PROCEEDING BOOK

BALKAN 12. ULUSLARARASI UYGULAMALI BİLİMLER KONGRESİ

ÜSKÜP
1 - 3 Kasım 2024

BALKAN 12. ULUSLARARASI UYGULAMALI BİLİMLER KONGRESİ

BALKAN 12th INTERNATIONAL CONFERENCE ON APPLIED SCIENECES
NOVEMBER 1 - 3, 2024
SKOPJE

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NOVEMBER 1 - 3, 2024 – SKOPJE

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Oral presentation

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In the conference 72 papers have been presented by Turkish participants and 100 apers by foreign participants.
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Fakültemiz Tıbbi Biyokimya Anabilim Dalı'nda görevli öğretim üyesi Prof. Dr. Hülya ÇİÇEK'in Yükseköğretim Genel Kurulunun 15.06.2023 tarihli, 10 sayılı oturumunda alınan 2023.10.183 sayılı kararı gereğince Doçentlik Başvuru Şartlarında bulunan ve doçent olacak adaylardan istenen "Diğer uluslararası/ ulusal bilimsel toplantının düzenleme komitesinde resmi olarak görevlendirilmiş üniversite akademisyen temsilcisi bulunması zorunludur." maddesi gereğince, Academy Global Conference & Journals tarafından yapılan kongrelerin düzenleme kurullarında yolluksuz ve yevmiyesiz olarak görevlendirilme talebi ile ilgili dilekçesi ekte gönderilmiştir

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1 Kasım / November 1, 2024 / 11:00 – 13:00 Time zone in Turkey (GMT+3)

Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 1	**Dr. Öğretim Üyesi Hamide Merve GÜÇLÜ**	1	A REVIEW AIMED AT DETERMINING THE DIFFICULTIES EXPERIENCED BY LOGISTICS ENTERPRISES IN THEIR GREEN PRACTICES	Doç. Dr., SALİH MEMİŞ Öğr. Gör. Dr., ZAFER CESUR
		2	THE DEVELOPMENT OF LOGISTICS VILLAGES IN TURKEY AND SAMPLE APPLICATIONS	Öğr. Gör. Dr., ZAFER CESUR Doç. Dr., SALİH MEMİŞ
		3	MÜŞTERİ ŞİKAYETLERİNİN YAPAY ZEKA TEMELLİ BİR UYGULAMA İLE DEĞERLENDİRİLMESİ: CHAT GPT ÖRNEĞİ	Öğr. Gör. Dr., ESRA TÜRK
		4	THE MEDIATING ROLE OF MATERIALISM IN THE RELATIONSHIP BETWEEN PERSONALITY TRAITS AND CONSPICUOUS CONSUMPTION	Esra KAHYA Asst. Prof. Bilal CELIK
		5	6331 SAYILI KANUN'UN 13. VE 25. MADDELERİNİN, UZAKTAN ÇALIŞMAYA UYGULANIP UYGULANAMAYACAĞININ DEĞERLENDİRİLMESİ	Dr. Öğretim Üyesi Hamide Merve GÜÇLÜ
		6	LOJİSTİK KÖYLERE AKADEMİK BAKIŞ	Prof. Dr. Burcu ERŞAHAN Prof. Dr. İsmail BAKAN Yüksek Lisans Öğrencisi Fatma Nur DEMİR
		7	THE NATURAL RESOURCE RACE IN TOURISM – THE CASE OF VIETNAM AND SINGAPORE	Nhu-Y Huynh PHAM Mong-Tuyen LUONG Thuy-Uyen Thi NGUYEN Yen-Vy Ha NGUYEN Anh-Thu Thi LE Lam-Thu VO Que-Nhu DUONG
		8	THE IMPACT OF LOCAL FOOD ON SUSTAINABLE DEVELOPMENT	Assist. Prof. Dr. Gizem Sultan KAMAN Assist. Prof. Dr. Rabia BÖLÜKBAŞ
		9	DIGITAL TRANSFORMATION AND REFLECTIONS ON INDEPENDENT AUDIT PROCESSES	Doç. Dr., Betül Şeyma ALKAN Merve YAVAŞ

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HALL / SALON 2	**Prof. Dr. Mesut Bulut**	1	EXAMINING THE PERCEPTIONS OF PROFESSIONALS WHO WILL WORK IN THE FORENSIC FIELD TOWARD CRIMINALS	Doç.Dr. Rumeysa AKGÜN Arş.Gör. Seda ERKUŞ DEMİR
		2	SINIF ÖĞRETMENLERİNİN ÖĞRETİM SÜREÇLERİNDE YARARLANABİLECEĞİ DİJİTAL ZEKÂ OYUNLARININ İNCELENMESİ	Öğretmen, GÖKÇEN BAHAR AYDIN Prof. Dr., BELGİN ARSLAN CANSEVER
		3	EXAMINING THE RELATIONSHIP BETWEEN MOTIVATION LEVELS AND INDEPENDENT LEARNING BEHAVIORS IN PRESCHOOL CHILDREN	Rukiye DIĞRAK Prof. Dr. Saide ÖZBEY
		4	TÜRK DİLİ VE EDEBİYATI ÖĞRETMENİ ADAYLARININ "DÜNYA EDEBİYATI" DERSİNE İLİŞKİN GÖRÜŞ VE DENEYİMLERİNİN İNCELENMESİ	Prof. Dr. Mesut Bulut
		5	EVALUATION OF STUDENT SUCCESS WITH MACHINE LEARNING CLASSIFIERS ON EDUCATIONAL SYNHETIC DATA	Prof. Dr. Akın ÖZÇİFT Assoc. Prof. Dr. Fatih YÜCALAR

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HALL / SALON 3	**Dr. Öğr. Üyesi Hilal OK ERGÜN**	1	RELATIONSHIP BETWEEN GREEN FINANCE, HEALTH EXPENDITURES AND ENVIRONMENTAL QUALITY: THE CASE OF TÜRKİYE	Doç. Dr. Tolga ERGÜN Dr. Öğr. Üyesi Hilal OK ERGÜN
		2	THE RELATIONSHIP BETWEEN DISCONTENT INDEX AND CORRUPTION PERCEPTION INDEX: THE CASE OF BRICST COUNTRIES	Assoc.Dr. AYŞE DURGUN KAYGISIZ R. A. SEÇKİN KABAK
		3	INTRA-INDUSTRY TRADE ANALYSIS OF THE TRADE STRUCTURE OF TURKIYE AND THE TURKISH REPUBLIC OF NORTHERN CYPRUS (TRNC)	Prof. Dr. LEVENT KÖSEKAHYAOĞLU R. A. SEÇKİN KABAK Assoc.Dr. AYŞE DURGUN KAYGISIZ
		4	THE RELATIONSHIP BETWEEN DISPLACEMENT ASSOCIATED WITH DISASTERS AND POVERTY IN LESS DEVELOPED COUNTRIES	Öğr. Gör. Aynur KAYA Doç. Dr. Hikmet AKYOL Uzman Şeyma AKÇİÇEK Mücahit ÇELİK

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Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 4	**Mehmet Safa BİNGÖL**	1	SOLAR POWER PLANT ELECTRICITY GENERATION FORECASTING USING NONLINEAR AUTOREGRESSIVE NEURAL NETWORK	Şahin YILDIRIM Mehmet Safa BİNGÖL
		2	MECHANICAL PERFORMANCE OF BIODEGRADABLE AND METALLIC SCREWS IN FIFTH METATARSAL FRACTURES	Assoc. Prof. Dr. Hamid ASADI DERESHGI Researcher Dilan DEMIR
		3	WAVE ENERGY AND TURKEY: POTENTIAL, APPLICATIONS, AND FUTURE	Student, Zeynep KOÇ Faculty Member, Assoc. Prof. Dr. Fatih Ünal
		4	THE FUTURE OF DESALINATION IN MERSIN: INTEGRATION OF RENEWABLE ENERGY AND TECHNOLOGY	Student, Zeynep KOÇ Faculty Member, Assoc. Prof. Dr. Fatih Ünal
		5	NUMERICAL MODELLING OF PHOTOVOLTAIC PANELS BY USING MATLAB-SIMULINK	Ceren KARADENIZ Doç. Dr. Sahin GUNGOR
		6	AN EXPERIMENTAL INVESTIGATION ON THE RELATIONSHIP BETWEEN TRANSMITTANCE AND PV PANEL PERFORMANCE	Ceren KARADENIZ Doç. Dr. Sahin GUNGOR

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Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 5	**Prof., KADRİYE AYDEMİR**	1	THE RAYLEIGH QUOTIENT FOR ONE SINGULAR STURM-LIOUVILLE PROBLEM	Prof., OKTAY SH. MUKHTAROV Prof., KADRİYE AYDEMİR Assoc. Prof. HAYATİ OLĞAR
		2	TEKİL İKİ-ARALIKLI STURM-LİOUVİLLE PROBLEMLERİNİN ÖZDEĞERLERİNİN POZİTİFLİĞİ	Prof., KADRİYE AYDEMİR Prof., OKTAY SH. MUKHTAROV Assis. Prof. Dr. MERVE YÜCEL
		3	EXISTENCE OF SOLUTIONS FOR GENERALIZED CAPUTO FRACTIONAL BOUNDARY VALUE PROBLEMS	Dr., OZLEM BATIT OZEN
		4	TIME SERIES BASED FINANCIAL COMPONENT FORECASTING MODELS FOR THE E-COMMERCE SECTOR	Emre Taşbaş Mahmut Burak Kazçin Zehra Sude Sarı M. Fatih Akay
		5	DEVELOPMENT OF STATISTICS AND MACHINE LEARNING BASED CASH FORECASTING MODELS FOR AN ELECTRONIC PAYMENT COMPANY	Yusuf Ozan Köftegül Yusuf Ali Koyuncu Zehra Sude Sarı M. Fatih Akay

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HALL / SALON 6	**Assoc. Prof. Dr. Fatih YÜCALAR Prof. Dr. Akın ÖZÇİFT**	1	DEVELOPMENT OF A DIGITAL HOUSEKEEPING SYSTEM TO OPTIMIZE MEZZANINE LOCATIONS IN A WAREHOUSE	Murat Yüce Alişan Araslı Ceren Ulus M. Fatih Akay
		2	DETECTION OF FIELD INVENTORIES IN ENERGY SERVICE COMPANIES USING IMAGE PROCESSING AND DEEP LEARNING	HATICE ÖZDEMİR EYMEN BERKAY YORULMAZ GÖZDE UYGUR ADEM SELLER PROF. DR. M. FATİH AKAY
		3	GEOMETRIC APPROACH FOR PARAMETER ESTIMATION IN THROUGH-THE-WALL RADARS	Assist. Prof. Ridvan Firat Cinar
		4	SYNTHETIC DATA GENERATION WITH LARGE LANGUAGE MODELS TO EVALUATE ENSEMBLE REGRESSION ALGORITHMS	Assoc. Prof. Dr. Fatih YÜCALAR Prof. Dr. Akın ÖZÇİFT
		5	RIDGE REGRESSION PARAMETER OPTIMIZATION IN HOUSE PRICE PREDICTION	Prof. Dr. Akın ÖZÇİFT Assoc. Prof. Dr. Fatih YÜCALAR

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HALL / SALON 7	**Prof. Dr. Elchin Mammadov**	1	ANALYZING KEY FACTORS INFLUENCING CLIENT SATISFACTION IN CONSULTING ENGINEERING FIRMS	Ling Zhang, Prof. Dr. Kenji Nakamura, Akira Yamamoto
		2	DEVELOPMENT OF AI-DRIVEN PREDICTIVE MAINTENANCE SYSTEM FOR ENHANCING EQUIPMENT RELIABILITY	Dr. Kenji Nakamura, Prof. Dr. Mei Ling Chen, Dr. Hyun Soo Park
		3	DEVELOPMENT OF AN INTELLIGENT TASK MANAGEMENT SYSTEM USING AI TECHNOLOGIES	Dr. Leyla Mammadova, Prof. Dr. Farid Aliyev, Dr. Elchin Guliyev
		4	INNOVATIVE APPROACHES FOR CAPTURING SUBCONSCIOUS CONSUMER INSIGHTS IN E-COMMERCE	Dr. Elvin Aliyev, Prof. Dr. Leyla Mammadova, Aysel Huseynova
		5	CONTRACTOR SELECTION IN CONSTRUCTION PROJECTS USING MULTI-CRITERIA DECISION-MAKING AND SUPPLY CHAIN MANAGEMENT	Dr. Leyla Aliyeva, Prof. Dr. Elchin Mammadov
		6	FRAMEWORK FOR ENHANCING QUALITY CULTURE IN ALGERIAN HIGHER EDUCATION INSTITUTIONS	Dr. Ahmed Benali, Prof. Dr. Fatima Zahra, and Mr. Samir Khaled
		7	ENHANCING INSTITUTIONAL EFFECTIVENESS: THE STRATEGIC IMPORTANCE OF WORKFORCE BUDGETING IN FINANCIAL	Dr. Samira El Amrani, Prof. Dr. Ahmed Bouziane, Fatima Zahra Laaroussi
		8	EXAMINING URBANIZATION AND INCOME INEQUALITY IN ALGERIA	Dr. Amina Benali, Prof. Dr. Khalid Ziani, Fatima Zahra Lala
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HALL / SALON 8	**Prof. Dr. Noraida Mustaffa,**	1	CROSS-CULTURAL DYNAMICS AND INNOVATION: INSIGHTS INTO CHINESE FOREIGN DIRECT INVESTMENT IN ALGERIA	Dr. Ahmed Bensaid, Prof. Dr. Leila Nasr, Dr. Farid Touati
		2	EVALUATING THE INFLUENCE OF MARITIME TRANSPORT ON ECONOMIC GROWTH IN MALAYSIA	Dr. Ahmad Zainal, Prof. Dr. Noraida Mustaffa, Eng. Firdaus Rahman
		3	CROSS-CULTURAL COLLABORATIONS AND INNOVATION: ANALYZING CHINESE FOREIGN DIRECT INVESTMENT IN MALAYSIA	Dr. Siti Nurhaliza, Prof. Dr. Ahmad Faizal, Dr. Zainal Abidin
		4	KEY DETERMINANTS OF COST OVERRUN IN BUILDING CONSTRUCTION PROJECTS IN MALAYSIA	Dr. Ahmad Z. Ismail, Prof. Dr. Nurul H. Rashid, Eng. Farhan K. Ali
		5	THE EFFECTS OF THE COVID-19 PANDEMIC ON THE REAL ESTATE SECTOR	Dr. Mihai Ionescu, Prof. Dr. Elena Popescu, Andreea Vasilescu
		6	ASSESSING THE IMPACT OF CHINESE FOREIGN DIRECT INVESTMENT IN AFRICA: ETHICAL AND CULTURAL DIMENSIONS	Dr. Amina Nkosi, Professor Michael Adebayo, Dr. Lindiwe Tshabalala
		7	ENHANCING OPERATIONAL EFFICIENCY THROUGH LEAN METHODOLOGIES IN AFRICAN INDUSTRIES	Dr. Amina O. Kone, Prof. Dr. Samuel T. Ndung'u, Dr. Zainab I. Moyo
		8	EXPLORING LEAN METHODOLOGIES IN CONSTRUCTION: CHALLENGES AND OPPORTUNITIES	Dr. Aisha Mwanga, Prof. Dr. Samuel Ndungu, Grace Ochieng
			EXPLORING THE METHODOLOGICAL FRAMEWORK OF ISLAMIC ECONOMICS: OPPORTUNITIES AND CHALLENGES	Prof. Dr. Idris Karamoko
		9	EXPLORING THE INTERCONNECTION BETWEEN INDIVIDUAL AND ORGANIZATIONAL RESILIENCE IN THE CONSTRUCTION SECTOR	Dr. Amina Nkosi, Prof. Dr. Kofi Mensah, Thandiwe Moyo

