin arttığı şeklinde yorumlamışlardır (Galmes ve ark., 2007).

Akuaporinler, asmalarda köklerin (Vandeleur ve ark., 2009) ve yaprakların (Pou ve ark., 2013) hidroliğinin düzenlenmesinde önemli bir rol oynar. Akuaporinler köklerden yapraklara suyun devamlı taşınımında rol alırlar ve membran su geçirgenliğini düzenleyerek hücrenin hidrolik iletkenliğinde hızlı ve tersine değişimler meydana getirebilirler (Hayes ve ark., 2007; Surbanovski ve Grant, 2014). Akuaporinler hücreden hücreye metabolik yolda plazma membranları boyunca su hareketinin düzenlenmesinde ve ksilem embolizasyonunun düzeltilmesinde görev almaktadır (Lovisolo ve Schubert, 2006; Lovisolo ve ark., 2008a). Kuraklığa karşı toleransı yüksek olduğu söylenen 110R anacında moleküler seviyede yapılan çalışmalar sayesinde 8 adet akuaporin tanımlanmıştır (Baiges ve Schaffner, 2001). Asmalarda, yüksek yaşam gücüne sahip anaçlar daha yüksek akuaporin ifade ve aktivitesinden dolayı daha yüksek kılcal kök hidrolik iletkenliğine sahiptir. Öte yandan, farklı *Vitis vinifera* L. çeşitlerinin köklerinde topraktaki su eksikliğini tolere etme yeteneğinin ve akuaporin düzenleme yoğunluğunun, çeşitlerin adaptasyon yeteneğine göre değiştiği saptanmıştır (Vandeleur ve ark., 2009). Farklı anaçlar üzerine aşılanan Cabernet Sauvignon üzüm çeşidi ile yapılan bir çalışmada, akuaporin aktivitesinin olgun kök bölgesine kıyasla köklerin uç kısmında daha aktif olduğu vurgulanmıştır (Gambetta ve ark., 2012).

Portekiz'de yerli bir üzüm çeşidi olan Tourigo Nacional üzerinde kuraklık stresi ile ilgili yapılan çalışmada, hem kök ve hem de yapraktan alınan örneklerde farklı akuaporin (*Vv*PIP2-1; *Vv*TIP1-1; *Vv*TIP2-2 ve *Vv*SIP) ifadeleri incelenmiştir. PIP-TIP grubu akuaporinlerin stresin farklı aşamalarında köklerde ve yapraklarda farklı düzeylerde ifade olduğu, *Vv*SIP geninde herhangi bir değişim olmadığı saptanmıştır. Araştırmacılar, özellikle *Vv*TIP1-1 geninin hem kökte hem de yapraklarda vakuoller sayesinde sitoplazmanın ozmotik düzenlenmesinde önemli bir rolü olduğunu ileri sürmüşlerdir (Zarrouk ve ark., 2015).

7. OMİKS TEKNOLOJİLER

Anaç-kalem iletişiminin kuraklığa karşı nasıl bir tepki geliştirdiğinin anlaşılmasında farklı "omiks" (transkriptomik, proteomik ve metabolomik) yaklaşımların birleştirilerek çalışılması bu mekanizmasının çözülmesine katkı sağlayacaktır. Asma tür ve çeşitleri, 1970'lerden bu yana

kuraklık stresine karşı kompleks bitkilerin tepkilerinin incelendiği araştırmalarda model bitki olarak kullanılmaktadır. Moleküler çalışmalar 1990 itibariyle başlamış olmakla birlikte son yıllarda omiks teknolojiler ile ivme alarak hızla artmaya devam etmektedir (Fischer ve Efferth, 2021; Lovisolo ve ark., 2010). Transkripsiyonel çalışmalarda Northern blot tekniği ile mRNA kantitatif olarak ölçülmeye başlanmış, günümüzde mRNA teknolojisinin ilerlemesi ile qPCR, mikroarray ve Yeni Nesil dizileme gibi yöntemler geliştirilmiştir. Çok fazla gen bölgesinin incelenmesi mikroarray ve Yeni Nesil dizileme ile yapılmaktadır. Ancak mikroarray teknolojisinin çip üzerine ekilen belirli bölgelere bağlı olmasının yanı sıra tekrarlanabilirliği de düşüktür. Günümüzde Yeni Nesil Dizileme teknolojisi hazırlanan kütüphaneler ile daha spesifik bölgelerin stres ile birlikte aktivitesindeki değişiminde daha güvenilir veriler alınması nedeniyle tercih edilen bir yöntem olmaktadır (Malone ve Oliver, 2011). Genetik bilgilerin aşılama yoluyla değişimi üzerine spesifik olarak asmalarda çok fazla çalışma olmasa da diğer bitki türlerinde DNA ve/ya da RNA genetik değişiminin var olduğu ile ilgili kanıtlar vardır. Asmada mRNA moleküllerinin aşı bölgesi boyunca geçtiği saptanmıştır (Yang ve ark., 2015).

Yapılan mikroarray çalışmalarında 110R, 5BB anaçları ve Sultani Çekirdeksiz (K-7 klonu) çeşidinde kuraklık stresine karşı köklerde özellikle 110R anacında MtN3 ve LTP proteinlerine ait transkriptler diğer genotiplere göre çok yüksek seviyede ifade göstermiştir (Sucu, 2016). Kuraklık ve tuza tolerans mekanizmalarının farklılıklarını transkriptomik düzeyde belirlemek amacıyla yapılmış olan bir çalışmada, transkripsiyon faktörleri transkriptleri (NAC domain, Myb-related transcription factor), metabolit transkriptleri (1-prolin-5 –Karboksilat sintetaz, arjinin dekarboksilaz) ve hormonlarla ilgili transkriptlerin (ABA, oksin ve etilen) stresle aktivitelerinin etkilendiği ve bu transkriptlerin oranlarının stres tipine bağlı önemli farklılıklar gösterdiği belirlenmiştir (Bakır, 2012).

Üzümde yapılan proteomik bir çalışmada, Chardonnay üzüm çeşidinin Cabernet Sauvignon çeşidinden kuraklığa daha toleranslı olduğu belirlenmiştir. Ayrıca Cabernet Sauvignon çeşidinde protein metabolizmasındaki proteinler üst düzenleyici olsa da Chardonnay üzüm çeşidindeki üst düzenleyici pek çok protein ya sınıflandırılamamış ya da fonksiyonu bilinmemektedir. Araştırmacılar, geçmiş çalışmalar ile paralel olarak strese adaptasyonda PR-10, PRX ve bHLH proteinlerinin ifade edildiği vurgulanmışlar ve ilk defa NMCP1, RPL39, DEL ve PPR proteinlerinin de abiyotik stres tarafından etkilendiğini ortaya koymuşlardır (Vincent ve ark., 2007).

8. SONUÇ

Bu çalışmada, Amerikan asma anaçlarının kuraklık stresine karşı verdikleri tepkiler farklı yönleriyle değerlendirilmiştir. Kuraklık, bağcılıkta verim ve kaliteyi sınırlayan en önemli abiyotik streslerden biridir. Anaçların bu strese karşı geliştirdiği savunma mekanizmaları; su alma kapasitesi, antioksidan enzim aktivitesi ve gen ekspresyon düzeyinde farklılık göstermektedir.

Yeni Nesil Dizileme (NGS) gibi ileri düzey transkriptomik yaklaşımlar sayesinde, kuraklık stresi altında farklılaşan genetik yanıtların yüksek doğrulukla belirlenebildiği görülmüştür. Bu durum, stres toleransının moleküler düzeyde anlaşılmasına ve bu bilgilerin ıslah programlarında kullanılmasına olanak sağlamaktadır. Sonuç olarak, kuraklığa toleranslı anaçların belirlenmesi ve kullanımı, bağcılığın iklim değişikliğine karşı sürdürülebilirliğini sağlamak açısından büyük önem taşımaktadır.

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ASSESSMENT OF LAND DEGRADATION SENSITIVITY IN SEMI-ARID REGIONS WITH FUZZY LOGIC APPROACH AND SPATIAL GEOGRAPHIC DATA: THE CASE OF KIRSEHIR, TURKIYE

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ABSTRACT

This study aims to assess land degradation vulnerability (LDV) in Kırşehir Province, located in the Central Anatolia Region of Türkiye, using fuzzy logic and spatial geographic data. Variables such as land capability classification (AKK), slope-depth combination (TOK), current land use (SAK), erosion status (ERZ), and Normalized Difference Vegetation Index (NDVI) were integrated using expert knowledge-based membership functions within a Mamdani fuzzy inference system. The spatial distribution of LDV classes was determined, and planning contradictions (AKK-SAK and AKK-NDVI inconsistencies) along with spatial autocorrelation analyses (Moran's I and LISA) were performed. Results indicated that approximately 86% of the study area falls into "High" and "Very High" LDV classes. Significant risks of degradation were identified, particularly due to steep slopes, low NDVI values, and unsuitable land use. The presence of inconsistencies between AKK and SAK was evaluated as a critical indicator of unsustainable land use practices. Furthermore, Moran's I analysis revealed that LDV values exhibit significant spatial clustering rather than random distribution. The results provide valuable insights for developing sustainable land management policies and offer important decision-support mechanisms for future land use planning.

Keywords: Fuzzy inference system, Land management, Spatial analysis, Land planning conflict, Erosion risk

BULANIK MANTIK YAKLAŞIMI VE MEKÂNSAL COĞRAFİ VERİLERLE YARI KURAK BÖLGELERDE ARAZİ BOZULUMU HASSASİYETİNİN DEĞERLENDİRMESİ: KIRŞEHİR, TÜRKİYE ÖRNEĞİ

ÖZET

Bu çalışma, Türkiye'nin İç Anadolu Bölgesi'nde yer alan Kırşehir ilinde, bulanık mantık ve mekânsal coğrafi veriler kullanılarak arazi bozulumu hassasiyetinin değerlendirilmesini amaçlamaktadır. Çalışmada arazi kullanım kabiliyeti (AKK), eğim ve toprak derinliği kombinasyonu (TOK), mevcut arazi kullanımı (SAK), erozyon durumu (ERZ) ve Normalleştirilmiş Fark Bitki Örtüsü İndeksi (NDVI) değişkenleri kullanılmıştır. Bu parametreler uzman bilgisine dayalı üyelik fonksiyonları ile modellenmiş ve Mamdani tipi bulanık mantık çıkarım sistemiyle değerlendirilmiştir. Arazi bozulma duyarlılığı (LDV) sınıflarının mekânsal dağılımı belirlenmiş, planlama çelişkileri (AKK-SAK ve AKK-NDVI uyumsuzlukları) ile mekânsal otokorelasyon analizleri (Moran's I ve LISA) gerçekleştirilmiştir. Bulgular, çalışma alanının yaklaşık %86'sının "Yüksek" ve "Çok Yüksek" LDV sınıfında olduğunu ortaya koymuştur. Özellikle yüksek eğim, düşük NDVI değerleri ve uygunsuz arazi kullanımı nedeniyle ciddi bozulma riskleri tespit edilmiştir. AKK ve SAK arasındaki uyumsuzlukların varlığı, sürdürülebilir olmayan arazi kullanımının kritik bir göstergesi olarak değerlendirilmiştir. Ayrıca Moran's I analizi ile LDV değerlerinin rastgele olmadığı, belirgin mekânsal kümeler halinde dağıldığı kanıtlanmıştır. Elde edilen sonuçlar, sürdürülebilir arazi yönetim politikalarının geliştirilmesine katkı sağlamakta ve gelecekteki arazi kullanımı planlamaları için önemli karar destek mekanizmaları sunmaktadır.

Anahtar Kelimeler: Bulanık çıkarım sistemi, Arazi yönetimi, Mekânsal analiz, Arazi planlama çelişkisi, Erozyon riski

INTRODUCTION

Land degradation vulnerability (LDV) refers to a negative trend in land condition caused by direct or indirect human-induced processes, including climate change, that result in long-term reduction or loss of biological productivity, ecological integrity, or societal value of the land (IPCC, 2019a). This concept extends beyond biophysical drivers such as climate variability, soil erosion, and vegetation decline to encompass socioeconomic factors, urban expansion, agricultural intensification, and mining, that further exacerbate resource depletion (UNDRR, 2022; Geneva Environment Network, 2024). In the face of accelerating climate variability and mounting anthropogenic pressures, accurately characterizing LDV is indispensable for developing targeted land-management strategies and informing policy frameworks aimed at reversing degradation trends (IPCC, 2019b; UNFCCC, 2019). Although determinants vary by physiographic setting, key factors consistently include fluctuating precipitation and temperature regimes, soil deterioration processes (e.g., compaction and erosion), vegetation cover loss, and land-use changes driven by human activity (Halbac- Cotoara-Zamfir et al., 2020; Nickayin et al., 2022; Seifollahi et al., 2022).

Modern LDV assessments integrate both quantitative and qualitative methods to capture landscape sensitivity holistically. Field surveys and expert elicitation provide essential ground-truth and contextual insights into local degradation drivers (Geneva Environment Network, 2024). Remote-sensing techniques, extracting vegetation indices such as NDVI and EVI, and erosion indicators from satellite imagery, are combined with Geographic Information Systems (GIS) to produce high-resolution vulnerability maps (Dubovyk, 2017). Multi-criteria decision-making frameworks, notably the Analytic Hierarchy Process (AHP), systematically weight and rank contributing drivers (climate, soil properties, vegetation, and human pressures) via pairwise comparisons to yield composite vulnerability indices (Chatterjee, 2023; Pandey et al., 2022; Yadav et al., 2023). Advanced modeling tools, including fuzzy-logic expert systems that simulate soil-based reasoning processes (Lue et al., 2022) and process-based numerical models that project degradation trajectories over time, offer mechanistic insight into LDV dynamics across heterogeneous landscapes (IPCC, 2019b). Together, these integrated approaches enable practitioners to prioritize high-risk zones, optimize resource allocation, and develop adaptive management strategies that address both biophysical and socioeconomic dimensions of land degradation (FAO and ITPS, 2015).

Among analytical techniques, fuzzy logic stands out due to its ability to handle uncertainty, imprecision, and non-definitive data (Lu et al., 2022; Islam et al., 2024). Unlike traditional crisp-set methods, fuzzy logic assigns continuous membership values to degradation states, better reflecting transitions between varying degrees of land degradation (Lu et al., 2022). This capability is particularly advantageous when integrating quantitative inputs such as remote-sensing indices, and qualitative judgments, such as expert opinions, within a unified evaluation framework (Islam et al., 2024). Moreover, fuzzy-logic approaches yield more flexible and reliable degradation-risk maps by mimicking human reasoning and adapting to local land conditions (Lu et al., 2022). Practically, these strengths make fuzzy logic indispensable for addressing the multidimensional nature of LDV assessments, enhancing both the accuracy of susceptibility mapping and the interpretability of results for decision-makers (Yadav et al., 2022).

This study was conducted to assess the susceptibility of Kırşehir Province to land degradation. Variables such as land use capability, slope gradient, soil depth, current erosion status, land use type, and Normalized Difference Vegetation Index (NDVI) were evaluated to determine land degradation susceptibility. The sensitivity classification was performed using a fuzzy logic approach based on expert knowledge-driven membership functions and a Mamdani-type inference system, reflecting field conditions. The primary objective is to spatially identify degradation risks through the developed fuzzy logic inference system and provide decision support for sustainable land management by analyzing planning conflicts.

MATERIAL and METHODS

Study Area

Kırşehir Province (Figure 1) is located in Turkey's Central Anatolia Region and stands out for its geological and geomorphological features. Geographically, Kırşehir can be defined as a closed basin area that includes Seyfe Lake. This basin hosts significant ecosystems due to its position among the tributaries of the Kızılırmak River and its wetland characteristics. Seyfe Lake, classified as a Class-A wetland in Turkey, is a critical natural resource that enhances regional biodiversity (Çiftçi et al., 2021).

The geological structure of Kırşehir is shaped by volcanic and sedimentary rocks, which are part of the Central Anatolian Massif. This geological foundation supports fertile soil formations, contributing to agricultural productivity (Abacı Bayar et al., 2019). Geomorphologically, Kırşehir is characterized by rugged terrain (Uysal, 2015).

The region has a continental climate, with hot, dry summers and cold, snowy winters. These climatic conditions facilitate the widespread cultivation of crops such as barley, wheat, and chickpeas (Abacı Bayar et al., 2019).

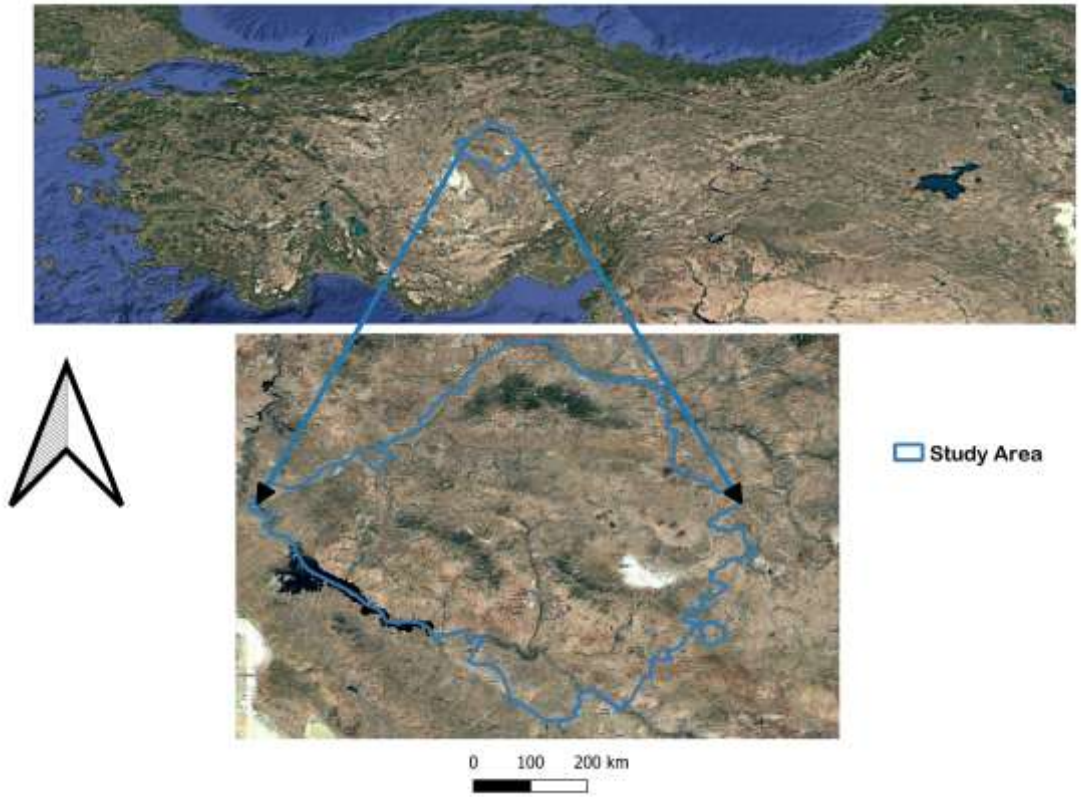


Figure 1. Location of Study Area

Data Set

In this study, both field-based attribute data and remotely sensed data were used to assess land degradation vulnerability. Data obtained from various sources were integrated within a Geographic Information Systems (GIS) environment. The variables used in this analysis include Land Capability Classes (LCC), Texture, Slope and Depth Combination (TSD), Soil Erosion Status (SER), Current Land Use (CLU), and the Normalized Difference Vegetation Index (NDVI) (Equation 1).

$NDVI = (\rho^8 - \rho^4)/(\rho^8 + \rho^4)$ (Eşitlik 1)

In Equation 1, ρ_8 represents Band 8 (Near-Infrared) and ρ_4 represents Band 4 (Red) of the Sentinel-2A optical satellite imagery.

The Land Capability Classification (LCC) system is used to categorize land based on its suitability for agricultural production, ranging from Class 1 (highly suitable) to Class 8 (very limited suitability) (Deviren Saygın & Yüksel, 2008). The TSD variable (Texture, Slope, and Depth Combination) is a composite classification comprising soil group classes, slope percentages, and effective soil depth information (Aygün et al., 2017). The Soil Erosion Status (SER) reflects physical land surface loss and is classified based on the influence of water and wind erosion (Aygün et al., 2017). Current Land Use (CLU) identifies the actual land use types in the area, such as dry farming, irrigated farming, vineyards, orchards, and pasture.

Fuzzy Logic Model and Inference System

In this study, a Mamdani-type fuzzy logic inference system was employed to predict land degradation vulnerability. This approach is widely recognized as an effective tool for modeling complex and uncertain natural systems, and it is particularly valuable in supporting expert-based decision-making in agricultural land management (Rezvani et al., 2016). The input variables used in the model were selected based on a combination of literature review and field conditions. For each variable, appropriate triangular (trimf) or trapezoidal (trapmf) membership functions were defined (Table 1).

Table 1. Classes, membership function types, and threshold values for input variables used in the fuzzy logic model

Input Variable	Class Name	Type of Function	Threshold Value
Land Use Capability	Low	trapmf	1 – 1 – 1.75 – 3
	Moderate	trimf	2.25 – 4 – 5.75
	High	trimf	4.5 – 6 – 7.25
	Very High	trapmf	6.5 – 7.25 – 8 – 8
Soil Composite Variables (Slope, Depth Combination)	Low	trapmf	1 – 1 – 8 – 11
	Moderate	trimf	10 – 14 – 18
	High	trimf	17 – 22 – 26
	Very High	trapmf	25 – 27 – 30 – 30
SER (Soil Erosion Status)	Low	trapmf	1 – 1 – 1.5 – 2
	Moderate	trimf	1.5 – 2.5 – 3.5
	High	trapmf	3 – 3.5 – 4 – 4
NDVI	Low	trapmf	-1.00 – -1.00 – 0.10 – 0.25
	Moderate	trimf	0.20 – 0.45 – 0.65
	High	trimf	0.55 – 0.75 – 0.90
	Very High	trapmf	0.85 – 0.95 – 1.00 – 1.00

For each input variable, triangular (trimf) and trapezoidal (trapmf) membership functions were defined and structured based on expert evaluation to reflect site-specific conditions and field realities.

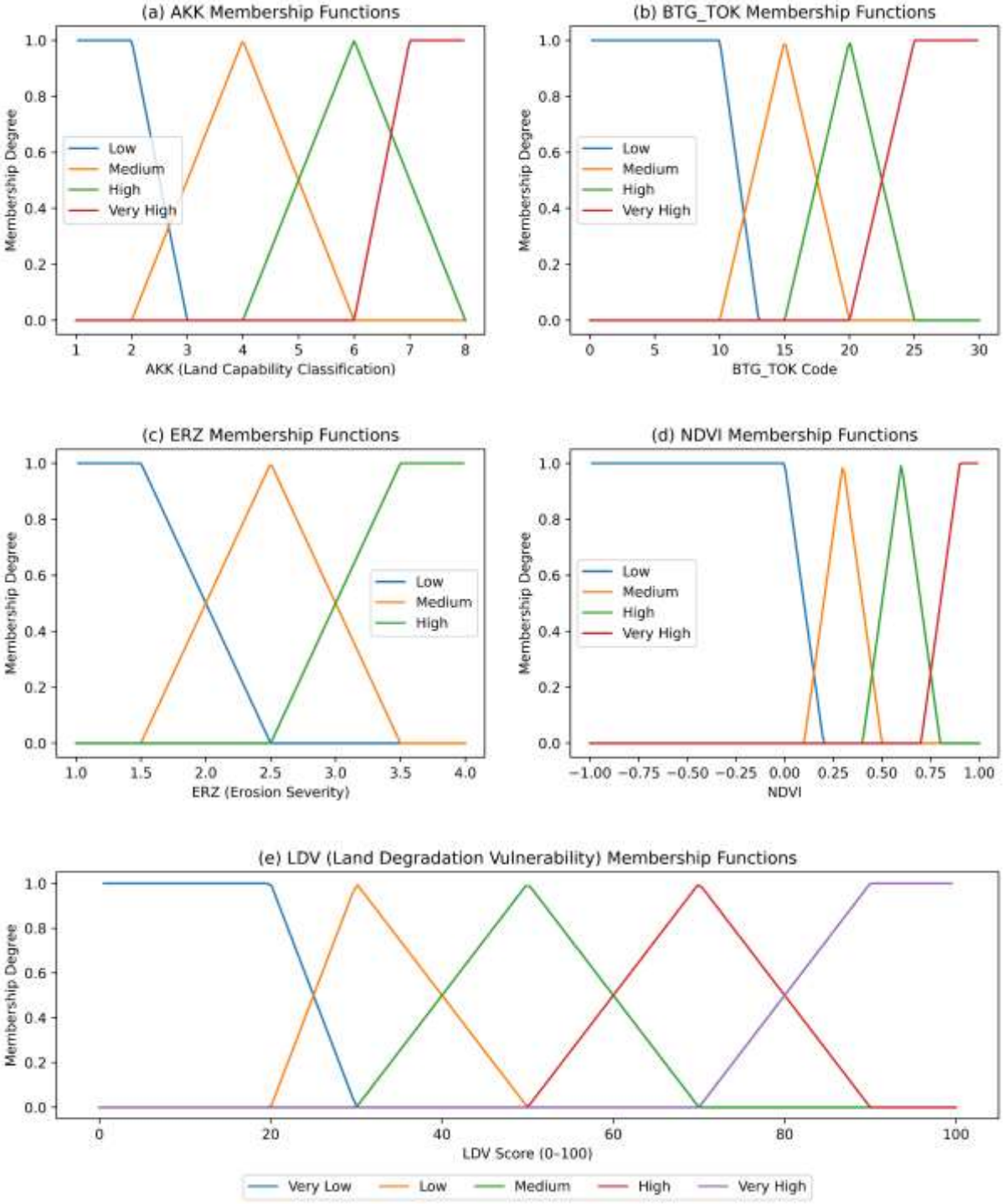


Figure 2. Membership functions for fuzzy logic classification: (a) AKK (Land Capability Classification), (b) BTG_TOK (Erosion Severity), (c) ERZ (Erosion Severity), (d) NDVI (Vegetation Index), and (e) LDV (Land Degradation Vulnerability). Each subplot depicts the degree of membership (y-axis) for linguistic variables (Low, Medium, High, Very High) across respective input ranges (x-axis).

The decision-making mechanism of the fuzzy inference system is based on a rule base composed of expert-defined "IF–THEN" rules. Each rule evaluates a combination of multiple input variables to determine the output variable, Land Degradation Vulnerability (LDV). The LDV output is categorized into four risk levels: Low, Moderate, High, and Very High. The inference rules in the rule base were designed to align with observed field conditions (Table 2). A total of 192 rules were formulated, and 15 representative rules are presented in Table 2.

An analysis of the rule combinations in Table 2 reveals that low NDVI values, which indicate weak vegetation cover, are associated with high degradation risk. High values of LCC and TSD classes reflect increasing natural limitations of the soil, which correspond to greater susceptibility to potential degradation. Similarly, in areas where the SER (erosion status) class is high, the dominant influence of both water and wind erosion contributes to elevated LDV. In this context, the rule base enables a holistic and ecologically grounded estimation of degradation vulnerability by evaluating all input variables in combination. The decision rules ensure the system operates with high accuracy and allow spatial variability in risk levels to be effectively captured in the analysis (Table 3).

Table 2. Sample Fuzzy Rule Combinations for Land Degradation Vulnerability Classification

Rule No	**LUK**	**SCC**	SER	**NDVI**	**LDV (Output)**
1	Low	Low	Low	Very High	Low
2	Moderate	Moderate	Moderate	High	Moderate
3	High	High	High	Moderate	High
4	Very High	Very High	Very High	Low	Very High
5	Moderate	High	Moderate	Low	High
6	Low	Moderate	Low	Moderate	Moderate
7	Moderate	Low	High	Low	High
8	High	Very High	Moderate	Moderate	High
9	Very High	High	Low	High	Moderate
10	Low	Low	Low	Low	Moderate
11	Low	Moderate	High	Low	High
12	Moderate	Very High	Very High	Very High	Moderate
13	Very High	Moderate	High	Low	Very High
14	Moderate	Low	Low	High	Low
15	High	Moderate	Moderate	Moderate	Moderate

Table 3. Spatial Risk Classes and Descriptions Based on Land Degradation Vulnerability

Land degradation vulnerability Classes	Score Range	Description
Very High	0 – 20	Highly vulnerable to land degradation. Characterized by steep slopes, high erosion risk, and low productivity. Requires urgent protection and rehabilitation.
High	21 – 40	High-risk areas. Vulnerable due to soil properties or land use practices. Erosion control and appropriate agricultural techniques are recommended.
Moderate	41 – 60	Areas with moderate risk. Exhibit certain limitations. Agricultural use is possible but requires careful management.
Low	61 – 80	Generally suitable areas. Low slope and erosion risk, with above-average soil quality. Sustainable use is feasible.
Very Low	81 – 100	Least vulnerable to land degradation. High potential for agriculture and other land uses. Not a priority for protection or conservation.

Spatial Consistency Analysis and Autocorrelation Assessment

Autocorrelation and Cluster Analysis (Moran's I and LISA)

Global Moran's I is a statistical measure used to assess spatial autocorrelation across an entire dataset, returning a single summary value between -1 and +1. A value close to +1 indicates strong positive spatial autocorrelation (i.e., clustering of similar values), while a value near -1 reflects negative autocorrelation (i.e., dispersed or checkerboard-like patterns). Values near 0 suggest a random spatial distribution (Fu et al., 2015; Nguyen and Nguyen, 2023). The calculation is based on spatial weights that define the relationships between neighboring observations, either by adjacency or distance (Tokarz and Novak, 2018; Zhu et al., 2018). Statistical significance is commonly determined through permutation tests, which confirm that the observed spatial patterns are not due to random chance (Bai et al., 2022).

Local Indicators of Spatial Association (LISA), developed by Luc Anselin (1995), decompose global spatial autocorrelation into localized statistics, allowing the identification of spatial clusters, such as hot spots or cold spots, at specific locations. LISA results are typically visualized through maps that highlight areas where high or low values are surrounded by similar values, thereby supporting targeted interventions. Like Global Moran's I, LISA uses spatial weights and permutation testing to assess significance; however, its localized detail helps reveal sub-regional patterns that may be masked in global statistics (Bai et al., 2022; Zhu et al., 2018).

Consistency Analysis

This analysis aims to identify conflicts between the land's potential use and its current land use conditions by evaluating inconsistencies among key input variables. The consistency status was assessed for each pixel or polygon using a binary logic approach (Figure 3):

Consistent (1): When the Land Capability Classification (LCC) aligns with parameters such as Current Land Use (CLU), NDVI, or TSD (Texture–Slope–Depth), indicating a supportive relationship.

Inconsistent (0): When there is a clear contradiction between the limitations indicated by LCC, NDVI, or TSD and the actual land use (CLU).

These matches and mismatches were spatially mapped to reveal both the geographic distribution of potential degradation risk and its underlying, resource-based causes. For instance, the occurrence of irrigated agriculture (CLU = irrigated) in areas classified as LCC 7–8, characterized by limited productive potential, signals unsustainable land use practices.

In this study, both planning inconsistency analysis and spatial autocorrelation tests were conducted to evaluate the spatial patterns of land degradation vulnerability (LDV).