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HALL / SALON 9	**Dr. Dmitry Sokolov**	1	STRATEGIC PLANNING FOR SUSTAINABILITY IN NGOS AND ITS INFLUENCE ON DONOR COMMITMENT	Dr. Nino Chikovani, Prof. Dr. Levan Kapanadze, Anna Tskhvedadze
		2	EXAMINATION OF SUSTAINABILITY REGULATION IN THE FINANCIAL SECTOR OF GEORGIA	Nino Janelidze, PhD; Giorgi Kvesitadze, MSc
		3	FORECASTING COPPER PRICES: A HYBRID APPROACH FOR ECONOMIC VARIABILITY	Prof. Dr. Giorgi M. Jojua, Dr. Nino K. Koberidze, Mr. Alexander T. Tsiklauri
		4	IMPACT OF ORGANIZATIONAL CULTURE ON DISPUTE FREQUENCY IN COMMERCIAL CONSTRUCTION PROJECTS: A CONTRACTOR'S PERSPECTIVE	Dr. Alexei Ivanov, Dr. Elena Petrovna, Andrei Sokolov
		5	IDENTIFYING NEET YOUTH RISK FACTORS IN RUSSIA: A MACHINE LEARNING ANALYSIS	Dr. Alexei Ivanov, Prof. Dr. Maria Petrovna, Dr. Dmitry Sokolov
		6	EVALUATION OF INNOVATION STRATEGIES IN SMALL AND MEDIUM-SIZED ENTERPRISES USING THE STAGE-GATE MODEL	Dmitry Ivanov, Elena Petrovna, Alexey Sokolov

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HALL / SALON 10	**Prof. Dr. Antonio R. Delos Reyes,**	1	ENHANCEMENT OF LITERACY SKILLS THROUGH A PROPOSED MODULE FOR BAYBAYIN INSTRUCTION	Dr. Elena Marie J. Cruz, Prof. Dr. Antonio R. Delos Reyes,
		2	ENHANCING ADULT EDUCATION INITIATIVES TO COMBAT FEMALE GENITAL MUTILATION AND ACHIEVE SUSTAINABLE DEVELOPMENT GOALS	Dr. Maria Santos, Prof. Dr. Juanita Reyes, Carlos Delgado
		3	ENHANCING LITERACY COMPETENCIES THROUGH AN INNOVATIVE MODULE FOR JAVANESE SCRIPT INSTRUCTION	Rina S. Aditya, Prof. Dr. Hendra Y. Santosa, and Ms. Maya P. Pramesti
		4	EMOTIONAL INFLUENCES ON STUDENT LEARNING AND ACADEMIC PERFORMANCE	Dr. Aisha Abdulaziz, Prof. Dr. Oluwaseun Bamidele, Mr. Dapo Kehinde
		5	INNOVATIVE APPROACHES IN SMART LEARNING SYSTEMS FOR MUSIC EDUCATION	Dr. Elena Vasilaki, Prof. Dr. Dimitris Kourouklis, Dr. Sofia Christodoulou
		6	THE ROLE OF URBAN ART IN FOSTERING REFLECTIVE PRACTICES IN EDUCATION	Dr. Alain M. Ngoy, Prof. Dr. Celestine T. Mbuyi, Ms. Amani N. Kalu
		7	ENHANCING INTERDISCIPLINARY APPROACHES IN EDUCATION: A FOCUS ON MATHEMATICS	Dr. Jean-Pierre Monga, Prof. Dr. Mireille Ngalula, Claude Makaya
		8	ENHANCING MATHEMATICAL UNDERSTANDING THROUGH ORIGAMI: A CASE STUDY	Dr. Fatma Al-Masri, Prof. Dr. Ahmed El-Sayed
		9	DECENTRALIZED ASSIGNMENT MANAGEMENT SYSTEM UTILIZING BLOCKCHAIN TECHNOLOGY	Dr. Ahmed Farouk, Prof. Dr. Sara Mahmoud, Nour El-Sayed, Dr. Khaled Hassan Prof. Dr. Fatima Zohra

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HALL / SALON 11	**Assoc. Prof. Aibek Shakirov,**	1	EXPLORING THE EFFECTS OF INADEQUATE TEACHER-STUDENT INTERACTIONS ON CHRONIC ABSENTEEISM IN SECONDARY SCHOOLS OF BANGLADESH	Dr. Rina Bhatia, Prof. Anwar Hossain, Asif Rahman
		2	UNDERSTANDING MOTIVATIONAL FACTORS IN ENGLISH LANGUAGE ACQUISITION: A STUDY AT A BELGIAN UNIVERSITY	Dr. Elise Dubois, Prof. Henri Martin, Laura Petit
		3	ENHANCING PROGRAMMING EDUCATION THROUGH AN INNOVATIVE COLLABORATIVE LEARNING MODEL	Authors: Dr. Annelies Vermeulen, Prof. Thomas Devries Joris Van Dyck
		4	EVALUATING THE IMPACT OF DIGITAL TECHNOLOGIES ON ASSESSMENT PRACTICES IN HIGHER EDUCATION	Dr. Amina Rahimi, Prof. Jamil Azizi, Ms. Fatima Mohseni
		5	INFLUENCE OF NON-PARENTAL EARLY CHILDHOOD EDUCATION ON VIRTUAL FRIENDSHIP DYNAMICS	Dr. Aigerim Tulegenova, Assoc. Prof. Aibek Shakirov, and Nurlan Askarov
		6	INFLUENCE OF NON-PARENTAL EARLY CHILDHOOD EDUCATION ON VIRTUAL FRIENDSHIP DYNAMICS	Dr. Aigerim Tulegenova, Assoc. Prof. Aibek Shakirov, and Nurlan Askarov
		7	THE IMPACT OF SUCCESS EXPECTATION ON STUDENT PERFORMANCE IN SUMMATIVE ASSESSMENTS	Dr. Marko Novak, Prof. Ivana Petrovic, and Ana Kovač
		8	STRATEGIC FRAMEWORK FOR DIGITAL CONTENT MANAGEMENT: A COMPREHENSIVE ANALYSIS	Dr. Ivan Petrov, Ms. Hana Kovač, Prof. Luka Jurić, Dr. Marija Novak
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HALL / SALON 1	**Prof. Dr. Mehmet Nuri ÇINARCI**	1	Museum Anthropology	Assoc. Prof. Dr. Zekiye ÇILDIR,
		2	MİĞFER ADLI ÇOCUK TİYATROSU METNİ ÜZERİNE BİR ÇÖZÜMELEME	Doç. Dr. Erhan ŞEN
		3	“AKLINDAN DÜŞÜNCELER GEÇEN ÇOCUK” ADLI ÇOCUK ROMANI ÜZERİNE BİR İNCELEME	Doç. Dr. Erhan ŞEN
		4	POEM AND POET IN THE EARLY PERSIAN TEZKIRES	Prof. Dr. Mehmet Nuri ÇINARCI
		5	ALLEGORICAL INTERPRETATION IN ANNOTATION OF VEHBÎ-İ KONEVÎ’S ŞERH-İ DÎVÂN-I HÂFIZ	Prof. Dr. Mehmet Nuri ÇINARCI
		6	MEMMED ARİF DADAŞZADE’NİN EDEBİ FAALİYETLERİ	Doç. Dr. Ayvaz MORKOÇ
		7	ELEŞTİRMEN KİMLİĞİYLE BEKİR NEBİYEV	Doç. Dr. Ayvaz MORKOÇ
		8	THE INTELLECTUALS OF CLASSİCAL TURKİSH LİTERATURE	PhD Student ŞEYDA GÖLLÜ

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HALL / SALON 2	**Assoc. Prof. SERVET SAY**	1	CALCULATION AND ACCOUNTING OF RISTURN IN COOPERATIVES	Assoc. Prof. SERVET SAY
		2	THE EFFECTS OF LEAVEİSM İN MODERN BUSİNESS LİFE	Dr., Fatih İbrahim KURŞUNMADEN
		3	INFLATİON ACCOUNTİNG	Dr. Fırat KINALI
		4	EVALUATION OF METROPOLITAN DISTRICT MUNICIPALITY MANAGEMENT BODIES IN TURKEY	Lect. Mehmet Nuri ÖDÜK

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HALL / SALON 3	**Prof. Dr. Belgin COŞGE ŞENKAL**	1	MODELING THE OPTIMUM IRRIGATION THAT PROVIDES THE HIGHEST TOMATO YIELD IN ANKARA REGION WITH DSSAT	Ziraat Yüksek Mühendisi, Abdelrahman Amr Ali Rabie Elsayed SALEH Araştırma Görevlisi, Elifnaz TORUN Profesör, Halit APAYDIN
		2	EVALUATION OF RELATIONSHIPS BETWEEN SEED YIELD AND SOME AGRONOMIC CHARACTERS IN SAFFLOWER (CARTHAMUS TINCTORIUS L.)	Prof. Dr. Belgin COŞGE ŞENKAL
		3	SAFFLOWER (CARTHAMUS TINCTORIUS L.) BREEDING OBJECTIVES	Prof. Dr. Belgin COŞGE ŞENKAL
		4	DETERMINATION OF FORAGE PERFORMANCES OF SOME SORGHUM (Sorghum bicolor (L.)) VARIETIES IN ANTALYA CONDITIONS	Assoc. Prof. Dr. Cengiz ERDURMUŞ
		5	IMPACTS OF CLIMATE CHANGE ON IRRIGATION AND AGRICULTURAL PRODUCTION: THE FUTURE OF WATER IN ANTALYA, TÜRKİYE	Assoc. Prof. Köksal AYDİNŞAKİR,
		6	DETERMINATION OF THE SUITABILITY OF DIFFERENT WATER RESOURCES FOR IRRIGATION IN AYAŞ REGION	Ziraat Yük. Müh. Ayfer BURDURLUOĞLU Prof. Dr. Ahmet ÖZTÜRK

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HALL / SALON 4	**Assoc. Prof. Dr. MÜJGAN GÜNEY**	1	THE ROLE OF SECONDARY METABOLITES IN PLANT STRESS RESPONSES: BIOTECHNOLOGICAL APPROACHES FOR CROP IMPROVEMENT	Assoc. Prof. Dr. MÜJGAN GÜNEY Assoc. Prof. Dr. HAKAN KELES Assoc. Prof. Dr. SERVET ARAS
		2	CHITOSAN NANOPARTICLES AND THEIR INFLUENCE ON GENE EXPRESSION AND SECONDARY METABOLISM IN FRUITS	Assoc. Prof. Dr. MÜJGAN GÜNEY Assist. Prof. Dr. GÖKÇE AYDÖNER ÇOBAN Assoc. Prof. Dr. MURAT GÜNEY
		3	USE OF ROOTSTOCKS IN WALNUT CULTIVATION	Doç. Dr. HAKAN KELES Doç. Dr. MÜJGAN GÜNEY Dr. Öğr. Üyesi GÖKÇE AYDÖNER ÇOBAN
		4	USE OF NANOPARTICLES IN AGRICULTURE	Doç. Dr. HAKAN KELES Doç. Dr. Servet ARAS Doç. Dr. Murat GÜNEY
		5	ANATOMICAL ALTERATIONS AFFECT BIODIVERSITY OF FRUIT SPECIES	Assoc. Prof. Dr. Servet ARAS Assoc. Prof. Dr. MURAT GÜNEY Assoc. Prof. Dr. Hakan KELES
		6	EFFECTS OF ABIOTIC STRESS FACTORS ON FRUIT SPECIES BIODIVERSITY	Assoc. Prof. Dr. Servet ARAS Assoc. Prof. Dr. Müjgan GÜNEY Assist. Prof. Dr. Gökçe AYDONER ÇOBAN
		7	APPLE (Malus domestica) miRNA EXPRESSION AND HORTICULTURAL IMPLICATIONS	Assoc. Prof. Dr. Murat GÜNEY Asst. Prof. Dr. Gökçe Aydöner ÇOBAN Assoc. Prof. Dr. Zeynep ERGÜN
		8	SSR AND TRANSCRIPTOME ANALYSIS IN HORTICULTURAL FRUITS	Assoc. Prof. Dr. Murat GÜNEY Assoc. Prof. Dr. Hakan KELES Assoc. Prof. Dr. Servet ARAS
		9	SOME AMINO ACIDS USED TO ENHANCE STRESS TOLERANCE IN VEGETABLES AND THEIR EFFECTS	Assist. Prof. Dr. GÖKÇE AYDÖNER ÇOBAN Assoc. Prof. Dr. ZEYNEP ERGÜN Assoc. Prof. Dr. SERVET ARAS
		10	THE POTENTIAL USE OF *CHLORELLA VULGARIS* AS A BIOFERTILIZER IN SOILLESS CULTURE	Assist. Prof. Dr. GÖKÇE AYDÖNER ÇOBAN Assoc. Prof. Dr. HAKAN KELES Assoc. Prof. Dr. MURAT GÜNEY

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HALL / SALON 5	**Doç. Dr. Yasemin BAKİ**	1	GLOBAL RESEARCH TRENDS OF TRANSFORMATIONAL LEADERSHIP IN ICT DEVELOPMENT IN FAITH-BASED SCHOOLS AND BIBLIOMETRIC ENGINEERING CULTURE	Nuniek Rahmatika Suyatno Dody Hartanto
		2	DİLBİLİMDE SÖYLEM ANALİZİ NEDİR?	ILAHE NIYAZOVA
		3	ÇOCUK YAZININDA ELEŞTİREL DÜŞÜNME BECERİLERİ VE YETERLİKLERİ: ÇANTAMDAN FİL ÇIKTI ÖRNEĞİ	Öğretmen, Mehtap DURMUŞ Doç. Dr. Yasemin BAKİ
		4	ÇOCUK YAZININDA ÇATIŞMA TÜRLERİ VE ÇATIŞMA ÇÖZME YÖNTEMLERİ: MAVİ RÜYALAR GÖREN ÇOCUK	Doç. Dr. Yasemin BAKİ Öğretmen, Mehtap DURMUŞ
		5	ÇOCUK YAZININDA ELEŞTİREL DÜŞÜNME BECERİLERİ VE ENGELLERİ: BİLGE ÇİÇEĞİ	Uzm. Öğretmen Esengül Gündoğdu

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HALL / SALON 6	**Prof. Dr. Nihal BALOĞLU UĞURLU**	1	ÇOCUK KİTAPLARININ DEĞERLER EĞİTİMİ AÇISINDAN İNCELENMESİ: DEDEMİN KURABİYELERİ ÖRNEĞİ	Öğretmen, Şehriban GÜNCE
		2	FEN LİSESİ ÖĞRENCİLERİNİN BEDEN EĞİTİMİ DERSİ SPORTMENLİK DAVRANIŞLARININ İNCELENMESİ	Seda AKBULUT Dr. Mesut BULUT Prof. Dr. Oğuzhan ALTUNGÜL Dr. Didem YAVUZ SÖYLER
		3	KALIP YARGILAR ÖLÇEĞİ'NİN (KYÖ) GELİŞTİRİLMESİ: GEÇERLİK VE GÜVENİRLİK ÇALIŞMASI	İbrahim KAYA Prof. Dr. Nihal BALOĞLU UĞURLU
		4	DİL BİLGİSİ KONULARININ ÖĞRETİMİNDE OYUNLAŞTIRMANIN KULLANIMI; BİR LİTERATÜR TARAMA ÇALIŞMASI	Yüksek Lisans Öğrencisi Işıl ÖZTÜRK Doç. Dr. Perihan Gülce ÖZKAYA
		5	ÖZEL EĞİTİMDE TEKNOLOJİ KULLANIMI: BİR META-ANALİZ ÇALIŞMASI	Prof. Dr. SEVAL ERDEN ÇINAR BÜŞRA CEYHAN
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HALL / SALON 7	**Lect. Mehmet Nuri ÖDÜK**	1	THE EFFECT OF BLOCKCHAIN TECHNOLOGY ON ACCOUNTING	Assoc. Prof. SERVET SAY
		2	THE IMPACT OF DIGITAL TRANSFORMATION ON BUSINESS MANAGEMENT AND INNOVATIVE STRATEGIES	Dr., Fatih İbrahim KURŞUNMADEN
		3	DIGITAL TRANSFORMATION IN ACCOUNTING AUDIT	Dr. Fırat KINALI
		4	USE OF FUZZY EXPERT SYSTEM IN DIAGNOSIS OF CORONAVIRUS (COVIT 19) DISEASE	Lect. Mehmet Nuri ÖDÜK

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HALL / SALON 8	**Assoc. Prof. Dr. Luka Kovač,**	1	THE ROLE OF NARRATIVE IN FOSTERING EMOTIONAL INTELLIGENCE AMONG PRIMARY SCHOOL STUDENTS	Dr. Maria Rossi, Prof. Luca Verdi
		2	EVALUATING LEARNING ENHANCEMENT IN FREE-FALL MOTION THROUGH PRIOR CONCEPT UTILIZATION	Dr. Andrei Ionescu, Prof. Elena Popescu, Radu Mihai
		3	ENHANCING READING COMPREHENSION THROUGH INTEGRATED INSTRUCTIONAL MODELS	Dr. Anjali Sharma, Prof. Ramesh Patel, Dr. Priya Mehta
		4	ENHANCING THE BIOMEDICAL ENGINEERING COMMUNITY THROUGH OUTREACH INITIATIVES IN INDIA	Dr. Aditi Sharma, Prof. Rohan Mehta, Sneha Gupta, Dr. Vikram Singh, Priya Joshi
		5	ENHANCING UNIVERSITY ACCESS FOR STUDENTS WITH SPECIAL EDUCATIONAL NEEDS: REFLECTIONS ON TEACHER TRAINING	Assoc. Prof. Dr. Luka Kovač, Ana Petrić
		6	EXPLORING TEACHER LEADERSHIP IN CLASSROOM INTERACTIONS: A LIFEWORLD PERSPECTIVE	Prof.Dr. Ana Petrovic, Maja Kovač
		7	EXPLORING THE CHARACTERISTICS OF EFFECTIVE, EXCEPTIONAL, AND INSPIRATIONAL EDUCATORS	Prof. Dr. Marko Petrovic, Jela Kralj
		8	EVALUATING SECONDARY SCHOOL CURRICULA FOR ENHANCING STUDENTS' QUALITY OF LIFE	Prof. Jan Novák, Dr. Eva Dvořáková, Petr Šebek, Bc. Anna Svobodová,
		9	INNOVATIVE APPROACHES TO DIGITAL LEARNING IN SUSTAINABLE AGRICULTURAL EDUCATION	Prof. Martina Horakova, Klara Dvorak, Dr. Eva Zelenkova

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HALL / SALON 9	**Dr. Adnan Mujkić,**	1	VISUAL NARRATIVES IN CHILDREN'S LITERATURE: EMOTIONAL IMPACT AND EDUCATIONAL POTENTIAL	. Amir Dervišević, Prof. Selma Husić, Dr. Kenan Avdić
		2	VISUAL PERCEPTION OF ONLINE MARKETING STRATEGIES BY INTERNATIONAL STUDENTS AT A BOSNIAN UNIVERSITY	Authors: Dr. Adnan Mujkić, Prof. Dr. Lejla Husić, and Fatima Delić
		3	EVALUATING THE IMPACT OF VIRTUAL REALITY ON STUDENT ENGAGEMENT IN ENGLISH LANGUAGE LEARNING	Dr. Luca Rossi, Prof. Dr. Maria Bianchi, Giulia Conti
		4	EXPLORING STUDENTS' COMMUNICATION ANXIETIES AND EVALUATION CHALLENGES IN ONLINE SPEECH ACTIVITIES	Dr. Alessandro Rossi, Prof. Maria Verdi, and Luca Bianchi
		5	EXPLORING THE TRANSITION OF ITALIAN CHILDREN FROM KINDERGARTEN TO PRIMARY SCHOOL: A QUALITATIVE STUDY	Dr. Alessandro Rossi, Elena Bianchi, Dr. Marco Verdi
		6	ASSESSING EDUCATOR CULTURAL PROFICIENCY: A STUDY OF THREE LOCAL PRIMARY SCHOOLS	Dr. Amina El-Hamidi, Youssef Bensalem, Fatima Zahra Idrissi
		7	EVALUATING THE INFLUENCE OF INTRODUCTORY TECHNOLOGY COURSES ON STEM MAJOR CHOICES	Dr. Amina El Haddad, Prof. Dr. Khalid Bouchara, Fatima Zahra Benali
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NOVEMBER 1 - 3, 2024
SKOPJE
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HALL / SALON 10	**Assoc. Prof. Dr. Amina Suleiman,**	1	ENHANCING MULTIVARIABLE CALCULUS LEARNING THROUGH AUGMENTED AND VIRTUAL REALITY TECHNOLOGIES	Dr. Ahmed Al-Saad, Dr. Layla Farhan, Dr. Samir Khaled
		2	RETHINKING THE CRIMINALIZATION OF HOMELESSNESS: INNOVATIVE APPROACHES AND THE IMPLEMENTATION OF JAMAICA'S HOPE COURT	Dr. Marcus Johnson, Leila Grant, Ms. Talia Brown
		3	ECONOMIC IMPACT ASSESSMENT OF TOURISM: A COMPREHENSIVE FRAMEWORK	Dr. Janelle Smith, Prof. Marcus Hinds, Dr. Alex Thompson
		4	THE PARADOX OF EMPOWERMENT: ANALYZING THE ROLE OF GOSSIP IN FEMALE AGENCY	Dr. Amina Bouazizi, Prof. Dr. Sami Ben Ali
		5	ADDRESSING HUMAN RIGHTS VIOLATIONS AGAINST HEALTHCARE WORKERS IN TUNISIA: A POLICY PERSPECTIVE	Dr. Samira Ben Ali, Prof. Khaled Elhadi, Dr. Fatima Zohra Mansour, Dr. Aymen
		6	FAITH-BASED RESPONSES TO HUMANITARIAN CRISES: THE ROLE OF THE ANGLICAN CHURCH DURING THE BIAFRAN CONFLICT	Professor Adebayo Ogunleye, Dr. Chiamaka Ijeoma, Yetunde Alabi
		7	EXPLORING THE ROCK ART OF THE NORTHERN REGION: SITES OF NSUKKA, NIGERIA	Dr. Chijioke Okafor, Assoc. Prof. Dr. Amina Suleiman, and Dr. Ifeoma Nwosu
		8	CINEMATIC NARRATIVES OF DISPLACEMENT: A STUDY OF MEMORY REPRESENTATION IN BANGLADESHI AND INDIAN FILMS	Dr. Amina Rahman, Prof. Haris Chowdhury, and Mr. Anik Hasan
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HALL / SALON 11	**Prof. Jacques Martin,**	1	SCIENTIFIC INSIGHTS INTO THE CONCEPT OF "FERTILIZING WINDS" IN QURANIC VERSE 15:22	Dr. A. H. Rahman, Prof. S. N. Khan, Mr. T. Z. Rahman
		2	NAVIGATING IMMIGRATION CHALLENGES FOR CONVENTION REFUGEES IN BELGIUM	: Dr. Eliane Dubois, Prof. Jacques Martin, Dr. Sofia Vermeer
		3	INVESTIGATING THE ROOTS OF ANTI-WESTERN SENTIMENT IN THE ARAB WORLD AND ITS IMPACT ON SUPPORT FOR RUSSIA IN THE UKRAINE WAR	Dr. Anisa Kamel, Prof. Dr. Emil Novak, and Dr. Liam Schmidt
		4	THE TRANSFORMATIVE ROLE OF TELECOMMUNICATION IN EUROPE: ENHANCING CONNECTIVITY AND QUALITY OF LIFE	Prof. Elena Schmidt, Dr. Marco Rossi, Ms. Ana Ivanova
		5	CULTURAL DIMENSIONS INFLUENCING QUALITY ASSURANCE IMPLEMENTATION IN HIGHER EDUCATION: A COMPARATIVE STUDY	Dr. Mateo Alvarado, Prof. Dr. Lucia Martinez, Dr. Sergio Ramos
		6	ADDRESSING THE TRIADIC CHALLENGES OF SUSTAINABILITY IN HIGHER EDUCATION	Dr. Youssef Elhaj, Amina Fassi, Dr. Latifa Bouhlal
		7	GENDER REPRESENTATION IN PRIMARY EDUCATION: INSIGHTS FROM TEACHERS	Dr. Erdenebat Gankhuyag, Sarnai Baatar, Nomin Erdene
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HALL / SALON 12	**Dr. Leila M. Bouali**	1	COMPUTER GRAPHICS AND UNDERSTANDING SEMIOTICS IN DESIGN	Manoj Majhi, Debkumar Chakrabaty
		2	ANALYZING STUDENT SATISFACTION AMONG WORK-BASED LEARNERS	Julia L. Harris, Ahmed T. Fawzi
		3	ASSESSING THE USABILITY OF AN EDUCATIONAL PORTAL FOR IT FACULTY AT THE UNIVERSITY OF LIBYA	Khaled R. Badr, Laila S. Hamed
		4	DEVELOPING PROBLEM-SOLVING SKILLS IN ENGINEERING STUDENTS THROUGH ENGLISH LANGUAGE INSTRUCTION	Dr. Sarah J. Al-Sayed
		5	TEXTURES FOR THE VISUALLY IMPAIRED: A STUDY OF HIMMAPAN CREATURES	Dr. Alex Thompson, Emily Carter
		6	ENGLISH LANGUAGE TEACHING IN THE CONTEXT OF LMD REFORMS: A STUDY FROM ALGERIA	Dr. Leila M. Bouali
		7	DEVELOPING INFORMATIONAL CULTURE AMONG STUDENTS: STRATEGIES AND METHODS	Aigerim K. Nurpeissova
		8	VIRTUAL COLLABORATIVE LEARNING: ENHANCING STUDENT PERFORMANCE IN BAHRAIN	Dr. Omar S. Al-Nasr
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HALL / SALON 13	**Dr. Chika Afolabi,**	1	TOWARD A MODEL FOR KNOWLEDGE DEVELOPMENT IN VIRTUAL ENVIRONMENTS: STRATEGIES FOR STUDENT OWNERSHIP	N.B. Adams
		2	THE FUTURE OF OPEN EDUCATION AND DISTANCE LEARNING IN ZAMBIA	*Jane Mwansa*
		3	NAVIGATING BETWEEN POLICY FRAMEWORKS AND TECHNOLOGICAL INNOVATIONS: EVALUATING THE SUSTAINABILITY OF DISTANCE EDUCATION	*Ravi Desai*
		4	FACULTY PERCEPTIONS ON THE IMPORTANCE OF COMPONENTS IN A VIRTUAL LEARNING ENVIRONMENT	Assoc. Prof. Dr. Emily Roberts, Michael Chen
		5	APPLYING THE STUDENT-CENTRIC APPROACH IN TECHNOLOGY EDUCATION: STUDENT INSIGHTS	Amina Shah
		6	LEVERAGING BLOGGING TO FOSTER CRITICAL THINKING: A PILOT STUDY	Lena Kim, Daniel Zhang
		7	THE EXPERIENCES OF NIGERIAN SECONDARY SCHOOL GIRLS IN A DIGITAL MAKERSPACE	Dr. Chika Afolabi, Sadiq Adediran
		8	INVESTIGATING SELF-DIRECTED LEARNING IN YOUNG LEARNERS	Sara A. Kahn, Hassan Faridi
		9	THE ROLE OF GOVERNMENT, LOCAL COMMUNITIES, AND PARTICIPATORY GOVERNANCE: OPPORTUNITIES FOR TRANSFORMATION	Elena V. Petrov

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2 Kasım / November 2, 2024 / 11:00 – 13:00 Time zone in SKOPJE

Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 1	**Asst. Prof., MUAMMER AYATA**	1	A COMPREHENSIVE STUDY OF THE KAUP-KUPERSHMIDT EQUATION WITH CONFORMABLE DERIVATIVE	Asst. Prof., MUAMMER AYATA
		2	INVESTIGATION OF MAIZE GENOTYPES BASED ON SEEDLING AND FIELD TRAITS FOR DROUGHT TOLERANCE	Assoc. Prof. Dr. Sekip ERDAL Dr. Akın TEPE Agricultural Engineer Mehmet PAMUKÇU Dr. Senem Sabancı BAL Msc. Burak YILDIZGÖRER
		3	AN OVERVIEW TO THE ACTIVITIES AND ACADEMIC STUDIES IN GREEN MANUFACTURING	Asst. Prof. Dr. Şafak ATAŞ Assoc. Prof. Dr. Serhat Orkun TAN Prof. Dr. İlker TÜRKER
		4	Production of Alumina-Copper Hybrid Composites by Hot Pressing Technique: Investigation of Mechanical, Structural, and Tribological Properties	Merve HORLU Eda ÇULLU FERŞAT Cevher Kürşat MACİT Bünyamin AKSAKAL
		5	PEEK CF30 TERMOPLASTİK MALZEMENİN DELİNMESİNDE DELME PARAMETRELERİNİN OPTİMİZASYONU	Doç. Dr. Mehmet BOY Doç. Dr. Nafiz YAŞAR Doç. Dr. Mehmet Erdi Korkmaz
		6	BÖHLER K490 ÇELİĞİNİN SERMET KESİCİ TAKIMLA İŞLNEBİLİRLİĞİNİN ARAŞTIRILMASI	Doç. Dr. Mehmet BOY Ahmet AYDİN