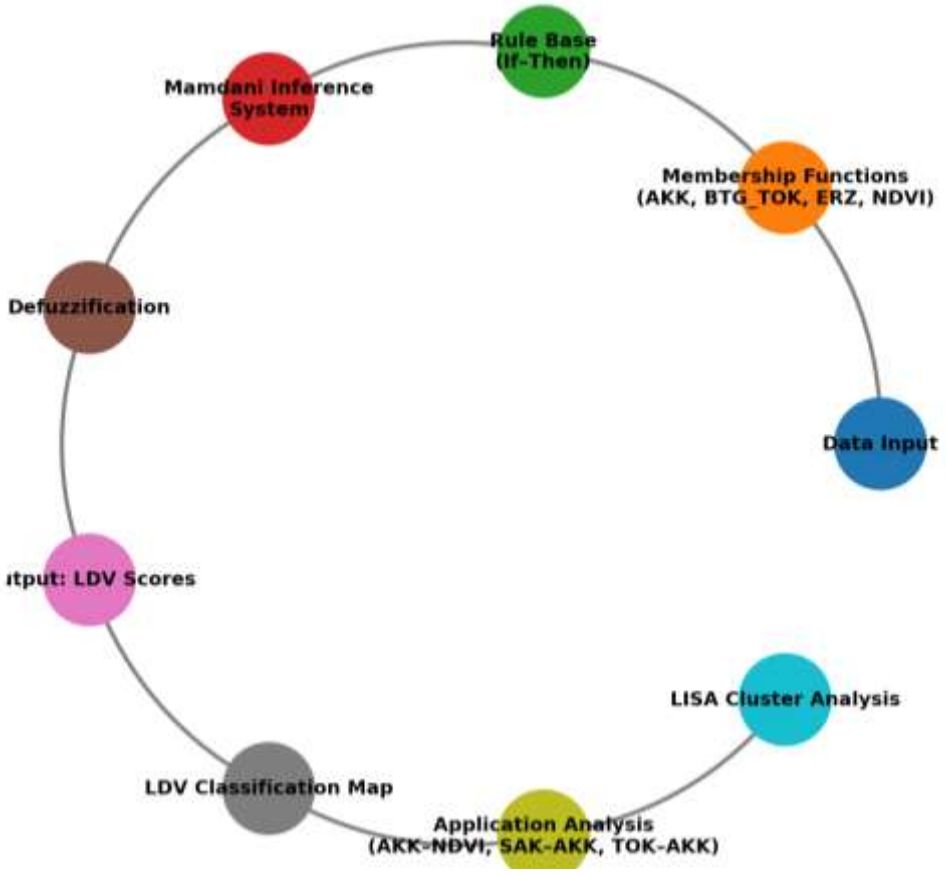


Figure 3. Modeling workflow: Sequential steps of the LDV analysis, from input variable definition to spatial outcome evaluation.

RESULTS and DISCUSSION

Spatial Distribution of LDV Classes

The fuzzy logic-based land degradation vulnerability (LDV) sensitivity analyses conducted in the study area revealed that 86% of the region (comprising 66.36% "Very High" and 19.7% "High" susceptibility classes) is at significant risk of degradation. This finding indicates that physical constraints, such as erosion, topographic limitations, low productivity, and drainage issues, are predominant across most of the land. The combined coverage of "Low" (9%) and "Moderate" (5%) classes accounts for only 14% of the area, while the "Very Low" class is nearly absent. These results underscore the region's severe degradation risk, driven by both biophysical and anthropogenic pressures.

Areas classified as "Very High" risk exhibit critical limitations, as evidenced by their mean values for soil depth (LCC: 5.40), slope gradient (SCC: 13.66), and vegetation cover (NDVI: 0.31). These metrics reflect steep slopes, shallow soils, and low land potential. The moderate NDVI values suggest ongoing agricultural activity but highlight critical degradation risks.

In the "High" susceptibility class, while LCC (3.17) and SCC (9.94) values are relatively lower, slope-related challenges and moderate productivity constraints necessitate monitoring and controlled land use. These findings align with Abuzaid et al. (2021), whose study in the Farafra Oasis similarly identified topographic factors (e.g., slope and surface drainage conditions) and physical soil constraints (e.g., shallow depth and textural imbalances) as key drivers of degradation.

The LCC and SCC values observed in the "High" LDV class further indicate moderate risks associated with soil depth and slope, underscoring the need for protective soil management and targeted monitoring strategies. This aligns with Abuzaid et al. (2021)'s model, which warns that poorly managed medium-risk areas can rapidly transition to higher-risk categories.

The "Moderate" LDV class (LCC: 2.49; SCC: 6.12; NDVI: 0.25) represents transitional zones where physical limitations have partially decreased and which possess potential for improvement. In contrast, areas in the "Low" class (LCC: 1.26; SCC: 2.17; NDVI: 0.27) offer ideal conditions for sustainable agriculture due to low slope and deep soil structure. However, the lower-than-expected NDVI suggests that these areas might be lying fallow. In the "Very Low" class (LCC: 1.00; SCC: 1.66), despite excellent land characteristics, the extremely low NDVI value of 0.18 reflects a condition that may require vegetation preservation or rehabilitation.

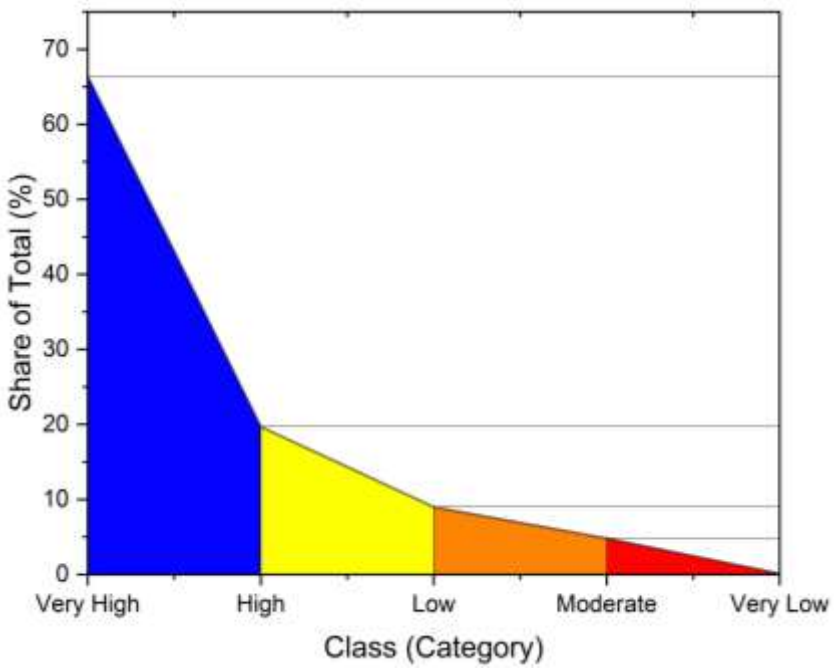


Figure 4. Proportional distribution of LDV classes.

The spatial distribution map of LDV based on GIS, created using the Mamdani fuzzy logic analysis (Figure 5), reveals a distinct geographical distribution of LDV classes across the study area. Areas belonging to the Very High LDV class (red tones) are concentrated in the southeastern, southwestern, and northeastern parts of the map. These regions are characterized by high slope values (>15%), LCC classes ranging between 6 and 8, weak vegetation cover (NDVI: 0.18–0.31), and pronounced erosion risk. In particular, areas surrounding the Kırşehir-Aksaray, Kırşehir-Kırıkkale, and Kırşehir-Yozgat road corridors face critical degradation risks due to high agricultural intensity, soil fatigue, and unplanned land use.

In a study conducted by Lu et al. (2022) in China's Loess Plateau, it was reported that slope, loss of soil organic carbon, and scarcity of vegetation cover play a decisive role in land degradation. The study found that fuzzy logic-based LDI (Land Degradation Index) values were significantly higher in areas with steep slopes and poor vegetation cover.

The High LDV class (yellow tones) is mostly distributed as transitional zones surrounding the Very High class. It is associated with moderate to high slopes (10–15%), drainage problems, and limited agricultural productivity. These areas consist of sloped lands opened to agricultural activities, typically along topographic break lines. In these regions, which require controlled use and close monitoring, LCC values are measured at 3.17 and SCC at 9.94.

The Moderate LDV class (turquoise) is represented with a homogeneous distribution in the eastern and southeastern parts of the map. In this class, moderate slope (5–10%), improved drainage conditions, and a relatively denser vegetation cover (NDVI: 0.25) are observed. The LCC value of 2.49 and SCC value of 6.12 reflect limited but manageable risk levels. These areas have rehabilitation potential when managed with sustainable land practices. This finding aligns with the study by Dutta et al. (2024) in the Subansiri Basin, where soil erosion supported

by fuzzy logic methods showed that regions with moderate slopes are open to rehabilitation under controlled management strategies.

The Low and Very Low LDV classes (green tones) are concentrated primarily in the northeast of Kırşehir, east of the Seyfe Lake Nature Reserve, and alluvial plains. The low slope (<5%), deep soil profiles (LCC: 1.00–1.26), high NDVI values (0.27–0.18), and SCC consistency (1.66–2.17) indicate that these regions are ideal for agricultural and ecological sustainability. This is also confirmed by the study of Lei et al. (2020) in Iran, which reported that low-slope and deep-soil regions present minimal land degradation risk and form optimal zones for sustainable agriculture.

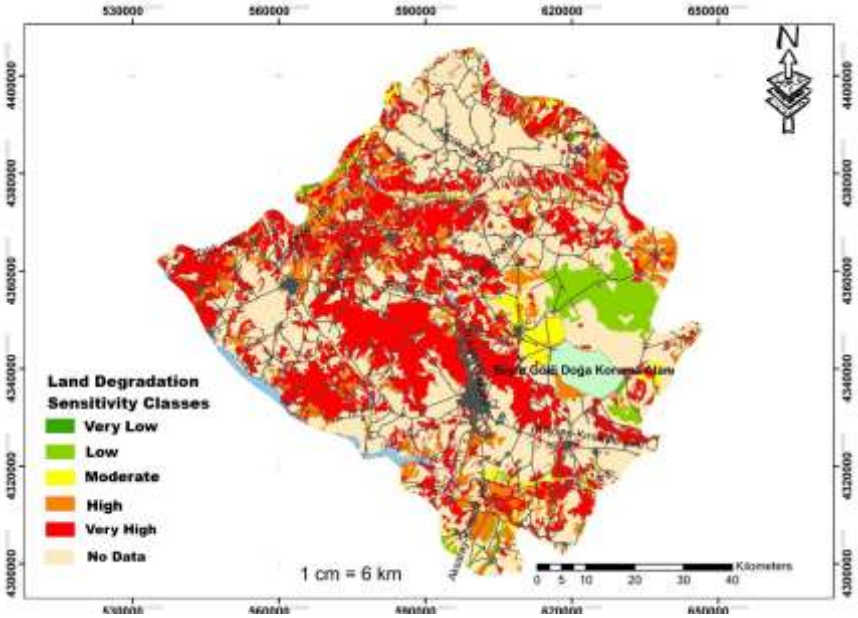


Figure 5. Spatial Distribution Map of Land Degradation Vulnerability (LDV) Classes in Kırşehir Province

Consistency Analysis Among Input Variables

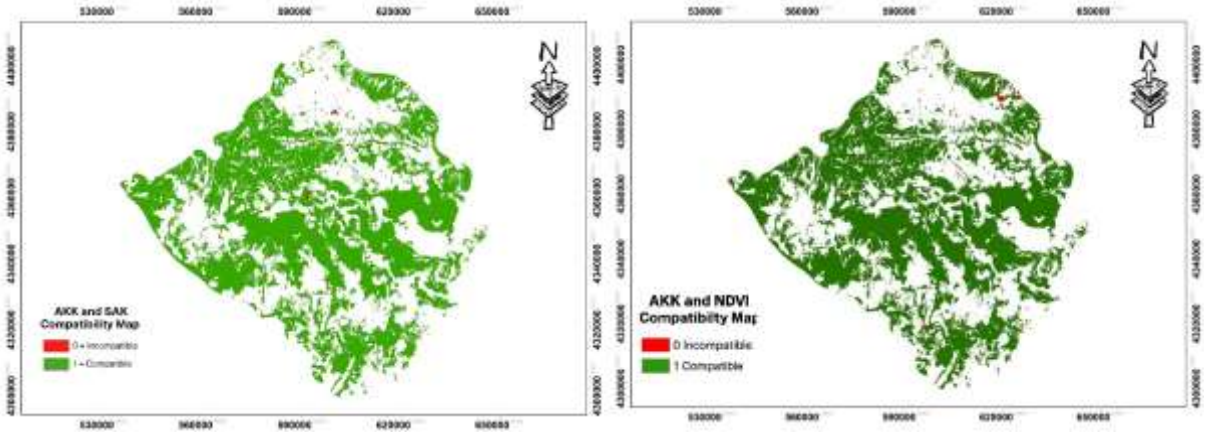
The compatibility map between Land Capability Classes (LCC) and Current Land Use Types (CLU) (Figure 6a) evaluates the degree to which actual land use aligns with the potential of the land. CLU represents how the land is currently being used, such as for irrigated agriculture, pasture, or abandoned purposes, while LCC indicates the ideal use of the land based on its physical and edaphic (soil-related) characteristics, rated on a scale from 1 to 8. The analysis revealed that a total of 3.7 km² of land shows incompatibility between current use and land potential.

Compatible areas (coded as value 1) include situations where high-potential lands (LCC 1–2) are used appropriately for agriculture or low-potential lands (LCC 7–8) are maintained in natural states, such as pasture or left fallow. These represent sustainable and ecologically sound land-use practices. In contrast, incompatible areas (coded as value 0) indicate unsustainable conditions, such as highly productive lands (LCC 1–2) being left idle or underutilized, or

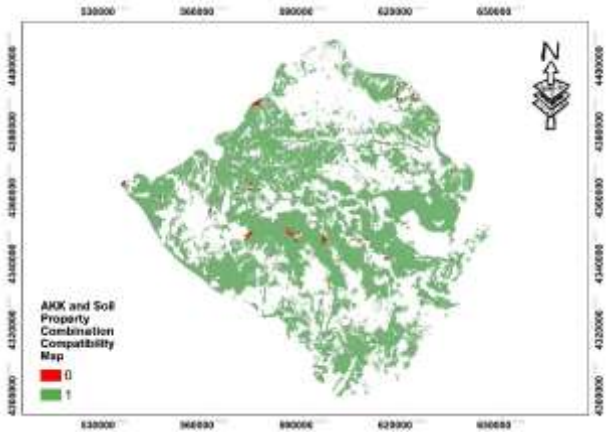
marginal lands (LCC 7–8) being subjected to intensive agricultural activities like irrigated farming. These mismatches reflect a disregard for land suitability and can contribute to degradation risks. Kılıç et al. (2023) emphasize that such discrepancies between land capability and actual land use are among the primary drivers of land degradation. Their findings underscore that both the misuse of fertile lands and the overuse of poorly suited areas lead to accelerated economic losses and environmental deterioration. In this study, specific examples of these inconsistencies include the abandonment of highly capable lands (LCC 1–2) and the intensification of agriculture on limited-capacity lands (LCC 7–8). These patterns are, as Schillaci et al. (2023), point out, direct indicators of land degradation, resulting in significant reductions in ecosystem services and long-term sustainability challenges. Verheijen et al. (2010) in their comprehensive review, also noted land-use intensity and abandonment as critical processes contributing to soil degradation across Europe. Furthermore, Oldeman et al. (1991) in the GLASOD assessment, identified inappropriate land use as a major global driver of soil degradation. The principle of aligning land use with land capability is fundamental to sustainable resource management, as highlighted by Sys et al. (1993) in their work on land evaluation.

The map examining the relationship between LCC and the NDVI (Figure 6b) analyzes the consistency between land potential and vegetation productivity. While NDVI values (ranging from 0.16 to 0.55) reflect the instantaneous condition of vegetation density, LCC represents the long-term potential and suitability of land based on its inherent physical characteristics.

The study identified significant inconsistencies across 101 km² of land. For example, low NDVI values (<0.2) in high-potential lands (LCC classes 1–2) may indicate fallow periods or stress due to water scarcity, which lead to a decline in productivity. Conversely, in low-potential lands (LCC 7–8), elevated NDVI values (>0.5) achieved through intensive artificial inputs (such as excessive irrigation or fertilization) increase the risk of soil degradation. These findings emphasize that vegetation data alone are insufficient for sustainable land assessments. Instead, integrating NDVI with LCC is essential for developing effective and sustainable land management strategies.



(a) (b)



(c)

Figure 6. Incompatibility Maps for Co-variates

The map comparing LCC with topographic constraints such as soil depth and slope (Figure 6c) investigates how accurately the classification system reflects topographic realities. The analysis revealed 1.6 km² of notable inconsistencies between land capability classifications and physical land characteristics. For instance, some areas categorized under LCC classes 1–2, which are theoretically optimal for agriculture, were found to have slopes between 12% and 20% and shallow soil depth, both of which are limiting factors for agricultural use. Similarly, areas with slopes over 30% and very shallow soils were also labeled as LCC class 2, indicating a mismatch between classification and terrain conditions. These inconsistencies suggest that current LCC classifications may overlook critical topographic factors, and that parameters such as slope and soil depth need to be more thoroughly integrated into land capability assessments to improve the accuracy of land-use planning.

Spatial Autocorrelation and Clustering Analysis

Spatial autocorrelation measures like Moran's I and local Moran's I (LISA) are increasingly used to map land degradation and vulnerability. Global Moran's I tests whether values (e.g. a vulnerability index) cluster more than random, while the local LISA identifies hotspots and outliers. LISA classifies each location into one of four spatial association types: high–high (H-H), low–low (L-L), high–low (H-L), or low–high (L-H) cluster, based on whether a location and its neighbors have similarly high or low values (Zhang et al., 2023). These classifications provide intuitive, statistically grounded representations of spatial dynamics across a landscape.

In the present study, Moran's I value of 0.3565 ($p<0.001$) indicates significant spatial autocorrelation in Land Degradation Vulnerability (LDV) values, affirming that degradation sensitivity is not randomly distributed but instead forms meaningful spatial patterns. The LISA cluster map (Figure 7) reveals several statistically significant clusters that align closely with regional environmental and agricultural features. Specifically, H–H clusters (Blue Areas), concentrated in the northeastern and eastern zones, are characterized by high fuzzy logic scores, translating into low LDV and thus low degradation vulnerability. These areas, particularly around Lake Seyfe and its surrounding plains, emerge as ecological strongholds and should be prioritized for sustainable agriculture and conservation initiatives.

Conversely, H–L clusters (Red Areas) appear primarily in the western and southwestern belts, indicating local zones of environmental stability that are bordered by more vulnerable areas. Policy-driven initiatives, economic development disparities, natural conditions, and technological dissemination are crucial factors influencing the spatial distribution of these clusters. Areas with strong policy support for specific agricultural practices, for instance, might exhibit clusters of compatible agricultural land use on suitable lands. Conversely, regions experiencing economic disparities might show clusters of incompatible land use, such as the abandonment of fertile lands due to a lack of economic incentives or the intensification of agriculture on marginal lands driven by economic necessity (Jing et al, 2024).

The L–H clusters (Purple Areas) are scattered as localized anomalies. These zones exhibit high degradation vulnerability, yet they are surrounded by areas with lower vulnerability, making them spatial outliers of concern. Lastly, L–L clusters (Turquoise Areas) are concentrated in the central, southern, and southeastern parts of the study area. These regions demonstrate high degradation risk both locally and in their surrounding context, indicating widespread environmental vulnerability that may require urgent attention.

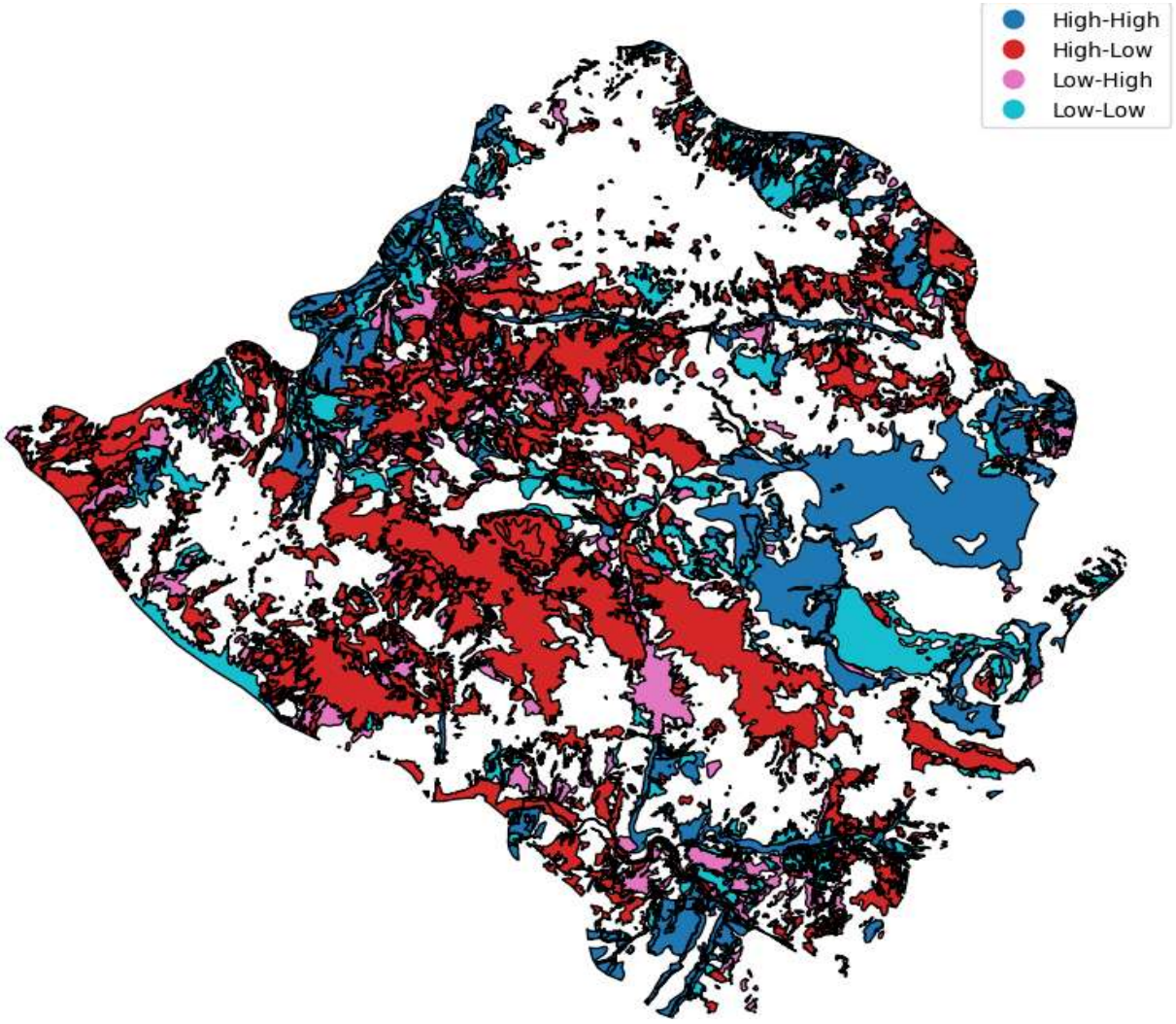


Figure 7. LISA Cluster Map

CONCLUSION

This study evaluates land degradation vulnerability (LDV) in the province of Kırşehir using a fuzzy logic model and spatial analysis, offering critical insights for sustainable land management. The results reveal that 86% of the study area falls under the "Very High" and "High" LDV classes, indicating a serious risk of degradation. This high vulnerability is primarily due to a combination of steep slopes, shallow soil depths, erosion pressure, and incompatible land use practices across the region.

The Mamdani-type fuzzy logic model, with its flexibility in modeling uncertain natural systems and its effective integration with GIS, has enabled the high-accuracy generation of risk maps. The model successfully captured complex interactions between environmental variables and provided a spatially explicit risk assessment framework. Compatibility analyses between land capability classification (LCC) and current land use (CLU) show that mismatches, particularly unplanned agricultural use in high-potential areas and intensive pressure on low-potential areas,

significantly increase degradation risks. Furthermore, inconsistencies between NDVI and LCC highlight the insufficiency of relying solely on vegetation productivity. Instead, integrated evaluations considering parameters like soil depth, slope, and land potential are essential for accurate land assessments.

Spatial autocorrelation analyses confirmed that degradation risk is not randomly distributed, but instead occurs in distinct spatial clusters. The LISA cluster maps showed that high-risk areas are concentrated in the western and southwestern regions, whereas low-risk areas are located around alluvial plains and protected zones. These findings suggest the need for urgent interventions, such as erosion control measures and regulated agricultural practices, especially in high-risk zones. Moreover, the study recommends that land capability classifications be updated to better incorporate dynamic parameters like slope and soil depth for more effective and sustainable land-use planning. A key limitation of the study is that the model was constrained by the limited set of selected variables. Future research should integrate socioeconomic factors and compare alternative modeling techniques to broaden the scope and accuracy of risk assessments.

In conclusion, this study provides a quantitative foundation for developing effective land management policies at the local scale and contributes meaningfully to climate change adaptation strategies.

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THE DEVELOPMENT AND OPPORTUNITIES OF CARBON MARKETS IN TURKEY: CURRENT STATUS AND FUTURE OUTLOOK

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ABSTRACT

This study provides an integrated assessment of global carbon market evolution, greenhouse gas mitigation practices in agriculture, and Turkey's climate policy landscape. The first section explores the structure of compliance and voluntary carbon markets, including pricing mechanisms, cap-and-trade systems, and the principle of additionality. The second section evaluates agricultural practices such as precision irrigation, no-till farming, biochar application, cover cropping, and agroforestry in relation to their potential to generate carbon credits. The role of MRV (Monitoring, Reporting, and Verification) systems is emphasized, focusing on data transparency, quality assurance, and long-term tracking. The final section discusses Turkey's efforts toward its 2053 net-zero goal, covering its preparation for a national Emissions Trading System (ETS), alignment with the EU Carbon Border Adjustment Mechanism (CBAM), and integration into the European Green Deal framework. The paper highlights Turkey's strategic potential in carbon markets and offers policy recommendations including the enhancement of MRV infrastructure, support for agricultural carbon projects, and harmonization with international carbon credit standards to ensure environmental integrity and market credibility.

Keywords: Carbon Market, Emissions Trading System, Agricultural Carbon Credits, MRV Infrastructure, Additionality

TÜRKİYE'DE KARBON PİYASALARININ GELİŞİMİ VE FIRSATLARI: MEVCUT DURUM VE GELECEĞE BAKIŞ

ÖZET

Bu çalışma, karbon piyasalarının küresel gelişimini, tarım sektöründe sera gazı emisyonlarının azaltımına yönelik uygulamalarını ve Türkiye'nin iklim politikalarını bütüncül şekilde ele almaktadır. İlk bölümde, zorunlu ve gönüllü karbon piyasalarının yapısı, fiyatlandırma mekanizmaları ve katkısallık kriteri gibi temel ilkeler incelenmiştir. İkinci bölümde, tarımsal uygulamalar kapsamında hassas sulama, toprak işlemesiz tarım, biyokömür, örtü bitkileri ve agroforestry gibi yöntemlerin karbon kredisi üretimine etkisi değerlendirilmiştir. MRV sistemlerinin (İzleme, Raporlama, Doğrulama) bu süreçteki rolü detaylandırılmış; veri bütünlüğü, kalite kontrolü ve uzun vadeli izleme önemi vurgulanmıştır. Son bölümde, Türkiye'nin 2053 net sıfır hedefi doğrultusunda ETS (Emisyon Ticaret Sistemi) hazırlıkları, CBAM uyumu ve AB ile entegrasyon süreci ele alınmıştır. Çalışma, Türkiye'nin karbon piyasalarındaki potansiyelini ortaya koymakta; MRV altyapısının güçlendirilmesi, tarımda karbon projelerinin yaygınlaştırılması ve uluslararası standartlara uyumun artırılması yönünde öneriler sunmaktadır.

Anahtar Kelimeler: Karbon Piyasası; Emisyon Ticaret Sistemi, Tarımda Karbon Kredisi, MRV Sistemi, Katkısallık

1. KÜRESEL ISINMA VE EMİSYON GERÇEKLİĞİ

Yirmi birinci yüzyılın en ciddi çevresel tehditlerinden biri haline gelen küresel ısınma, insan faaliyetleri kaynaklı sera gazı salımlarının hızla artması sonucu, iklim sisteminde geri döndürülemez değişikliklere neden olmuştur. IPCC'nin 2023 raporuna göre, mevcut emisyon eğilimleri devam ederse, 2100 yılına kadar sıcaklık artışının 3.1-3.7 °C aralığında gerçekleşeceği öngörülmektedir. Bu durum dünya nüfusunun yaklaşık 3.6 milyarını doğrudan etkileme riski taşımaktadır. Sanayi Devrimi sonrası ortaya çıkan karbon yoğunluklu büyüme modelinin artık sürdürülebilir olmadığı açıktır. Paris Anlaşması ise bu tehdidi azaltmak amacıyla, 1.5 °C hedefini koruyarak, 2050'ye kadar net sıfır emisyon hedefi koymuştur.

2. KARBON PİYASALARI VE FİYATLANDIRMA MEKANİZMALARI

Artan sera gazı emisyonunun azaltılması ve atmosfere biriken gazların miktarının azaltılması amacı ile geliştirilen karbon piyasaları, çevresel maliyetlerin içselleştirilmesini hedefleyen piyasa-temelli mekanizmalardır (Solarin, 2025). Türkiye gibi gelişmekte olan ülkeler için bu piyasalar, hem uluslararası yükümlülükleri yerine getirme hem de ekonomik fırsatlar yaratma açısından stratejik önem taşımaktadır. Karbon fiyatlandırma, karbon vergisi ve emisyon ticaret sistemleri (ETS) gibi araçlarla, firmaların karbon salımlarına bir maliyet yüklenmesini sağlar. Böylece firmalar, düşük karbon teknolojilerine geçmeye teşvik edilir (Delbeke, 2024). Cap-and-trade sistemleri, emisyon izinleri vererek firmaların bu izinleri birbirleriyle ticaret yapmasına olanak tanır (Battocletti et al., 2024). Ancak etkin bir karbon piyasası için fiyat istikrarı, sertifikasyon süreçlerinin güvenilirliği ve katkısallık ilkesi büyük önem taşır.

Karbon fiyatlandırması, iklim değişikliğiyle mücadelede giderek daha merkezi bir politika aracı olarak öne çıkmaktadır ve arazi kullanımı sektörünü de etkileme potansiyeline sahiptir. Dünya Bankası'nın (2023) verilerine göre, karbon vergileri ve ETS'ler, küresel sera gazı emisyonlarının önemli bir kısmını (%23) fiyatlandırmaktadır (World Bank, 2023). Bu mekanizmalar, emisyonları olan faaliyetlere maliyet getirerek ekonomik teşvikler yaratır ve arazi sahiplerini ile yöneticilerini daha sürdürülebilir uygulamalara yönlendirebilir. Örneğin, ETS ve karbon vergileri, tarım ve ormancılık gibi sektörlerde sera gazı emisyonlarını azaltma veya karbonu tutma yönündeki çabaları ekonomik olarak destekleyebilir. Bu durum, orman restorasyonu, tarımsal ormancılık veya azaltılmış toprak işleme gibi karbonu toprakta veya biyokütlede depolayan arazi kullanım şekillerinin yaygınlaşmasına katkıda bulunabilir. Avrupa Birliği'nin ETS reformları ve Çin'in ulusal ETS'si gibi uygulamalar, karbon fiyatlamanın etkin bir politika aracı olabileceğini göstermekle birlikte, düşük fiyat seviyeleri ve kapsam dışı sektörler gibi devam eden zorluklar, bu mekanizmaların arazi kullanımı üzerindeki tam potansiyelini henüz ortaya koymamaktadır. Yine de, karbon fiyatlandırmasının, arazi kullanımının sürdürülebilirlik hedefleriyle uyumlu hale getirilmesinde önemli bir rol oynaması beklenmektedir.

2.1. KARBON KREDİLERİ: KATKISALLIK VE GREENWASHING SORUNU

Karbon kredileri, bir ton CO_2 eşdeğeri azaltan veya tutan projelere yatırım yapılarak oluşturulan ve alınıp satılabilen dijital veya kağıt tabanlı sertifikalardır. Bu mekanizma, özellikle gelişmekte olan bölgelerde yenilenebilir enerji, orman koruma ve toprak yönetimi gibi faaliyetleri finanse

etmeyi hedeflemektedir. Krediler, gönüllü veya zorunlu (düzenlenmiş) piyasalarda işlem görebilir; gönüllü piyasalar esnekliği, düzenlenmiş piyasalar ise zorunluluğu ön plana çıkarır (Seymour ve Langer, 2021).

Bir projenin yalnızca karbon piyasasından elde edilen gelirle mümkün olması beklenir, buna "katkısallık" ilkesi denir. Başka kaynaklarla finanse edilseydi hayata geçmeyecek projeler "ek" sayılır. Bu kriter, piyasanın çevresel bütünlüğünü koruyabilmesi için Core Carbon Principles tarafından zorunlu kılınmıştır (Integrity Council, 2025). Katkısallık değerlendirmesi, finansal fizibilite analizleri, alternatif finansman opsiyonlarının incelenmesi ve şirket içi strateji dokümanlarının analizi yoluyla yapılır. Calyx Global'e göre, kredinin gelirinin proje kararlarında belirleyici rol oynaması, katkısallığın temel göstergesidir (Calyx Global, 2024).

Verra'nın VM0042 metodolojisi kapsamında katkısallık üç temel test üzerinden değerlendirilmektedir: regülasyon fazlası, yaygın uygulama analizi ve engel analizi. Regülasyon fazlası testi, projede uygulanacak faaliyetlerin mevcut yasa ya da yönetmeliklerle zorunlu kılınmadığını göstermeyi hedefler. Örneğin, Hindistan'ın Pencap eyaletinde anız yakma yasaklanmış olduğundan, bu faaliyetten kaçınmak katkısal sayılmamaktadır (Cariappa ve ark., 2024).

İkinci test olan yaygın uygulama analizi, hedeflenen faaliyetlerin uygulama öncesi alanda %20'nin altında bir yaygınlığa sahip olması gerektiğini belirtmektedir. Bu eşik, BM Temiz Kalkınma Mekanizması'nın "yaygın uygulama" metodolojisinden türetilmiştir. Bu sınırın amacı, teknolojilerin veya uygulamaların henüz erken benimsenme aşamasında olduğunu ve dış destek (örneğin karbon geliri) olmadan daha fazla yaygınlaşamayacağını varsaymaktır (Michaelowa ve ark., 2019; Cariappa ve ark., 2024).

Üçüncü test olan engel analizi ise, söz konusu projenin karşılaştığı kurumsal, ekonomik ya da teknik engelleri ortaya koymaktadır. Bu bağlamda, katkısallığın sağlanabilmesi için yalnızca düzenlemelere aykırı olmamak yeterli değildir; aynı zamanda uygulamanın karşılaştığı pratik zorluklar da belgelenmelidir. Örneğin, bazı bölgelerde sıfır toprak işleme gibi uygulamalar için gerekli ekipman erişimi, bilgi eksikliği ve risk algısı önemli engeller olarak değerlendirilmiştir (Cariappa ve ark., 2024).

Aksi takdirde, bu tür krediler "greenwashing" riski taşımaktadır. Örneğin, hâlihazırda ekonomik getirisi olan yenilenebilir enerji projelerine verilen karbon kredileri, çevresel değil finansal araçlar haline gelmektedir. Bu durum, şirketlerin gerçek karbon azaltımı yapmak yerine yalnızca dışsal faaliyetleri finanse ederek çevreye duyarlı göründükleri bir sistem yaratır. Bu tür uygulamalar, karbon denkleştirme mekanizmasının algılanan değerine dayalı olarak şirketlerin sürdürülebilirlik stratejilerinde yüzeysel davranmalarına neden olabilmektedir (Abadie ve ark., 2024).

Yapılan deneysel çalışmalara göre, karbon kredisi satın alma istekliliği yüksek olan firmaların genellikle çevresel performansı düşük, ancak yeşil iletişim faaliyetleri yüksek olmaktadır. Bu durum, dışsal karbon kredisi alımının içsel çevresel dönüşümün yerine geçtiğini ve böylece "greenwashing" davranışlarını beslediğini göstermektedir. Aynı araştırmada, yüksek karbon kredi fiyatlarının firmaları daha güçlü çevresel niyetler sergilemeye teşvik edebileceği bulunmuş, ancak bu niyetin çoğu zaman iletişim stratejileri ile sınırlı kaldığı, somut içsel değişimlerin ise gözlemlenmediği belirtilmiştir. Böylece şirketler, gerçek çevresel dönüşüm yerine, yüksek ödeme gücü sayesinde itibar kazanımı peşinde koşmaktadır (Szabo ve Webster,

2021). Örneğin, Shell'in karbon kredisi satın alımlarını gerçek emisyon azaltımından çok iletişim stratejisi olarak kullanması, bu eleştirilerin somut örneklerinden biridir (Civillini, 2024).

Dolayısıyla, karbon kredisi kullanımı sadece dışsal dengeleme aracı olarak değil, aynı zamanda içsel sürdürülebilirlik çabalarının tamamlayıcısı olarak kurgulanmalıdır. Aksi takdirde karbon piyasaları, çevresel bütünlüğü sağlamak yerine yalnızca itibar kazanımı amacı güden birer araç haline gelir.

2.2. KAÇAK EMİSYON (LEAKAGE) VE ÇİFTE SAYIM RİSKİ

Karbon dengeleme projeleri, sera gazı (GHG) emisyonlarını azaltma ve doğal yutakları artırma amacıyla geliştirilen piyasa-temelli araçlardır. Ancak bu projeler, uygulama sürecinde çeşitli yapısal sorunlarla karşı karşıya kalmaktadır. Bu sorunların başında kaçak emisyon (leakage) gelmektedir. Kaçak emisyon, bir bölgede emisyon azaltımına yönelik alınan önlemlerin, başka bir bölgede emisyonların artmasına neden olmasıdır. Özellikle tarım ve orman tabanlı projelerde bu risk yüksektir. Çünkü bu projelerde arazi kullanımı değişiklikleri ve ekonomik faaliyetlerin yer değiştirmesi sık görülür (Khurana ve ark., 2024).

Örneğin, Hindistan'daki agri-karbon projelerinde çiftçilerin anlık ekonomik ihtiyaçlarını karşılamak için ormansızlaştırma riskini artıran arazi değişimlerine yöneldiği, bunun da toplam emisyon faydasını düşürdüğü gözlemlenmiştir (Khurana ve ark., 2024). Benzer şekilde, bir bölgede uygulanan düşük karbonlu tarım uygulamaları, yüksek emisyonlu tarım faaliyetlerinin başka bölgelere kaymasına yol açarak iklim açısından küresel net faydayı azaltabilmektedir (West ve ark., 2020). Bu nedenle, projelerin ekolojik bütünlük ve mekânsal sürdürülebilirlik açısından dikkatle tasarlanması gerekir.

İkinci önemli sorun ise çifte sayım (double counting) olgusudur. Bu sorun, aynı emisyon azaltımının birden fazla iklim politikası veya aktör tarafından raporlanmasıyla ortaya çıkar. Örneğin bir ülke, Paris Anlaşması kapsamındaki Ulusal Katkı Beyanı (NDC) içinde bir emisyon azaltımını raporlarken; aynı proje gönüllü karbon piyasasında özel bir şirket tarafından da karbon kredisi olarak kullanılıyorsa, aynı azaltım iki kez "sayılmış" olur (Gehring ve Phillips, 2016). Bu tür çifte muhasebe, karbon piyasasının güvenilirliğini zedelerken, aynı zamanda iklim politikalarında yapay başarı algısı yaratabilir.

Khurana ve ark. (2024), tarım sektörüne yönelik karbon kredilendirme sistemlerinin, düzenleyici çerçeve ve doğrulama standartları yetersiz kaldığında bu iki soruna oldukça açık hale geldiğini belirtmektedir. Özellikle VERRA ve Gold Standard gibi sertifikasyon mekanizmalarının bu riskleri azaltmak amacıyla "ek katkısallık," "kalıcılık (permanence)," "sızıntı kontrolü" gibi kalite kriterlerini sıkılaştırması gerektiği ifade edilmiştir. Bu bağlamda, Yüksek Nitelikli Karbon Kredi İlkeleri (Core Carbon Principles) gibi küresel çerçeveler ve hükümet destekli uyum protokolleri, bu sorunların önüne geçilmesinde önemli rol oynamaktadır (Alexander, 2023).

Küresel anlamda bu tür sorunları çözebilmek için uluslararası koordinasyon gerekmektedir. Aksi halde, gelişmiş ülkelerde karbon nötrlüğü hedeflenirken, emisyonlar gelişmekte olan ülkelere kaydırılarak sadece mekânsal bir yer değişikliği yaşanır ve iklim krizi derinleşir

(Bohringer ve ark., 2017; Kawasaki, 2023). Bu nedenle karbon piyasalarında etkili MRV (ölçme, raporlama, doğrulama) altyapısı ve şeffaf veri paylaşımı şarttır.

2.3. GÖNÜLLÜ VE ZORUNLU PİYASALARIN KARŞILAŞTIRMASI

Karbon piyasaları, gönüllü ve zorunlu olmak üzere iki ana kategoriye ayrılır. Gönüllü karbon piyasaları, bireysel ve kurumsal aktörlerin emisyonlarını gönüllü olarak telafi etme çabalarına dayanır. Bu piyasaların temelinde, karbon emisyonlarını azaltıcı veya giderici projeler aracılığıyla üretilen karbon kredilerinin satışı yer alır. Ancak Battocletti ve ark. (2024)'nın belirttiği gibi, gönüllü piyasalar bir dizi yapısal zayıflıktan muzdariptir: Özellikle şeffaflık eksikliği, denetim ve doğrulama süreçlerinin zayıflığı, katkısallık kriterlerinin karşılanmasındaki belirsizlik ve kalite standardı eksikliği, bu piyasanın iklim değişikliğiyle mücadelede potansiyel etkinliğini sınırlandırmaktadır (Battocletti ve ark., 2024).

Proje geliştiriciler, doğrulayıcı kuruluşlar ve standart belirleyici kurumlar (örneğin Verra, Gold Standard) arasında oluşan mali teşvik yapısı, karbon ofsetlerinin gerçekte olduğundan daha fazla emisyon azaltımı sağladığı yönünde sistematik bir "ofset şişirmesi" problemi yaratmaktadır. Bu çıkar birliği, piyasada karbon kredisi arzının niteliksel olarak zayıflamasına ve piyasada güven erozyonuna yol açmaktadır. Dahası, bilgi asimetrisi nedeniyle alıcıların kaliteli ve katkısallığı yüksek ofsetleri diğerlerinden ayırması neredeyse imkânsız hale gelmekte, bu da piyasayı düşük kaliteli, etkisiz karbon kredileriyle doldurmaktadır (Battocletti ve ark., 2024).

Öte yandan, zorunlu karbon piyasaları hükümetler tarafından düzenlenen ve yasal yükümlülüklere dayanan sistemlerdir. Bu piyasalar, genellikle emisyon ticaret sistemleri (ETS), karbon vergileri veya hibrit mekanizmalar gibi araçlarla yürütülür. Dao et al. (2024), zorunlu piyasa araçlarının karbon nötrlüğü hedefleri için kritik olduğunu ve emisyon kapsama oranlarının ve karbon fiyat seviyelerinin belirleyici faktörler olduğunu vurgulamaktadır. Emisyon ticareti sistemleri, belli bir toplam emisyon kotası belirleyerek şirketlere sınırlı sayıda emisyon izni tahsis eder. Bu izinlerin alınıp satılabilir olması, piyasada bir karbon fiyatı oluşmasını sağlar. Karbon vergileri ise sabit bir fiyat aracılığıyla her bir ton emisyon için maliyet yükleyerek emisyonları azaltmayı hedefler (Dao ve ark, 2024).

Bu araçlar arasında temel farklar mevcuttur: Emisyon ticaret sistemleri emisyon miktarını sabitlerken fiyatı değişken bırakır; karbon vergileri ise fiyatı sabitler ancak emisyon miktarı belirsizdir. Bu durum, politika yapıcıların önceliklerine göre tercih ettikleri mekanizmaları şekillendirir. Örneğin AB Emisyon Ticaret Sistemi (EU ETS), piyasaya esneklik ve maliyet etkinliği sağlarken, fiyat oynaklığı gibi sorunlar yaratabilmektedir (Dao ve ark., 2024). Buna karşın karbon vergileri daha öngörülebilir bir maliyet yapısına sahiptir ancak emisyon hedeflerine ulaşma konusunda belirsizlik taşırlar.

Zorunlu sistemlerin bir diğer üstünlüğü, daha geniş sektörel kapsama ve daha sıkı izleme-doğrulama sistemlerine sahip olmalarıdır. Dao ve ark. (2024)'nın analizine göre, 2023 itibarıyla ETS programları dünya çapında 38 örnekle temsil edilirken, karbon vergileri 37 farklı yargı alanında uygulanmaktadır. Ancak sadece %23 oranında küresel emisyon, bu sistemlerle gerçekten kapsanabilmektedir. Emisyonların yalnızca %5.4'ü karbon vergileriyle, %17.6'sı ise

ETS ile regüle edilmektedir (Dao ve ark., 2024). Üstelik bu kapsama oranı; serbest tahsisatlar, istisnalar ve muafiyetler nedeniyle daha da düşmektedir.

Emisyon fiyatlandırması açısından, zorunlu piyasalardaki karbon fiyatları çoğu zaman yeterli düzeyin altında kalmaktadır. Stern ve Stiglitz (2017) tarafından belirlenen hedeflere göre 2030 yılına kadar karbon fiyatlarının \$50–\$100/tCO_2e arasında olması gerekirken, mevcut sistemlerin %90'ı \$25/tCO_2e'nin altında kalmaktadır. Örneğin İsviçre ETS'si nominalde \$95/tCO_2e fiyatlandırma yapsa da yalnızca %12 emisyonu kapsadığı ve %87'si serbest tahsis edildiği için etkin fiyat çok daha düşüktür (Dao ve ark., 2024).

Gönüllü piyasaların etkinliğini artırmak adına, standart belirleyici kurumların teşvik yapısının yeniden tasarlanması, doğrulayıcı kuruluşların hesap verebilirliğinin artırılması ve şeffaflık düzeyinin yükseltilmesi gibi reformlara ihtiyaç duyulmaktadır. Aksi halde, gönüllü karbon piyasalarının iklim hedeflerine katkısı sınırlı kalacaktır.

2.4. İZLEME, RAPORLAMA VE DOĞRULAMA (MRV) SİSTEMİ

Karbon piyasalarının etkinliği yalnızca fiyatlandırma mekanizmalarına değil, aynı zamanda güçlü bir düzenleyici ve teknik altyapıya, özellikle de İzleme, Raporlama ve Doğrulama (Monitoring, Reporting and Verification – MRV) sistemlerinin varlığına bağlıdır. MRV sistemleri, karbon piyasalarının çevresel bütünlüğünü ve piyasa güvenilirliğini sağlamak adına kritik öneme sahiptir. Bu sistemler sayesinde emisyon verilerinin doğruluğu teyit edilmekte, piyasa aktörleri arasında şeffaflık ve hesap verebilirlik artmaktadır (Dominioni ve Efthymiou, 2025).

MRV altyapıları tipik olarak üç temel aşamadan oluşur: (1) İzleme, yani tesis seviyesinde sera gazı emisyonlarının metodolojik olarak ölçülmesi ve kayıt altına alınması aşamasıdır. (2) Raporlama, bu emisyon verilerinin düzenli periyotlarla yetkili otoritelere bildirilmesidir. Avrupa Birliği'nin CRCF düzenlemesi, sertifikalı karbon giderme birimlerini kaydetmek için bir AB kayıt sistemi oluşturuyor. (3) Doğrulama, bildirimlerin bağımsız üçüncü taraf kuruluşlar tarafından incelenerek teyit edilmesi aşamasıdır. Örneğin ISO 14064-2 ve ISO 14065 standartları, proje doğrulaması için küresel kılavuzlar sunmaktadır. Avrupa Birliği Emisyon Ticaret Sistemi bu konuda kapsamlı bir yasal ve teknik çerçeve sunmakta ve diğer ülkeler için örnek teşkil etmektedir (Bencini ve ark., 2025).

Türkiye'de yürürlükte olan MRV sistemi, AB ETS ile yüksek oranda uyumludur. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı tarafından yürütülen sistem kapsamında yaklaşık 770 tesisten elde edilen yıllık emisyon verileri, akredite üçüncü taraf doğrulayıcı kuruluşlar aracılığıyla denetlenmekte ve Bakanlığa raporlanmaktadır. Türkiye'nin 2012 yılından bu yana uyguladığı Sera Gazı Emisyonlarının Takibi Hakkında Yönetmelik, özellikle izleme metodolojilerinde IPCC ve AB yönergelerine dayalı yaklaşımı benimseyerek teknik bütünlük sağlamaktadır.

Ancak literatür MRV sistemlerinin yalnızca teknik kapasiteyle değil, aynı zamanda kurumsal uyum, cezai yaptırımlar, dijital veri yönetimi altyapısı ve düzenleyici bağımsızlık gibi yönleriyle de değerlendirilmesi gerektiğine dikkat çekmektedir (Dominioni ve Efthymiou, 2025). Örneğin AB sisteminde, emisyon verileri merkezi bir dijital platformda saklanmakta, doğrulayıcı kuruluşların lisansları düzenli olarak gözden geçirilmekte ve hatalı beyanlar ciddi

yaptırımlara tabi tutulmaktadır. Türkiye'de ise MRV uygulamaları henüz piyasa bazlı karbon fiyatlandırma mekanizmasıyla bütünleşmiş değildir, ancak ETS'ye hazırlık sürecinde bu altyapının çok kritik olduğu açıktır.

Çin gibi gelişmekte olan ekonomilerde ise MRV teknolojisinin karbon piyasalarını desteklemede oynadığı rol giderek artmaktadır. Çin'in ulusal ETS sistemine geçiş sürecinde demiryolu taşımacılığı gibi yeni sektörlerin dahil edilmesiyle birlikte MRV teknolojisinin dijitalleştiği, uzaktan izleme ve otomatik veri analitiği gibi çözümlerin geliştirildiği bildirilmektedir (Wei ve Wang, 2025). Bu örnekler, Türkiye gibi geçiş aşamasındaki ülkeler için MRV sistemlerinin yalnızca bir veri raporlama aracı değil, aynı zamanda piyasa güvenliğini sağlayan temel bir yapı taşı olduğunu göstermektedir.

Karbon piyasalarının adil, etkin ve çevresel bütünlüğe sahip bir şekilde işlemesi için MRV sistemlerinin sadece teknik doğruluk değil, aynı zamanda kurumsal kapasite, bağımsızlık, dijitalleşme ve düzenleyici uyum boyutlarıyla geliştirilmesi gerekmektedir. Türkiye'nin AB ile uyumlu MRV altyapısını ETS uygulamalarına entegre etmesi, piyasanın güvenilirliğini artıracak ve uzun vadeli iklim hedeflerinin gerçekleştirilmesine katkı sağlayacaktır.

3. TARIM VE HAYVANCILIK SEKTÖRÜNDE KARBON DENGELEME POTANSİYELİ

Tarım sektörü, iklim değişikliği ile mücadelede hem önemli bir sera gazı (GHG) kaynağı hem de yüksek karbon yutak kapasitesine sahip stratejik bir alandır. Küresel düzeyde tarımsal faaliyetlerin, özellikle arazi kullanımı değişikliği dâhil olmak üzere, %14 ila %24 arasında sera gazı salımından sorumlu olduğu tahmin edilmektedir (Shukla ve ark., 2020). Özellikle metan (CH_4) ve azot oksit (N_2O) gibi tarıma özgü gazlar, toplam emisyonlarda belirgin paya sahiptir (Richards ve ark., 2015). Ancak tarım arazileri aynı zamanda büyük bir karbon yutağı olup, atmosferik CO_2'nin %30'a kadarını absorbe etme potansiyeline sahiptir (Shukla ve ark., 2020).

Bu çift yönlü yapı, tarımı hem sorunun hem de çözümün bir parçası haline getirmektedir. Nitekim Acampora ve ark. (2023), tarım sektörünün karbon nötrlüğüne geçişte diğer sektörlere kıyasla daha yüksek bir teknik azaltım potansiyeline sahip olduğunu vurgulamaktadır. OECD (2019) raporuna göre, 2030 yılına kadar tarım sektörünün teknik sera gazı azaltım potansiyeli 5500–6000 $MtCO_2eq$/yıl seviyesindedir. Bu miktar, karbon kredisi piyasasında ciddi bir finansal değer yaratabilecek düzeydedir.

Karbon kredisi üretimi açısından, tarım sektöründe uygulanabilecek çeşitli stratejiler mevcuttur. Toprak işlemesinin azaltılması, hassas gübre ve sulama tekniklerinin kullanılması, hayvansal yem formülasyonlarının değiştirilmesi ve biyogaz sistemlerinin yaygınlaştırılması gibi uygulamalar, hem doğrudan emisyon azaltımı sağlar hem de toprakta karbon depolamasını artırır (Acampora et al., 2023). Özellikle entansif hayvancılıkta metan salımı önemli bir sorun olup, yem içerikleri ve sindirim süreçlerini düzenleyici tekniklerle bu salımlar azaltılabilir.

Ancak bu süreçlerin başarılı olabilmesi için belirli kurumsal altyapılar gereklidir. İlk olarak, MRV (Measure-Report-Verify) sistemlerinin tarım özelinde geliştirilmesi gerekir. Acampora ve ark. (2023), mevcut karbon muhasebesi yaklaşımlarının tarımda karmaşık üretim zincirleri nedeniyle eksik ve karşılaştırılamaz olduğuna dikkat çekmiştir. Özellikle "scope 3" yani tedarik zincirine dayalı emisyonların ölçülmesi ve raporlanması hâlen ciddi metodolojik sorunlar

barındırmaktadır. Ayrıca, küçük ölçekli çiftçilerin karbon piyasasına dahil edilmesini engelleyen yüksek proje geliştirme maliyetleri ve sertifikasyon ücretleri de önemli bir engel olarak ortaya çıkmaktadır (Klaaßen ve Stoll, 2021).

Buna ek olarak, üreticilerin bu tür projelere katılımı için sadece ekonomik teşvik değil, aynı zamanda teknik destek ve kapasite geliştirme desteği sağlanması elzemdir. Acampora ve ark. (2023), yaptıkları saha çalışmasında, agri-food firmalarının karbon nötrlüğüne geçiş sürecinde en çok ihtiyaç duydukları araçların başında sübvansiyonlu sertifikasyon, teknik danışmanlık ve tedarik zinciri düzeyinde destek paketleri olduğunu ortaya koymuştur.

3.1. TARIMSAL KARBON AZALTICI/TUTUCU UYGULAMALAR

Tarımda karbon piyasasına konu olabilecek başlıca faaliyetler, sera gazı emisyonlarını azaltan veya karbon depolanmasını artıran yöntemlerdir. Bunların birçoğu aynı zamanda "iklim akıllı tarım" uygulamaları olarak çiftçinin verimliliğine ve arazinin sağlığına katkı sağlar.

3.1.1. ORGANİK MADDE MİKTARININ ARTTIRILMASI

Tarım topraklarında organik madde miktarını artırmak, hem toprak verimliliğini hem de uzun dönemde karbon tutulumunu destekleyen en etkili yöntemlerden biridir. Meta-analizlere göre, çiftlik gübrelerinin uygulanmasıyla toprak organik karbon stoklarında ortalama %35,4 artış ve 10,7 Mg C ha^{-1}'lik kazanç sağlandığı gösterilmiştir (Gross ve Glaser, 2021) . Benzer biçimde, toprakta yüksek nem koşullarında kompost karıştırmanın organik maddenin ayrışma hızını yavaşlatarak korunmasını artırdığı ve böylece karbon havuzunu genişlettiği tespit edilmiştir (Dijkstra ve Keitel, 2024).

Kompostlama ve gübrelemede temel uygulamalar; hayvan gübresinin olgunlaştırılarak kompost haline getirilmesi, hasat artığı bitki materyalinin sahada parçalanıp toprağa karıştırılması ve organik atık biyokütlelerin düzenli olarak toprak yüzeyine verilmesidir. FAO'nun "Soil Organic Carbon – The Hidden Potential" raporunda, bu tür organik girişlerin hem serbest organik madde hem de mikrobiyal biyokütleyi artırarak topraktaki karbon bakımını optimize ettiği vurgulanmıştır (FAO GSP, 2015)

Kompost ve gübre uygulamalarının saha ölçeğinde en somut örneklerinden biri, Kenya Tarımsal Karbon Projesi'dir. Batı Kenya'daki yaklaşık 60.000 küçük çiftçi; tarlalarında kompost, ahır gübresi ve diğer Sürdürülebilir Arazi Yönetimi (SALM) tekniklerini uygulayarak toprak organik maddesini önemli ölçüde artırmıştır (Tennigkeit ve ark., 2019). Bu proje, organik madde artışı sayesinde 2014 yılında VCS standardı altında 24.788 ton CO_2e azaltımına karşılık gelen ilk toprak kaynaklı gönüllü karbon kredilerinin ihraç edilmesini sağlamıştır (World Bank, 2014).

Toprak organik maddesinin artırılması yalnızca karbon tutulumunu değil, toprak sağlığını ve tarımsal verimliliği de destekler. Kompostla zenginleştirilen tarlalarda su tutma kapasitesi yükselir, besin maddeleri daha dengeli dolaşıma girer ve toprağın fizikokimyasal özellikleri iyileşir. Bu sayede bitki kök gelişimi desteklenir ve verim artışları elde edilir (Pustian ve ark., 2019). Karbon piyasalarında organik madde artışı projeleri, MRV süreçleriyle desteklenir. Saha sensörleri, portatif gaz analizörleri ve uydu tabanlı izleme yöntemleri kullanılarak karbon

azaltım etkileri hesaplanır ve bağımsız kuruluşlarca sertifikalandırılır. Bu sayede çiftçiler hem iklim değişikliğiyle mücadeleye katkıda bulunur hem de gönüllü karbon piyasalarında güvenilir krediler oluşturarak uzun vadeli ekonomik sürdürülebilirlik sağlarlar (Verra, 2014)

3.1.2. BİYOKÖMÜR KULLANIMI

Biyokömür, organik atık biyokütlenin oksijensiz ortamda yüksek sıcaklıkta ısıtılması (piroliz) sonucu elde edilen, karbon açısından zengin ve biyolojik olarak dayanıklı bir maddedir. Toprağa uygulandığında, yüzlerce hatta binlerce yıl boyunca bozulmadan kalabilen bir karbon havuzu oluşturarak atmosferdeki CO_2'nin uzun vadeli depolanmasını sağlar .

Örneğin, pirinç sapları, fındık kabukları ve ağaç dalları gibi tarımsal atıkların yakılması yerine biyokömüre dönüştürülmesi, bu atıkların karbon içeriğinin toprağa gömülerek kalıcı karbon depolama imkânı sunar. Ayrıca, biyokömür toprağın su tutma kapasitesini artırır, besin maddelerini daha iyi korur ve mikrobiyal aktiviteyi destekleyerek tarımsal verimliliği yükseltir.

Gönüllü karbon piyasalarında biyokömür projeleri, karbonun kalıcı olarak depolandığı miktarların hesaplanıp doğrulanmasıyla karbon kredileri oluşturmakta ve bu krediler satılabilmektedir. Örneğin, Kenya'da yürütülen Kenya Tarımsal Karbon Projesi, 60.000 çiftçinin 45.000 hektarlık alanda sürdürülebilir tarım uygulamalarıyla hem verimi artırmalarını hem de karbon kredisi elde etmelerini sağlamıştır (World Bank, 2014). Küresel ölçekte, biyokömür uygulamalarının yıllık 0,44 ila 2,62 gigaton CO_2'yi atmosferden uzaklaştırma potansiyeline sahip olduğu tahmin edilmektedir (Moya, 2023).

3.1.3. TOPRAK İŞLEME

Toprak işleme yöntemlerinin değiştirilmesi, tarımsal faaliyetlerin karbon ayak izini azaltmada kritik bir rol oynamaktadır. Anızın toprakta bırakılması, minimum toprak işleme veya doğrudan ekim gibi uygulamalar, toprağın karbondioksit salımını azaltır ve organik karbon birikimini teşvik eder. Geleneksel sürüm yerine toprağı mümkün olduğunca az rahatsız eden ekim teknikleri, bitki kalıntılarının toprakta kalarak çürümesini sağlar; bu da karbonun toprağa hapsolması anlamına gelir. Ayrıca, bu yöntemler yakıt kullanımını azaltarak fosil kaynaklı emisyonların düşmesine katkıda bulunur. Örneğin, ABD Tarım Bakanlığı'nın tahminlerine göre, sıfır toprak işlemeli tarım uygulayan çiftçiler yılda yaklaşık 588 milyon galon dizel yakıttan tasarruf etmektedir. Bu miktar, 720.000'den fazla evin bir yıllık enerji ihtiyacına eşdeğerdir. Ayrıca, sıfır toprak işleme ile yapılan tarım, toprağın su tutma kapasitesini artırır, erozyonu azaltır ve toprak sağlığını iyileştirerek tarımsal verimliliği destekler (Bertrand ve ark., 2022).

Tarımsal üretimde nitroz oksit (N_2O) emisyonlarının azaltılması, toprak yönetim uygulamalarının iklim değişikliğiyle mücadeledeki en kritik bileşenlerinden biridir. FAO tarafından hazırlanan “Recarbonizing Global Soils” kılavuzunda, hem organik hem de sentetik gübrelerin bitki ihtiyaçlarına göre optimize edilmesiyle toprak kaynaklı N_2O salımında %20–50’ye varan düşüşlerin sağlanabileceği vurgulanmıştır (FAO and ITPS, 2021). Aynı rehber, kapalı havza ikliminden tropik koşullara kadar farklı tarım sistemlerinde en iyi toprak yönetimi uygulamalarının karbon tutulumunu artırdığını göstermektedir.

3.1.4. GÜBRE UYGULAMALARI

"Doğru Kaynak, Doğru Oran, Doğru Zaman ve Doğru Yer" ilkeleri, gübre yönetiminde yaygın kabul gören bir çerçeve sunmaktadır. 4R uygulamalarıyla, üretilen birim mahsul başına çıkan N_2O emisyonlarında %50'ye yakın azalmalar kaydedilmiştir (Canadian 4R Research Network, 2015). Özellikle azot bazlı gübrelerin uygun derinliğe yerleştirilmesi ve zamanlamanın bitki büyüme fazlarına göre ayarlanması, amonyak volatilizasyonunu ve nitroz oksit oluşumunu önemli ölçüde engellemektedir (Venterea ve ark., 2016).