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HALL / SALON 1	**Prof. Dr. REFİKA ALTIKULAÇ DEMİRDAĞ**	1	Çocuk Edebiyatında Tip Problemi ve Örnek Bir Uygulama: Lo	Prof. Dr. REFİKA ALTIKULAÇ DEMİRDAĞ Arş. Gör. BİLGE DESTEGÜLOĞLU Arş. Gör. MERVE ERCAN
		2	ÇERKES TOPLUMUNDA GELENEKSEL ÇAY OLARAK TÜKETİLEN LABADA BİTKİSİNİN GASTRONOMİK AÇIDAN İNCELENMESİ	Öğr. Gör. Sevinç KUŞ
		3	İŞ YERİ MUTLULUĞUNUN TESİSİNDE OLUMLU VE DESTEKLEYİCİ ÖRGÜT KÜLTÜRÜNÜN ETKİN ROLÜ	Öğr. Gör. Dr. BETÜL GÜMÜŞ

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HALL / SALON 1	**Doç. Dr., MUSTAFA NAL**	1	YÖNETİCİLER AÇISINDAN DOĞRU VE ZAMANINDA KARAR ALMANIN ÖNEMİ	Dr. Öğretim Üyesi SELAMİ ÖZKAN
		2	DÖNÜŞÜMCÜ LİDERLİK: BİBLİYOMETRİK ANALİZ	Doç. Dr., MUSTAFA NAL
		3	YALIN YÖNETİM ARAŞTIRMALARINA GENEL BAKIŞ: BİBLİYOMETRİK ANALİZ	Doç. Dr., MUSTAFA NAL
		4	SAĞLIK ÇALIŞANLARININ TEKNOSTRES VE TÜKENMİŞLİK DÜZEYLERİNİN İNCELENMESİ	Arş.Gör.Dr. GÜLİZAR GÜLCAN ŞEREMET Dr.Öğr.Üyesi DİLEK USLU
		5	TÜRKİYE'DE HAVAYOLU ULAŞIMINDAN MEMNUNİYET DÜZEYİ VE İLİŞKİLİ FAKTÖRLER	Dr. Öğr. Üyesi Şeyda ÜNVER Prof. Dr. Ömer ALKAN
		6	THE ROLE OF PARASOCIAL INTERACTION IN IMPULSE BUYING BEHAVIOR	Asst. Prof. Bilal CELIK Irem Deniz BILGI

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HALL / SALON 2	**Assoc. Prof. SANVER ÖZGÜVEN**	1	PASSPORT AND VISA APPLICATIONS IN THE CONTEXT OF FREEDOM OF TRAVEL DURING THE REPUBLICAN ERA	Dr. Research Assistant Elif AŞCI
		2	ENDÜLÜS İSMİ ÜZERİNE TARTIŞMALAR VE PROBLEMLER	Arş. Gör. Yaşar Emrah KOŞDAŞ
		3	"TANZİMAT" LİTERARY SOURCES OF AZERBAİJANİ ENLİGHTENED REALİST PROSE	TELLİ ƏLİYEVA
		4	AKILAY'DA DEĞERLER EĞİTİMİ	Öğr. Gör. Sedef GÖLTAŞ
		5	INFLUENCES OF COMMEDIA DELL'ARTE IN COMIC OPERA: THE MARRIAGE OF FIGARO	Öğretim Görevlisi, FURKAN AKTAKKA
		6	GÜNCEL SANATTA DESENİN SOYUTLANMASI ÜZERİNE BİR İNCELEME	Yüksek Lisans Öğrencisi Deniz ÖZTÜRK ÖÇAL Doc.Dr.Ahmet Kürşat ALBAYRAK
		7	PICTORIAL EXPRESSION IN MOLLY HATCH'S CERAMICS	Assoc. Prof. SANVER ÖZGÜVEN
		8	AN ANALYSIS OF BIOMIMETIC ELEMENTS IN LOUIS C. TIFFANY'S DESIGNS	Assoc. Prof. SANVER ÖZGÜVEN

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HALL / SALON 3	**Prof. Dr. Oya ŞAKI AYDIN**	1	THE UNBEARABLE LIGHTNESS OF DEATH" IN DIGITAL MEDIA	Assoc. Prof. Dr. Ayşe Gül SONCU
		2	DIGITAL CULTURE AND EVERYDAY LIFE EXPANSIONS OF MEDIA: ACTIVE USERS OR PASSIVE CONSUMERS?	Prof. Dr. Oya ŞAKI AYDIN
		3	DIGITAL CULTURE, ARTIFICIAL INTELLIGENCE AND THE FUTURE OF CHILD USERS	Prof. Dr. Oya ŞAKI AYDIN
		4	VISUAL COMMUNICATION AND ALTERNATIVE EXPRESSION METHODS: LESSONS TO LEARN FROM DAVID CARSON	Arş. Gör. Dr., EMİNE TUBA ERDOĞAN
		5	GEÇMİŞTE BİR ARADA YAŞAMA KÜLTÜRÜ: DEĞİŞKENLER VE PEKİŞTİREÇLER	Dr. REYYAN AKKAŞ PROF. DR. İHSAN ÇAPCIOĞLU
		6	GÜNÜMÜZDE BİR ARADA YAŞAMA KÜLTÜRÜNÜ ETKİLEYEN FAKTÖRLER ÜZERİNE SOSYOLOJİK BİR DEĞERLENDİRME	Dr. REYYAN AKKAŞ PROF. DR. İHSAN ÇAPCIOĞLU

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HALL / SALON 4	**Assistant Professor ÖMER FARUK NEMUTLU**	1	EXAMINATION OF GROUND MOTION RECORDS OF 16 OCTOBER 2024, KALE-MALATYA 5.9 (Mw) EARTHQUAKE	Assistant Professor ÖMER FARUK NEMUTLU
		2	EXAMINATION OF TRANSPORTATION PROJECTS PLANNED TO BE CONDUCTED IN BURSA IN TERMS OF FEASIBILITY AND APPLICABILITY	Res. Ast., AHMET ÜNAL Prof. Dr., Ahmet TORTUM
		3	DETERMINATION OF POINT BASED LIQUEFACTION POTENTIAL FOR KARŞIYAKA DISTRICT OF İZMIR PROVINCE	Dr., ESRA GÜNERİ
		4	APPLICATION FIELDS OF GEOTECHNICAL ENGINEERING AND IMPORTANCE IN CIVIL ENGINEERING	Dr., ESRA GÜNERİ
		5	ROCK FRAGMENTATION IN TUNNELLING WITH LOADING AND UNLOADING CYCLES IN DYNAMIC DISC TECHNOLOGY	Prof. Dr. Nazife Erarslan
		6	INVESTIGATION OF THE EFFECT OF CRUSHED ZONE FORMATION WITH SHARP AND BLUNT TYPE BITS ON DRILLABILITY IN DEEP DRILLING	Prof. Dr. Nazife Erarslan

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HALL / SALON 5	**Prof. Dr. ALİ BİLGİLİ Prof. Dr. BAŞAK HANEDAN**	1	GIDA GÜVENCESİ VE GIDA SİSTEMLERİ	Dr. Öğr. Üyesi, NİLGÜN ÖNCÜL
		2	IMPACTS OF LIFE CYCLE ANALYSIS IN THE FOOD INDUSTRY	Dr. Gamze KOR SIMSEK Prof. Dr. Filiz ICIER
		3	EAR INFLAMMATION IN CATS AND TREATMENT OPTIONS	Prof. Dr. ALİ BİLGİLİ Prof. Dr. BAŞAK HANEDAN
		4	BACTERIAL VACCINES IN SHEEP AND GOATS	Prof. Dr. İsmail Aytekin
		5	VIRAL VACCINES IN SHEEP AND GOATS	Prof. Dr. İsmail Aytekin
		6	ÇİFTLİK HAYVANLARI İÇİN SELENYUM KATKILARININ DEĞERLENDİRİLMESİ	Nuri ALKAN Doç.Dr. Habip MURUZ
		7	RUMİNANT ETİNİN FONKSİYONEL YAĞ ASİTLERİ İÇERİĞİNİ İYİLEŞTİREN BESLEME YAKLAŞIMLARI	Nuri ALKAN Doç.Dr. Habip MURUZ

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HALL / SALON 6	**Doç.Dr. ELİF ÇAĞDA KANDEMİR**	1	DISASTER RISK ASSESSMENT OF URBAN TRANSFORMATION PROJECT AREAS: THE CASE OF KAHRAMANMARAŞ	Lecturer. Dr. Sıtkı Alper ÖZDEMİR Prof. Dr. Mustafa Tolga ÇÖĞÜRCÜ Res. Asst. Mehmet Akif ARSLAN Asst. Prof. Dr. Mustafa ONÜÇYILDIZ
		2	USE OF INNOVATIVE TECHNOLOGIES IN CONSTRUCTION OCCUPATIONAL HEALTH AND SAFETY	Res. Asst. Mehmet Akif ARSLAN Prof. Dr. Mustafa Tolga ÇÖĞÜRCÜ Lecturer. Dr. Sıtkı Alper ÖZDEMİR Asst. Prof. Dr. Mustafa ONÜÇYILDIZ
		3	SEISMIC DAMAGE TO ADJACENT STRUCTURES: A HISTORICAL PERSPECTIVE	Doç.Dr. ELİF ÇAĞDA KANDEMİR
		4	INSIGHTS INTO THE RESPONSE OF NEIGHBORING BUILDINGS	Doç.Dr. ELİF ÇAĞDA KANDEMİR
		5	SUSTAINABLE ARCHITECTURE IN THE MEDITERRANEAN BASIN: COMPARATIVE INSIGHTS INTO VERNACULAR PRACTICES IN ALBAICÍN AND KALEİÇİ	Architect, BESTE TAŞ Assoc. Prof., GÖKHAN UŞMA
		6	WATER RECYCLING IN SUSTAINABLE HOUSING AND ITS IMPACT ON DESIGN	Architect Fatma Tuba YILDIRIM Assoc. Prof. Dr. Gökhan UŞMA

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HALL / SALON 7	**Prof. Dr. W. Thammarat,**	1	ENHANCING SUSTAINABILITY THROUGH ADAPTIVE SYSTEM ARCHITECTURES	Maria Sanchez, Arjun Desai, Lingwei Zhou, Natalia Popova
		2	ESTABLISHING A COMPREHENSIVE ASSESSMENT FRAMEWORK FOR BUILDING COMPONENT SUSTAINABILITY"	Elena Kovalevskaya, Dimitrios Xenopoulos, Esha Sharma, Jian Li, Henrietta Lefèvre
		3	ADAPTIVE RESILIENT ARCHITECTURE: STRATEGIES FOR FLOOD MITIGATION	Ravi K. Sharma, Mei Lin Wei
		4	BETWEEN TADAO ANDO AND CHARLES CORREA: AN ‘AFFINITARIAN’ ARCHITECTURAL INQUIRY	Rina Sato
		5	INNOVATIVE DESIGN OF ADAPTIVE TEMPORARY SHELTERS FOR DISPLACED COMMUNITIES	A. Jamsran, T. Davaajargal, E. Erdene, K. Sukhbaatar, L. Amarsanaa, B. Bat-Erdene, N. Bold, D. Ganbold
		6	STRATEGIC APPROACHES TO FINANCING AFFORDABLE HOUSING IN EMERGING ASIAN ECONOMIES	Amir Khan, Nguyen Thi Lan Huong
		7	RETHINKING ARCHITECTURE FOR A SUSTAINABLE FUTURE: INTEGRATIVE APPROACHES IN THE AGE OF CLIMATE CRISIS	Ayanthi Perera, Assis. Prof. Dr. Wei Ming Zhu
		8	DESIGN RECOMMENDATIONS FOR INCLUSIVE HOUSING TO MEET DIVERSE ACCESSIBILITY NEEDS	L. Nakamura, S. Gupta, J.-H. Kim, M. Rizwan
		9	ASSESSMENT OF FIRE HAZARDS ASSOCIATED WITH FUEL STATIONS AND LAND-USE PLANNING CONSIDERATIONS IN CHIANG MAI, THAILAND	P. Sukjai, Prof. Dr. W. Thammarat, L. Noppakun

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HALL / SALON 8	**Assis. Prof. Dr. Haruto Tanaka,**	1	REINTERPRETING PERSPECTIVE: THE REVIVAL OF SPATIAL REPRESENTATION IN RENAISSANCE ITALY	Lila Tanaka, Amir Rashid, and Hiroshi Nakamura
		2	EVALUATING PEAK DEMAND PROJECTIONS FOR OFFICE BUILDINGS UTILIZING EQUEST	Yuki Tanaka, Aisha Kim, Chen Wei, Amir S. Ahmad
		3	FRAMEWORK DEVELOPMENT FOR DIGITAL TWINS IN THE BUILT ENVIRONMENT	Mei Zhang, Hiroshi Tanaka, Ayesha Khan,
		4	INFLUENCING FACTORS FOR ADOPTING SUSTAINABLE CONSTRUCTION PRACTICES IN ASIAN RESIDENTIAL DEVELOPMENT	Haruto Yamamoto, Aisha Rahman, Li Wei, Siti Noor
		5	ADAPTING SPATIAL DESIGN TO PANDEMIC CHALLENGES: A FRAMEWORK FOR FUTURE RESILIENCE	Prof. Dr. Amina Khosravi, Mei Lin Zhang
		6	THE RISE OF CONSTRUCTION SYNDICATES IN SOUTH AFRICA: CONSEQUENCES FOR THE CONSTRUCTION SECTOR	Aisha Khan, Rajiv Mehta, Lin Chen
		7	STRATEGIES FOR ACHIEVING ENERGY SUSTAINABILITY IN MODERN ENTERPRISES	Mei Lin Zhang, Assis. Prof. Dr. Haruto Tanaka, Amina K. Rahman,
		8	FUNDING SUSTAINABLE INITIATIVES: A STUDY ON CROWDFUNDING FOR ECO-FRIENDLY PROJECTS IN AZERBAIJAN	Aydin Mammadov, Leyla Aliyeva, Rauf Hasanov, Fidan Aliyeva, Tural Jafarov
		9	EXPLORING CROWDFUNDING OPPORTUNITIES FOR SUSTAINABLE PROJECTS IN SAUDI ARABIA	Farah Alqurashi, Nasser Alzahrani, Lina Alshahrani, Saif Alharbi, Nour Alharthi, Omar Alghamdi