Emisyon azaltımlarının güvenilir biçimde ölçülmesi, izlenmesi ve doğrulanması ise ACR VM0022 metodolojisi gibi uluslararası standartlarla gerçekleştirilir. Verra tarafından yayımlanan VM0022, tarla düzeyinde farklı toprak ve bitki koşullarına göre N_2O salım değerlerinin saha sensörleri ve portatif gaz analizörleriyle ölçülmesini öngörmektedir. Böylece elde edilen veriler, bağımsız üçüncü taraf sertifikasyon kuruluşları tarafından onaylanarak karbon kredisi üretimine temel oluşturur (Verra, 2023).

3.1.5. TARIMSAL SULAMA

Sulama yönetiminde ise damla sulama, geleneksel oluklu veya yağmurlama sistemlerine kıyasla N_2O emisyonlarında sırasıyla ortalama %32 ve %46 oranında azalma sağlar. Toprağın nem profilini stabilize eden damla sulama; aşırı su birikimini engelleyerek nitrifikasyon–denitrifikasyon döngülerini düzenler ve azot kayıplarını düşürür (Kuang ve ark., 2021).

Türkiye'nin Konya Kapalı Havzası'nda Netafim ve Virridy iş birliğiyle başlatılan karbon kredisi programı, 1.000 ha'dan fazla alanda damla sulama ve hassas gübre yönetimini entegre ederek yıllık en az 3,5 ton CO_2e/ha azaltım sağlamayı hedefler (Virridy, 2024; PR Newswire, 2025). Çiftçilere dijital toprak nem sensörleri ve otomasyonlu kontrol sistemleri kurulmakta; böylece hem verim artışı hem de su ve azot kullanım verimliliği yükselmektedir. Bu bütüncül yaklaşımlar, hem çevresel hem de ekonomik faydalar doğurmakta; tarımsal üretimde sürdürülebilirliği artırırken, gönüllü karbon piyasalarında satılan karbon kredileri çiftçilere ek gelir imkânı sunmaktadır (Virridy, 2024). Ayrıca, saha verilerinin anlık izlenmesi ve bağımsız doğrulama süreçleri, projelerin şeffaflığını ve güvenilirliğini pekiştirmektedir (Verra, 2023).

3.1.5. ÖRTÜ BİTKİLERİ KULLANIMI

Örtü bitkileri, ana ürün ekiminden sonra ya da kış döneminde tarlayı örterek erozyonu önler, toprağa organik madde kazandırır ve toprağın biyolojik çeşitliliğini destekler (SARE, 2023). Bu bitkiler; baklagiller (fiğ, yem bezelyesi), tahıllar (yulaf, çavdar) ya da karışım halinde ekildiğinde hem kök yapılarıyla toprağı havalandırır hem de yüzey örtüsüyle nem kaybını azaltır (Bertrand ve ark., 2021). Dünya genelinde 8,1 milyon ha örtü bitkisi alanı, yılda yaklaşık 60 milyon ton CO_2-e oranında karbonun toprağa bağlanmasına olanak tanımaktadır (SARE, 2023).

Örtü bitkilerinin karbon tutulum potansiyeli, yapılan meta-analizlere göre yılda ortalama 0,88 Mg C ha^{-1} $yıl^{-1}$ (yaklaşık 3,2 Mg CO_2 ha^{-1} $yıl^{-1}$) olarak hesaplanmıştır (Joshi ve ark., 2023). Çift tür cover crop uygulamaları—bir baklagil ve bir tahıl karışımı—ise 1,20 Mg C ha^{-1} $yıl^{-1}$'e kadar yükselmektedir (Villat ve Nicholas, 2024). Modern tarımda yer altı sensörleri ve uzaktan

algılama ile gerçek zamanlı izleme imkânı, bu tutulum değerlerinin güvenilir biçimde ölçülmesini ve sahaya özgü uygulama optimizasyonunu sağlar (Opoku ve ark., 2024).

Baklagil türü örtü bitkileri, atmosferik N_2 fiksasyonu yaparak toprağın azot içeriğini zenginleştirir; böylece sonraki ürün için sentetik gübre ihtiyacını azaltır. Amerika Tarım Bakanlığı Araştırma Servisi'nin kışlık çavdar uygulamalarında, nitrat kayıpları azalırken nitrifikasyon–denitrifikasyon dengesi sağlanmış, buna bağlı olarak N_2O emisyonlarında düşüş gözlenmiştir (USDA ARS, 2023). Bu dolaylı etki, örtü bitkilerinin hem karbon hem de diğer sera gazı dengelemelerinde çift fayda yaratmasını mümkün kılar.

Karbon kredisi piyasalarında, örtü bitkisi uygulamaları Indigo Ag ve Nori gibi platformlar üzerinden ticarileştirilmektedir. Indigo Ag'in standart programında, karbon kredisi gelirinin %75'i çiftçiye geri dönerken (Indigo Ag, 2024), Nori pazarında 2024 itibarıyla 125.000'den fazla toprak karbon kredisi listeye eklenmiştir (Bayer, 2024). Bu modeller, dört yıllık geriye dönük uygulama takibi ve hem saha ölçümleri hem de modellemeye dayalı doğrulama süreçleriyle çalışmaktadır.

3.1.6. TARIMSAL ORMANCILIK

Agroforestry, tarım arazilerinde veya meralarda tarımsal ürünlerle ağaçların uyumlu biçimde bir arada yetiştirildiği sistemleri ifade eder. Bu sistemler; tarlaların kenarına rüzgâr kıran olarak ağaç sıraları dikmeyi, hızlı büyüyen azot bağlayıcı türleri ekim nöbetine dahil etmeyi ya da kahve ve kakao gibi ürünleri, gölge ağaçları altında yetiştirmeyi kapsamaktadır (Montagnini ve Nair, 2004). Agroforestry uygulamaları, yalnızca karbon yakalamakla kalmaz; tarımsal verim artışı, toprak erozyonunun engellenmesi, biyolojik çeşitliliğin korunması ve mikroiklim düzenlemesi gibi çok sayıda yarar sunar (Hance, 2025).

Ağaçlar, büyümeleri sırasında atmosferden CO_2'yi fotosentezle alarak odun dokusunda uzun süreli karbon depolar. Kök sistemleri aracılığıyla toprağa organik karbona katkı sağlar ve toprağın toplam karbon havuzunu büyütür. Karışık ağaç türlerine sahip agroforestry sistemleri, tek tür orman veya monokültür ağaç plantasyonlarına göre %70'e varan oranda daha fazla karbon tutma kapasitesi gösterebilmektedir (Warner ve ark., 2023).

3.2. TARIM SEKTÖRÜNDE MRV

MRV sistemleri yalnızca bir teknik raporlama aracı değil, aynı zamanda piyasa şeffaflığını sağlayan, teşvik sistemlerini yönlendiren, çevresel faydaları güvence altına alan çok katmanlı bir yapı olarak karşımıza çıkmaktadır. Brummitt ve ark. (2024) tarafından yayımlanan kapsamlı bir çalışma, MRV sistemlerinin bilimsel temellerini ve uygulamadaki karşılıklarını gözler önüne sermektedir. ABD'de 553.743 hektar genişliğindeki tarım arazilerinde uygulanan "CAR1459" kodlu karbon kredilendirme sistemi, toprak karbon kredilendirmesine dayalı izleme sistemlerinin nasıl yapılandırılması gerektiğine dair önemli ipuçları sunmaktadır. Çalışmada kullanılan MRV yaklaşımı, klasik veri toplama yöntemlerinin ötesine geçerek, sahadan alınan gözlemleri uzaktan algılama teknolojileri, tarla ekipmanlarından gelen dijital kayıtlar, iklim ve toprak verileriyle entegre eden çok kaynaklı bir veri altyapısına dayanmaktadır. Bu veriler, DayCent-CR isimli biyogeo-kimyasal bir model aracılığıyla analiz

edilmiş; böylece arazi bazında karbon tutumundaki değişiklikler yıl bazında tahmin edilebilmiştir. Bu ileri düzey modelleme, MRV sistemlerinin sadece nicel değil, aynı zamanda çevresel olarak anlamlı çıktılar üretmesini sağlamıştır.

Karbon piyasalarında kredilerin güvenilirliği, ne kadar emisyonun azaltıldığı kadar, bu azaltımın ne ölçüde "ilave" olduğuna da bağlıdır. Brummitt ve ark. (2024), bu ilavelik ilkesini sağlamak amacıyla kredileri %70 güven düzeyine göre hesaplamış; böylece oluşturulan karbon kredilerinin çoğunlukla gerçek etkiden daha düşük olmasını sağlayarak piyasaya muhafazakâr ve güvenilir bir arz sunmuştur. Bu yaklaşım, emisyon azaltımına ilişkin iddiaların temkinli biçimde yönetilmesini ve piyasa güvenliğinin artmasını sağlamaktadır. Çalışmanın dikkat çeken bir diğer yönü ise, karbon tutumunun zamanla değişen doğasının MRV sistemlerine entegre edilmesidir. Özellikle toprak işlemesiz tarım gibi uygulamaların beş ila on yıl boyunca artan karbon tutumu sağladığı bulgusu, izleme sistemlerinin yalnızca kısa vadeli değil, uzun vadeli izlemeyi de kapsaması gerektiğini ortaya koymaktadır. Bu, karbon piyasalarında geçici değil, kalıcı çevresel faydaların teşvik edilmesini sağlamaktadır.

MRV sistemleri yalnızca izleme işlevi görmemekte, aynı zamanda teşvik mekanizmalarının yönünü de belirlemektedir. "Pay-for-outcome" (sonuç temelli ödeme) modeli bu bağlamda dikkat çeken bir uygulamadır. Bu modelde, çiftçilere ya da uygulayıcılara yalnızca uygulamayı gerçekleştirdikleri için değil, uygulamanın çevresel sonuçları doğrultusunda ödeme yapılmaktadır. Bu teşvik yapısı, çevresel çıktıyı merkeze alan, daha etkin bir karbon yönetimi anlayışına işaret etmektedir.

Son olarak, çalışmada belirsizliklerin şeffaf biçimde yönetilmesi de MRV sistemlerinin ayrılmaz bir parçası olarak ele alınmıştır. Veri eksiklikleri, modelleme hataları ya da uygulayıcı davranışlarındaki değişkenlik gibi unsurlar nicel biçimde hesaplanmakta ve sistem içinde belirsizlik tamponu aracılığıyla dengelenmektedir. Böylece, fazla kredi verilmesinin önüne geçilmekte ve karbon piyasalarının bütünlüğü korunmaktadır.

4. TÜRKİYE'NİN 2053 NET SIFIR HEDEFİ, NDC GÜNCELLEMESİ VE ETS GEREKLİLİĞİ

Türkiye, 2021 yılında ilan ettiği 2053 Net Sıfır emisyon hedefi ile iklim politikasında köklü bir dönüşüm sürecine girmiştir. Bu hedef doğrultusunda, 2023 yılında Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi'ne sunulan güncellenmiş Ulusal Katkı Beyanı (NDC) kapsamında, 2030 yılına kadar referans senaryoya göre emisyon azaltım hedefi %21'den %41'e çıkarılmıştır (Tümer ve van Zeben, 2024). Bu artış, Türkiye'nin iklim taahhütlerini güçlendirme yönündeki niyetini ortaya koymakla birlikte, uygulama kapasitesi ve altyapı gereksinimleri açısından önemli zorluklar da barındırmaktadır.

Bu hedefler, yalnızca iç politikalar bağlamında değil, aynı zamanda Avrupa Birliği'nin 2026'da uygulamaya koyacağı Sınırda Karbon Düzenleme Mekanizması (CBAM) çerçevesinde dış ticaret ilişkileri açısından da kritik önemdedir. CBAM, demir-çelik, çimento, alüminyum, gübre ve elektrik gibi karbon yoğun sektörlerden AB'ye yapılan ihracatlar için karbon fiyatlandırması yükümlülüğü getirmektedir. Bu da, Türkiye gibi AB ile derin ticaret entegrasyonuna sahip ülkeler için karbon maliyetlerini hesaba katan sanayi politikaları geliştirmeyi zorunlu kılmaktadır (Tümer ve van Zeben, 2024; Ediger ve ark., 2024).

Türkiye'nin ihracatının yaklaşık %40'ının AB ülkelerine yönelik olduğu dikkate alındığında, CBAM'ın etkileri hem makroekonomik düzeyde hem de sektör bazında hissedilecektir. Örneğin, demir-çelik sektörü, CBAM kapsamında ilk etkilenecek alanlardan biri olarak öne çıkmaktadır (Ediger ve ark., 2024). Bu durum, Türkiye'nin üretim yapısını karbon yoğun olmaktan çıkarmasını, yani "karbon verimliliği yüksek" teknolojilere geçmesini gerektirmektedir.

Bu bağlamda, ulusal bir karbon fiyatlandırma mekanizması, özellikle de ETS kurulması, Türkiye için yalnızca çevresel değil, aynı zamanda ekonomik ve ticari bir zorunluluk haline gelmiştir. Hâlihazırda Türkiye, ETS'ye geçiş süreci için teknik hazırlıklar yürütmekte olup, Dünya Bankası'nın PMR programı kapsamında pilot çalışmalar gerçekleştirilmiştir. Ayrıca Türkiye'nin MRV altyapısı da AB standartlarıyla uyumlu hale getirilmiştir, bu da ETS altyapısı için kritik bir ön koşuldur (Bencini ve ark., 2025).

Ancak politika belgeleri ve analizler, Türkiye'nin mevcut güncellenmiş NDC hedeflerinin hala Paris Anlaşması'nın 1.5°C hedefiyle uyumlu olmadığını göstermektedir (Tümer ve van Zeben, 2024). Bu da, ETS'nin etkili bir şekilde devreye alınması, karbon fiyatının yeterli düzeye ulaşması ve sanayide düşük karbon teknolojilerine hızlı geçiş yapılmasını gerektirmektedir.

Sonuç olarak, Türkiye'nin 2053 net sıfır hedefiyle uyumlu hareket edebilmesi için, karbon maliyetlerinin içselleştirildiği, piyasaya dayalı ve şeffaf bir ETS mekanizması kurması kaçınılmazdır. Bu mekanizma, hem AB ile ticari uyumu sağlar hem de yeşil dönüşüm hedeflerine ulaşmada temel araç işlevi görür.

5. TÜRKİYE'NİN EMİSYON PROFİLİ

Türkiye'nin 2023 yılı toplam sera gazı emisyonu, bir önceki yıla göre %6,9 oranında artarak 598,9 milyon ton CO_2 eşdeğeri ($MtCO_2e$) düzeyine ulaşmıştır. Bu emisyonların sektörel dağılımı, gelecekte uygulanacak karbon fiyatlandırma mekanizmaları ve ETS açısından öncelik verilecek alanları da doğrudan şekillendirmektedir. Resmi TÜİK verilerine göre, enerji sektörü 2023 yılında toplam emisyonların %73,8'ini oluşturarak açık ara en büyük paya sahip olmuştur. Bu oran, fosil yakıt kullanımına dayalı enerji üretiminin ve sanayi ile ulaşım sektörlerindeki enerji tüketiminin Türkiye'nin emisyon profilindeki belirleyici rolünü teyit etmektedir (TUIK, 2024).

Tarım sektörü, toplam emisyonların %12'sini oluşturarak ikinci sırada gelmektedir. Bu oran, metan (CH_4) ve diazot monoksit (N_2O) gibi yüksek küresel ısınma potansiyeline sahip gazların, özellikle gübreleme, pirinç üretimi, hayvancılık ve toprak işleme gibi faaliyetlerden kaynaklandığını göstermektedir. Tarımsal emisyonlar doğrudan enerji tüketiminden çok biyolojik süreçlerden kaynaklandığı için, MRV sistemlerinin bu sektöre özel olarak tasarlanması önemlidir. Ayrıca, düşük karbonlu tarım uygulamaları ile tarım sektörü, yalnızca emisyon kaynağı olmakla kalmayıp aynı zamanda karbon yutağına dönüşme potansiyeli de taşımaktadır.

Endüstriyel işlemler ve ürün kullanımı sektörü ise toplam emisyonların %11,8'ini oluşturarak üçüncü sırada yer almaktadır. Bu alandaki emisyonlar genellikle çimento, kimya ve metalürji gibi enerji yoğun sanayi kollarından kaynaklanmakta ve doğrudan üretim süreçlerinden ortaya

çıkmaktadır. Bu sektörü, izlenebilir ve ölçülebilir nitelikteki emisyonları sayesinde karbon piyasalarına entegrasyon için oldukça elverişlidir.

Atık sektörü ise emisyonların yalnızca %2,3'ünü oluşturmaktadır. Bu emisyonlar, katı atık depolama sahaları, atık su arıtma sistemleri ve biyolojik ayrışma süreçlerinden kaynaklanmakta olup, sektördeki düzenleyici reformlar ve teknolojik yatırımlar sayesinde uzun vadede azaltılabilir niteliktedir. Bu dağılım, Türkiye'de karbon piyasalarının hangi sektörleri öncelemesi gerektiğini açık biçimde ortaya koymaktadır. Enerji sektörü, hem toplam emisyon yükünün büyüklüğü hem de alt sektörleri kapsayan yapısı nedeniyle emisyon ticaret sistemi kapsamında öncelikli olarak düzenlenmelidir. Tarım sektörü ise her ne kadar ikinci sırada yer alsa da emisyon kaynaklarının doğası gereği, gönüllü piyasa mekanizmaları, sonuç temelli teşvik sistemleri ve tarımsal karbon kredilendirme programlarıyla desteklenmelidir. Endüstriyel süreçler ise doğrudan kapsama alınabilecek teknik yeterliliğe sahip sektörler arasında yer almaktadır.

6. SONUÇLAR VE ÖNERİLER

Küresel iklim hedeflerine uyum sağlamak ve Avrupa Yeşil Mutabakatı gibi dış ticaret düzenlemelerine entegrasyonu güçlendirmek adına, Türkiye'nin emisyon azaltımını piyasaya dayalı araçlarla desteklemesi kaçınılmaz hale gelmiştir. Emisyon Ticaret Sistemi (ETS), bu süreçte temel bir politika aracı olarak ön plana çıkmakta; enerji, sanayi ve tarım gibi yüksek emisyon potansiyeline sahip sektörlerde emisyonları azaltmayı hedeflemektedir. Türkiye, MRV (İzleme-Raporlama-Doğrulama) altyapısını AB standartlarına uyumlu hale getirmiştir ve bu durum ETS'nin hayata geçirilmesi için güçlü bir temel oluşturmaktadır.

Tarım ve doğa temelli çözümler, gönüllü karbon piyasalarında potansiyel arz etmektedir. Ancak katkısallık, kalıcılık, sızıntı ve çifte sayım gibi risklerin dikkatle yönetilmesi gerekmektedir. Özellikle katkısallık ilkesinin net biçimde karşılanmadığı projeler, karbon kredilerinin "greenwashing" amacıyla kullanılmasına neden olabilir. Bu risklerin bertarafı için Verra ve Gold Standard gibi doğrulayıcı kurumların metodolojileri sıkılaştırılmalı; kamu denetimi ve veri şeffaflığı artırılmalıdır.

Etkin bir karbon piyasası, yalnızca fiyatlandırma sistemine değil; aynı zamanda güçlü ve bütünleşik bir MRV altyapısına dayanır. Tarımda toprak karbonu, metan ve azot oksit emisyonlarının izlenmesi; sahadan gelen verilerin modelleme yazılımlarıyla birleştirilmesi; sonuç odaklı ödeme sistemleri ile teşvik yapılarının kurulması önerilmektedir. Türkiye'nin MRV altyapısını dijitalleştirmesi, uzaktan algılama ve sensör teknolojilerini kullanması, piyasanın şeffaflığını ve yatırım güvenliğini artıracaktır.

Toprak işleme azaltımı, örtü bitkileri, biyokömür, hassas sulama ve gübre yönetimi gibi yöntemler; hem çiftçiye ek gelir hem de uzun vadeli karbon faydası sağlar. Türkiye'nin tarım politikaları bu tür uygulamaları destekleyecek şekilde yeniden yapılandırılmalıdır. Özellikle küçük çiftçilerin karbon piyasasına girişini kolaylaştırmak için sübvansiyonlu sertifikasyon sistemleri, teknik rehberlik ve kamu-özel ortaklıkları oluşturulmalıdır.

Yüksek kaliteli karbon kredisi arzı ve etkin karbon fiyatlaması, sadece çevresel fayda değil aynı zamanda sanayinin dönüşümünü teşvik eder. Türkiye, karbon fiyatlarını sürdürülebilir seviyelere çekerek düşük karbon teknolojilerine geçişi hızlandırmalı; serbest tahsisat oranlarını

kademeli olarak düşürmelidir. Ayrıca CBAM'a hazırlık kapsamında, ihracat yapan firmalar için karbon hesaplama ve raporlama zorunlulukları getirilmelidir.

Dünya Bankası, VCMI, Integrity Council gibi uluslararası kurumlarla teknik ve finansal iş birlikleri artırılmalı; karbon projelerinin kredilendirilmesi ve pazarlanması süreçleri için küresel standartlara uyum sağlanmalıdır. Özel sektörün karbon piyasasına aktif katılımı, yalnızca kurumsal sorumluluk değil aynı zamanda rekabetçilik açısından da önem taşımaktadır.

Türkiye'nin net sıfır hedeflerine ulaşabilmesi için, tarım, sanayi, enerji ve atık sektörlerinde uygulanan politikaların karbon piyasalarıyla uyumlu hale getirilmesi gereklidir. Ayrıca, NDC hedeflerinin Paris Anlaşması'nın 1.5°C sınırına uygun şekilde revize edilmesi, yatırımcı ve proje geliştiriciler için yön gösterici olacaktır.

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EFFECT OF IRON OXIDE (Fe_3O_4) NANOPARTICLES ON THE ROOTING OF BLACKBERRY (*Rubus fructicosus* L.) CUTTINGS

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ABSTRACT

In recent years, nanoparticles have become a preferred alternative to traditional products in agricultural production due to their compact size, ease of transport, long shelf life, and high efficiency. This has increased the significance of the role of nanoparticles in agriculture for achieving environmental sustainability.

In this study, the effects of Indole-3-butyric acid (IBA) and iron oxide (Fe_3O_4) nanoparticles on shoot growth and rooting parameters of hardwood cuttings of Jumbo blackberry grown at the Agricultural Practice and Research Center of Bilecik Şeyh Edebali University were investigated. Along with the control group, treatments included 4000 ppm IBA, 1 ppm Fe_3O_4, and a combination of 1 ppm Fe_3O_4 + 4000 ppm IBA. The cuttings were planted on rooting benches containing perlite medium with bottom heating (22±2 °C).

After 90 days in the rooting environment, the following parameters were measured: rooting percentage (%), callus formation rate (%), number of roots per cutting, root length (cm), root diameter (mm), and shoot length (cm). At the end of the experiment, it was determined that Fe_3O_4 nanoparticles had a positive effect on rooting. As a result, it is suggested that nanoparticles may be used to enhance rooting in difficult-to-root fruit species, and further research is needed in this area.

Keywords: Iron oxide nanoparticle, rooting, shoot development, propagation, Indole-3-butyric acid (IBA)

DEMİR OKSİT (Fe_3O_4) NANOPARTİKÜLÜNÜN BÖĞÜRTLEN (*Rubus fructicosus* L.) ÇELİKLERİNİN KÖKLENMESİ ÜZERİNE ETKİSİ

ÖZET

Nanopartiküller, kompakt boyutları, kolay taşınabilirlikleri, uzun raf ömürleri ve yüksek verimlilikleri sayesinde son yıllarda tarımsal üretimde geleneksel ürünlere kıyasla daha fazla tercih edilmeye başlanmıştır. Bu durum, sürdürülebilir bir çevre hedefi doğrultusunda tarımda nanopartiküllerin rolüne olan ilgiyi artırmıştır.

Bu çalışmada Bilecik Şeyh Edebali Üniversitesi Tarım Uygulama ve Araştırma Merkezi'nde bulunan Jumbo böğürtlen odun çeliklerinde Indol-3 bütirik asit (IBA) ve demir oksit (Fe_3O_4) nanopartikülünün sürgün büyümesi ve köklenme parametreleri üzerine etkisi incelenmiştir. Kontrol grubu ile birlikte, 4000 ppm IBA, 1 ppm Fe_3O_4 ve 1 ppm Fe_3O_4 +4000 ppm IBA kombinasyon uygulamaları yapılmıştır. Çelikler alttan ısıtmalı (22±2 °C) perlit ortamından oluşan köklendirme masalarına dikilmiştir.

Köklendirme ortamından 90 gün sonra çıkarılan çeliklerde; köklenme oranı (%), kallus oluşum oranı (%), kök sayısı (çelik başına), kök uzunluğu (cm), kök çapı (mm) ve sürgün uzunlukları (cm) belirlenmiştir. Deneme sonunda, köklenme üzerine Fe_3O_4 nanopartikülün olumlu etkisi belirlenmiştir. Sonuç olarak çeliklerin köklenmesi üzerine nanopartiküllerin kullanılabileceği zor köklenen meyve türleri üzerine de daha fazla araştırmaya ihtiyaç duyulabileceği düşünülmektedir.

Anahtar Kelimeler: demir nanopartikülü, köklenme, sürgün, çoğaltım, Indol-3 bütirik asit

1. GİRİŞ

Rosaceae familyasına ait olan *Rubus* cinsi, Asya, Avrupa, Kuzey ve Güney Amerika'daki çeşitli çevre koşullarına adapte olmuş 700'den fazla türü kapsamaktadır. Bu adaptasyon yeteneği, *Rubus*'u tarımsal açıdan önemli bir cins haline getirmiştir (Lee ve ark 2016). *Rubus* cinsi içerisinde yer alan böğürtlen (*Rubus fructicosus*), Kuzey Amerika ve Avrupa'nın ılıman bölgelerinde önemli üretim gerçekleştirilmiştir (Ladyzhenskaya ve ark., 2023; Varzaru ve ark., 2023).

Böğürtlen meyvesi, taze olarak tüketiminin yanında reçel, jöle, şarap, çay, dondurma ve tatlı gibi çeşitli ürünlere işlenebildiği için yüksek ticari değere sahiptir (Kaume ve ark., 2011). Meyvelere ek olarak, bitkinin diğer kısımlarından da yararlanılmaktadır. Genç sürgünler sıklıkla salatalarda tüketilmekte ve kökler yiyecek olarak pişirilmektedir. Bu durum böğürtlenlerin hem kültürel önemini hem de besin potansiyelini vurgulamaktadır. Bunun yanında böğürtlenler, esas olarak yüksek antioksidan kapasitelerinden sorumlu olan antosiyaninler, flavonoidler ve ellagitanninler dahil olmak üzere fenolik bileşikler açısından özellikle zengindir (Kaume ve ark., 2011).

Böğürtlenler birçok vejetatif çoğaltma yöntemi ile çoğaltılmaktadır. Böğürtlen genellikle yaz aylarında yaprak tomurcuğu çeliklerinden ve yaz sonlarında uç katmanlar primocanes'lerinden çoğaltılır (Hartmann ve ark., 2011; Takeda ve Soria, 2011). Böğürtlen çeliklerinde köklenme başlangıcı, kullanılan yöntemlere (çelik materyali, toplama zamanı ve oksin uygulaması) göre de değişmektedir. Bunun yanında böğürtlen çeliklerinin köklenmesini iyileştirme amacıyla İndol-3-bütirik asit (IBA) uygulamasının böğürtlen çeliklerinde köklenmeyi iyileştirdiği gösterilmiştir, ancak bazı araştırmalar farklı çeşitler arasında sonuçların tutarsız olabileceğini göstermektedir (Takeda ve ark., 2011; Debner ve ark., 2019).

Tarımda yenilikçi nanoteknoloji uygulaması, ürün veriminde önemli artışlar elde etmek için umut verici yaklaşımlardan biri olarak kabul edilmektedir (Liu ve ark., 2015; Farooqui ve ark., 2016). Çeşitli tipteki nanopartiküllerin (NP) bitki büyümesi ve gelişimi üzerindeki etkileri üzerine yapılan birçok çalışma mevcuttur (Huang ve ark., 2015; Farooqui ve ark., 2016; Siddiqi ve ark., 2016). Bu çalışmalar, NP'lerin tohum çimlenmesi, fotosentetik aktivite, proteinler de dahil olmak üzere çeşitli metabolitlerin sentezi ve azot içeren metabolitler dahil olmak üzere farklı fizyolojik süreçleri geliştirerek ürün verimini artırabileceğini göstermektedir (Huang ve ark., 2015; Rui ve ark., 2016). Çelikle köklenme çalışmalarında literatürde nanopartikül uygulamasına rastlanmamıştır. Bu nedenle, bu çalışmada Jumbo böğürtlen çeşidinin köklenme üzerine IBA ile demir oksit nanopartikülünün karşılaştırılması amaçlanmıştır.

2. MATERYAL VE METOT

Çalışma Bilecik Şeyh Edebali Üniversitesi Tarımsal Uygulama ve Araştırma Merkezinde yüksek tünel içerisinde yer alan köklendirme sisteminde yürütülmüştür. Kullanılan materyal araştırma merkezinde bulunan Jumbo böğürtlen çeşidinden elde edilmiştir. Jumbo böğürtlen çeşiti, kesin orijini bilinmemekle birlikte 1920 yılından bu yana Amerika'da yetiştiriciliği yapılmakta olup, ülkemizde yapılan adaptasyon çalışmalarında iyi sonuçlar verdiği bilinmektedir (Akbulut ve ark., 2003; Cangi ve İslam, 2003; Gerçekcioğlu ve ark., 2003). Çalışmada kullanılan Fe_3O_4 NP kaynağı olarak, Sigma firmasına ait (cas: 1317-61-9) taramalı

elektron mikroskobu (sem) cihazı ile partikül boyutu belirlenmiş (50-100 nm) ticari ürün kullanılmıştır. Bu çalışmada kullanılan IBA dozu, Edizer (2011) tarafından en uygun doz olarak bildirilen 4000 ppm düzeyinde uygulanmıştır.

Çalışmada 1 yaşlı dallardan kesilen 15-20 cm'lik böğürtlen odun çeliklerine %0.3 fungisit (Benlate) püskürtülerek, yaklaşık on dakika kurumaya bırakılmıştır. Aşağıda verilen uygulamalara çelikler 5 sn hızlı bandırma işlemine bırakıldıktan sonra köklendirme ünitesine dikilmiştir.

- **U1**: Kontrol
- **U2**: 4000 ppm IBA
- **U3**: 1 ppm Fe_3O_4
- **U4**: 4000 ppm IBA + 1 ppm Fe_3O_4

Böğürtlen çelikleri perlit içeren köklendirme masalarında 90 gün süreyle tutulmuştur. Çalışmanın tamamlanmasının ardından çelikler çıkarılarak; köklenme oranı (%), kallus oluşum oranı (%), kök sayısı (çelik başına), kök uzunluğu (cm), kök kalınlığı (mm), sürgün uzunluğu (cm) belirlenmiştir. Deneme, 3 tekerrürlü, tesadüf parselleri deneme desenine göre yürütülmüş olup, her tekrarlamada 15 adet çelik kullanılmıştır. Varyans analizinin ardından, uygulamalarının ortalamaları Duncan Çoklu Aralık Testi (DMRT), SPSS 23.0 yazılımı kullanılarak $p < 0,05$ düzeyindeki ortalama değerleri karşılaştırmak için kullanıldı.

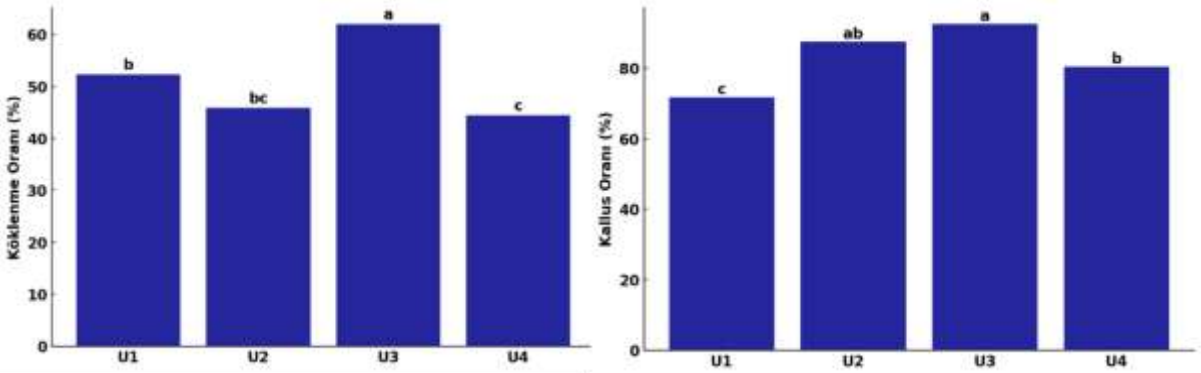
3. BULGULAR VE TARTIŞMA

Deneme sonucunda elde edilen veriler değerlendirdiğinde, böğürtlen çeliklerinde kök çapı hariç diğer özelliklerde istatistiksel olarak önemli farklılıklar tespit edilmiştir. En yüksek köklenme oranı %62 ile 1 ppm Fe_3O_4 uygulamasından elde edilmiştir. Demir, fotosentez, solunum ve azot fiksasyonu gibi çeşitli bitki fizyolojik süreçlerinde görev alan ve kök oluşumu ile kök sağlığını etkileyen temel bir mikro besin elementi olarak önemli bir rol oynamaktadır (Rui ve ark., 2016; Hat ve ark., 2021). Nanopartikül olarak uygulanan Fe_3O_4 fitohormon aktivitesini teşvik ederek bazı türlerde kök uzunluğunu ve genel bitki biyokütlesini artırabileceği düşünülmektedir. Hat ve ark. (2021), düşük konsantrasyonlarda demir oksit nanopartiküllerinin baklagillerde kök kılı gelişiminin artmasına ve daha iyi besin alımına yol açtığını ve kök büyümesine olumlu katkıda bulunduğunu göstermiştir. Bu durum da besin alımı için etkili yüzey alanını artırarak, köklerdeki metabolik aktiviteyi geliştirerek ve muhtemelen oksinler gibi kök gelişimini düzenleyen bitki hormonlarıyla etkileşime girerek böğürtlen çeliklerinde köklenmeyi uyarabileceğini düşündürmektedir (Overvoorde ve ark., 2010).

Kallus oranı bakımından en yüksek oran sırasıyla Fe_30_4 (%92.5) ve IBA (%87.5) uygulamasından elde edilmiştir (Şekil 1). Nanopartiküller bitki büyümesini artırmakta, kallus oluşumunu ve bitki rejenerasyonu için daha elverişli bir ortam sağladığını göstermiştir (Moradiasl ve ark.,2025). Fe_3O_4 nanopartikülleri potansiyel olarak temel mikro besinleri serbest bırakarak, gelişmiş kallus büyümesine yol açan metabolik yolları uyardığı bilinmektedir (Rui ve ark., 2016). Chang ve ark. (2023), tarafından yapılan bir çalışmada, kesim yüzeylerinin

kallus oluşumu da dahil olmak üzere rejeneratif yetenekleri önemli ölçüde artırabileceğini göstermektedir. Bu durum bizim çalışmamızdaki bulgularla uyumludur.

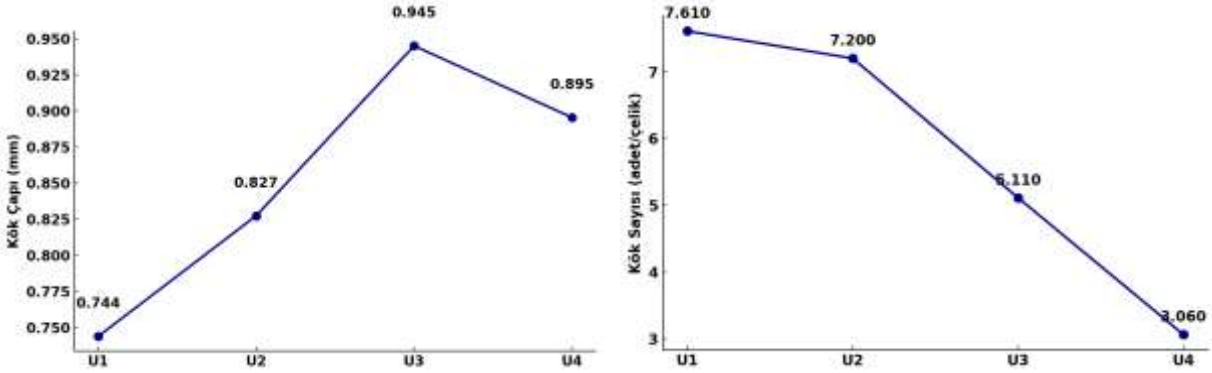
Şekil 1. Demir Oksit Nanopartikülünün Böğürtlen (*Rubus Fructicosus* L.) çeliklerinin köklenme oranı (%) ve kallus oranı (%) üzerine etkisi



Demir oksit nanopartikülünün böğürtlen çeliklerinin kök çapı üzerine etkisi istatistiki olarak önemsiz bulunmuştur. Kök çap değerlerinin 0.74 mm-0.94 mm arasında değiştiği belirlenmiştir (Şekil 2). Kök çap değerleri üzerine demir nanopartiküllerinin etkisi sınırlı olarak görülse de bu sonuç nanopartikül ile bitki fizyolojisi arasındaki hem yararlı hem de zararlı etkileri kapsayan çok yönlü etkileşimlerin daha derinlemesine araştırılmasını gerektirmektedir. Demir oksit nanopartiküllerinin özellikle besin alımını kolaylaştırarak ve bitkilerde oksidatif stresi azaltarak kök gelişimini destekleyebileceğini öne sürmektedir (Saeedi ve ark., 2016; Oijagbe ve ark., 2021).

Çalışma sonucunda, kök sayısı bakımından en yüksek sayıya 7.6 adet/çelik ile kontrol grubundan ve 7.2 adet/çelik ile 4000 ppm IBA uygulamasında belirlenmiştir. Kök sayısı, bitki çoğaltımında büyüme artırma etkinliğini değerlendirmede önemli bir ölçüt olarak bilinmektedir. Çeşitli türlerin IBA'ya farklı tepkiler göstermesine rağmen, daha yüksek konsantrasyonların daha iyi köklenme sonuçlarıyla ilişkili olmadığını vurgulamaktadır. Shabala ve ark. (2010), aşırı oksin konsantrasyonlarının potansiyel toksisiteye veya stres tepkilerinin ortaya çıkmasının kök büyümesi inhibisyonuna yol açabileceğini bildirmiştir. Buna karşılık, 1 ppm Fe_3O_4 ve 4000 ppm IBA içeren ve çelik başına ortalama 5.4 ile en düşük kök sayısını veren kombinasyon uygulaması, demir oksit nanopartikülleri ile yüksek IBA seviyeleri arasındaki etkileşimlerin olumsuz bir şekilde etkilendiğini göstermektedir. Gözlemlenen zararlı etkinin birçok faktörden kaynaklanıyor olabileceği düşünülmektedir.

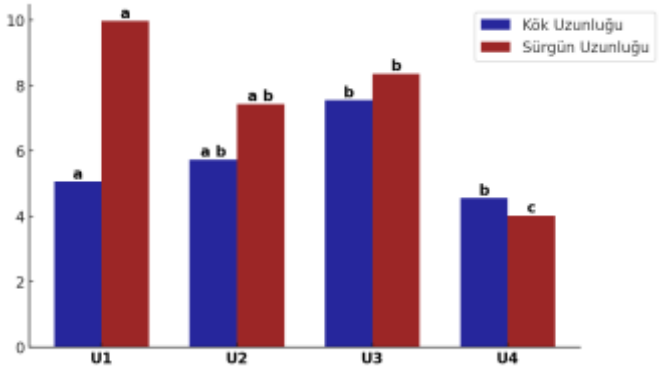
Şekil 2. Demir oksit nanopartikülünün böğürtlen (*Rubus Fructicosus* L.) çeliklerinin kök çapları (mm) ve kallus oranı (%) üzerine etkisi



Şekil 3'de verilen kök uzunlukları istatistiki olarak önemli bulunmuştur. En uzun kök uzunluğuna 1 ppm Fe_3O_4 (7.55 cm) ve 4000 ppm IBA (5.73 cm) uygulamasından elde edilmiştir. Bu sonuçlar hem demir nanopartiküllerinin hem de büyüme düzenleyicilerinin uygulanmasının bitki kök gelişimini sinerjik olarak iyileştirebileceğini öne süren artan kanıtlarla uyumludur. 1 ppm gibi düşük konsantrasyonlarda demir oksit nanopartiküllerinin çeşitli bitki türlerinde olumlu fizyolojik tepkiler uyandırdığı gösterilmiştir. Win ve ark. (2021), Fe_3O_4 nanopartiküllerinin uygulanmasının bitki büyümesini uyarabileceğini ve hem büyüme iyileştirebileceğini göstermiştir. Aynı şekilde, IBA uygulamasının köklenmeyi desteklemede genellikle köklenme üzerine olumlu sonuçlar verdiği belirlenmiştir (Rautela ve ark., 2018).

Çalışma sonuçlarımıza göre en yüksek sürgün uzunluğuna kontrol (9.97 cm) ile 1 ppm Fe_3O_4 (8.35 cm) uygulamalarından elde edilmiştir. Demir nanopartiküllerinin bitkiler üzerindeki etkisi, besin emilimi ve iyileştirilmiş bitki morfolojisi gibi büyümeyi teşvik etme konusunda faydaları olmasına rağmen, nanopartiküllerin her zaman tüm büyüme parametreleri için optimum sonuç veremeyeceği bilinmektedir. Podlasova ve Лебедев (2022), buğday üzerine uygulanan nanopartikül uygulamasının artan büyüme gösterdiği ancak 1 ppm gibi daha düşük konsantrasyonların tek uygulamalarındaki etkileşim etkileri tam olarak bilinmemektedir. Nanopartikül konsantrasyonlarının etkilere göre değiştiği ilgili çalışmalarda görüldüğü gibi, demirin bitki sistemine entegre edilmesi için optimum bir konsantrasyon olmayabileceğini göstermektedir (Raiesi-Ardali ve ark., 2022). Bu nedenle her bitki türüne hatta çeşidine göre konstrasyonu miktarları değişmekle birlikte bundan sonraki çalışmalarda önerilmektedir.

Şekil 3. Demir oksit nanopartikülünün böğürtlen çeliklerinin kök uzunluğu (cm) ve sürgün uzunluğu (cm) üzerine etkisi



4. SONUÇ

Nanopartiküller tarım her alanında kullanılarak bitki üzerine birçok fayda sağlamaktadır. Çalışma, demir nanopartikülünün odun çeliklerin köklenmesi için kullanılabileceğini göstermektedir. Köklenme üzerine bir avantaj tespit edilmiştir. Nanopartikül türüne, bitki türü hatta çeşidine göre değiştiği düşünülmektedir. Bu nedenle her çeşit için ayrı araştırmalar ve nanopartiküller için ayrı araştırmalar gerekmektedir.

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EFFECTS OF FUEL SUBSIDY REMOVAL ON PRICE TREND OF STAPLE FOOD CROPS IN KADUNA MUNICIPAL, NIGERIA

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ABSTRACT

Fuel in Nigeria is an inelastic product both at the demand and supply sides. Therefore, it is challenging for consumers to find substitutes daily. The focus of this study was to examine the effects of fuel subsidy removal on the price trend of major staple food crops in Kaduna Municipal, Nigeria. Primary data was collected from 90 respondents with structured questionnaires and interview schedules in the 2023 market survey. The T-test results show a significant difference between the prices of rice, sorghum and maize before and after fuel subsidy removal. The coefficient of distance to purchase food commodity (2.110), statistically significant at 1% level of probability. This indicates that a unit increase in distance will lead to a ₦2.11 increase in the cost of transportation. The results indicate that the price trend of three staple food crops from 2019 to 2023 has been fluctuating but tilting more towards a persistent increase. The upsurge in prices of staple food items during these periods has been linked majorly to fuel subsidy removal, which culminates in an increase in farm inputs as seeds, fertilizer and herbicides. Findings also show that insecurity, import bans, intervention of speculators, and institutional investors in the commodity markets have also been brought into play to explain the recent behaviour of commodity prices' fluctuations. The results established that the cost of food items is greatly affected by the cost of transportation and the distance covered in purchasing the produce. The government should give more attention to refining its petroleum products locally and invest in building new refineries.

Keywords: Staple food crop, fuel, subsidy, transportation, refinery.

Introduction

The removal of fuel subsidies has been a longstanding and contentious issue in Nigeria, given the country's heavy reliance on petroleum products for both revenue generation and meeting domestic fuel demands. Fuel prices in Nigeria, as an essential input across sectors, are intricately linked to transport costs, which, in turn, have far-reaching implications for the cost structure of goods and services (Meludu *et al.*, 2023). As such, changes in fuel pricing have a significant impact on broader economic indicators, particularly in developing economies, where fuel is inelastic in both demand and supply. In Nigeria, fuel is indispensable for daily life and economic activities such as transportation and electrification or power provision, making any alterations to the fuel subsidy policy particularly sensitive (Abdulkadir *et al.*, 2023).

The Nigerian government's decision to remove the fuel subsidy in May 2023 under President Bola Ahmed Tinubu marked a pivotal moment in the nation's economic policy. Historically, fuel subsidies have been implemented to alleviate the burden of fuel costs on ordinary citizens (Ani *et al.* 2021), but such subsidies have come at a significant fiscal cost. Between 2011 and 2020, fuel subsidy spending accounted for nearly 30% of government expenditure, diverting resources from critical sectors such as education, health, and infrastructure (Umeji *et al*., 2021). The International Monetary Fund (IMF) and other international institutions have long advocated for the removal of fuel subsidies, citing inefficiencies in resource allocation, price distortions, and corruption risks that stem from the subsidized system (Okwanya, Ogbu, & Pristine, 2015). Despite these critiques, fuel subsidies have remained a vital mechanism for maintaining socio-economic stability, particularly in the face of Nigeria's rising population and the country's heavy dependence on oil.

In May 2023, with the removal of the subsidy, the Nigerian government implemented a substantial increase in fuel prices, moving from ₦240 to ₦960 per liter to correct the long-standing market distortions and promote economic reform. This policy shift was met with widespread protests and criticism as Nigerians feared the potential adverse effects on living costs, particularly for essential items like food. Given that transport costs play a crucial role in determining the prices of goods, including agricultural products, the rise in fuel prices was expected to exacerbate the cost of living and further strain food security, particularly in impoverished regions of the country (Houeland, 2021).

This study seeks to examine the immediate effects of fuel subsidy removal on food prices, specifically focusing on three staple agricultural products, viz., maize, sorghum, and rice, in Zaria, Nigeria. Zaria, located in the northern region of Nigeria, is a key commercial and agricultural hub, making it an ideal location to investigate the broader implications of fuel price changes on the food supply chain. The research will analyze the price trends of these food items before and after the subsidy removal, with a particular emphasis on the socio-economic impact on both producers and consumers in the region.

Understanding the multifaceted effects of fuel subsidy removal on food prices is critical for policymakers, businesses, and consumers alike. While the government argues that the removal of the subsidy will enhance long-term economic growth, reduce fuel smuggling, and eliminate

market inefficiencies, the immediate effects on food prices and the living standards of vulnerable populations must not be overlooked. By investigating these dynamics, this study aims to contribute valuable insights into the socio-economic consequences of subsidy removal and provide evidence to guide future policy decisions in Nigeria and similar economies.

RESEARCH METHODOLOGY

Description of the Study Area

This study was conducted in the Sabon Gari Local Government Area (LGA) of Kaduna State, Nigeria. Sabon Gari LGA is situated in the northern plains of the state, geographically located between latitude 11°7'25" N and longitude 7°43'52" E (NPC, 2022). With an estimated population of approximately 200,000 people, the area is predominantly rural, although it contains several towns and villages. Sabon Gari is widely recognized for its vibrant economic activities, particularly in trade and commerce. The LGA serves as a key commercial hub within Kaduna State, attracting merchants, traders, and business owners from both local and regional areas. The area is characterized by its bustling markets, where a diverse range of food items are bought and sold, making it an important center for food trade.

Given its status as a commercial epicenter, Sabon Gari is an ideal location to examine the effects of fuel subsidy removal. The region is heavily influenced by changes in fuel prices, which significantly impact transportation costs and the logistical aspects of food distribution. As transportation costs increase or decrease, they directly affect the pricing and availability of food in the local markets. Additionally, Sabon Gari is home to a substantial number of fuel retailers whose operations are also impacted by fuel price fluctuations, providing a unique opportunity to explore the broader economic implications of the fuel subsidy removal policy in the region. The proximity of Sabon Gari to major trade routes and its central role in local commerce makes it a critical area for studying the cascading effects of fuel price changes on local economies, particularly in terms of food pricing, market dynamics, and the livelihoods of traders and consumers alike.

Sampling and sample size determination

A purposive sampling technique was adopted in selecting the markets based on the predominance of grain marketers in the Samaru market, Sabon Gari market, Tudun Wada market, and Dan – Magaji markets, respectively. The second stage involves the random selection of grain marketers from the list of marketers drawn from the sample frame of 117. The third stage involves the selection of 90 respondents as the sample size using Slovin's formula adopted by Umar (2021.

$$n = \frac{N}{1 + N\,(e)^2} \qquad (1)$$

Table 1: Population and Sample size of marketers

LGA	Selected Market	Sample Frame	Sample Size

Sabon Gari	Samaru	36	30
	Sabon Gari	29	25
	Tudun Wada	24	15
	Dan Magaji	28	20
Total	**4**	**117**	**90**

Source: Kaduna state ADP

Method of Data Collection

The data was obtained from primary sources only. The primary data were collected with the aid of well-structured questionnaires administered to the respondents. Data were collected based on the socio–economic variables such as gender, age, trading experiences, educational status, household size and income level of the respondents. Also, data were collected for the prices of food crops before and after the subsidy removal.

Analytical Techniques

The tools that were used for the study are: Descriptive statistics, Regression, T-Test and E-View.

Descriptive Statistics

Descriptive statistics was used, which involves the use of percentages, means and frequency distributions to describe the socio-economic characteristics of the respondents in the area.

Multiple Regression Model

Multiple regression is a statistical analysis that uses several explanatory variables to predict the outcome of a response variable. It compares the relationship of two or more factors or trends to determine the correlation between the variables. The relationship between transportation, distance and prices of food was analyzed using the regression model. This study used the multiple regression model to determine the relationship between the dependent and independent variables, which estimates the extent to which food prices are affected by transportation and distance.

To examine the effect of subsidy removal on selected food item prices in the study area, the Cobb Douglas production function was used. This function can be expressed in a logarithm form as

$$LogY = Loga + b1Logx1 + b2Logx2 + b3Logx3 + b4Logx4 + Log\ U \ldots\ldots (2)$$

Where

Y= Output (Cost of transportation before the subsidy removal)

b_1= Price of Rice, b_2= Price of Sorghum, b_3= Price of Maize, b_4= Distance from the point of purchase to the market, U= Random Error term

This function can further be expressed below

$$l_n\gamma = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \vartheta i - \mu i \quad (3)$$

T-Test (two samples assuming unequal variance)

A T-test is a statistical test that is used to compare the means of two groups. It is often used in hypothesis testing to determine whether a process or treatment affects the population of interest or whether two groups are different from one another. This was used to analyse the impact of subsidy removal on the price of maize, sorghum and rice.

E-View

EViews is a software used to analyse the price trends in selected food prices before and after the subsidy removal for over five years.

RESULT AND DISCUSSION

Socio-Economic Characteristics of Food Traders

Age of Traders

Analysis of the age distribution of the traders in the study area is presented in Table 2. Age of food marketers could, to a certain degree, affect their marketing ability as it involves interaction with different classes of actors in and outside markets. The result revealed that the mean age of the traders involved in trading in the study area was 37. The result further revealed that most of the traders were between the ages of 31 and 40 years, representing 47.8%. This implies that they are economically active and are in their prime stage, young and agile with enough vigor and innovative ideas to pursue the marketing activities. Ogeto, Cheruiyot, Mshenga, and Onyari (2013) opined that the active ages of 30-39 years are more active in life in terms of enterprise development and management, which may have a positive influence.

Distribution of Traders based on gender

The distribution of the traders in respect of gender revealed that 94.4% of males were involved in trading. The results indicated that only 5.6% of the traders involved in food trading were females. Additionally, outdoor marketing is tedious and involves mingling with males of different backgrounds and characters, a situation that is seen as strange in Northern Nigeria due to religious and socio-cultural settings. This corroborates the statement of Olagunju *et al*. (2020) that the religious beliefs and cultural background of the people in northern Nigeria restrict women from participating in some economic activities.

Marital Status of the Traders

Analysis of the marital status of the traders in the study area revealed that 97.8% were married, while only 1.1 single and 1.1 widowed were involved in trading in the study area. Being married increases the socio-economic responsibility of traders, which could improve their decision-making abilities. (Abdulaziz *et al*., 2018), Stated that marital responsibility could make farmers/traders make more rational decisions with high accuracy on their own, which could, in turn, increase their efficiency.

Household size of the Traders

The size of the household of the traders shows that 7.8% of the traders had less than 5 members per household, while 75.6% of the traders had between 5-10 members per household. The average household size of the traders was 7.4. This result shows that most traders in the study area have relatively large households. This is in line with the findings of Ichsan *et al.* (2022 and Christopher *et al. (*2021), who reported that the average household size of marketers in northern Nigeria is 7, which implies that the marketers may utilize members of the household as labour for some activities relating to marketing. This may reduce some transaction costs that may be incurred, thereby increasing the net income of the marketers.

Table 2: Socio-Economic Characteristics of Food Traders

Variables	Frequency	Percentage	Mean
Age			
21-30 years	3	3.3	37
31-40 years	43	47.8	
41-50 years	36	40	
>50 years	8	8.9	
Total	**90**	**100**	
Gender			
Male	85	94.4	
Female	5	5.6	
Marital status			
Married	88	97.8	
Single	1	1.1	
Widowed	1	1.1	
Household size			
0-4	7	7.8	7.5
5-9	68	75.6	
10-15	15	16.7	
Educational Qualification			
No Formal Education	3	3.3	
Primary Education	6	6.7	
Secondary Education	67	74.4	

Tertiary Education	14	15.6
Trading Experience		
1-5	3	3.3
6-10	62	68.9
11-15	20	22.2
16-20	5	5.6
Source of Shop		
Rent	62	68.9
Inheritance	20	22.2
Purchased	8	8.9
Income Distribution		
15,000 – 25,000	1	1.1
25,000 – 35,000	1	1.1
35,000 – 45,000	43	47.8
45,000 – 55,000	34	37.8
55,000 & above	11	12.2
Total	**90**	**100**

Source: Field Survey, 2023

Educational Status of the Traders

The distribution of food traders according to educational attainment is presented in Table 2. The result revealed that 15.6% of the traders in the study area attained at least a tertiary level of education while 74.4% attained SSCE (Senior Secondary School Certificate Examination). Education is very important in every human endeavor as an avenue through which technology is conveyed. Marketers with formal education have a greater ability to adopt innovations, ideas, information and marketing strategies to increase the volume of sales. It is expected that the level of education will significantly influence the decision-making of marketers. Furthermore, Fikire *et al. (*2022 and Esiobu *et al. (*2014) opined that exposure to high levels of education is an added advantage in terms of achieving a higher volume of sales, huge profit and efficient marketing.

Trading Experience of the Traders

The distribution of the years of trading by the traders showed that 3.3% of the traders had 1-5 years' experience while 68.9% of the traders had 6-10 years' experience. This finding implies that the traders in the study area were experienced. Years of experience have a profound influence on managerial ability and decision-making in the marketing of agricultural commodities. (Christopher *et al.*, 2021). opined that long years of involvement in marketing expose the marketers to marketing ideas that will help them to overcome marketing intricacies.

Method of Shop Acquisition

The results of the distribution of traders according to the source of shop acquisition show that about 68.9% of the traders in the study area acquired their shop through rent, 22.2% obtained

theirs through inheritance, and 8.9% purchased theirs. This indicates that the predominant source of shop acquisition in the study area is Lease.

Income Distribution

Analysis of the income distribution of the traders in the study area revealed that 47.8% gain below N45, 000 monthly while 37.8% gain above 45, 000 monthly. According to economic theory, the level of consumption of an individual depends largely on his level of current income, as propounded by Keynes. This is in line with Abdulkadir Baba Mohammed *et al. (*2020), who opined that the higher the individual's level of income, the higher his consumption level.

Impact of subsidy removal on prices of maize, sorghum and rice from 2019-2023.

The result of the T-test in table 3.1, 3.2, 3.3, 3.4 and 3.5 shows a significant difference between the prices of Rice, Sorghum and Maize. The mean prices of Rice, Sorghum and Maize after the subsidy removal are 90255.5, 53855.5, 53966.6 which are higher than the mean prices between 2019 to 2022, (34677.7, 9794.4, 9961.1), (40688.8, 12644.4, 12822.2), (48555.5, 15766.6, 15911.1), (58388.8, 21444.4, 21844.4)}, which implies that after the subsidy removal, we realized higher increase in prices of Rice, Sorghum and Maize and it is significant at 10% level of probability. This implies that there is a significant difference between the prices of rice, sorghum and maize after the subsidy removal. This suggests that subsidy removal contributes to the high price of Rice, Sorghum and Maize, as affirmed by Omotosho (2020).

Table 3.1: T-test Analysis revealing the effect of subsidy removal on selected food item prices in 2019.

Crop	Mean	Variance	T-stat
Rice	34677.7	8243320.8	1.975
Sorghum	9794.4	3617384.5	1.973
Maize	9961.1	3372066.1	1.973

Table 3.2: T-test Analysis revealing the effect of subsidy removal on selected food item prices in 2020.

Crop	Mean	Variance	T-stat
Rice	40688.8	10733583.0	1.973
Sorghum	12644.4	2748564.2	1.973
Maize	12822.2	2574781.5	1.973

Table 3.3: T-test Analysis revealing the effect of subsidy removal on selected food item prices in 2021.

Crop	Mean	Variance	T-stat
Rice	48555.5	7732833.9	1.977
Sorghum	15766.6	2119101.1	1.973
Maize	15911.1	2025717.8	1.973

Table 3.4: T-test Analysis revealing the effect of subsidy removal on selected food item prices in 2022.

Crop	Mean	Variance	T-stat
Rice	58388.8	11341448.1	1.981
Sorghum	21444.4	1283395.7	1.973
Maize	21844.4	1756429.4	1.973

Table 3.5: T-test Analysis revealing the effect of subsidy removal on selected food item prices in 2023.

Crop	Mean	Variance	T-stat
Rice	90255.5	27967665.4	1.980
Sorghum	53855.5	4754182.2	1.973
Maize	53966.6	4437078.6	1.973

Computed from field survey data 2019, 2021, 2022 and 2023

Effects of subsidy removal on food items

A Multiple A regression model was used to analyze the effect of subsidy removal on food items. Table 4 shows the effect of subsidy removal on prices of rice, sorghum and maize. The result of the regression in the table reveals an F-Value of 22.39322, which is highly significant, indicating that the model is well-fitted for the regression. The R-square was 0.513097304, which indicates that about 50% variation of the dependent variable is explained by the independent variable. From the result, out of four variables, only one variable was found to be significant at a 1% level of significance. The variable is the distance.

The model result indicated that distance had a positive coefficient of 2.109853 and was significant at a 10% level of significance. This indicates that a unit increase in distance will lead to a 2.109853 increase in the cost of transportation. This conforms with a priori expectation because an increase in distance will lead to an increase in the cost of transportation. This is because of the subsidy removal, which led to an increase in the price of fuel, which is the main source of transportation, as confirmed by Raji *et al.* (2018).

Table 4: Regression analysis revealing the effect of subsidy removal on prices of rice, sorghum and maize.

Variable	Coefficient	Standard error	T-Value

Constant	-40.0924	24.01646	-1.66937
Rice	1.31803	1.210252	1.089054
Sorghum	3.824598	8.82926	0.433173
Maize	-1.46268	9.14924	-0.15987
Distance	2.109853*	0.225847	9.341947***

Adjusted R square 0.490184235

R Square 0.513097304

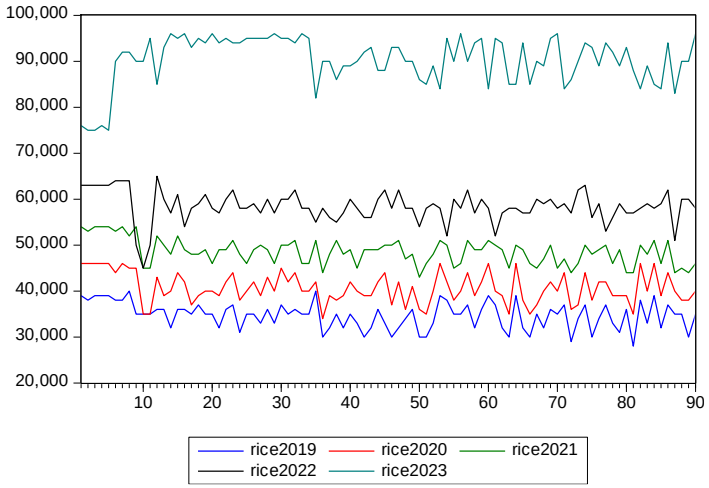
F Value 22.39322

Source: Computed from field survey data, 2023

Price Trends of Selected Food Prices

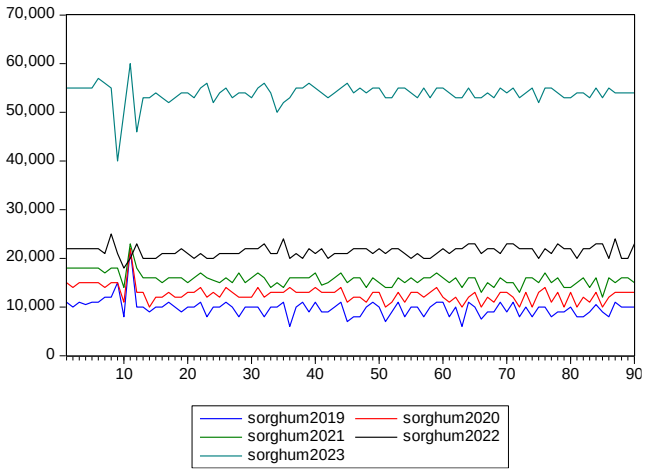
The graphs in figure 1 show the price trend of Rice, Sorghum and Maize from 2019 to 2023. From the graph below, it was observed that an upsurge in prices occurred from the beginning of 2022 to 2023. However, between 2019 and 2022, the index showed a persistent decline. The upsurge in the price of food items between 2022 and 2023 has been linked to some economic forces such as an increase in farm inputs as seeds, fertilizer and herbicides. The world has now entered a period of sustained high prices, particularly in the case of food. However, apart from economic dynamics, the geopolitical stress, intervention of speculators, hedged funds and institutional investors in the commodity markets, the behavior of monetary policy and the weakness of dollar have also been brought into play to explain the recent behavior of commodity prices (Ocampo and Parra, 2008).