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HALL / SALON 9	**Prof. Dr. Dwi Anggoro,**	1	PATHWAYS TO ACHIEVING NET ZERO ENERGY IN OFFICE SPACES: A RETROFIT CASE STUDY FOR TROPICAL CLIMATES	Siti A. Rahman, Prof. Dr. Budi S. Nugroho
		2	ANALYSIS OF ELECTRON DENSITY ANOMALIES IN ENERGY METABOLISM ENZYMES	Dimas Setiawan, Intan R. Kartika
		3	UTILIZATION OF ARTIFICIAL INTELLIGENCE FOR IDENTIFYING POTENTIAL BIOMARKERS IN BREAST CANCER	Prof. Dr. Dwi Anggoro, Dr. Putri Sari, Rahmat Hidayat
		4	DEVELOPMENT OF A BIOMIMETIC SALTWATER BATTERY UTILIZING ELECTROCHEMICAL PROPERTIES OF BIOLOGICAL SYSTEMS	Maria Santos, Juan dela Cruz, and Leila Reyes
		5	ENHANCING GENE NAME DETECTION FROM BIOLOGICAL PATHWAY ILLUSTRATIONS USING SIAMESE NETWORKS	Juan Dela Cruz, Maria Santos, Enrique Villanueva, Angela Reyes, Roderick Lim
		6	FRAMEWORK FOR ASSESSING INFORMATION DYNAMICS IN LIVING ORGANISMS	Alina S. Zhanabayev, Nurzhan A. Askarov
		7	IMPACT OF SILVER NANOPARTICLES ON RRNA MATURATION GENES IN SACCHAROMYCES CEREVISIAE	Aisulu Kairbekova, Yerbolat Zhanbotaev

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HALL / SALON 10	**Prof. Dr. Stefan Jovanović**	1	ASSESSMENT OF ARCOBACTER AND HELICOBACTER PYLORI CONTAMINATION IN FRESH ORGANIC VEGETABLES: A CULTURAL AND MOLECULAR APPROACH	Nikola Marković, Assoc. Prof. Milica Petrović, Prof. Dr. Stefan Jovanović
		2	ACCELERATED DATA PROCESSING FOR SINGLE-CELL CHROMATIN ACCESSIBILITY USING HIGH-THROUGHPUT SEQUENCING	Milica Jovanović, Stefan Petrov
		3	INTEGRATING SEMANTIC LEXICAL INSIGHTS INTO CNN ARCHITECTURE FOR DIAGNOSING PEDIATRIC DISEASES	Marko Petrovic, Ana Jovanovic, Nikola Milic,
		4	DYNAMICS OF LAGRANGIAN COHERENT STRUCTURES IN THE WAKE OF SWIMMING NEMATODES	Marko Jovanović, Ana Petrović, Stefan Radosavljević
		5	THE FUNDAMENTAL PRINCIPLES OF EVOLUTIONARY FORCES: GENE ENGINEERING THROUGH SYNTHETIC EVOLUTIONARY INTELLIGENCE	A. J. Kovács, M. T. Szabó
		6	RADIOPROTECTIVE PROPERTIES OF SILVER NANOPARTICLES DERIVED FROM CHLOROPHYTUM BORIVILLIANUM AGAINST GAMMA RADIATION-INDUCED TESTICULAR DAMAGE IN SWISS ALBINO MICE	László Szabó, Anna Tóth, Zoltán Kovács
		7	IMPACT OF VERMICOMPOST FROM COW MANURE TREATED WITH BEETLE LARVAE AND WORM SPECIES ON AGRICULTURAL YIELD	Dr. Zsófia P. Kovács, Assis. Prof. Dr. Gábor T. Székely
		8	PHYLOGENETIC ANALYSIS OF NYMPHAEA SPECIES BASED ON 18S RDNA SEQUENCES	L. Petrović, M. Šimunić,
		9	ASSESSMENT OF POTATO VIRAL INFECTIONS VIA DAS-ELISA IN CROATIA	Marko Jurić, Ivana Novak,

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HALL / SALON 11	**Prof. Dr. Rajiv Mehta**	1	DUAL PRODUCTION OF EICOSAPENTAENOIC ACID AND FUCOXANTHIN FROM COLD-RESILIENT DIATOM STRAINS	Aarav Kumar, Sneha Mehta, Raghav Sharma, Priya Verma
		2	BIOPROPHYLAXIS OF SAPROLEGNIASIS IN INCUBATED CLARIAS GARIEPINUS EGGS USING PYOCYANIN EXTRACTED FROM PSEUDOMONAS AERUGINOSA ,	Dr. A. S. Kumar, Dr. R. N. Verma
		3	INNOVATIVE UAS APPLICATIONS FOR FOREST FIRE DETECTION AND 3D FUEL ASSESSMENT	Dr. Ravi Sharma, Arjun Singh
		4	RESEARCH TRENDS IN WILDFIRE MANAGEMENT PRACTICES IN MEDITERRANEAN CLIMATE ZONES .	Aarav Singh, Prof. Dr. Meera Patel
		5	MICROBIAL CONTAMINANTS IN DRINKING WATER ACROSS DIFFERENT STATES OF INDIA	Dr. Anaya Sharma, Prof. Dr. Rajiv Mehta, Priya Singh
		6	ASSESSMENT OF MICROBIAL CONTAMINATION IN DRINKING WATER ACROSS VARIOUS REGIONS OF INDIA	Dr. Ramesh Kumar Patel, Dr. Anjali Sharma, Vikas Singh
		7	UNDERSTANDING FARMERS' ATTITUDES AND CAPABILITIES IN USING HOUSEHOLD SEWAGE SLUDGE AS ORGANIC FERTILIZERS FOR PERI-URBAN AGRICULTURE IN TASHKENT, UZBEKISTAN	Dr. Azamat Qodirov, Prof. Dr. Shahnoza Nurmatova, Dilshodbek Karimov, Dr. Saida Abdullaeva
		8	REGRESSION ANALYSIS OF CHLORODIFLUOROMETHANE (HCFC-142B) CONCENTRATION TRENDS USING THE LEAST SQUARES METHOD	Dr. Ahmadbek Iskandarov, Prof. Dr. Gulnara Yusupova, Riza Shodmonov, Elvira Makhmudova
		9	INVESTIGATION OF EPIGENETIC ALTERATIONS INDUCED BY ALPHA-PARTICLES IN DROSOPHILA MELANOGASTER	Dr. Zainab M. Biyasheva, Prof. Dr. Mukhtar Zh. Tleubergenov,

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HALL / SALON 12	**Prof. Dr. Malikbek Tashkentov,**	1	TAXONOMIC INSIGHTS AND FAUNISTIC ASSESSMENT OF THE GENUS TRIASPIS HALIDAY, 1835 (HYMENOPTERA: BRACONIDAE: BRACHISTINAE) IN UZBEKISTAN	Dr. Zafarbek Khamidov, Ms. Nodira Murodova, Prof. Dr. Abdulazizbek Nuriddinov
		2	EXPLORATION OF BIODIVERSITY IN USEFUL PLANT FAMILIES IN UZBEKISTAN	Professor Azamatov Bahodir, Dr. Zainiev Dilshod, Assistant Professor Mirzaeva Sitora
		3	ECONOMIC IMPACT AND YIELD ASSESSMENT OF GRAFTED TOMATO VARIETIES USING SOLANUM TORVUM AS ROOTSTOCK	Dr. Azizbek Tursunov, Fatima Suyunova, Prof. Dr. Malikbek Tashkentov, Shahnoza Ismoilova
		4	QUANTITATIVE AND FOURIER TRANSFORM INFRARED ANALYSIS OF SAPONINS IN THREE PAKISTANI RUELLIA SPECIES: RUELLIA PROSTRATA, RUELLIA LINEARI-BRACTEOLATA, AND RUELLIA BIGNONIIFLORA	Dr. Aisha M. Khan, Prof. Dr. Ahmed R. Zafar, Dr. Sara L. Qureshi, Mr. Bilal S. Ahmed, Dr. Fatima Z. Malik
		5	DYNAMIC INTERACTIONS OF LEAF CARBON, NITROGEN, AND PHOSPHORUS WITH CLIMATIC INFLUENCES ACROSS DIVERSE ECOSYSTEMS	Dr. Amina Shah, Prof. Dr. Faisal Malik, Dr. Zara Khan
		6	COMPARATIVE ANALYSIS OF LEAF PHENOLOGY AND SEEDLING GROWTH IN QUERCUS SUBER L., QUERCUS CANARIENSIS WILLD., AND THEIR HYBRID QUERCUS AFARES POMEL	Dr. Aisha Khan, Prof. Dr. Bilal Ahmad, Ms. Sara Malik, Dr. Zainab Iqbal, Omar Raza, Dr. Asad Noor
		7	IMPACT OF PHYSICAL ACTIVITY ON REPRODUCTIVE PERFORMANCE AND SEMEN CHARACTERISTICS IN SAHIWAL BULLS	Dr. Aamir Hussain, Prof. Dr. Fatima Noor, Bilal Khan
		8	ASSESSMENT AND CLASSIFICATION OF HERITAGE TREES: A KENYAN PERSPECTIVE	Dr. Amani Ndungu, Prof. Dr. Jane Karanja, Mr. David Kamau
		9	EVALUATING THE CURRENT STATE AND FARMERS' PERCEPTIONS OF AGROFORESTRY IN NYERI, KENYA	Dr. J. Mwangi Prof. Dr. L. Karanja A. Ochieng Ms. S. Akinyi R. M. Ndung'u
		10	FUNGAL PATHOGENS IMPACTING THE DECLINE OF ACACIA NILOTICA AND EUCALYPTUS CAMALDULENSIS IN KENYA	Prof. Dr. J. Mwangi, Dr. P. Karanja, A. Nyaga, M. Wamuyu, Dr. L. Ndung'u, Ms. S. Odhiambo, Mr. K. Ochieng

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HALL / SALON 1	**Doç. Dr., BEYZA ERKOÇ**	1	ENGELLİLERDE SOSYAL DIŞLANMA	Doç. Dr., BEYZA ERKOÇ
		2	GÖÇLER, KADINLAR ve SOSYAL HİZMET	Doç. Dr., BEYZA ERKOÇ
		3	NADİR HASTALIKLAR VE SOSYAL HİZMET	Doç. Dr., BEYZA ERKOÇ
		4	SOSYAL MEDYA VE ÇOCUK HAKLARI	Doç. Dr., BEYZA ERKOÇ
		5	AN OVERVIEW OF EMOTION-FOCUSED THERAPY-BASED GROUP INTERVENTION PROGRAMS IN THESES IN TURKEY	PhD Student Ebru ÇANAKÇI UĞUR Prof. Dr. Fulya YÜKSEL ŞAHİN
		6	OKUL ÖNCESİ DÖNEM ÇOCUKLARDA SALDIRGANLIK DAVRANIŞI İLE EBEVEYN TUTUMLARI ARASINDAKİ İLİŞKİ	Yüksek Lisans Öğrencisi, Gülay ÇOBAN Dr. Öğr. Üyesi Özlem YILMAZ DEMİREL
		7	INVESTIGATION OF THE LEVEL OF HAPPINESS AND PSYCHOLOGICAL RESILIENCE IN SPORTS SCIENCE STUDENTS AND OTHER INDIVIDUALS	Prof. Dr. Hakkı ULUCAN Doç. Dr. Hayati ARSLAN Sevim KIR
		8	AN ASSESSMENT OF DEPRESSION LEVELS AMONG PHYSICAL EDUCATION AND SPORTS TEACHING STUDENTS	Arş. Gör. Dr. AYKUT ŞAHİN Prof. Dr. YUNUS EMRE KARAKAYA
		9	INVESTGATION OF FUTURE-ORIENTED ATTITUDES OF PHYSICAL EDUCATION AND SPORTS TEACHER CANDIDATES	Arş. Gör. Dr. AYKUT ŞAHİN Prof. Dr. YUNUS EMRE KARAKAYA

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HALL / SALON 2	**Dr.Öğr.Üyesi MEHMET SALİH TAN Dr.Öğr.Üyesi EBRU YILDIRIM**	1	YOĞUN BAKIM ÜNİTESİNDE TELE-TIP UYGULAMALARI	Pınar AYVAT Başak YAVUZ Nurbanu SEZAK
		2	AVRUPA'DA DİŞ HEKİMLİĞİ EĞİTİMİ	Taylan ÇETİNER Pınar AYVAT Gülşah ŞEHİTOĞLU ALPAĞUT
		3	FACTORS AFFECTING NURSES' PERSPECTIVES ON PATIENT PRIVACY IN SURGICAL CLINICS	Res. Assist. Dr. Hatice Eda YOLTAY Prof. Dr. Meryem YAVUZ van GIERSBERGEN
		4	VIEWS OF NURSES WORKING IN SURGICAL CLINICS ON DEATH AND EUTHANASIA	Res. Assist. Dr. Hatice Eda YOLTAY Prof. Dr. Meryem YAVUZ van GIERSBERGEN
		5	THE RELATIONSHIP BETWEEN COGNITIVE STATUS, DEPRESSION LEVEL AND FEAR OF FALLING WITH THE QUALITY OF LIFE IN THE ELDERLY AT HOME	Dr.Öğr.Üyesi MEHMET SALİH TAN Dr.Öğr.Üyesi EBRU YILDIRIM
		6	THE EFFECT OF CYBERCHONDRIA SEVERITY LEVEL ON TRADITIONAL ALTERNATIVE MEDICINE	Öğr. Gör Furkan KARAHÜSEYİNOĞLU Doç. Dr. Muhammet DÜŞÜKCAN
		7	ADÖLESANLARA YÖNELİK AFET OKURYAZARLIĞI: BİR ÖLÇEK GELİŞTİRME ÇALIŞMASI	Doç. Dr. Hasret Yalçınöz Baysal Dr. Öğr. Üyesi Nihan Türkoğlu Doktora öğrencisi Saadet Güzel
		8	ADLİ ALANDA ÇALIŞACAK OLAN ÖĞRENCİLERİN ADLİ BİYOLOJİK ANALİZLER KONUSUNDAKİ BİLGİ DURUMLARININ ÖLÇÜLMESİ	Yüksek Lisans Öğrencisi, ZEYNEP DOĞAN Doçent Doktor, DEMET TATAR

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HALL / SALON 3	**Assoc. Prof. Dr., URKIYE AKAR TARIM**	1	Potansiyel biyoaktif tiyeno[2,3-c]pirol-5(6H)-karboksamit türevlerinin sentezi	Yüksek Lisans Öğrencisi Hazal ÜZMEZLER ORTA Prof. Dr. Gani KOZA
		2	THE HISTORICAL DEVELOPMENT OF PHOTODETECTORS	Yüksek Lisans Öğrencisi Serkan YÜCEL Prof. Dr. Nilgün KALAYCIOĞLU ÖZPOZAN
		3	ONE POT ETHANOL CATALYIC ACTIVITY: EFFECT OF RU LOADING ON CERIUM-TITANIUM DİOXİDE (CE-TIO 2) SUPPORT	Dr. Ugur Caglayan Assoc. Prof. Dr. Bahar Meryemoglu
		4	RESEARCH ON SOME LIQUIDS SUBSTITUTE OF CORTICAL BONE: GAMMA RAY ENERGY DEPOSITION STUDIES	Assoc. Prof. Dr., URKIYE AKAR TARIM