Fig 1 Price Trend of Rice from 2019 – 2023



The graph in Fig 2 shows the price trend of Rice from 2019 to 2023. In 2019, the price of rice was relatively stable, and then there was an increase and decline in price. And a continuous rise and fall, i.e. fluctuation in prices. In 2020, the price was stable, and then there was a decline in the price followed by an increase and a continuous rise and fall in the price. The main cause of disparity in prices between 2022 and 2023 was linked to the fuel subsidy removal, which led to an increase in the cost of transportation of the rice from the farm to the market. Other factors include rising insecurity in the country, import bans, and activities of speculative middlemen who take advantage of price fluctuations in the market by hoarding the rice during the on-season when there is availability and bringing them out when market is scarce at high prices Soile, Tsaku, & Musa-Yar'Adua, 2014).

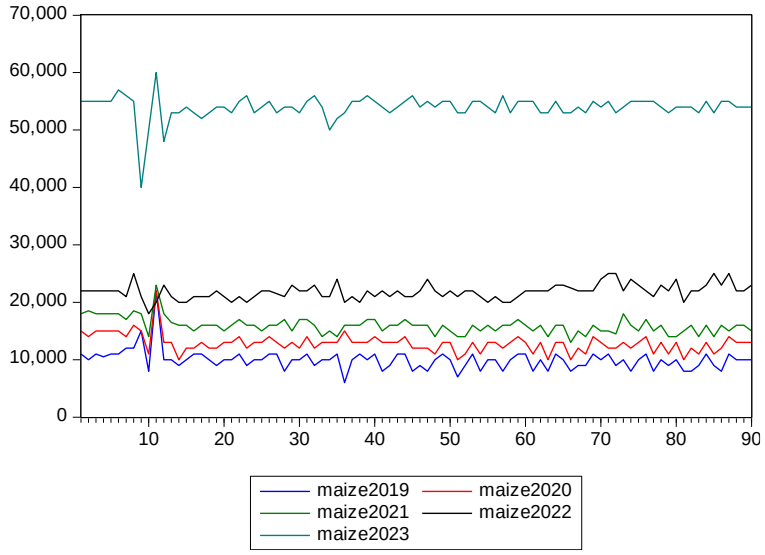
Fig 2 Price Trend of Sorghum from 2019 – 2020



The graph in Fig 3 shows the price trend of Sorghum from 2019 to 2023. Between 2019 and 2022, the price of sorghum was relatively stable with consistent rise and fall, i.e. fluctuation in prices. The main cause of disparity in prices between 2022 and 2023 was linked to the fuel subsidy removal, which led to an increase in the cost of transportation of the sorghum from the

farm to the market. Other factors include weather conditions and natural disasters such as floods, Scarcity of rainfall, and higher increases in demand for the crop.

Fig 3 Price trend of Maize from 2019 - 2023



The above graph shows the price trend of maize from 2019 to 2023. Between 2019 and 2022, the price of sorghum was relatively stable with consistent rise and fall, i.e. fluctuation in prices. The main cause of disparity in prices between 2022 and 2023 was linked to the fuel subsidy removal, which led to an increase in the cost of transportation of the maize from the farm to the market. Other factors include the cost of inputs used in production such as seeds, fertilizers and labour.

Conclusion

From the findings of the study, it was concluded that the cost of food items is highly affected by the cost of transportation, which is also affected by the distance covered. The major factor that led to the increase in food price is as a result of the fuel subsidy removal which led to the increase in fuel price which is the main source of transportation. Other factors include rising insecurity in the country, import bans, and activities of speculative middlemen who take advantage of price fluctuations in the market by hoarding commodities during the on-season when there is availability and bringing them out when market is scarce at high prices.

Recommendations

Efforts to curtail extreme spikes in the price of cereals can substantially enhance food security and the overall economic welfare of households. If policy actions which curtail excessive increases in fuel prices are complemented with food distribution and sensitively guided welfare-related gender interventions, more improvements for livelihoods can be achieved. Effectiveness of complementary efforts can be enhanced through proper appraisal of local context and by investing in sectors by supplying farm inputs where the poor benefits the most, and by proper identification of socially deserving people in order to better allocate resources for poverty alleviation, food insecurity and/or malnutrition reduction programs.

i. It is recommended that government give more attention on refining her petroleum here in Nigeria by fixing her refineries and possibly build new ones and also deregulate the downstream sector of the petroleum industry.
ii. Traders should form a cooperative union where they can pick representatives to purchase the goods from the markets to reduce the cost of transportation.
iii. Traders should purchase goods from nearby markets as distance also affects the cost of transportation which in turn affects the prices of food.
iv. Revitalize the railway system to enable the transportation of agricultural commodities across the country.

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EVALUATION OF DEVELOPMENT TREND OF BREEDING ACTIVITIES: THE CASE OF KIRŞEHİR PROVINCE

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ABSTRACT

Cattle breeding, which is carried out by small and medium-sized family farms in rural areas of Turkiye, makes a significant contribution to economic growth and employment. Kırşehir province is one of the regions that stands out in this respect and where cattle breeding is practiced intensively. In Kırşehir, one of the most important centres of agriculture and livestock farming in Central Anatolia, livestock farming is one of the most important sources of income for the rural population. The aim of the study is to evaluate the sustainability level and development potentials of livestock farms in Kırşehir province and to propose solutions for local agricultural policies and animal husbandry strategies. The data obtained will be analyzed to show the impact of socio-economic factors on business performance. It is expected that this data will enable concrete proposals for the development of the agricultural and livestock sector in the region.

Keywords: Livestock Policies, Beef Cattle Farming, Kırşehir Province, Türkiye.

BESİ SIĞIRCILIĞI FAALİYETLERİNİN GELİŞİM TRENDİNİN DEĞERLENDİRİLMESİ: KIRŞEHİR İLİ ÖRNEĞİ

ÖZET

Türkiye'nin kırsal bölgelerinde küçük ve orta ölçekli aile işletmeleri tarafından gerçekleştirilen besi sığırcılığı, ekonomik büyüme ve istihdam açısından önemli katkılar sağlamaktadır. Kırşehir ili, bu açıdan öne çıkan ve hayvancılığın yoğun olarak yapıldığı bölgelerden biridir. Orta Anadolu'nun önemli tarım ve hayvancılık merkezlerinden biri olan Kırşehir'de, besi sığırcılığı, kırsal nüfus için temel geçim kaynaklarından biridir. Çalışmanın kapsamı, Kırşehir ilindeki besi sığırcılığı işletmelerinin sürdürülebilirlik düzeylerini ve kalkınma potansiyellerini değerlendirerek, yerel tarım politikaları ve hayvancılık stratejileri için çözüm önerileri sunmaktır. Elde edilen veriler, sosyo-ekonomik faktörlerin işletme performansına etkisini ortaya koyacak şekilde analiz edilecek ve bu veriler, bölgedeki tarım ve hayvancılık sektörünün gelişimine yönelik somut önerilerde bulunulmasına olanak sağlaması beklenmektedir.

Anahtar Kelimeler: Hayvancılık Politikaları, Besi Sığırcılığı, Kırşehir, Türkiye.

1.INTRODUCTION

Livestock breeding is the rearing of animals in stables or on pastures, regardless of their sex, breed and age, and the rearing for meat production through refinement and weight gain in a way that increases profitability over a certain period of time. Livestock breeding is one of the most important branches of modern livestock farming and involves special feeding and breeding methods aimed at increasing meat production. The rapid increase in the human population and the growing demand for protein have made livestock production a strategic sector. Especially in recent years, as the consumption of red meat has increased worldwide, the demand for livestock farming has also accelerated. The efficient use of agricultural land is a priority for the country's development. As an important branch of the livestock industry, cattle breeding helps to reduce hidden unemployment, prevent migration from the countryside to the cities and utilize plant and animal waste. It also contributes to a balanced diet for the growing population. (Karakaş, 2002). While animal husbandry has the largest share in the agricultural sector in developed countries with over 50%, this share is 25-30% in Turkiye. (Yılmaz and Köknaroğlu, 2007; Hozman and Akçay, 2016). While in industrialized countries animal husbandry has priority in agricultural production, crop production is more dominant in Turkiye. Government subsidies and projects are also largely geared towards plant production. However, it can be observed that incentives for the development of animal husbandry have increased in recent years and new projects have been implemented in this area. (Ören and Bahadır, 2005).

While dietary habits in industrialised countries are mainly based on animal protein, in developing countries such as Turkiye, plant-based foods, especially cereals, are among the basic sources of nutrition. However, it is said that for a healthy and balanced diet, half of the proteins should come from plant sources and the other half from animal sources. (DPT, 2001). Although Turkiye occupies an important position in the world in terms of animal abundance, it lags behind developed countries in terms of animal productivity. The main reasons for this are that most of the livestock consists of low-yielding breeds and that the environmental conditions are inadequate. In addition, the low slaughter weight achieved per animal prevents the desired level of meat production. (Ayyıldız, 2001).

1.1 Araştırmanın Önemi

Animal husbandry, one of the fundamental dynamics of the agricultural economy in developed countries, is of great importance in two respects. On the one hand, it can create jobs at low cost, and on the other, it transforms feed that is not suitable for human consumption into food with high nutritional value. While many countries are promoting the livestock sector and conducting development studies, the desired success cannot be achieved in Turkiye. The problems that occur especially in the areas of productivity and production have a negative impact on the sector. Although Turkiye ranks second in Europe and sixth in the world in terms of the number of animals, it cannot maintain this rank and its livestock population is gradually decreasing. (Kutlu et al 2003). Livestock farming makes a significant contribution to the country's economy and can create high added value per unit area at low cost. Generally, high investment is required to establish a new business line in industry, but only 20% of the cost is sufficient to establish the same business line in animal husbandry. This situation shows that an investment in the industrial sector can create 5 times more jobs if it is made in the livestock sector. However, the livestock sector was not given enough importance and although there were suitable conditions

for livestock farming in Turkiye, this potential was not utilized. As a result, the sector deteriorated even further (Peşmen and Yardımcı, 2008).

The main objective in cattle breeding, as in all other sectors, is to make a profit. First of all, meat is obtained from fattening cattle, and after slaughter, by-products are also obtained, which are used as raw materials in many sectors such as the food, clothing, medicine, cosmetics and animal feed industries. In order to achieve efficiency and profit in cattle breeding, it is necessary to understand the cost structure of the business well, to control the cost elements and to master the various factors that directly affect profitability. (Çiçek and Sakarya, 2003; Çiçek, 2005). In cattle breeding, all expenses such as the supply of feed and raw materials, personnel, electricity, water, veterinary services as well as taxes, interest and insurance must be covered during the fattening period. These expenses can only be covered by the producers at the end of the fattening period, as fattening farms do not have a daily income like dairy farms. It is very difficult for small farms to make a profit from fattening cattle. Small farms with 5-10 people can be run as subsistence family farms and cannot benefit from economies of scale. Such farms usually work with family labor and can only cover their own expenses. To make a profit, a cattle farm must produce roughage and other feed on its own land, have a farm with at least 50-100 animals and be able to market its livestock products at affordable prices. One of the biggest obstacles to livestock farming is the lack of capital. The continuous increase in basic input costs, especially for feed, and inflation further increase the capital requirements of breeders. However, the fact that meat prices are rising more slowly compared to the increase in input costs is having a negative impact on breeders' profitability. One of the main reasons for this situation is the illegal import of cheaper live animals and meat from neighboring countries. In addition, the increase in imports of animal products puts the domestic livestock sector in a difficult situation and reduces the competitiveness of producers. (Anonymous 1996).

One of the biggest problems in cattle breeding in Turkiye is the difficulties in marketing and pricing. The producer organization plays an important role in solving these problems. An effective organization can help eliminate structural deficiencies in the sector, use the resources used in the production process more efficiently and avoid waste. The organizational model to be chosen should be suitable for the social and economic structure of Türkiye. Such an organization should aim to support the economic development of rural enterprises and increase the social and economic welfare of producers. (Aral, 1974; Aral and Cevger, 1998; Aral and Cevger, 2000; Çiçek, 2005).

It is of great importance to provide financial resources to cover input costs and increase investment in livestock production. However, the economic crises and high inflation rates that our country has experienced in recent years have significantly increased the interest rates on loans, which has had a negative impact on the livestock sector. The high interest rates have made it difficult for producers to access the necessary credit and have led to an increase in financial liabilities. This situation has prevented livestock farmers from making new investments and expanding their existing farms. (SPO, 2001). In this context, it has become urgent to reduce lending rates and create more suitable financing options to increase the sustainability and competitiveness of the livestock sector. The desired progress in livestock production, increasing productivity and ensuring profitability depends on other important factors such as high quality breeding stock, suitable environmental conditions, veterinary health services, product evaluation and marketing, and high quality roughage production. Since feed

expenditure accounts for 60-70% of livestock farm expenditure, solving the feed problem in this sector can increase income by about 30. (Kabukçu, 1985). The most important element that accounts for a large part of the costs in livestock enterprises is feed. In order to reduce costs in livestock production and ensure efficient and profitable operations, the need for roughage and concentrates must be met in large quantities, in high quality and at affordable prices. The way to achieve this goal is to give the necessary importance to the production of forage crops. (Aral and Cevger, 1998).

Profitability in cattle breeding is based on the animal yielding the expected live weight gain in an economical manner. Fattening performance is evaluated in terms of daily live weight gain and the amount of feed used to achieve this gain and is a phenotypic trait shaped by the effects of genetic and environmental factors. Regardless of how high the genetic capacity of an animal is, the provision of suitable environmental conditions is essential to achieve the desired level of productivity. (Akcan et al., 1991). In addition, barns for cattle, regardless of type, should be clean, odor-free, sufficiently bright and healthy. Although closed barns are generally built in our country and region, it is said that fixed investments should be kept as low as possible in order to increase the profitability of fattening and that cattle can show efficient fattening performance even at temperatures as low as -17°C. (Ateş, 2004).

1.2. Purpose of the Research

In this research, the development of cattle breeding in Kırşehir province is examined from a macro perspective and the sector is evaluated. The results of this research will provide a scientific basis for the development of strategic planning for the sector by showing the economic sustainability of cattle farms in Kırşehir and their impact on regional development.

2. MATERIAL AND METHOD

The main research material consists of data from electronic data sources such as FAO and TUIK. In addition, studies, dissertations and reports on the topic were consulted to evaluate the research in relation to the literature. The study has a general evaluation concept and the data scope was evaluated as the last 10 years.

3. FINDINGS

3.1. Cattle Presence in the World

Tablo 1.1. Cattle Presence by Country

Ülke	Sığır Varlığı
Brazil	238.626.442,0
India	194.478.229,0
United States	88.841.000,0
China	73.718.307,0
Ethiopia	70.904.004,0
Pakistan	55.450.000,0
Argentina	54.242.595,0
Tanzania	37.913.129,0
Chad	37.647.402,0
Mexico	36.619.592,0

Reference: FAO, (2023)

The countries with the largest cattle populations in the world are listed in detail in Table 1.1. The country with the largest cattle population in the world is Brazil with 238 million animals, followed by India with 194 million animals (FAO 2023). These countries account for a large share of global cattle production. The reason for the high cattle population in Brazil is the large agricultural areas, the climatic conditions suitable for animal husbandry and a large meat and dairy production industry. India is one of the leading countries in the world in terms of milk production, but its share of beef production is lower because cattle are considered sacred in Hinduism and meat consumption is low. The United States ranks third with 88 million cattle, although its meat production and processing capacity is quite high. The fact that the meat industry has a large export market can also explain this figure. Turkiye's 21st place with 16.8 million cattle reflects the size and potential of the country's livestock sector. Turkiye is an important producer, especially in milk production. However, there is still room for improvement in meat production and productivity per head of cattle. In general, the presence of cattle varies from country to country around the world and these differences are directly related to the livestock policies, geographical conditions and consumption habits of each country. Turkiye's place in the ranking shows that the country has a strong livestock sector, but has not yet fully realized its potential in this area.

3.2. Cattle Presence in Turkiye

Tablo 1.2. Cattle Breed

Year	Culture	Hybrid	Native	Total
2015	6 385 343	5 733 803	1 874 925	13 994 071
2016	6 588 527	5 758 336	1 733 292	14 080 155
2017	7 804 588	6 536 073	1 602 925	15 943 586
2018	8 419 204	7 030 297	1 593 005	17 042 506
2019	8 559 855	7 554 625	1 573 659	17 688 139
2020	8 838 498	7 594 127	1 532 857	17 965 482
2021	8 824 784	7 641 100	1 384 659	17 850 543
2022	8 295 825	7 324 866	1 231 265	16 851 956
2023	8 070 159	7 303 667	1 047 430	16 421 256
2024	8 213 136	7 669 922	941 150	16 824 208

Reference: TURKSTAT, (2024)

The development of the cattle population in Turkiye over the years is shown in detail in Table 1.2. Looking at Table 1.2, the number of breeding cattle in Turkiye was 6,385,343 in 1995, while this number reached 8,213,136 in 2024. There is no continuous and regular increase in the number of breeding cattle. The number of bred cattle continued to increase from 2015 to 2020, and a decrease in this number was observed from 2021 to 2023. The decline in the number of bred cattle gave way to an increase in 2024. While the number of crossbred cattle bred in 2015 was 5,733,803, it reached 7,669,922 in 2024. During the reporting period, the number of crossbred cattle bred continued to increase until 2021. The number of crossbred cattle followed an upward and downward trend. The number of cattle, which had been declining since 2022, has shown an upward trend since 2024. While the number of domestic cattle was 1,874,925 in 2015, it fell to 941,150 by 2024. The number of domestic cattle is continuously decreasing. (TUİK, 2024). The main reasons for this decline in the number of domestic cattle are the low meat and milk yield of domestic cattle breeds, the increasing use of modern methods in large breeding farms instead of traditional methods, the decline in grazing areas and climate change, as domestic cattle breeds are usually bred on the basis of grazing methods that make it difficult to raise these animals. In addition, the majority of government support is provided for breeding breeds that produce higher yields. When the incentives for native breeds are not sufficient, breeders turn to breeding breeds. In order to increase the productivity of native cattle breeds, crossbreeding with cultivated breeds is carried out. In this case, the number of cattle of native breeds has decreased and the number of cattle from cross-breeds has increased. While the total number of cattle in 2015 was 13,994,071, it was set at 16,824,208 for 2024. While an increase in the total number of cattle was observed until 2021, it has been declining since 2022. The total number of cattle reached its highest level in 2020 (TUİK, 2024). The main reason for the decline in the total number of cattle in Turkiye in recent years is the rising production costs and

economic difficulties. In particular, the increase in expenses for feed, energy, veterinary services and care has made livestock farming increasingly costly. In recent years, high feed prices have become a major problem for livestock producers. The fact that feed prices in Turkiye are largely dependent on foreign sources and exchange rate fluctuations have led to an increase in costs that has put producers in a difficult position. As a result, many breeders have had to send their animals to slaughter earlier, which has accelerated the decline in cattle numbers. In addition, the import policy is also having a negative impact on domestic producers. The increasing demand for live animal and meat imports has weakened the competitiveness of domestic producers and caused many producers to withdraw from the sector. In addition, the decline in profit margins has prompted small and medium-sized enterprises to abandon livestock farming, which has accelerated the decline in cattle numbers. Another important factor is the gradual decline in grazing land. The shrinking of agricultural land due to industrialization and urbanization has made it difficult for animals to graze in natural environments, which has had a negative impact on the sustainability of livestock farming. When all these factors are taken into account, the reasons for the decline in cattle numbers in Turkiye become clearer.

3.3. Cattle Presence in Kirsehir Province

Tablo 1.3. Cattle Breeds (Kırşehir)

Year	Culture	Hybrid	Native	Total
2015	63 442	60 372	16 038	139 852
2016	101 548	56 529	15 851	173 928
2017	112 432	69 608	16 076	198 116
2018	136 605	89 960	18 756	245 321
2019	141 132	91 024	18 525	250 681
2020	172 892	109 401	17 911	300 204
2021	152 057	100 200	10 110	262 367
2022	164 960	115 849	9 080	289 889
2023	163 024	112 950	8 950	284 924
2024	171 569	143 034	997	315 600

Referece: Kirsehir Provincial Directorate of Agriculture (2024)

The change in the cattle population in the province of Kırşehir over the years is shown in detail in Table 1.3. The number of breeding cattle in Kırşehir province was 63,442 in 2015 and increased continuously to reach 171,569 cattle in 2024. The number of hybrid cattle was 60,372 in 2015 and showed a continuous increase to 143,034 in 2024. The number of local breed cattle was determined as 16,038 in 2015. In 2016 and 2017, the number of local breed cattle decreased, and although there was an increase in 2018 and 2019, a rapid decline has been observed since 2020. While the total number of cattle in Kırşehir was 139,928 in 2015, it was determined to be 315,600 in 2024. The total number of cattle continued to increase until 2020 and followed a fluctuating trend in 2021 (TUİK, 2024). When this fluctuation was compared

with Turkiye as a whole, it was found to follow the same trend. When the number of wild cattle was compared with Turkiye as a whole, it was found that it did not show the same trend. While the number of native breeds in Turkiye is continuously decreasing, it can be observed that the decrease in Kırşehir province increased after 2020.

Tablo 1.4. Cattle Breeds (Türkiye) Annual Change Rates

Year	Culture	Hybrid	Native	Total
2015	-	-	-	-
2016	3,18	0,43	-7,55	0,62
2017	18,46	13,51	-7,52	13,23
2018	7,88	7,56	-0,62	6,89
2019	1,67	7,46	-1,21	3,79
2020	3,26	0,52	-2,59	1,57
2021	-0,16	0,62	-9,67	-0,64
2022	-5,99	-4,14	-11,08	-5,59
2023	-2,72	-0,29	-14,93	-2,56
2024	1,77	5,01	-10,15	2,45
Mean	3,04	3,41	-7,26	2,20

Tablo 1.5. Cattle Breeds (Kırşehir) Annual Change Rates

Year	Culture	Hybrid	Native	Total
2015	-	-	-	-
2016	60,06	-6,37	-1,17	24,37
2017	10,72	23,14	1,42	13,91
2018	21,50	29,24	16,67	23,83
2019	3,31	1,18	-1,23	2,18
2020	22,50	20,19	-3,31	19,76
2021	-12,05	-8,41	-43,55	-12,60
2022	8,49	15,62	-10,19	10,49
2023	-1,17	-2,50	-1,43	-1,71
2024	5,24	26,63	-88,86	10,77
Mean	13,17	10,96	-14,62	10,10

(Reference: Authors' own calculations)

Looking at Table 1.4 and Table 1.5, an absolute decline can be observed for all breeds in the years in question, both in Turkiye and in the province of Kırşehir. The downward trend, especially after 2021, is due to the inflationary market and supply chain disruptions that occurred after COVID-19. However, the direction of the distribution across animal breeds during the reporting period indicates that producers are trending towards the more productive breeds.

4. CONCLUSION AND RECOMMENDATIONS

In this study, the development process of cattle breeding in Kırşehir province was analyzed on a macro level. In line with the findings, the changing trends of the cattle population over the years in both Turkiye and Kırşehir were evaluated; an increase in the number of breeding and crossbred cattle and a significant decrease in local breeds were observed. This situation shows that producers tend to turn to genotypes that can achieve higher productivity. In addition, based on the literature results, it would be correct to state that the reduction in production costs generally seen in Turkiye can be achieved by ensuring feed supply (the need for agricultural production in the dry climatic conditions of Kırşehir province is a major handicap in terms of feed crops), activating marketing processes and strengthening the producer organization. Especially considering the high share of feed costs in total expenditures, the need to increase feed production and the restructuring of feed policies are important dynamics observed in this area.

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RELATIONSHIP BETWEEN URBAN SPREADING AND THE AGRICULTURAL SECTOR: A CONCEPTUAL ASSESSMENT

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ABSTRACT

The demand for agricultural land outside the agricultural sector means that it is being used for purposes other than its intended use. With rapid population growth and increasing migration from the countryside to the cities, it becomes apparent that urban settlement areas cannot meet demand and are gradually growing. This growth is generally shifting to agricultural land, which is located near the cities and is cheaper than land in the city centers. This form of urban sprawl can be referred to as urban sprawl. When the rapidly growing population and the demand for land required in this context are combined with the phenomenon of urban renting, it becomes apparent that fertile agricultural land is being diverted from its intended purpose to meet current needs, with agricultural land around cities being targeted. In addition, expectations of high rents and leases for non-agricultural uses mean that agricultural land is negatively impacted by urban sprawl. This research discusses the relationship between urban sprawl and the agricultural sector at a conceptual level. By discussing the potential impact of urban sprawl on the agricultural sector and the extent to which the agricultural sector is affected, a scientific approach is provided to the arguments that agricultural land is decreasing, which has been a particular concern of public opinion in recent years.

Keywords: Urban Sprawl, Agricultural Sector, Agricultural Land, Türkiye

KENTSEL SAÇAKLANMA VE TARIM SEKTÖRÜ İLİŞKİSİ: KAVRAMSAL BİR DEĞERLENDİRME

ÖZET

Tarımsal sektör dışında tarımsal arazileri için oluşan talep, arazilerinde amacı dışında kullanılmalarına neden olur. Hızlı yaşanan nüfus artışı ve kırsal kesimden kentlere olan göçlerin artması ile birlikte kentlerdeki yerleşim alanlarının oluşan ihtiyaçlara cevap veremediği ve giderek büyüdükleri görülmektedir. Bu büyümenin genellikle kentlere yakın mesafede yer alan, kentlerin merkezindeki arsalara göre daha ucuz olan tarımsal alanlara doğru kaydığı görülmektedir. Kentlerin dışına doğru oluşan bu yayılma şekli saçaklanma olarak ifade edilebilir. Hızlı bir artış gösteren nufüs ve bağlamda ihtiyaç duyulan arazi talebi kentsel rant olgusuyla birleşince, ağırlıklı olarak kentlerin çevresindeki tarım alanlarını hedef alarak verimli tarım arazileri günümüz ihtiyaçlarının karşılanması amacıyla amacı dışında kullanıldığı görülmektedir. Ayrıca tarım dışı kullanımlara yönelik yüksek kira ve rant elde etme beklentisi beklentileri, tarımsal alanların kentsel saçaklanmalardan olumsuz etkilenmesine sebep olmaktadır. Bu araştırmada, kentsel saçaklanma ve tarım sektörü ilişkisi kavramsal boyutta ele alınacaktır. Kentsel saçaklanmanın tarım sektörüne olası etkileri ve tarım sektöründen etkilenme boyutunun tartışılmasıyla özellikle son yıllarda kamuoyunu meşgul eden tarım arazilerinin azaldığı yönündeki argümanlara bilimsel bir yaklaşım oluşturacaktır.

Anahtar Kelimeler: Kentsel Saçaklanma, Tarım Sektörü, Tarım Arazileri, Türkiye

1.INTRODUCTION

Although the culture of urbanization dates back to antiquity, the modern urbanization process developed primarily in the 20th and 21st centuries. It developed in the 19th century. In the early period, cities, which were mostly founded in areas unsuitable for agriculture, expanded over time under the influence of dynamics such as population growth, industrialization and economic growth; during this expansion process, they generally changed the functions of these areas by covering the fertile agricultural land around them. As a result, the use of agricultural land for urbanization purposes has become widespread due to its lower cost and ease of implementation.

Urban sprawl is the spread of irregular, low-density settlements from urban centers to remote rural areas. This process is generally characterized by low population density, inadequate transport infrastructure and weak social capital.

The unplanned and uncontrolled expansion of urban areas through urban sprawl leads to the destruction of agricultural land and ecologically sensitive areas on the one hand, and threatens the sustainability of open and green areas at regional level on the other. If this process is not brought under control, serious environmental damage and loss of ecosystem services are inevitable in the long term. This study discusses a conceptual assessment of urban sprawl, which has accelerated urban life and caused complex problems in the sociological strata of society and food security in recent years.

2. MATERIAL AND METHOD

In this research, evaluations were made by using scientific literature and studies on the subject and suggestions were made for the results obtained.

3. CONCEPTUAL FRAMEWORK

3.1.The Concept of Urban Sprawl

Since the industrial revolution at the beginning of the 20th century in the industrialized countries and after the Second World War in the developing countries, economic development efforts and industrial policy have accelerated the migration of the population from rural areas to the cities.

Under the pressure of rapid urbanization, rural areas surrounding cities have gradually been transformed into urban areas, and new formations known as urban sprawl have emerged in these areas. Urban sprawl generally refers to the physical expansion of urban areas; it is an area that is squeezed between urban and rural areas and has neither urban nor rural characteristics. The uncontrolled and rapid change taking place in these areas has resulted in unplanned, irregular settlements as these areas are subject to rapid and uncontrolled change.

The area between the populated area and the rural area of the cities is the urban sprawl area. Urban sprawl is the result of the expansion and dispersion of cities and can be seen as the boundary between rural and urban areas. It can be defined as the urban area that attracts population from the center and surrounding settlements of cities and where the element of development and growth is most pronounced in developed countries (Özçevik, 1999). Although

the terms urban sprawl and urban sprawl are similar in meaning and are sometimes used synonymously, they have different characteristics in the literature. Urban sprawl, which is defined as the expansion of cities into their surrounding areas, is mainly observed in developing countries. This type of growth is a type of growth that expresses development at the same density without gaps instead of leapfrog development (Wei & Ewing, 2018). The term fringe areas refers to the areas around cities, on the boundary between rural areas and urban areas. (Mukherjee J, 2018).

The theory of urban sprawl encompasses not only a part of urban development policy, but also a settlement area outside the city. As the density and continuity of these areas will increase over time during the urban growth process, the cluster element and proximity dimension will also increase over time (Glaeser & Kahn, 2003).

Urban sprawl has some basic characteristics and can be simply defined as the migration from cities to rural areas that occurs spontaneously or for political reasons (Morris, 2005). The National Trust for Historic Preservation, which was established to protect historic preservation areas, defines sprawl as dispersion. According to another definition, it is the development that results from land use and the dominance of the automobile (Karagülle, 2011). Another definition of sprawl states that the city center spreads like an oil slick and the city center grows towards the areas formed outside the city. (Barnett, 1995). Staley, on the other hand, defines the phenomenon of urban sprawl as the areas in transition between rural areas and urban areas (Staley, 1999).

3.1.1. Causes of Urban Sprawl

The factors that pave the way for urban sprawl, especially as a result of the rapid development of large cities, are manifold. There are various examples of urban sprawl from the past to the present. The first urban sprawl occurred in developed European countries in the early 19th century and took place in suburbs where professional and social groups working in mining and heavy industry lived. In the 20th century, urban sprawl was mainly caused by the relocation of industrial centers. Today, while the industrial sector is still influential in the choice of where to produce, it is clear that the choice of where to live is also influential as a result of rapid population growth and class changes in social structures. The economic improvements that occurred with the end of the Second World War have strengthened the middle class, and thus the need of this class to escape the urban centers has paved the way for the formation of land rental markets around the cities, which in turn has paved the way for the formation of urban sprawl on the periphery of the cities. In addition, the desire for a second home also plays a role in these processes (Kaygalak, 2006). The main reasons for urban sprawl are urban land use decisions, the expansion of the transportation network, social and economic development and urban growth.