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HALL / SALON 4	**Dr. Öğr. Üyesi ALİ ÇİÇEK**	1	AVRUPA ÜLKELERİNDE MÜFETTİŞ SEÇİM VE YETİŞTİRME SÜREÇLERİ: TÜRKİYE İLE KARŞILAŞTIRMALI BİR İNCELEME	EMİNE DENİZ İĞDELİ Doç. Dr. NESLİN İHTİYAROĞLU
		2	CENİNİN VE DONDURULMUŞ EMBRİYONUN MİRASÇILIĞI	Yüksek Lisans Öğrencisi, ZELİHA AYDIN Yüksek Lisans Öğrencisi, ÜMRAN BOZKUŞ ARAÇ
		3	BASIC PRINCIPLES OF THE RIGHT TO REASONED DECISION IN CRIMINAL PROCEDURE JUDICIAL DECISIONS IN THE LIGHT OF THE DECISIONS OF THE ECHR	Öğr. Gör., Zeynep Büşra KORKMAZ
		4	CITIZEN PARTICIPATION IN URBAN POLITICS: THE ROLE OF LOCAL GOVERNMENTS IN THE DEMOCRATISATION PROCES	Dr. Öğr. Üyesi ALİ ÇİÇEK
		5	LIBERAL DEMOCRACY vs. DELIBERATIVE DEMOCRACY: BALANCING REPRESENTATION AND PARTICİPATION IN MODERN GOVERNANCE	Dr. Öğr. Üyesi ALİ ÇİÇEK
		6	İFADE ÖZGÜRLÜĞÜ HAKKI BAĞLAMINDA ÖZGÜR İRADEYE TEHDİT OLARAK YAPAY ZEKA SİSTEMLERİ	Bilal Kapısız
		7	THE ASSIMILATION EXPERIENCE OF THE TURKISH MINORITY IN GREECE AND ITS SOCIETAL IMPLICATIONS	Dr. Rejhan RAHMAN

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HALL / SALON 5	**Prof.Dr.Seyit TAŞER**	1	BOARDING SCHOOLS AND CULTURAL GENOCIDE IN EAST TURKESTAN: THE TRANSFORMATION OF UYGHUR IDENTITY	Dr. Adilcan ERUYGUR
		2	CHINA'S NEW EDUCATION CURRICULUM AND THE UYGHUR EDUCATION SYSTEM: IDENTITY, LANGUAGE AND ASSIMILATION IN EDUCATION	Dr. Adilcan ERUYGUR
		3	DETERMINATION OF BURNOUT AND SOCIAL SUPPORT LEVELS OF SPECIAL EDUCATION TEACHERS	Teacher. Fatmagül GÜNAYDI Assoc. Prof. Dr. Müzeyyen ELDENİZ ÇETİN
		4	EĞİTİM TARİHİNDE ELE ALINAN BİR MESELE OLARAK MEMUR-ÖĞRETMENLİK	Prof.Dr.Seyit TAŞER
		5	EĞİTİMDE YAPAY ZEKA İLE HAZIRLANAN SUNUMLARIN DEĞERLENDİRİLMESİ- OSMANLI TARİHİ DERSİNDEN BİR ÖRNEK	Prof.Dr.Seyit TAŞER
		6	İLKÖĞRETİM 8. SINIF FEN BİLİMLERİ DERSİ ÖĞRETİM PROGRAMININ CIPP MODELİNE GÖRE DEĞERLENDİRMESİ	Yüksek Lisans Öğrencisi, Maviş Melis GÜLYAZ Prof. Dr., ŞENEL ELALDI
		7	CROSS-SECTIONAL EXAMINATION OF THE CHANGES IN TEACHER CANDIDATES' COMPREHENSION LEVELS REGARDING THE CONCEPTS OF SIZE AND DISTANCE	DURSUN ÖZGÖKMEN Prof. Dr. HÜSEYİN KALKAN

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HALL / SALON 6	**Prof. Dr. Aissatou Sow,**	1	ASSESSING FOREST FIRE RISKS IN THE ABERDARE FOREST REGION OF KENYA: A REMOTE SENSING AND GIS APPROACH	Dr. Michael Waweru, Prof. Dr. Amani Kibera
		2	THE ROLE OF YOUTH IN THE CONSERVATION OF FORESTS AND PROTECTED AREAS IN SOUTH ASIA	Dr. Émilie Lefevre, Prof. Dr. Jean-Pierre Martin
		3	SEASONAL ASSESSMENT OF MINING IMPACT ON THE GA-SELATI RIVER QUALITY IN LIMPOPO PROVINCE, SOUTH AFRICA	Dr. Amina M. Mohamed, Prof. Dr. Hassan K. Elhadi, Rania A. Ali
		4	INVESTIGATING TREE GROWTH FACTORS AFFECTING CARBON SEQUESTRATION AMID CLIMATE CHANGE CHALLENGES	Dr. A. S. Ndour, Prof. Dr. M. C. Sow
		5	COMPARATIVE ANALYSIS OF MECHANIZATION TECHNIQUES FOR WEED MANAGEMENT IN THE ARTIFICIAL REGENERATION OF FAGUS ORIENTALIS	Dr. Amadou Diouf, Prof. Dr. Aissatou Sow, Ibrahim Ndiaye
		6	SEASONAL IMPACTS ON TERMITE INFESTATION OF BEEKEEPING HIVES IN DAKAR, SENEGAL	Dr. M. B. Ndiaye, Prof. Dr. S. F. Diallo, A. T. Mbaye B.
		7	MATHEMATICAL MODELING OF FOREST RESOURCE DEPLETION: IMPACTS OF SYNTHETIC INDUSTRIES	Dr. Sophie Dupont, Prof. Dr. Julien Moreau, Clara Van der Meer
		8	NITROGEN DYNAMICS IN A FORESTED HEADWATER STREAM IN BELGIUM	Dr. Elise Dupont, Prof. Dr. Laurent Moreau, Dr. Amélie Gérard
		9	A COMPARATIVE STUDY OF LAND USE MANAGEMENT IN HOKKAIDO, JAPAN	Dr. Abebe Tadesse, Prof. Dr. Amina Gebre, Solomon Mulu

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HALL / SALON 7	**Dr. Samuel Desta, Prof. Dr. Amira Hailu**	1	IMPACT OF MOLTEN BATH COMPOSITION ON HOT-DIP ALUMINIZING OF AISI 4140 STEEL	Dr. Samuel Desta, Prof. Dr. Amira Hailu
		2	CARBON-BASED COPPER OXIDE ELECTROCATALYST FOR ANODIC REACTIONS IN VANADIUM REDOX FLOW BATTERIES	Dr. Abebe Tadesse, Meskerem Admasu, Prof. Dr. Fikreab Tsegaye
		3	TRIBOLOGICAL PERFORMANCE OF WOOD-PLASTIC COMPOSITES AGAINST UNCOATED CEMENTED CARBIDE	Dr. Yared Tesfaye, Prof. Dr. Selamawit Kassa
		4	FIRST-PRINCIPLE ANALYSIS OF ELECTRONIC PROPERTIES AND DIELECTRIC RESPONSE OF ZNIN2SE4 AND ZNIN2TE4	Dr. Aarav S. Joshi, Prof. Dr. Neha K. Verma
		5	OPTIMIZATION OF TIRE VULCANIZATION PARAMETERS THROUGH TAGUCHI EXPERIMENTAL DESIGN	Dr. Amina Mbala, Prof. Dr. Thabo Ndlovu, Imani Kone
		6	ENHANCED PERFORMANCE OF ELECTROSTATIC FILTER MEMBRANES FOR ADVANCED FILTRATION APPLICATIONS	Dr. Amina Kamara, Prof. Dr. Idris Sow, Fatou Jallow
		7	GREEN SYNTHESIS AND CHARACTERIZATION OF ZINC OXIDE NANOPARTICLES USING MORINGA OLEIFERA LEAF EXTRACT	Dr. Amina Mohammed, Prof. Dr. Kwame Nkrumah, Dr. Zainab El-Amin, Tunde Adewale
		8	UPCYCLING AUTOMOTIVE TEXTILE WASTE: DEVELOPMENT OF RECYCLED PET/PP BLENDS FOR FURNITURE EDGE BANDING APPLICATIONS	Dr. Amina Diallo, Prof. Dr. Malik Ndoye, Fatou Bintou, Dr. Ousmane Sow

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HALL / SALON 8	**Prof. Dr. Mohammad Javad Sadeghi**	1	INVESTIGATION OF AMMONIA ADSORPTION CHARACTERISTICS OF METAL CHLORIDE-ENHANCED COMPOSITE CARRIERS	Authors: Dr. Amina Diallo, Prof. Dr. Samuel Nkrumah, Ms. Fatoumata Keita
		2	DEVELOPMENT AND CHARACTERIZATION OF PVA/MMT NANOCOMPOSITES FOR ENHANCED BIOMEDICAL APPLICATIONS	Dr. Amina Sylla, Prof. Dr. Idris Kamara, Dr. Fatoumata Diallo, Dr. Mamadou Ba,
		3	CHARACTERIZATION OF PRECIOUS AND SEMI-PRECIOUS STONES FROM THE BAM HISTORICAL CITADEL USING MICRO-RAMAN SPECTROSCOPY	Dr. Mohammad Reza Naderi, Prof. Dr. Sara Jalali, Nazli Darkhal
		4	EVALUATING THE EFFICIENCY OF MICROENCAPSULATED PHASE CHANGE MATERIALS IN FOOD PRESERVATION	Dr. Amir Hossein Sharifi, Fatemeh Nazari, Prof. Dr. Mohammad Reza Jafari
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		6	DEVELOPMENT OF ECO-FRIENDLY WOOD ADHESIVES USING MIMOSA TANNIN AND CORNSTARCH	Dr. Ahmad Reza Shams, Prof. Dr. Leyla Moradi, Fatemeh Jafari
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Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 9	**Prof. Dr. Marco Rossi,**	1	DEVELOPMENT AND CHARACTERIZATION OF A HIGH-EFFICIENCY HONEYCOMB CERAMIC HEATER WITH CONDUCTIVE COATING	Dr. Amir Hossein, Prof. Dr. Fatemeh Jafari, Ali Rezaei, Dr. Sara Mohammadi
		2	UTILIZATION OF ORGANIC SEMICONDUCTOR MATERIALS IN THE DEVELOPMENT OF FLEXIBLE PHOTOVOLTAIC DEVICES	Dr. Elena Petrova, Prof. Dr. Marco Rossi,
		3	DURABILITY ASSESSMENT OF RECYCLED POLYPROPYLENE COMPOSITES REINFORCED WITH FLAX FIBERS	Dr. Emma Jensen, Prof. Dr. Lukas Schmidt, Dr. Claudia Müller, Prof. Dr. Erik Van den Broeck
		4	IMPACT OF COMMONLY CONSUMED ACIDIC BEVERAGES ON THE SURFACE INTEGRITY OF ORTHODONTIC COMPOSITE MATERIALS	Dr. Elena Petrov, Prof. Dr. Marco Rossi
		5	ENHANCEMENT OF SILICON SOLAR CELL PERFORMANCE THROUGH OPTIMIZED ANTI-REFLECTIVE COATINGS	Dr. Emilia Novak, Prof. Dr. Lukas Müller, Janek Petrov
		6	INNOVATIONS IN CARBON MATERIALS FOR SUSTAINABLE ENERGY SOLUTIONS	Dr. Elena Novak, Prof. Dr. Antonij Petrov,
		7	ENHANCING TENSILE STRENGTH AND DUCTILITY OF TANBHFZRTI REFRACTORY HIGH ENTROPY ALLOYS THROUGH REVERSE ROLLING	Dr. Elena Petrov, Prof. Dr. Marko Ivanovic, Dr. Anna Schmidt
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Salon	Moderator		Bildiri No ve Başlığı / Paper ID and Title	Authors
HALL / SALON 10	**Prof. Dr. Lukas Schmidt,**	1	ENHANCING PATIENT-CENTRIC HEALTHCARE THROUGH DIGITAL ENGAGEMENT STRATEGIES	Dr. Anna Müller, Prof. Dr. Lukas Schmidt, Dr. Sarah Weiss, and Dr. Peter Hoffmann
		2	ASSESSING THE IMPACT OF LEADERSHIP STYLES ON HEALTHCARE PERFORMANCE IN TEACHING HOSPITALS: A STUDY IN JORDAN	Dr. Leila Al-Husaini, Prof. Dr. Ahmad Al-Masri, Dr. Sara Jaber
		3	EARLY ANTENATAL CARE VISITS AMONG WOMEN OF REPRODUCTIVE AGE: A MULTILEVEL ANALYSIS IN JORDAN	Dr. Layla Al-Mansour, Prof. Dr. Ahmad Al-Sharif, Ms. Fatima Zaidan, Dr. Omar
		4	OCCUPATIONAL HEALTH RISKS AMONG MEDICAL PERSONNEL AND CONTRIBUTING FACTORS IN PUBLIC HOSPITALS, BEIRUT-LEBANON	Dr. Layla Nasser, Prof. Dr. Omar El-Khoury, Dr. Sara Haddad
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SOLAR POWER PLANT ELECTRICITY GENERATION FORECASTING USING NONLINEAR AUTOREGRESSIVE NEURAL NETWORK

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ABSTRACT

The need for renewable energy has emerged due to the depletion of fossil fuels and humanity's search for cleaner energy. The vast majority of countries have been in search of renewable energy sources. In Turkey, the number of research and studies on renewable energy sources has been increasing rapidly in recent years. Turkey's annual sunshine duration is higher than many other countries. Therefore, the interest in solar power plants in Turkey is high. Neural network (NN) models are used in many different fields. One of these areas is the energy sector. NNs are used in applications such as load and price forecasting in the energy sector. In this study, the electricity generation at İkitelli solar power plant is forecasted using Nonlinear Autoregressive Neural Network (NAR-NN). A data set consisting of data from the 1200 kWp solar power plant located in İstanbul İkitelli drinking water treatment plant is used. 1935 data recorded between May 1-31, 2018 are used. The results are evaluated with Mean Squared Error (MSE), R performance metrics and the test set prediction is given graphically.

Keywords: Forecasting, NAR-NN, Power plant.

1. INTRODUCTION

Increasing industrialization and population in the world increases the need for energy day by day. At the same time, fossil fuels, which are limited in the world, are rapidly depleting. In addition, fossil fuels are known to be harmful to nature and the environment. For all these reasons, researchers have turned to clean energy sources. One of the clean energy sources is systems that generate electricity from solar energy [1]. Solar energy is the radiant energy released by the fusion process in the sun's core. Outside the atmosphere, the intensity of solar energy is approximately 1370 W/m², but the amount reaching the earth varies between 0-1100 W/m^2 due to the atmosphere [2].

Ateş and Şenol, in their study, made solar energy forecasting using the data set created by the American Meteorological Society [3]. They used bagging, extreme gradient boosting and K-nearest neighbor artificial intelligence based algorithms for prediction. The results are evaluated according to the mean absolute error (MAE) performance metric. Bagging gave the best result with 1340765.66 MAE. Bekciogullari et al. used different machine learning methods in solar

energy forecasting [4]. As a dataset, the output power data of a solar power plant named 1B: Trina, a solar power plant located in Alice Springs, Australia. Support vector machine, linear regression, gaussian process regression, decision tree regression and ensemble regression are used for prediction. As a result of the study, it is seen that the support vector machine gave the best result.