Urban sprawl from the center to the periphery is also due to the dense population and industry in cities, increasing air pollution, rising crime rates, increasing noise levels and insufficient open spaces in city centers, limited land in city centers and the formation of exorbitant prices in these areas, new technologies in housing construction and developments in mass housing, rapid population growth, the relocation of high-income residential areas to the outskirts of cities and the idea of having larger houses.

In a 2006 report by the European Environment Agency, the reasons cited for urban sprawl include economic and demographic reasons, changes in transportation and communication technologies, and urban sprawl. (Sezgin, 2010). Although the reasons for urban sprawl vary from region to region, the main reasons are the effects of globalization, technological development, population growth and industrialization on cities. (Hayrullahoğlu et al., 2021). There are many reasons for urban sprawl, the most important of which are the change in people's lifestyles and the increasing demand for low-density and independent areas, low land prices on the outskirts of cities, developed transportation systems, high costs in city centers, developed communication systems, increasing wealth levels with rising income levels, and governments' planning efforts to determine the direction of urban growth (Wu. J, 2006).

3.1.2 Effects of urban sprawl

The rapid increase in urban population has created a demand for urban areas. As the demand for urban areas increases, cities grow rapidly and spread out spatially. Urban growth and urban sprawl is one of the problems that many cities in the world have been struggling with since the 1960s. It can be seen that urbanization is losing control due to the effects of many factors such as increasing population growth, legal and administrative changes, planning processes and the variables associated with these factors.

Urban expansion has led to rapid changes in the surrounding areas of cities, but it has also created some problems. Today, many cities face numerous problems, such as housing, transportation networks, infrastructure systems and environmental factors, because they are growing too fast to be controlled. As can be seen from the high growth rate of the urban population, this situation will become an even greater problem in the coming years. The policies of developing countries have caused cities to grow continuously and uncontrollably, and the living environment and economic structures have become inefficient.

The problems caused by rapid population growth, which are also mentioned in the report "Our Common Future" prepared by the United Nations World Commission on Environment and Development in 1987, are discussed under the name of urbanization, and it can be seen that this paves the way for a reduction in the quality of life, causes excessive consumption of environmental resources and brings to the fore the problems associated with the uncontrolled expansion of cities. (Author, 2006). It can be seen that increasing development in rural areas consumes water resources, degrades water quality and leads to land warming. and warms the soil. Urban expansion also has a significant impact on natural thresholds. The unplanned and haphazard growth of cities threatens forest areas, valleys and watersheds and leads to overconsumption of natural resources (Türkten, 2015). Scientists who have studied this issue emphasize that urban sprawl will have negative consequences and point out that the social costs of this will be high. In their studies, they have calculated in detail the monetary equivalents of the costs that these negative effects will entail. While this form of growth has been criticized, it has also been argued that these processes should be accepted as natural, that they are difficult to prevent and that the negative effects are exaggerated [Özdemir, 1993]. In the Bruntland Report published by the World Commission on Environment and Development and at the United Nations Environment and Development Agency Conference in 1992, the concept of urban sprawl was seen as a problem. It was mentioned that it was necessary to take precautionary measures by reaching a consensus against the negative effects of urban sprawl

and it was decided to develop strategies to eliminate the negative effects of urban sprawl. (Yenigül and Çamur, 2009).

3.2. Relationship between Urban Sprawl and Agricultural Areas

The decreasing of agricultural lands, especially due to urbanization and industrialization, has become a significant problem today. Food is the most basic need for societies to continue their lives, therefore, sufficient measures must be taken to protect food. In this context, the protection of agricultural lands is especially important. While the type of land is not important in meeting the need for shelter, the type of land suitable for agriculture is important in meeting the need for food. In other words, housing etc. can be built on every type of soil, but agricultural activities cannot be carried out on every land. The decrease in agricultural activity, i.e. production, can endanger the lives of millions of people who have to fight hunger and the increasing population. Throughout history, cities have expanded towards their surroundings as people have needed more space to live and work. In a period when land was abundant, urban expansion was made possible by farmers moving to new plots. However, today, urban expansion threatens agricultural lands due to the fact that many cities are built on agricultural lands (Gardner, 1997). While efforts are being made to meet the shelter and security needs of the rapidly increasing world population due to the misuse of agricultural lands, it is seen that physiological needs such as food that are necessary for people to survive are also being ignored. As in all parts of the world, cities and rural areas in Türkiye have undergone rapid changes in the development process (Sertkaya Doğan and Gökburun 2019). In the 1960s, it is estimated that Türkiye lost at least 25,000 hectares of agricultural land per year due to urbanization and industrialization requirements. A study conducted by the Chamber of Architects stated that approximately 10,000 hectares of agricultural land were added to urban areas every year between 1965 and 1985. According to Çepel (2003), Turkey lost 326,000 hectares of agricultural land as of 1991 due to urbanization and related infrastructure developments. As can be seen from all these data, especially the residential areas and industrial facilities around Türkiye's big cities continue to put serious pressure on fertile agricultural lands (Akseki, 2011).

When the rapidly increasing population and the demand for land in this context are combined with the phenomenon of urban rent, it is seen that fertile agricultural lands are being used for purposes other than their intended purpose in order to meet today's needs, mainly targeting agricultural lands around cities. (Sezgin, 2010). In addition, high rents and expectations of rent for non-agricultural uses cause agricultural lands to be negatively affected by urban sprawl.

The effects of urban expansion and urban sprawl on agricultural lands can be evaluated from different perspectives. Sprawling cities cause agricultural lands to be fragmented, land prices to increase, and taxes in these areas to increase, making agricultural production unsustainable. (Nas, 2016).

The most important reason for the misuse of agricultural lands around cities is urbanization and urban sprawl. In this context, sprawl cities pose a threat to agricultural lands in these areas and businesses operating in these areas are negatively affected by this. Urban sprawl, the effects of which are strongly felt, not only destroys agricultural lands, but also causes the destruction of already scarce natural resources and negatively affects the use of open spaces in these areas (Brueckner, 2001).

4. CONCLUSIONS AND SUGGESTIONS

This study evaluates the phenomenon of urban sprawl, which has arisen as a result of the rapid urbanization process, and its impact on agricultural land within a conceptual framework. Urban sprawl, as an irregular structure and form of settlement spreading from the city center to the periphery, poses a significant threat to both the natural environment and agricultural production.

Reasons for urban sprawl include population growth, changing lifestyles, demand for cheap land, advanced transportation systems and high costs for the city center. The combination of these factors means that fertile agricultural land around the city is rapidly being released for development and the sustainability of agricultural production is at risk.

The decline in agricultural land not only has a negative impact on food production, but also on food security and rural development. This situation can lead to serious difficulties in meeting the basic needs of the world's growing population in the future. In addition, the environmental impact of urban sprawl leads to far-reaching environmental problems such as the pollution of water resources, the destruction of natural areas and the disruption of the climatic balance.

Therefore, planned urbanization, legislation to protect agricultural land and strategic policies to guide urban growth should be implemented. Deterrent measures should be taken against the misuse of agricultural land and the balance between agriculture and urbanization should be maintained in accordance with the principles of sustainable development.

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DETERMINATION OF FACTORS AFFECTING THE ATTITUDES AND BEHAVIORS OF YOUNG CONSUMERS TOWARDS GENETICALLY MODIFIED ORGANISMS (GMO) PRODUCTS: THE CASE OF KIRŞEHİR AHİ EVRAN UNIVERSITY

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ABSTRACT

Products derived from genetically modified plants and animals using modern biotechnological methods are referred to as genetically modified organisms (GMOs). These technologies aim to increase agricultural productivity, reduce environmental impacts, and provide resistance to pests, but consumer perceptions and evaluations of the potential benefits of GMOs can vary. While some consumers have safety concerns regarding GMOs, others express worries about health and ethics. This situation negatively affects how consumers perceive these products and hinders the realization of their potential benefits.

The purpose of this study is to determine the attitudes of young consumers towards GMO products, to examine their approaches, opinions, and levels of knowledge about these products. Additionally, the study aims to investigate the level of trust young consumers have in GMO products, their expectations regarding product labeling, the sources of information they rely on, and the impact of these factors on their attitudes and behaviors. In the research, the survey method was preferred, and data were collected from 248 participants. The results indicate that young consumers lack sufficient information about GMO products and exhibit a general mistrust towards them. It was found that young people are concerned about the potential health effects of GMOs and believe that labeling of these products should be mandatory. Labeling is seen as an important factor for ensuring transparency and building trust. Furthermore, there is a need for more research on the potential benefits and risks of GMOs. These studies would contribute significantly to reducing consumer mistrust towards GMOs and establishing more solid scientific foundations for informed decision-making. In conclusion, the attitudes of young consumers towards GMOs highlight the need for transparency, trust, and the flow of information for these products to be accepted in society.

Keywords: Agricultural Marketing, Genetically Modified Organisms, Biotechnology, Consumer Behavior

GENÇ TÜKETİCİLERİN GENETİĞİ DEĞİŞTİRİLMİŞ ORGANİZMALI (GDO) ÜRÜNLERE YÖNELİK TUTUM VE DAVRANIŞLARINI ETKİLEYEN FAKTÖRLERİN BELİRLENMESİ: KIRŞEHİR AHİ EVRAN ÜNİVERSİTESİ ÖRNEĞİ

ÖZET

Modern biyoteknoloji yöntemleri kullanılarak, genetik yapısı değiştirilmiş bitki ve hayvanlardan elde edilen ürünler genetiği değiştirilmiş organizmalar (GDO) olarak adlandırılmaktadır. Bu teknolojiler, tarımsal üretimde verimliliği arttırmayı, çevresel etkileri azaltmayı ve zararlılara karşı direnç sağlamayı amaçlamasıyla birlikte, GDO'ların potansiyel faydalarıyla ilgili tüketicilerin algılamaları ve değerlendirmeleri farklılaşabilmektedir. Kimi tüketicilerin GDO'ya karşı güvenlik endişesi yaşarken, kimisi de sağlık ve etik noktasında kaygılar taşıdıkları gözlenmektedir. Bu durum tüketicilerin nezdinde bu ürünleri algılamalarını olumsuz etkilerken ve potansiyel faydalarının önüne geçmektedir.

Yürütülen bu çalışmanın amacı genç tüketicilerin GDO'lu ürünlere yönelik tutumlarını belirlemek, bu ürünlere yaklaşımları ve görüşleri ile bilgi düzeylerini ortaya koymaktır. Ayrıca genç tüketicilerin GDO'lu ürünlere karşı duymuş oldukları güven düzeyini, ürün etiketlemesine yönelik beklentilerini ve bu ürünlere yönelik bilgi kaynaklarının neler olduğunu tespit etmek ve bu faktörlerin genç tüketicilerin tutum ve davranışları üzerindeki etkisini belirlemekte amaçlanmaktadır. Araştırmada, anket yönteminin kullanılması tercih edilmiş ve 248 katılımcıdan veri toplanılmıştır. Elde edilen sonuçlara göre, genç tüketicilerin GDO'lu ürünler hakkında yeterli bilgiye sahip olmadıkları ve bu ürünlere yönelik genel bir güvensizlik olduğunu ortaya koymuştur. GDO'lu ürünlerin sağlık üzerindeki potansiyel etkileri konusunda gençlerin endişe duydukları belirlenmiş ve bu ürünlerin etiketlenmesinin zorunlu olması gerektiği, şeffaflığın sağlanılması ve güven ortamının oluşturulması açısından önemli bir faktör olduğu görülmüştür. Ayrıca GDO'lu ürünlerin potansiyel faydaları ve riskleri hakkında daha fazla araştırma yapılması gerekliliği ortaya çıkmıştır. Bu araştırmalar, tüketicilerin GDO'lara karşı duyduğu güvensizliklerin azaltılması ve bilinçli kararlar verebilmeleri için daha sağlam bilimsel temellerin oluşturulması açısından önemli katkı sağlayacaktır. Sonuç olarak, genç tüketicilerin GDO'lara yönelik tutumları, bu ürünlerin toplumda kabul görmesi için gerekli olan şeffaflık, güven ve bilgi akışının sağlanması gerektiğini göstermektedir.

Anahtar Kelimeler: Tarımsal Pazarlama, Genetiği Değiştirilmiş Organizma, Biyoteknoloji, Tüketici Davranışı

1. GİRİŞ

Kentleşme ve sanayileşmedeki artış, tarıma uygun alanların azalmasına yol açmıştır. Bir taraftan artan dünya nüfusu ve değişen iklim koşulları, sınırlı tarımsal kaynakların gıda talebini karşılamada yetersiz kalmasına neden olmuştur. Bu durum, gıda üretiminde verimliliği artırmayı ve birim başına elde edilen ürün miktarını yükseltmeyi zorunlu hale getirmiştir.

Bu ihtiyaç doğrultusunda, 20. yüzyılın başlarında genetik biliminde kaydedilen ilerlemeler, bitki ve hayvan yetiştiriciliğinde yeni bir dönemin başlamasına öncülük etmiştir. Genetik bilginin yetiştirme çalışmalarına entegre edilmesi sayesinde, daha yüksek verimli bitki çeşitleri ve hayvan ırkları geliştirilmiştir. Bu gelişmelerin bir sonucu olarak, genetiği değiştirilmiş organizmalar (GDO'lar), daha dayanıklı ve verimli ürünler elde etme potansiyeliyle modern tarımın temel unsurlarından biri haline gelmiştir.

Ancak GDO'lar yalnızca biyoteknolojik bir yenilik olarak görülmemekte, aynı zamanda etik, çevresel ve sağlık açısından çeşitli tartışmaları da beraberinde getirmektedir. Bu noktada, özellikle genç tüketiciler, geleceğin karar vericileri ve bilinçli bireyleri olarak, GDO'lara karşı tutum ve davranışlarıyla önemli bir toplumsal kesimi temsil etmektedir. Gençlerin GDO'lara ilişkin bilgi düzeyleri, algıları ve tutumları, yalnızca kendi bireysel gıda tercihlerini değil, toplumun genel bilinç düzeyini ve gelecekteki politika geliştirme süreçlerini de etkileme gücüne sahiptir. GDO'lara yönelik tutumlar ise bireylerin eğitim aldıkları alan, yaşadıkları coğrafi bölge, bilgiye erişim olanakları ve sosyal çevre gibi çeşitli faktörlerin etkisiyle şekillenmektedir.

Genç tüketicilerin GDO ile ilgili algı ve farkındalık düzeylerini incelemek, günümüzde tarım ve gıda sektöründeki önemli bir konudur. GDO'ların sağlığa, çevreye ve genel olarak toplumsal yapıya olan etkileri üzerine süregeldiği tartışmalar, bu ürünlerin kabulü ve reddi konusunda toplumsal ve akademik tartışmaların temelini oluşturmaktadır.

2. Kavramsal Çerçeve

2.1. Biyoteknoloji ve GDO

Biyoteknoloji, özel bir kullanıma yönelik olarak ürün ya da işlemleri dönüştürmek ya da oluşturmak için biyolojik sistem, canlı organizmalar ve bunların türevlerini kullanan teknolojik uygulamalar olarak tanımlanmaktadır. Modern biyoteknoloji ise rekombinant DNA'nın hücre ya da organellere doğrudan enjeksiyonu ya da farklı taksonomik gruplar arasında uygulanan hücre füzyonu gibi doğal çoğalma ve rekombinasyon engellerini ortadan kaldıran ve klâsik ıslah ile seleksiyon yöntemlerince kullanılmayan in vitro nükleik asit tekniklerinin tamamı" olarak tanımlanmaktadır. Bir türe başka türden gen aktarılarak doğal yapının değiştirilmesiyle yeni genetik özellikler kazandırılmasını sağlayan bu modern biyoteknoloji tekniklerine "gen teknolojisi", gen teknolojisi kullanılarak doğal doğal olarak elde edilmesi mümkün olmayan yeni özellikler kazandırılmış organizmalara da "Genetik Yapıları Değiştirilmiş Organizma (GDO) adı verilmiştir.

Rekombinant DNA'nın hücrelere doğrudan enjeksiyonu ya da farklı taksonomik gruplar arasında uygulanan hücre füzyonu gibi, doğal çoğalma ve rekombinasyon engellerini ortadan kaldıran in vitro tekniklerin tamamı olarak tanımlanan bitkisel biyoteknoloji ve onun ürünü

olan transgenik çeşitlerden; herbisitlere, zararlılara ve hastalıklara dayanıklılık; vitamin ve protein kalitesini artırma ve döllenme sistemlerinin kontrolu gibi konularda yararlanılmaktadır (Özgen vd., 2005). Sağlık, çevre, agronomi, ekonomi, üretici ve tüketici hakları açısından önemli risklerinin olması nedeniyle, başta Avrupa Birliği ülkeleri olmak üzere, birçok ülkede transgenik çeşitlerin kullanılması son derece kısıtlıdır. Bununla birlikte, günümüzde, ABD, Kanada ve Arjantin gibi ülkelerde, özellikle transgenik soya, mısır, pamuk ve kolzada ekim alanı 70 milyon hektarı aşmıştır.

Dünyada başta transgenik bitkiler olmak üzere, biyoteknolojik ürünlerin üretilmesi ve kullanılmasına ilişkin gelişmeler uluslararası düzeyde izlenmekte, hedefler ülke ekonomisine katkısı dikkate alınarak belirlenmekte ve uluslararası iş birliği olanakları araştırılmaktadır. Son yıllarda, biyoteknoloji politikalarının oluşturulmasında gelişmiş ülkelerde önemli ilerlemeler sağlanmıştır. Geri dönüşü olmayan zarar verme olasılığı nedeniyle biyoteknolojik ürünlerin kullanımına yasal düzenlemelerle sınırlamalar getirilmektedir. Biyoteknoloji ile ilgili yasalar, AB ülkelerinde olduğu gibi ya özel olarak çıkarılmakta ya da ABD ve Japonya'da olduğu gibi yürürlükteki yasalara ek yapılarak oluşturulmaktadır.

Türkiye'de modern biyoteknoloji ve bu kapsamda yer alan bitkisel biyoteknoloji çalışmaları başlangıç aşamasında olup, yasal olarak transgenik bitkilerin ticari olarak üretilmeleri söz konusu değildir. Yani çiftçilerin GDO'lu ürünleri ekimleri yasaktır (Hayırlıdağ, Arslan ve Büken, 2016).. Ancak hayvan yeminde bazı GDO'lu mısır ve soya ürünlerinin kullanılmasına Biyogüvenlik kurulu kontrolünde izin verilmektedir. Birçok kurumda temel biyoteknoloji çalışmaları yapılmakla birlikte, agronomik öneme sahip izole edilmiş uygun genler bulunmadığından transgenik çeşit geliştirme aşamasına gelinememiştir. Bu nedenle, Türkiye'nin durumu transgenik bitki geliştiren değil, geliştirilmiş transgenik çeşitleri satın alıp kullanma potansiyeli olan ülke olarak ele alınmalıdır. Ülkemizde transgenik çeşitlerin ekimi, Tarım ve Orman Bakanlığı kontrolunda "Alan Denemeleri Yönetmeliği" kapsamında patates, mısır ve pamuk için Tarımsal Araştırma Enstitüleri'nde yapılmaktadır (Özgen vd.., 2005). Bu denemelerin amacı; çeşit özelliklerinin gözlenmesi, flora ve faunaya olan etkilerinin belirlenmesi olarak açıklanmakla birlikte, bu çalışmaların ne kadar bilimsel ve geçerli oldukları tartışma konusudur. Çevreye zarar vermemesi açısından alan denemelerinin çiçek tozu izolasyon koşullarına uyularak yapılması zorunludur. İzolasyon koşullarında yapılan denemelerde ise çevreye olan etkinin belirlenmesi mümkün değildir. Bu nedenle, alan denemelerinden bilimsel ya da uygulamaya yönelik önemi olan sağlıklı verilerin alınması beklenmemelidir.

Transgenik çeşitlerin ticaretinde alıcı ülke konumunda olan Türkiye, bu çeşitleri yetiştirmeye başlaması durumunda ekonomisini olumsuz etkileyecek durumlarla karşılaşabilecektir. Örneğin, en büyük dışsatım pazarı olan AB ülkeleri transgenik ürünler konusunda son derece duyarlı düzenlemelere sahip olduklarından, transgenik çeşitleri üretmemiz halinde, bulaşma riski nedeniyle klâsik çeşitlere ilişkin ürünlerin alımında da büyük zorluklar çıkarabilecektir. Özellikle son yıllarda önem kazanmaya başlayan organik tarım ürünlerinin dışsatımında da olumsuz gelişmeler söz konusu olabilecektir.

Türkiye'de tüm ürünlerin dışalımı Tarım ve Orman Bakanlığı'ndan kontrol belgesi alınması koşuluyla serbesttir. Türkiye, ABD ve Arjantin'den gıda ve yem amaçlı kullanılmak üzere önemli miktarda mısır ve soya fasulyesi ithalatı yapmaktadır (Büyüközer, 2009). 2024 yılında

soya dışalımı yaklaşık 3.7 milyon ton civarında iken mısır dışalımının parasal değeri 1 milyar TL'nin üzerindedir. Türkiye'de bu iki bitkiye ilişkin alım değerlerinin son yıllarda önemli düzeyde arttığı görülmektedir. Öte yandan, dış ticaret verilerinde başta mısır ve soya olmak üzere, transgenik ürünlerin dış alımına ilişkin herhangi bir bilgi bulunmamaktadır. Ancak, bu ürünlerin alındığı ülkelerde transgenik bitki üretiminin çok yaygın olması, dışalımı yapılan bu ürünlerin de transgenik olabileceğini akla getirmektedir. Ülkemizde transgenik ürün analizi yapabilecek laboratuvarların bulunmaması ve dışalımın tamamen satan ülkenin bildirimine göre yapılması, özellikle mısır ve soya başta olmak üzere bazı ürünler hakkında kuşkulu bir ortam oluşturmaktadır (Yılmaz, 2014).

Modern biyoteknolojinin özellikle transgenik bitkiler ve genetik olarak değiştirilmiş organizmalar (GDO) üzerinden sağladığı yenilikler, tarım ve sağlık gibi sektörlerde önemli değişimler yaratmaktadır. Bu bağlamda pazarlama, yeni ürün geliştirme ve ürün karma elemanlarında belirleyici bir rol oynamaktadır. Yeni teknolojiler ve biyoteknolojik ürünlerin, özellikle genetik yapıları değiştirilmiş ürünlerin pazara sunulması, firmaların ürün geliştirme süreçlerinde daha geniş bir stratejik bakış açısı gerektirmektedir. Yeni ürünlerin tüketiciye sunulmadan önce yapılan detaylı araştırmalar, inovasyonun pazarlama stratejileri ile uyumlu olmasını sağlamaktadır. Ayrıca, tüketicinin biyoteknolojik ürünlere olan ilgisi ve bu ürünlere karşı duyduğu güven, pazarlama çabalarını doğrudan etkilemektedir. Bu durum, ürün karma stratejisinde de önemli bir yer tutmakta; firmalar, farklı ürün seçenekleri ve tüketici taleplerine göre pazara sundukları ürünleri çeşitlendirmek zorundadır.

Bu noktada, biyoteknolojik ürünlerin pazara girişi ve tüketicilerin bu ürünlere yaklaşımı, tüketici davranışlarıyla doğrudan ilişkilidir. Tüketicilerin bu yenilikçi ürünleri nasıl algıladıkları ve hangi faktörlerin kararlarını etkilediği, pazarlama stratejilerinin başarısını belirleyen temel faktörlerden biri olacaktır. O nedenle, biyoteknolojik ürünlerin pazarlanması, yalnızca teknik özelliklere bağlı değildir. Tüketici davranışı bilinmesi, tüketicilerin algısı ve etik kaygılar çerçevesinde şekillenmektedir. Bu nedenle, GDO'lu ürünlerin pazar kabulünü anlamak için tüketici davranışları disiplininden yararlanmak gerekir. Özellikle, risk algısı, yenilikçilik eğilimi ve sosyo-kültürel normlar gibi faktörler, pazarlama iletişimi stratejilerinin kurgulanmasında önemli faktörler olarak görülmektedir.

2.2. Tüketici Davranışları

Tüketici davranışları, bireylerin ihtiyaçlarını ve isteklerini karşılamak için ürün veya hizmetleri nasıl seçtikleri, kullandıkları ve tükettikleri ile ilgili psikolojik, sosyal, ekonomik ve kültürel faktörlerin birleşiminden meydana gelen bir alandır (Durmaz ve Bahar, 2011). Tüketicinin ne istediği, genellikle bir içsel ihtiyaç veya dışsal bir etken tarafından tetiklenmektedir. İhtiyaçlar, fizyolojik gereksinimler (yemek, su, barınma) veya psikolojik gereksinimler (açıklık, aidiyet, prestij) olabilirken, istekler daha çok sosyal ve kültürel etmenler tarafından şekillenmektedir. Tüketiciler, yaşam tarzlarına, değerlerine ve çevrelerindeki insanlardan aldıkları etkilere göre farklı tercihler yapabilirler. Bir ürün ya da hizmet, tüketicinin kendisine katacağı değere ve karşılaşmış olduğu soruna yönelik çözüme ulaşma potansiyeline göre tüketici tarafından tercih edilmektedir.

Tüketici karar verme süreci, karmaşık bir dizi adımdan oluşmaktadır. İlk olarak, tüketici bir ihtiyacı fark eder ve ardından bu ihtiyacı karşılayacak seçenekleri araştırmaya başlar. Bu araştırma süreci, çeşitli kaynaklardan (arkadaşlar, aile, medya, internet) bilgi toplamakla devam

eder. Tüketici, farklı alternatifleri karşılaştırarak ve her birinin sağladığı faydaları değerlendirerek en uygun seçeneği belirlemeye çalışır. Karar verme aşamasında, fiyat, kalite, marka güvenilirliği, ürünün sunduğu faydalar ve hatta sosyal kabul gibi faktörler etkili olabilir. Tüketici bir satın alma kararı verir ve bu karar, bireysel tercihler, geçmiş deneyimler ve çevresel etkenlere dayalı olarak şekillenir.

Bir tüketicinin kararlarını etkileyen birçok faktör vardır. Bunlar arasında psikolojik faktörler (kişisel değerler, algılar, öğrenme ve motivasyon), sosyo-kültürel faktörler (aile, arkadaşlar, sosyal çevre), ekonomik faktörler (bütçe, fiyat duyarlılığı), çevresel faktörler (mevsimsel değişiklikler, kültürel eğilimler) ve pazarlama faktörleri (reklamlar, promosyonlar) sayılabilir. Bu faktörler, tüketicinin bir ürünü seçme, kullanma veya ondan vazgeçme kararlarını doğrudan etkileme potansiyeline sahiptir. Tüketiciler istekleri, tutumları, davranış şekilleri, demografik özellikleri gibi birçok bakımdan farklı olmaları, haliyle pazar içerisinde heterojenliğe neden olmaktadır (Altuntaş vd., 2015). Ayrıca, bireysel özellikler de bu süreci yönlendiren önemli bir faktördür; örneğin, yaş, cinsiyet, eğitim seviyesi ve gelir durumu, bir tüketicinin alışveriş alışkanlıkları üzerinde belirleyici olabilir.

Tüketici davranışlarının karmaşıklığı, biyoteknolojik ürünlere yönelik pazarlama stratejilerinin oluşturulmasında nicel araştırma yöntemlerini gerekli kılmaktadır.

3. MATERYAL VE METOT

Bu bölümde araştırmanın amacı ve önemi, araştırmanın kısıtları ile veri analizi açıklanmaktadır. İstatistiksel analizlerin neler olduğu yine bu bölümde açıklanmaktadır.

3.1. Araştırmanın Amacı ve Önemi

Genetiği değiştirilmiş organizmalar (GDO), tarım ve gıda üretimi alanında devrim niteliğinde yenilikler sunarken, biyoteknolojik gelişmelerin sosyal, ekonomik ve etik boyutları da giderek daha fazla tartışılmaktadır. GDO'lar, özellikle çevresel sürdürülebilirlik, gıda güvenliği ve sağlık üzerindeki potansiyel etkileriyle dikkat çekmektedir. Ancak, bu organizmaların kullanımı toplumun farklı kesimlerinde farklı bakış açıları oluşturmakta ve özellikle genç kuşaklar arasında bu konuda önemli bir farklılık gözlemlenmektedir. Gençlerin, GDO'lar konusundaki tutum ve davranışları, çevresel kaygılar, sağlık endişeleri ve etik değerlere dayalı olarak şekillenmektedir.

Bu çalışmanın amacı, genç tüketicilerin GDO'lara yönelik tutum ve davranışlarının geliştirilmesinde etkili olabilecek faktörleri belirmektir. Bir diğer amaç ise demografik değişkenler doğrultusunda GDO'lara yönelik tutum ve davranışlarını etkileyen faktörler yönünden anlamlı farklılıklar olup olmadığını incelemektir. Çalışma, GDO'ların sağlık, çevre ve güvenlik üzerindeki potansiyel etkileri hakkındaki endişeleri ile bu ürünlere yönelik duyulan güvensizliğin ardında yatan psikolojik ve sosyal dinamikleri anlamayı hedeflemektedir.

Genç tüketicilerin GDO'lara yönelik tutum ve davranışlarını incelemek, yalnızca mevcut tüketim eğilimlerini anlamaya değil, aynı zamanda gelecekteki gıda politikalarının, etik tartışmaların ve pazarlama stratejilerinin şekillenmesinde temel rol oynayacak dinamikleri belirlemesi açısından da önem arz etmektedir. Dolaysıyla yürütülen bu çalışmanın önemi de gençlerin GDO'lu ürünlere yönelik yaklaşımlarının ortaya konulması ile gerek tarım

politikalarının gerekse de pazarlama stratejilerinin belirlenmesi ve geliştirilmesine katkı sağlamasıdır.

Çalışmanın özgün değeri, GDO'ların yalnızca biyoteknolojik ve tarımsal boyutlarıyla değil, aynı zamanda tüketici psikolojisi ve davranışları açısından da incelenmesinden kaynaklanmaktadır. Tüketicilerin bu ürünlere karşı nasıl bir risk algılayışı geliştirdiği, ne tür koruyucu davranışlar sergilediği ve bu davranışların arkasındaki motivasyonları anlamak, GDO'ların pazarlanması ve tüketici davranışları üzerine önemli stratejik öngörüler sağlayacaktır.

Bu çalışma, GDO'lara yönelik genç tüketicilerin algısını anlamakta daha farklı boyutlarıyla ele alan bir anlayış geliştirilmesine olanak tanımayı ve özellikle biyoteknoloji, tarım ve gıda endüstrilerinde faaliyet gösteren şirketler için değerli bilgiler sunmayı hedeflemektedir. Çalışma bu alanda yapılacak olası yasal düzenlemeler ve pazarlama stratejilerinin şekillendirilmesinde etkili olabilecek, bilimsel ve toplumsal perspektiflerin bir araya getirilmesine temel oluşturabilme potansiyeli taşımaktadır. GDO'lar gibi tartışmalı teknolojilerin toplumda daha geniş bir kabul görmesi için, tüketicilerin bu ürünlere yönelik algı ve tutumlarının anlaşılması büyük önem taşımaktadır.