Gök et al. made a short-term production forecast for a solar power plant [5]. Solar power plant located in Kahramanmaraş province and cloudiness data from the global forecasting system are used. The Neural Network (NN) used is trained with Levenberg-Marquardt training algorithm. The analyses show that the NN using generation values as input along with cloudiness forecast performs better than the NN using generation values alone. In their study, Çetin and ışık used Long Short-Term Memory (LSTM) to predict the electricity generation in a solar power plant [6]. The data used in the study were taken from the solar power plants of Humartaş Energy Company. The results showed that the error rate varied between 1% and 15%.

In this study, the electricity generation at İkitelli solar power plant is forecasted using Nonlinear Autoregressive Neural Network (NAR-NN). The last 120 data of the dataset of 1935 data are reserved for testing. The remaining 85% of the data is used for training and 15% for validation. Two different training algorithms, Levenberg-Marquardt and Scaled Conjugate Gradient, are used in the training process. The results are evaluated with Mean Squared Error (MSE) and R performance metrics.

2. MATERIAL AND METHODS

NNs are highly adaptable instruments that find extensive use in several fields such as recognition, clustering, optimization, function approximation, pattern categorization, and forecasting [7-9]. NAR-NN, one of the NN models used for forecasting, is used in this study. The NAR-NN facilitates the forecast of future time series estimations. In NAR-NN forecasting, the future values of a time series are predicted only from the past values of that series. The output y(t) using n past values of y(t) as feedback delays in NAR-NN models. This compution as shown in Equation 1. f is a nonlinear function, and e(t) is the model approximation error at the time t [10-11].

$$y(t) = f(y(t-1), y(t-2), \ldots, y(t-n)) + e(t) \tag{1}$$

Neurons in the NAR-NN model make computations by using of Equation 2.

$$out_i = h_i \sum_j w_{i,j}.n_{i,j} + b_i \tag{2}$$

Where w weight, n past value, h activation function and b bias are given. Where i is neuron number and j represents each input connection.

NAR-NN models use different training algorithms. One of them is Levenberg-Marquardt training algorithm. Although Levenberg-Marquardt training requires more memory than other strategies, it is frequently the fastest training algorithm. The second one is Scaled conjugate

gradient. Weight and bias values are updated by scaled conjugate gradient algorithms in accordance with the scaled conjugate gradient algorithm. Scaled conjugate gradient is suggested for large problems because it makes use of gradient calculations, which are less memory consuming than the jacobian calculations involved in Levenberg-Marquardt regularization [12].

Two different performance criteria, MSE and R, are used in this study. The average difference between predicted and actual values is known as the MSE. Better models have low MSE values. This means that when the MSE value approaches 0, the performance of the model is high. The calculation of the MSE performance criterion is given by Equation 3. R is the correlation between outputs and responses. R is given by Equation 4 [13].

$$MSE = \frac{1}{N} + \sum_{j=1}^{N} \left(T_j - P_j\right)^2 \tag{3}$$

where T_j is the true value for the range j=1 and N, P_j is the predicted value for the range j=1 and N, N represents the number of total entries.

$$R = \sqrt{1 - \frac{\sum_{j=1}^{N} (T_j - P_j)^2}{\sum_{j=1}^{N} (T_j - \mathrm{M})^2}} \tag{4}$$

T_j, P_j and N are the same symbols used in Equation A. In addition to this M represents the mean of given data.

3. SIMULATION RESULTS

In this study, electricity generation forecasting is performed. For this purpose, the NAR-NN model is used. The data set used in the study is taken from the İstanbul Metropolitan Municipality open data program [14]. The data in the dataset consists of a 1200 kWp solar power plant located in the İkitelli Drinking Water Treatment Plant of İstanbul Water and Sewerage Administration. While creating the data set, data is recorded every 15 minutes. There are a total of 10 months of data in the data set. However, only the data from May 1-31, 2018 are used in this study. Therefore, the number of data used in the study is 1935. The last 120 of these data are reserved for testing. Of the remaining 1815 data, 85% is reserved for training and 15% for validation. Levenberg-Marquardt and Scaled Conjugate Gradient, are used in the training process. The training performances of Levenberg-Marquardt and Scaled Conjugate Gradient training algorithms are given in Figure 1 and Figure 2 respectively.

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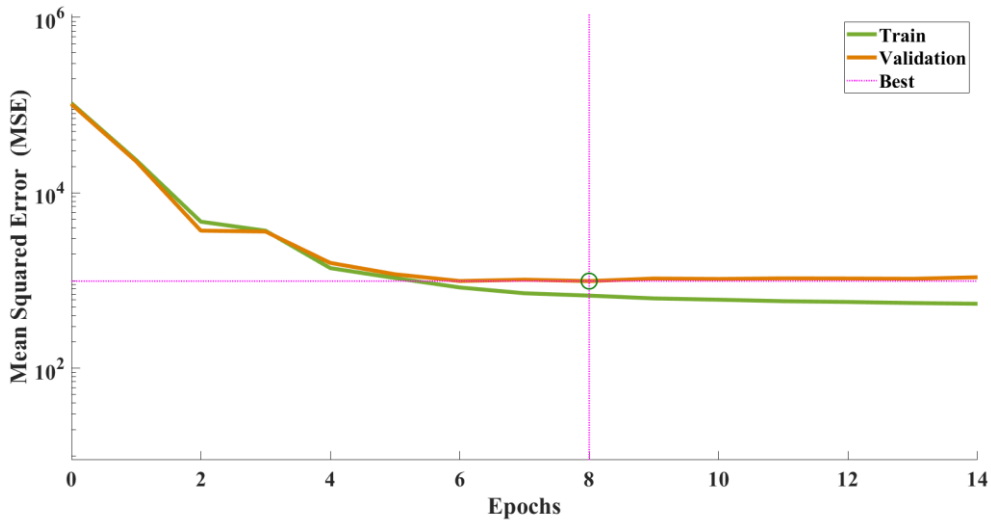

Figure 1. Levenberg-Marquardt training performance

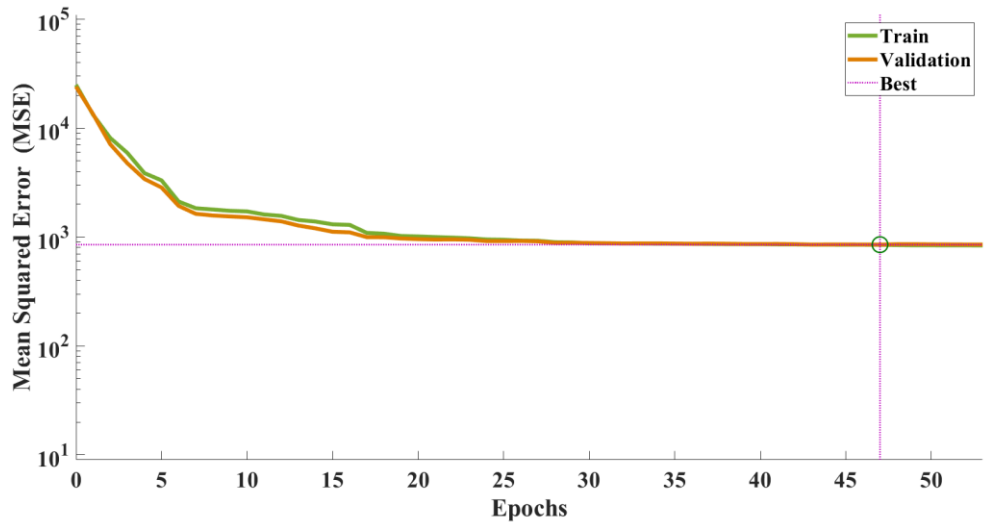

Figure 2. Scaled Conjugate Gradient training performance

When Figure 1 and Figure 2 are analyzed, it can be seen that the MSE value decreases over time in both training processes and after a while, the decrease slows down. Also, after a point in Figure 1, the difference between the train MSE and validation MSE starts to increase. From this point on, the possibility that the network is over fitting should be considered. The train, validation and test results are given in Table 1.

Table 1. Train, validation and test results

			Train		Validation		Test	
Training Algorithm	**Layer Size**	**Time Delay**	**MSE**	**R**	**MSE**	**R**	**MSE**	**R**
Levenberg-Marquardt	15	20	673.4966	0.9418	985.9051	0.9205	293.9756	0.9837
Scaled Conjugate Gradient	15	20	847.5089	0.9274	851.1732	0.9195	230.1362	0.9876

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When Table 1 is analyzed, it is seen that layer size 15 and time delay 20 are chosen for both training algorithms. The Levenberg-Marquardt training algorithm generally performed better in the training and validation processes. However, the Scaled Conjugate Gradient training algorithm performed better in both MSE and R performance metrics on the test data. The test plots of the models trained with Levenberg-Marquardt and Scaled Conjugate Gradient training algorithms are given in Figure 3 and Figure 4 respectively.

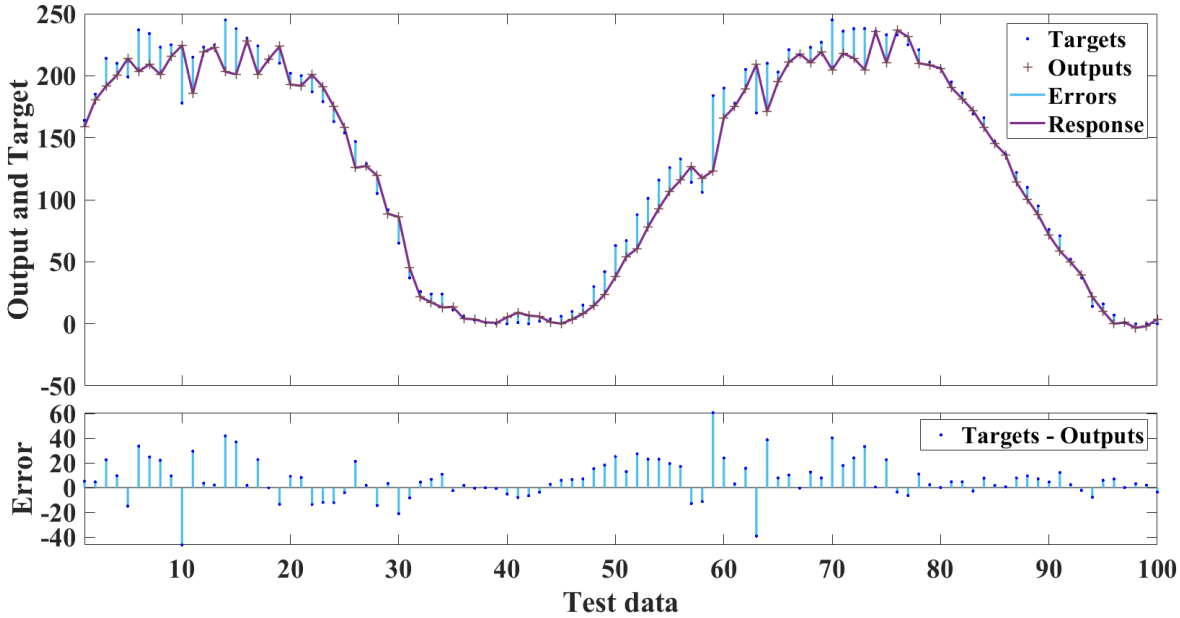

Figure 3. Levenberg-Marquardt test graphic

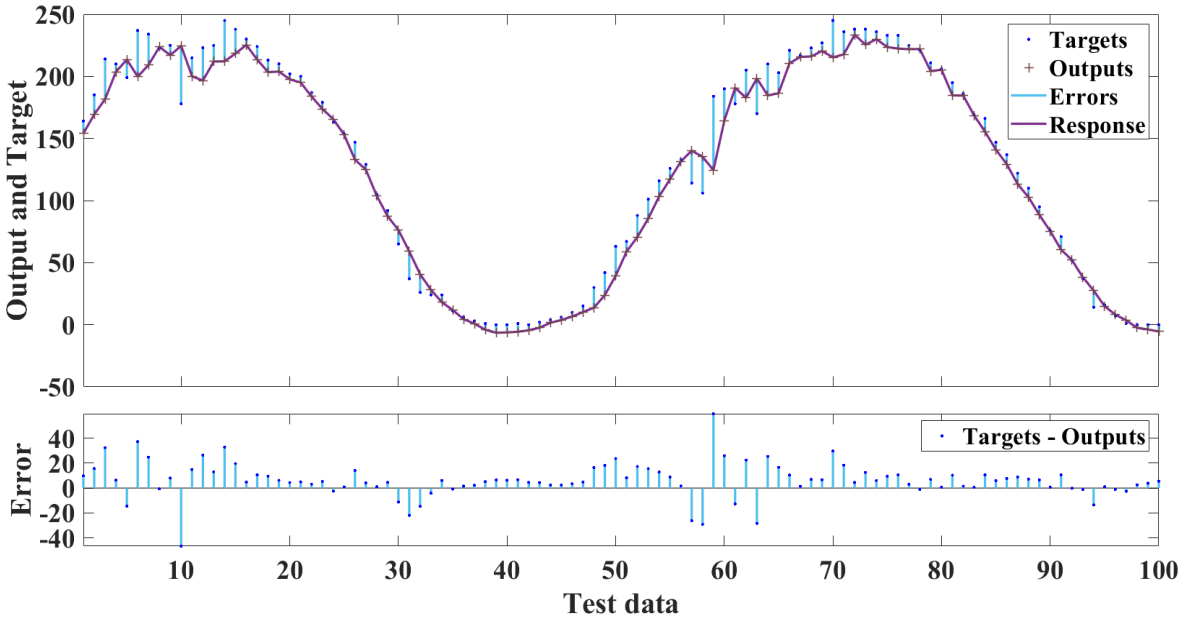

Figure 4. Scaled Conjugate Gradient test graphic

In Figure 3 and Figure 4, the top part of the figure shows the target (real data) and the NAR-NN output. In the lower part of the figures, the difference between these two values is given as error bars. The error pick points of the Levenberg-Marquardt training algorithm are larger than those of the Scaled Conjugate Gradient training algorithm.

4. CONCLUSIONS AND DISCUSSIONS

As the share of solar power plant electricity generation in renewable energy increases, research in this field is gaining momentum. In this study, the NAR-NN model is used to forecast the amount of electricity generation from solar energy. For this purpose, two different training algorithms, Levenberg-Marquardt and Scaled Conjugate Gradient, are used and their performance values are compared. Power plant located in the İkitelli Drinking Water Treatment Plant of İstanbul Water and Sewerage Administration is used as the dataset. When the results are analyzed, it is seen that in general, the results of the Levenberg-Marquardt algorithm are better in the training and validation process, while the Scaled Conjugate Gradient algorithm gives better results in the testing process. Through this study, it has been shown that electricity generation can be predicted with acceptable accuracy rates in facilities such as solar power plants.