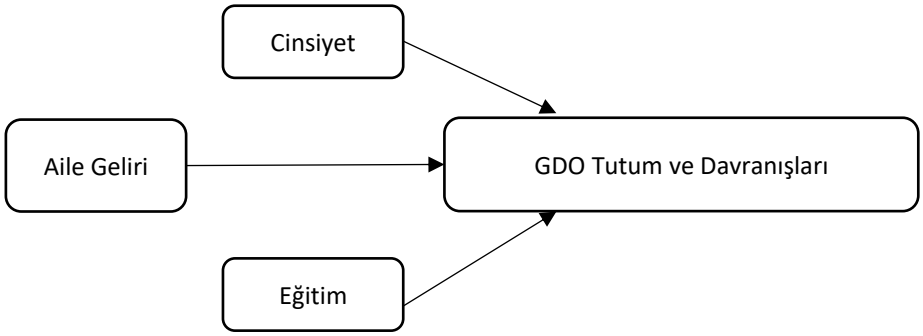
3.2. ARAŞTIRMANIN KAPSAMI VE SINIRLILIKLARI

Araştırma her ne kadar genç tüketicilerin tutum ve davranışlarını anlamaya yönelik olarak geliştirilmiş olsa dahi Kırşehir Ahi Evran Üniversitesi öğrencilerine yönelik yürütülmektedir. Üniversite öğrencilerinin homojen bir özellik göstermesine rağmen kapsamı coğrafi olarak sınırlandırılmış durumdadır. Bu çalışma GDO'lu ürünlere yönelik genç tüketicilerin algı düzeylerini, tutumlarını ve davranışlarını inceleme ile sınırlıdır. Yine çalışmanın kapsamı TÜİK'e göre genç olarak nitelendirilen 18-24 yaş grubunu kapsamaktadır. Ayrıca bu çalışma 2025 yılında yürütülmüş ve belirli bir dönem içerisinde tüketicilerin davranışını anlamaya yöneliktir. Tüketici davranışını birçok faktör tarafından etkileniyor olması ve bugünün bulgularının yarının durumlarında geçerli olabilmesi beklenmemelidir. O nedenle bu çalışmanın bir zaman kısıtı olduğunu belirtmek gerekmektedir. Son olarak çalışmada tutum ve davranış başta olmak üzere bilgi ve algı düzeyi, etik kaygılar, iletişim kaynakları ve sağlık endişesi boyutları ile ele alınmaktadır. Bunlar dışında GDO'lu ürünlere yönelik tutum ve davranışı etkileyebilecek faktörlerin olabileceği göz önünde bulundurulmalıdır.

3.3. Araştırma Modeli ve Hipotezleri

Genç tüketicilerin demografik özelliklerinin GDO'lu ürünlere yönelik algı, tutum ve davranışları üzerinde etkili olduğunu gösterebilmek amacıyla teorik evrende model kurgulanmıştır. Genç tüketicilerin yaş, eğitim gördükleri bölüm, cinsiyet ve gelir değişkenlerine göre GDO'lu ürün algılamalarında ilişki olabileceği bu model ile ortaya konulmaktadır. Araştırmanın modeli Şekil 1.'de ayrıntılı olarak gösterilmektedir.

Şekil 1. Araştırma Modeli



Bu model doğrultusunda test edilecek hipotezler şu şekildedir:

H1: Genç tüketicilerin cinsiyetleri ile GDO'lu ürün algılamaları arasında farklılık vardır.

H2: Genç tüketicilerin aile geliri ile GDO'lu ürün algılamaları arasında farklılık vardır.

H3: Genç tüketicilerin eğitim gördükleri bölüm ile GDO'lu ürün algılamaları arasında farklılık vardır.

3.4. Örneklem, Anket Tasarımı ve Saha Çalışması

Genç tüketicilerin GDO'lu ürünlere yönelik farkındalık ve bu ürünlere yönelik tutumlarını etkileyen faktörleri belirleyebilmek için yürütülen çalışmanın ana kütlesini "genç tüketiciler" oluşturmaktadır. Türkiye İstatistik Kurumu (TÜİK) 2024 yılı verilerine göre genç nüfus olarak nitelendirilen 15-24 yaş grubu toplam nüfusun %15,1'ini oluşturmaktadır ki bu rakam 12 milyon 872 bin 39 kişidir (TÜİK, 2024). Basit tesadüfi örnekleme yöntemine göre örnek hacmi belirlenmiştir. Örnek büyüklüğünü hesaplamada Krejcie ve Morgan (1970) çalışmasında ortaya koymuş olduğu formül kullanılmıştır, buna göre:

$$n = \frac{Z^2 . p . (1 - p)}{E^2}$$

n= Örneklem büyüklüğü; Z= %95 güven düzeyine göre Z-değeri; p=popülasyondaki başarı oranı (%50); E=hata payı; N=toplam popülasyon

Yapılan hesaplamalar neticesinde örneğe 384 katılımcının alınmasının yeterli olacağı belirlenmiştir. Anket uygulaması üniversite kampüsü içerisinde kolayda örnekleme yöntemiyle gerçekleştirilmiştir. Kampüs içerisinde rastgele öğrencilere ulaşılarak, gönüllük temelinde ankete katılımları sağlanmış, öğrencilerin özgür iradeleri doğrultusunda anketlere katıldıkları bir süreç izlenmiştir. Saha çalışmasında olası yanlış ya da eksik doldurma gibi geçersiz anketler olma olasılığına karşı ihtiyatlı davranılmış, hesaplanan örnek hacminin üzerinde anket uygulanmasına karar verilmiştir. Ayrıca demografik alt gruplara göre karşılaştırmalar yapılacağından daha anlamlı sonuçların elde edilmesi açısından da önemli olarak görüldüğünden %20 daha fazla anket uygulanmasına karar verilmiş ve 460 anket uygulanmıştır.

Ancak verilerin dijitalleştirilmesinde fark edilen ve analize uygun olmayan 24 anket veri analize dahil edilmemiş, böylelikle veri analizi 436 anket ile gerçekleştirilmiştir.

Saha çalışmasında veri hem yüz yüze anket yöntemiyle hem de dijital anket formları aracılığıyla toplanılmıştır. Anket formu iki bölümden oluşmaktadır. Birinci bölümü katılımcıların demografik bilgilerini belirlemeye yöneliktir. Bu bağlamda yaş, cinsiyet, ortalama gelir, eğitim bölümü ve ikamet ettiği il bilgilerinden oluşmaktadır. İkinci bölümde ise katılımcıların GDO'lu ürünlere yönelik tutum ve davranışlarını belirlemeye yönelik ifadeler yer almaktadır. 34 ifadenin yer aldığı bu bölümde ifadelerin değerlendirilmesi 1-kesinlikle katılmıyorum ile 5-kesinlikle katılıyorum şeklinde 5'li Likert Tipi ölçek kullanılmıştır. Ankette kullanılan ifadeler literatürde yer alan daha önceki çalışmalardan elde edilmiş ve çalışmanın amacına uygun biçimde uyarlaması yapılmıştır. Ankette kullanılan ölçek ifadelerinin oluşturulmasında çeşitli bilimsel çalışmalardan (Chen vd., 2010; Plotnikoff vd., 2010; Macdonell vd., 2013; Wang vd., 2019; Brooks ve Bubela, 2020; Yıldız vd., 2022) faydalanılmıştır.

Veri Analizinde SPSS 27 paket programı kullanılmıştır. Açıklayıcı araştırma türü olan bu çalışmada, özelden genele doğru tümevarım bir yaklaşım benimsenmiş ve hipotezler sınanmıştır.

4. BULGULAR

Ankete katılan 436 kişiyle ilgili özellikler aşağıda yer alan Tablo 1.'de ayrıntılı olarak sunulmuştur. Buna göre araştırmaya katılanların yaş ortalaması 21 olarak hesap edilmiştir. Bu yaş grubu araştırmanın amacını için hedeflemiş olduğu yaş grubudur. Araştırmaya katılanların %57,8'i kadın, %42,2'si ise erkektir. Katılımcıların %47,7'si aylık 55 – 100 bin TL arası aile gelirine sahip bir gruptan oluştururken, %27,5'i 55 bin TL altında ücret düzeyinde geliri bulunmaktadır. Ankete katılan gençlerin eğitim alanlarına göre yapılan sınıflandırmaları neticesinde ortaya çıkan dağılımları ise en fazla katılımcının %23,39 ile Ziraat Fakültesi'nden olduğu hemen ardından %17,89 ile Eğitim Fakültesi öğrencilerinin katılım sağladığı görülmektedir. Ardından sırasıyla İİBF (%16,51), Sosyal Bilimler MYO (%15,60), Fen Edebiyat Fakültesi 41 kişi, Sağlık Hizmetleri MYO 3 kişi ve Fizik Tedavi ve Rehabilitasyon Yüksekokulundan ise 36 kişi ankete katılım sağlamıştır.

Tablo 1. Katılımcıların Özellikleri

		Frekans	**Ortalama**	**Standart Sapma**
Yaş		436	21,21	1,885
		Frekans	**Yüzde**	**Kümülatif Yüzde**
Cinsiyet	Kadın	252	57,8	57,8
	Erkek	184	42,2	100,0
	Toplam	**436**	**100**	
Ailenizin ortalama aylık geliri	0-55.000 TL	120	27,5	27,5
	55.001-100.000 TL	208	47,7	52,3
	100.000 TL üstü	108	24,8	100,0
	Toplam	**436**	**100**	
Bölüm	Ziraat Fakültesi	102	23,39	26,6
	Eğitim Fakültesi	78	17,89	37,6
	İİBF	72	16,51	46,8
	Sosyal Bilimler M.	68	15,60	62,4
	Fen Edebiyat	41	9,41	72,5
	Sağlık Hizmetler M.	39	8,95	89,9
	Fizik Tedavi	36	8,25	100,0
	Toplam	**436**	**100**	

Veri analizine geçilmeden önce hangi istatistik yöntemlerin kullanılacağına karar vermek amacıyla veri setinin çarpıklık ve basıklık değerleri hesaplanmıştır. Bu değerlerin-1.5 ile +1.5 olduğu zaman normal dağılım olduğu kabul edilmektedir (Tabachnick ve Fidell, 2013). Yapılan analizler neticesinde değişkenlerin çarpıklık ve basıklık değerlerinin -0,559 ile 0,298 arasında değiştiği belirlenmiş ve verinin normal dağılım gösterdiğini tespit edilmiştir. O nedenle veri analizinde parametrik testler kullanılmıştır.

Araştırmada kullanılan ölçeğin güvenilirlik analizi için Cronbach's Alpha değerine bakılmıştır. Güvenilirlik düzeyi 0,784 olarak hesap edilmiştir. Güvenilirlik düzeyi yüksek olan veri setine faktör analizi uygulanmasına karar verilmiştir. Çünkü faktör analizi değişkenler arası ilişkilerden hareket ederek verilerin daha anlamlı ve özet biçimde sunulmasını sağlayan bir analiz türüdür. Bu analiz ile çok sayıda değişkenden oluşan ifade setini, korelasyonları yüksek olan gruplara ayırarak ortaya bir faktörün belirlenmesini sağlamakta ve toplam varyansın büyük bir kısmını ortaya çıkan bu az sayıdaki faktörler ile açıklayabilmektedir.

Bu araştırmada 34 ifadeden oluşan ölçek kullanılarak keşifsel faktör analizi gerçekleştirilmiştir. Öz değeri (eigenvalue) 1'den büyük olan ifadeleri gruplandırılması istenilmiştir. Örneklem büyüklüğüne ilişkin Kaiser-Meyer-Olkin (KMO) ve Barlett Küresellik değerleri öncelikli olarak kontrol edilmiştir. KMO testi 0,749 ve Barlett Küresellik Testi ise $X^2(561)=8719,834$, $p<0.001$ olarak hesaplanmış ve örneklem büyüklüğünün faktör analizi için uygun olduğu ortaya konulmuştur.

Principal Component ve rotasyon konverjansı 50 olarak belirlenmiş, rotasyon direct oblimim tercih edilmiştir. Çünkü bu rotasyon metodu faktörler arası korelasyona izin vermektedir. Bu doğrultuda yapılan faktör analizi sonucuna göre toplam varyansın %69,546'sını açıklayan toplam 7 faktörün genç tüketicilerin GDO ürünlere yönelik tutum ve davranışlarını etkilediği ya da belirleyen faktörler olduğu tespit edilmiştir. Bu faktörlerle ilgili incelenen desen matrisindeki ifadeler isimlendirilmiştir. Buna göre toplam varyansın %23,480'ini açıklayan, 6 ifadenin birleşimden oluşan ilk faktör ***"risk ve endişe algısı"*** olarak isimlendirilmiştir. İkinci bileşende 7 ifadenin bir faktörü oluşturduğu ve toplam varyansın %13,463'ünü açıklayan ***"olumlu tutum ve kabul"*** faktörü olarak isimlendirilmiştir. Toplam varyansın %7,847'sini açıklayan ve 4 ifadeden oluşan faktör ***"bilgi düzeyi ve dış etkiler".*** Genç tüketicilerin davranışlarını açıklamak için toplam varyansın %7,704'ünü açıklayan ve 7 ifade bileşeninden oluşan faktör ise ***"kaçınma davranışı"*** olarak isimlendirilmiştir. Toplam varyansın %4,451'ini açıklayan ve 3 ifadeden oluşan faktör ise ***"bilgi eksikliği ve eğitim ihtiyacı"*** faktörüdür. %3,511 varyansı açıklayan ve 3 ifadeden oluşan diğer faktör ise ***"sosyal etkileşim***" ve son olarak toplam varyansın %3,258'ini açıklayan 3 ifadeden oluşan faktör ise ***"etik sorumluluk"*** faktörü olarak isimlendirilmiştir. Bu faktörler ve faktörlere yüklenen ifadelerin içeriğini gösteren Tablo 2. Aşağıda verilmiştir.

Tablo 2. Faktör İfadeleri İçeriği ve Faktörlerin Tematik İsimleri

Faktör	Faktöre Yüklenen İfadelerin İçeriği	Faktör İsmi
1	GDO'ların sağlık ve çevresel risklere dair endişeler, uzun vadeli etkiler, güven eksikliği	Risk ve Endişe Algısı
2	GDO'ların faydaları, tarımsal verimlilik, olumlu tutum ve politik destek	Olumlu Tutum ve Kabul
3	GDO'lara ilişkin bilgi sahibi olma, medyanın etkisi ve etiketlemeye yönelik beklentiler	Bilgi Düzeyi ve Dış Etkiler
4	GDO'lu ürün tüketiminden kaçınma, sağlık ve çevre endişeleri, alternatif arayışları	Kaçınma Davranışı
5	Bilgi eksikliği, kamu eğitimi ihtiyacı, karar verme sürecinde ortaya çıkan belirsizlikler	Bilgi Eksikliği ve Eğitim İhtiyacı
6	Sosyal çevrenin etkisi, aile ve arkadaşlar ile görüş alışverişinde bulunma isteği	Sosyal Etkileşim
7	Akademik çalışmalara güven, sağlıkla ilgili etiksel kaygılar, hükümetin GDO'lu ürünler ile ilgili düzenleyicilik rolü	Etik Sorumluluk

Araştırmanın bu bölümünde katılımcıların demografik özelliklerine göre aile geliri, cinsiyet ve eğitim alanı değişkenlerine göre GDO'lu ürünlere yönelik ortaya çıkan faktörlere göre anlamlı farklılıkların olup olmadığına bakılmıştır.

Cinsiyet değişkenine göre GDO'lu ürünlere yönelik tutum ve davranışlarında farklılığı tespit etmek amacıyla ***bağımsız örneklem t-testi*** uygulanmıştır. Test sonuçlarına göre risk ve endişe algısı, bilgi düzeyi ve dış etkiler, kaçınma davranışı, bilgi eksikliği ve eğitim ihtiyacı, sosyal etkileşim ve etik sorumluluk faktörlerine göre Kadın ve Erkek katılımcılar arasında herhangi bir tutum ve davranış farklılığı görülmemiştir. Ancak olumlu tutum ve kabul faktöründe gruplar arası farklılık olduğu görülmüştür. Varyans homojenliğinin sağlanıldığı Levene testine (p> .01) göre belirlenmiştir. Tablonun çift kuyruk anlamlılık değerinin 0,028, p<0,05 olduğu görülmüştür. Kadın katılımcıların olumlu tutum ve kabul ortalamalarının (2,7404) erkek katılımcılarının oranından (3,0807) daha düşük olduğu belirlenmiştir. Cohen's d etki büyüklüğü testi sonucu ise .876 gibi büyük ve güçlü bir etkinin olduğu ve bu iki grup arasında fark edilebilecek düzeyde bir farklılık olduğunu göstermiştir.

Ailenin ortalama geliri ile GDO'lu ürünlere yönelik tutum ve davranışlarında farklılık olup olmadığını belirlemek için ***tek yönlü varyans (ANOVA)*** testi uygulanmıştır. Ailenin ortalama geliri ile GDO'lu ürünlere yönelik tutum ve davranışlarındaki risk ve endişe algısı, [F(2, 433) = 2.36, p=.095], kaçınma davranışı [F(2, 433) =2.00, p=.136] ve sosyal etkileşim [F(2, 433) =1.33, p=.265] faktörlerine göre gruplar arasında anlamlı bir farklılık bulunmamıştır.

Olumlu tutum ve kabul F(2, 433) = 8.83, p < .001; bilgi düzeyi ve dış etkiler F(2, 433) = 4.93, p = .008; bilgi eksikliği ve eğitim ihtiyacı F(2, 433) = 10.70, p < .001 ile etik sorumluluk F(2, 433) = 3.97, p = .020 faktörlerine göre gruplar arasında anlamlı farklılık olduğu tespit edilmiştir.

Levene test sonuçlarına göre varyansların homojenliğinin sağlanamadığı durum için post-hoc olarak Games Howell; varyans homojenliğinin sağlandığı durum için ise post-hoc test olarak Tukey testi tercih edilmiştir.

Aylık gelir düzeyi yüksek olarak kabul edilen 100.000 TL ve üzeri gelir grubu diğer gelir gruplarına göre daha düşük düzeyde olumlu tutum ve kabul göstermektedir. Aynı şekilde bilgi düzeyi ve dış etki faktörüne göre de diğer gruplara göre daha düşük düzeydedir. Bilgi eksikliği ve eğitim ihtiyacı düşük gelir grubunda yer alan (0-55.000 TL) genç tüketicilerin anlamlı derecede daha yüksek olduğu belirlenmiştir. Düşük gelir grubunda yer alan bireylerin etik sorumluluk algısı, yüksek gelir grubundaki bireylere göre daha düşüktür.

Genç tüketicilerin eğitim aldıkları bölüm ile GDO'lu ürünlere yönelik tutum ve davranışları arasındaki farklılığı tespit etmek için ***tek yönlü varyans (ANOVA)*** analizi uygulanmıştır. Değişkenler arasında istatistiki olarak anlamlı bir farklılık bulunmamıştır. Her ne kadar p>0.05 olsa da ortalama değerlere bakıldığında bazı fakülteler arasında belirgin eğilim farklılıkları gözlenmektedir. Özellikle Sağlık Bilimleri Meslek Yüksekokulu ve Ziraat Fakültesi öğrencilerinin, *olumlu tutum ve kabul (OTK)* ile *bilgi eksikliği ve eğitim ihtiyacı (BEEI)* boyutlarında diğer fakültelere kıyasla daha yüksek ortalamalara sahip olduğu görülmektedir. Bu durum, sağlık alanında eğitim alan bireylerin GDO'lu ürünlere ilişkin konulara daha duyarlı veya bilinçli yaklaşabileceğini düşündürmektedir. Diğer yandan, İktisadi ve İdari Bilimler Fakültesi öğrencilerinin birçok boyutta daha düşük ortalamalara sahip olması, bu gruptaki bireylerin GDO konusuna daha mesafeli ya da eleştirel bir tutum sergilemiş olabileceğini düşündürmektedir. Bu bulgular, GDO'lu ürünler konusundaki tutumların sadece bireysel

faktörlerle değil, aynı zamanda eğitimin alanına ve içeriğine bağlı olarak da şekillenebileceğini ortaya koymaktadır.

5. SONUÇLAR

Bu çalışma genç tüketici olarak kategorize edilen 18-24 yaş grubu bireyleri Genetiği Değiştirilmiş Organizmalara (GDO) yönelik tutum ve davranışını belirlemeye yönelik gerçekleştirilmiş, keşifsel bir çalışmadır. Genç tüketiciler geleceği tüketimi şekillendirmesi açısından önemli bir pazar bölümüdür. Gençler henüz kariyerlerinin başından, büyük çoğunlukta aile kurmamış bireylerdir. Bu durum gençlerin tüketim alışkanlıklarının nasıl ve ne yönde olabileceğine dair önemli bilgiler vermektedir. Gençlerin tercihleri, alışkanlıkları, bilgi düzeyleri ve tutumları gelecekteki pazar trendlerini belirlemede önemli değişkenlerdir. Bu nedenle gençlerin davranışlarını incelemek gelecekteki pazarlama stratejilerinin belirlenmesinde ve şekillendirilmesinde kritik rol oynamaktadır. Çalışmanın neticesinde elde edilen bulgular doğrultusunda oldukça dikkat çekici sonuçlar elde edilmiştir. Bu sonuçların GDO'lu ürünlere yönelik politikaların geliştirilmesinde, yasal mevzuatın düzenlenmesinde ve tüketiciler ile kurgulanacak iletişim stratejilerinin belirlenmesinde ve yön verilmesine etki edebilecek düzeydedir.

Araştırmada sahadan toplanan veriye uygulanan keşifsel faktör analizi sonucunda, GDO'lu ürünlere yönelik genç tüketicilerin tutum ve davranışını etkileyen ve belirleyen 7 faktör ortaya çıkmıştır. Faktör yükleri ve bu faktörlere yüklenen ifadelerin içerikleri incelenmiş ve tematik olarak adlandırılmıştır.

Genç tüketicilerin *risk ve endişe algısı* faktörüne göre bu ürünlerin başta sağlık olmak üzere, çevreye olası etkileri ile uzun vadedeki belirsizlikleri ve bilinmezlikleri konusunda bu tüketici kitlesinin endişelerini ortaya koymaktadır. O nedenle bu tüketicilerin GDO'ya karşı daha temkinli bir yaklaşım benimsemesine etki ettiği söylenebilir. Bu durum karşısında bakanlıklar düzeyinde (Sağlık ve Tarım Orman Bakanlıkları) eğitim yayım faaliyetleri çerçevesinde ve hatta üniversitelerin de dahil olabileceği oluşumlar ile bilgilendirme ve iletişim kampanyalarının yapılması bu tüketicilerin endişeleri bertaraf etmede faydalı olabilecektir. Bir diğer faktör olan bilgi düzeyi ve dış etkiler faktörüne göre genç tüketiciler kendilerinde bilgi eksikliği hissettiklerini göstermektedir. Bu kitle medya başta olmak üzere ürün etiketlemelerinden de etkilenmektedir. O nedenle bu kitlenin tutum ve davranışını GDO'lu ürün lehine etkileyebilmek için medyanın güçlü bir araç olarak kullanılır hale getirilmesi, tarafsız dijital bilgi platformları ile bu gençlere ulaşılması faaliyetlerinde bulunmak faydalı olabilecektir.

Çalışma sonuçlarına göre çıkan önemli bir faktörde GDO'lu ürünlerin bilinçli olarak tercih edilmemesini içeren *kaçınma davranışı* faktörüdür. Buna göre genç tüketiciler etiketleri incelemekte, alternatif ürün arayışına girmektedir. Genç tüketicilerin davranışlarında risk algısının doğrudan etkisinin olduğunu ortaya koymaktadır. O nedenle gençlerin risk olarak görmüş oldukları durumların (sağlık, çevre riski gibi) ortadan kaldırılması bu tüketici kitlesinin olumlu yönde ikna edilmesine etki edeceği öngörülebilir.

Genç tüketiciler *bilgi eksikliğinin* tutum ve davranış gelişimi üzerinde olumsuz etkisinin olduğunu belirtmektedirler. O nedenle bu kitleye neden GDO'lu ürün tercih edilebileceği?

Risklerinin neler olduğu? gibi konularda daha şeffaf ve akılcı yöntemler ile bilgi sağlanması gerekmektedir.

GDO'lu ürünler ilgili kararların sosyal çevreden ve aileden etkilendiğine dair bir başka faktörün varlığı söz konusudur. Gençlerin GDO'ya karşı tutum ve davranışlarının gelişmesinde sosyal çevrenin etkisinin olduğu görülmektedir.

Son bir faktör olarak ise GDO'lu ürünlerle ilgili düzenlemelerin, bilimsel denetimin ve etik sorumlulukların yeterliliği sorgulanmaktadır. O nedenle etik kurul raporlarının kamuya açık hale getirilmesi, tarım ve gıda politikaları konularında sivil toplum örgütleriyle iş birliklerinin geliştirilmesinin konunun geniş kitlelerce kabulü noktasında önemli etkileri olabilecektir.

Genç tüketiciler, GDO'lu ürünlerin faydalarını gören akılcı ve yenilikçi bir bakış açısı içermesi nedeniyle olumlu tutum ve kabul davranışı sergileyebilme potansiyeli olan ve bilinçli olduğu görülen bir tüketici kitlesi olarak görülmelidir.

Araştırmada elde edilen bir diğer önemli sonuç ise kadınların, erkek katılımcılara göre olumlu tutum ve kabul davranışı gösterme durumlarının daha düşük olduğudur. Bu durum kadınların daha rasyonel ve daha fazla koruyucu güdüsü içerisinde olma özellikleri ile anlaşılabilir. O nedenle GDO'lu ürünlerin kullanılması ya da tüketilmesinde daha temkinli olduklarını göstermektedir.

Ailenin ortalama gelirine göre değerlendirildiğinde yüksek gelir grubu (100.000 TL ve üzeri) katılımcıların diğer gelir gruplarına göre GDO'lu ürünlere karşı olumlu tutum ve kabul davranışı daha düşük düzeydedir. Yüksek gelir düzeyinde aile geliri olan katılımcıların tüketim konusunda daha çok bildikleri ve güvendikleri ürün grubunu tercih ettiği, henüz bilmediği, risklerini öngöremediği ürünlere karşı daha temkinli olduğu sonucuna ulaşabiliriz. Yine aynı gelir grubu aile mensubu katılımcıların bilgi düzeyi ve dış etkiler konusunda da diğer gruplara göre daha düşük düzeyde olduğu görülmektedir. Bu katılımcıların GDO'lu ürünlere karşı çevresel etkilere daha az duyarlı olduğunu ve GDO'lu ürünleri kabulünü sınırlandırdığı düşünülmektedir.

Düşük gelirli aile bireylerinin GDO'lu ürünlere yönelik tutum ve davranışlarının gelişmesinde bilgi eksikliği yaşadıkları ve eğitim ihtiyaçlarının diğer gelir grubundaki bireylere göre daha fazla olduğu sonucuna ulaşılmıştır. Yüksek gelirli aile bireylerinin, etik sorumluluk bilincinin daha yüksek olduğu, bu gruptaki bireylerin çevresel ve toplumsal etkiler konusunda daha bilinçli olduklarını göstermektedir. O nedenle düşük gelir grubundaki kişilerin daha fazla bilgilendirilmesine yönelik çaba ve faaliyetlere girilmesinin gerekliliği ortaya çıkmaktadır. Çalışmanın üniversite öğrencileriyle birlikte yapılmış olması, homojen bir örnek oluşturması nedeniyle, tanımlayıcı istatistiklerde de görüldüğü üzere katılımcıların büyük bir kısmı (%75,2) düşük ve orta gelirli aile bireyleri olması nedeniyle, bahsi geçen bilinçlendirme faaliyetlerin önemi daha fazla ortaya çıkmaktadır.

GDO'lu ürünlere yönelik tutumların fakültelere göre farklılaştığını, ancak bu farklılığın istatistiksel olarak anlamlı olmasa da belirli bir eğilim oluşturduğu belirlenmiştir. Özellikle sağlık ve ziraat ile ilgili alanlarda eğitim alan öğrencilerin daha bilinçli ve olumlu tutumlar sergilemesi, bu alanlarda verilen eğitimin bilgi düzeyini ve tutumları etkileyebileceğini ortaya koymaktadır. Buna karşın sosyal bilimler ve idari bilimler alanlarında daha düşük tutum ortalamalarının gözlemlenmesi, bu alanlarda konunun yeterince işlenmediğini

düşündürmektedir. Bu doğrultuda, GDO'lu ürünler gibi toplum sağlığını, çevreyi ve etik değerleri doğrudan etkileyen konuların fakülteler arası ortak derslerle veya müfredat içi entegre modüllerle daha kapsayıcı bir şekilde ele alınması bu alanlarda eğitim alan bireyler açısından fayda sağlayacaktır. Ayrıca, üniversitelerde düzenlenecek bilgilendirici seminerler, çalıştaylar ve paneller ile öğrencilerin konu hakkında daha fazla bilgi edinmesi ve bilinçli tutum geliştirmesi teşvik edilmelidir. Böylece öğrenciler GDO konusunda daha bütüncül ve bilinçli bir şekilde yaklaşabilecek ve değerlendirebileceklerdir.

Yapılan araştırmalar (Konar vd., 2014) genç tüketicilerin GDO'lara yönelik tutumlarının, demografik değişkenlerle ilişkili olarak anlamlı farklılıklar gösterip göstermediğini doğrulamakta ve bu durum, tüketici davranışlarının anlaşılmasında önemli bir katkı sunmaktadır. Yürütülen bu çalışmanın sonuçları da bu paralelde olup, demografik değişkenlere göre farklılıklar söz konusu olmaktadır.

Gelecekte bu alanda yapılacak çalışmalarının gerek hedef kitle seçimi gerekse de farklı değişkenler modele eklenerek kapsamının genişletilmesi farklı sonuçların elde edilmesine katkı sağlayabilecektir. GDO konusunun çok farklı disiplinler ile iç içe bir konu olması nedeniyle, farklı alanlarda ortaklaşa yürütülecek çalışmalara ihtiyaç duyulduğu görülmektedir. Ayrıca GDO konusu yerli literatürde daha fazla işlenmesi gereken bir konu olarak görülmektedir. Bu durum ankete katılanların bilgi eksikliği ve eğitim ihtiyacı faktöründen de belli olmaktadır. O nedenle akademik camianın bu alana daha fazla yoğunlaşması bilimsel bilgi açısından önem arz etmektedir.

Sonuç olarak, yürütülen bu araştırma GDO konusunda tüketici algısının yalnızca bilimsel olmadığı aynı zamanda psikolojik, sosyolojik ve etik boyutları da içerdiği ortaya konulmuştur. Bu nedenle karar vericilerin belirleyeceği stratejilerin çok yönlü, katılımcı ve en önemlisi güven inşa eden bir yapıda olması gerekmektedir.

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İLGİLİ MAKAMA SUNULMAK ÜZERE
(Prof.Dr.Selahattin ÇINAR)

İlgi : Üniversitemiz Ziraat Fakültesinin 20.01.2025 tarihli ve E-92550236-903.99-00000718310 sayılı yazısı.

Üniversitemiz Ziraat Fakültesi tarafından 25-27 Nisan 2025 tarihlerinde gerçekleştirilecek olan 17. Uluslararası Tarım, Hayvancılık ve Kırsal Kalkınma Kongresi başlıklı bilimsel toplantısının üniversitemiz ev sahipliğinde düzenlenmesi planlanmaktadır.

Söz Konusu Kongrenin düzenleme kurulu başkanı olarak Üniversitemiz Ziraat Falültesi Dekan Vekili Prof. Dr. Selahattin ÇINAR Rektörlüğümüzce görevlendirildirilmiştir.

Bilgilerini ve gereğini arz/rica ederim.

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