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THE FUTURE OF DESALİNATİON İN MERSİN: RENEWABLE ENERGY AND TECHNOLOGY INTEGRATİON

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Abstract

This study comprehensively examines desalination methods as a solution to the global water crisis, which is characterized by increasing water demand and the pollution and depletion of existing water resources. Desalination is a water purification technology that utilizes physical and chemical processes to convert saline water, particularly seawater, into drinking water. Population growth, climate change, and the inadequacy of natural water sources are significant factors threatening water security, especially in arid regions. In this context, the study addresses various desalination methods, detailing the processes, advantages, and disadvantages of each technique, including reverse osmosis, distillation, electrodialysis, and ion exchange. For instance, the reverse osmosis method facilitates the separation of water from salts and contaminants through a semi-permeable membrane, while distillation methods operate by evaporating and condensing water. Electrodialysis uses electric current to separate ions, and ion exchange aims to reduce water hardness and remove specific pollutants. Furthermore, the role of membrane technologies in desalination processes, along with critical factors such as energy efficiency, environmental impacts, and cost considerations, is emphasized. The study highlights the importance of these methods for sustainable water management and security, identifying future research and development needs in this field. Ultimately, it suggests that desalination technologies offer an effective solution to the water crisis and are a vital tool for the sustainable management of water resources.

Keywords: Desalination, Renewable Energy, Technology Integration

Özet

Bu çalışmada, dünya genelinde artan su talebinin ve mevcut su kaynaklarının kirlenmesi ile azalması gibi küresel su krizinin etkilerine yönelik çözüm olarak desalinasyon yöntemleri kapsamlı bir şekilde incelenmiştir. Desalinasyon, tuzlu suyun, özellikle deniz suyunun, içme suyu haline dönüştürülmesi için fiziksel ve kimyasal süreçlerin kullanıldığı bir su arıtma teknolojisidir. Nüfus artışı, iklim değişikliği ve doğal su kaynaklarının yetersizliği, özellikle kurak bölgelerde su güvenliğini tehdit eden önemli faktörlerdir. Bu bağlamda, çalışma çeşitli desalinasyon yöntemlerini ele almakta; ters osmoz, damıtma, elektrodiyaliz, iyon değiştirme gibi yöntemlerin her biri için işlem aşamaları, avantajları ve dezavantajları detaylı bir şekilde açıklanmaktadır. Örneğin, ters osmoz yöntemi, yarı geçirgen bir membran aracılığıyla suyun

tuz ve kirleticilerden ayrıştırılmasını sağlarken, damıtma yöntemleri, suyun buharlaştırılması ve yoğunlaştırılması süreci ile çalışır. Elektrodiyaliz, elektrik akımı kullanarak iyonların ayrılmasını sağlarken, iyon değiştirme ise suyun sertliğini azaltma ve belirli kirleticileri giderme amacı taşır. Ayrıca, membran teknolojilerinin desalinasyon süreçlerindeki rolü, enerji verimliliği, çevresel etkiler ve maliyet faktörleri gibi kritik unsurlar üzerinde durulmaktadır. Çalışma, bu yöntemlerin sürdürülebilir su yönetimi ve su güvenliği için ne denli önemli olduğunu vurgulamakta ve bu alanda gelecekteki araştırma ve geliştirme ihtiyaçlarını belirlemektedir. Sonuç olarak, desalinasyon teknolojilerinin, özellikle su krizine karşı etkili bir çözüm sunduğu ve su kaynaklarının sürdürülebilir yönetimi için kritik bir araç olduğu öne sürülmektedir.

Anahtar Kelimeler: Desalinasyon, Yenilenebilir Enerji, Teknoloji Entegrasyonu

1. Introduction

Water is an indispensable resource for sustaining life. It plays a critical role in various areas, including human health, agriculture, industry, and energy production. However, factors such as climate change, population growth, industrialization, and pollution are leading to the rapid depletion of freshwater resources and exacerbating the global water crisis. In particular, access to clean water is becoming increasingly challenging in arid regions, posing threats to human life and ecosystems. In this context, desalination has emerged as an increasingly important solution for converting seawater and saline water sources into potable water. Desalination can be defined as the process of removing dissolved salts and other contaminants from seawater or saline groundwater using physical or chemical methods. This process enhances water quality, serving various applications and acting as a crucial tool in ensuring water security by increasing water supply. Desalination methods encompass a wide range of technologies, each with its unique advantages and disadvantages. Techniques such as reverse osmosis, distillation, electrodialysis, and ion exchange are commonly employed to transform saline water into drinking water. The selection of these methods varies based on local conditions, economic factors, and water demand. Consequently, desalination projects and systems are regarded as integral components of effective water management strategies[1-2].

The aim of this study is to conduct a detailed examination of the increasing significance of desalination needs, existing desalination methods, and the advantages and disadvantages of these techniques. Additionally, the study will address new approaches and solutions to enhance the effectiveness of various desalination technologies and ensure access to sustainable water resources. This endeavor seeks to raise awareness regarding the management of water resources at both local and national levels and contribute to identifying the most suitable desalination methods.

2. Desalination

Desalination can be defined as the process of removing dissolved salts and other contaminants from saline water using physical or chemical methods. This process is based on the principle of

separating dissolved substances through parameters such as osmotic pressure, temperature, and electric fields. Desalination holds a significant position among water purification technologies, enhancing water quality and serving various applications [3].

Desalination projects are not a comprehensive solution; the true remedy lies in ending inequitable water management practices. Desalination is a method developed in response to the following challenges and is regarded as an important tool for enhancing water security: Population growth and industrialization are increasing the demand for freshwater, leading to the inadequacy of existing water resources. In arid regions, water resources are diminishing, and climate change is resulting in more frequent drought periods, necessitating a shift towards alternative water sources. Rivers, lakes, and groundwater sources can become contaminated due to industrial waste and agricultural chemicals. In such cases, desalination can provide a source of clean water. As a sustainable and reliable solution to the water crisis, it is possible to obtain freshwater by utilizing existing resources like seawater. Ensuring the availability of water necessary for agricultural production and industrial processes is crucial for economic sustainability. [4]

Desalination offers numerous advantages as a method for addressing water scarcity. Firstly, seawater is an abundant resource found globally, and desalination processes convert this resource into potable water. This approach is particularly valuable in regions where freshwater resources are limited, especially in arid climates and areas experiencing water shortages. Additionally, when integrated with renewable energy sources such as solar and wind, desalination can provide an environmentally friendly water supply. The water produced through desalination is typically of high quality, free from harmful microorganisms such as bacteria and viruses. This method can enhance water supply independence, thereby strengthening local economies and contributing to industrial development. However, there are also notable disadvantages associated with desalination. The installation and operation of desalination facilities can be costly, often resulting in a higher unit cost for the water produced compared to other sources. Moreover, the discharge of saline water back into the ocean may have detrimental effects on local ecosystems, as the elevated salt concentration can adversely affect marine life. In reverse osmosis systems, membranes may become fouled over time, leading to increased maintenance and replacement costs. Lastly, the chemicals used in the water purification processes can pose environmental risks and potential harm to human health[5].

Seawater typically has a salinity of approximately 3.5% and contains a variety of chemical compounds. Physically, its density is about 1.025 g/cm^3, and its temperature varies between 0°C and 30°C, depending on seasonal changes and depth. The pH value usually ranges from 7.5 to 8.4, indicating a slightly alkaline nature. The primary components of its chemical composition include sodium chloride (NaCl), magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), sulfate (SO_4^{2-}), and carbonate (CO_3^{2-}). Additionally, trace amounts of elements such as iron (Fe), zinc (Zn), and copper (Cu) are also present in seawater. These characteristics and compositions play a crucial role in determining the dynamics of marine ecosystems and the various applications of seawater [6].

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Desalination facilities are increasingly being established in seawater desalination plants, particularly in arid regions such as the Middle East, where alternative water sources are limited [7]. The implementation of desalination technologies aimed at providing potable water has seen rapid growth worldwide. For instance, total daily water production from desalination reached 17.3 million cubic meters in 1994, which dramatically increased to 68 million cubic meters by 2009. Projections for 2016 aimed for a target of 130 million cubic meters, reflecting the growing reliance on desalination as a critical water supply solution[8].

In Turkey, several notable desalination projects have been initiated in response to the country's water needs. Among these, the Mersin Tarsus Desalination Plant, which began operations in 2011, started as a pilot facility with an annual capacity of 30,000 cubic meters. Following this, the Antalya Desalination Plant, which opened in 2015, boasts a significant production capacity of 100,000 cubic meters of water per day. In the same year, the Cesme Desalination Project was launched by local governments with the aim of desalinating seawater to meet local water demands. Additionally, pilot desalination plants were established in Istanbul during the 2000s, further diversifying Turkey's approach to addressing water scarcity. Furthermore, in 2015, the KKTC Water Supply Project was implemented to provide desalinated seawater from Turkey to the Turkish Republic of Northern Cyprus, underscoring regional cooperation in water resource management[9].

When evaluating Turkey's water situation, it is noted that the country's total available water potential is approximately 205,109 million cubic meters, of which 110,109 million cubic meters can be economically utilized. With the current population estimated at 65 million, this translates to an annual water availability of 3,150 cubic meters per capita. However, when considering the economically accessible water supply, this figure significantly decreases to 1,735 cubic meters per person. It is generally predicted that regions rich in water resources should have at least 10,000 cubic meters of water potential per capita annually to ensure a sustainable supply. Areas with a water potential ranging between 1,000 and 2,000 cubic meters are experiencing water stress, while those with potential below 1,000 cubic meters face acute water scarcity. Given that Turkey’s annual per capita water potential is 1,735 cubic meters, the country is classified as a region experiencing water stress. Furthermore, population projections for 2025 indicate that Turkey's population could reach 79 million. In such a scenario, the per capita available water potential is expected to fall below 1,300 cubic meters, highlighting the urgency for developing alternative solutions for water supply[10].

Turkey's annual water resources capacity is determined by an average annual precipitation of 643 mm. Consequently, the total rainfall that falls on Turkey is estimated at 501 km^3. However, significant losses occur through evaporation, accounting for 274 km^3, while 41 km^3 infiltrates underground and 88 km^3 remains as unusable water. The amount of available surface water is calculated at 98 km^3, and the extractable groundwater is estimated to be 14 km^3. As a result, Turkey's total net available water capacity stands at approximately 112 km^3, emphasizing the critical need for effective water management strategies to address the challenges of water scarcity [11].

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The Mersin Desalination Plant, inaugurated in 2011, represents a significant advancement in seawater desalination technology, with a pilot capacity of 30,000 m³ per year. This facility plays a crucial role in transforming seawater into potable water by employing modern desalination technologies, particularly the reverse osmosis method. By enhancing the supply of drinking water in coastal regions such as Mersin, the plant contributes to water security while simultaneously mitigating the overexploitation of groundwater resources. Furthermore, the Mersin Desalination Plant supports environmental sustainability by reducing the pressure on local aquifers, which are often subject to depletion due to increased demand for water. The facility aims to gradually increase its capacity and improve its technology to meet the growing water needs of the region effectively. As part of Turkey's broader water management policies, the Mersin Desalination Plant plays a pivotal role in addressing the challenges posed by water scarcity and ensuring a sustainable water supply for future generations [12].

The integration of such desalination facilities into the national water management framework not only helps to diversify water sources but also enhances the resilience of water supply systems against climate change and other environmental pressures. Through its ongoing efforts, the Mersin Desalination Plant exemplifies a proactive approach to sustainable water resource management in an era where freshwater availability is becoming increasingly critical.

Desalination methods employ various techniques to convert saline water into potable water. These methods are increasingly recognized as significant solutions to the global water crisis and are continuously evolving with advancements in technology, making them more effective and sustainable. Each method has its unique advantages and disadvantages, and the choice of method should depend on local conditions, water demand, and economic factors. Reverse osmosis is a desalination technique that utilizes a semi-permeable membrane to separate water from salts and other contaminants. The membrane allows water molecules to pass while rejecting salt and impurities. It is one of the most widely used desalination methods today. Before the desalination process begins, water must be pre-treated to remove large particles and pollutants, typically using mechanical filters or chemical pre-treatment processes. This step is crucial for preventing membrane fouling and enhancing system efficiency. The purified water is then forced through the semi-permeable membrane under high pressure, typically between 50 to 80 bars. While the result is fresh water on one side, the salty concentrate is discarded as waste. The desalination efficiency of reverse osmosis can reach up to 99%. However, it has high energy consumption due to the pressure requirement, which can increase operational costs and necessitate regular maintenance to address membrane fouling. Distillation methods remove salts by heating water to vaporize it and then condensing the vapor back into liquid form. These methods vary in terms of energy efficiency. Traditional distillation involves heating water until it vaporizes and then cooling the vapor to condense it back into liquid. This straightforward method is one of the oldest water purification techniques. Water is heated to its boiling point using a stove or other heat sources. The vapor produced is collected through a cooling system, where it condenses and is collected as drinking water. However, traditional distillation typically produces less water, making it unsuitable for large-scale applications. Multi-Stage Flash (MSF) distillation allows water to vaporize rapidly in multiple stages, increasing energy efficiency. Water is initially vaporized under high pressure, then allowed to expand into lower-pressure

stages, where it vaporizes further. The resulting vapor is condensed back into liquid through cooling. This technique is suitable for processing large volumes of water, although energy consumption remains a significant concern. Multi-effect distillation (MED) uses multiple distillation stages designed to enhance energy efficiency. In this method, water is vaporized in the first stage, and the vapor produced is reused in subsequent stages, allowing for a reduction in overall energy consumption. Surfactants are chemicals used to aid in the removal of salts and contaminants from water. This method is often used as a supportive process in conjunction with other desalination techniques. Surfactants are added to water to enhance the interaction between pollutants and surfaces, facilitating their removal. However, careful management is essential as improper use of surfactants can affect water quality. In membrane distillation, a membrane serves as a selective barrier that allows certain molecules to pass while retaining others. This method operates under a driving force that separates chemical components based on their selective permeability. While conventional filters typically separate particles sized between 1 and 10 µm, membranes differ significantly in their separation capabilities. Although the development of membrane technology began in 1748 with Abbé Nolet, it continues to evolve, witnessing daily advancements. Water is heated to a specific temperature to produce vapor, which then passes through a semi-permeable membrane that retains salts and impurities. The vapor condenses on the other side of the membrane, resulting in purified water. Solar distillation harnesses solar energy to evaporate and then condense water, making it a renewable method of desalination. Water is heated by sunlight, facilitating evaporation. The vapor then condenses on a special surface, allowing for the collection of fresh water. This method has a low environmental impact due to its reliance on renewable energy, though its efficiency can be affected by weather conditions, particularly on cloudy days. Electrodialysis relies on the separation of salt ions from saline water through the application of an electric current. This technique is particularly suitable for low-salinity water sources. In an electrodialysis system, ion-selective membranes allow the passage of positively and negatively charged ions. As water flows between these membranes, salt ions are separated, with positive ions moving toward the negative electrode and negative ions moving toward the positive electrode. This process yields desalinated water, but its effectiveness diminishes with high salinity levels. Ion exchange is a desalination method based on the replacement of salt ions in water with specific ions. It is commonly used to reduce water hardness and eliminate contaminants. Water is passed through specially designed ion-exchange resins that capture certain ions (such as calcium and magnesium), resulting in softer water. This method requires periodic regeneration or cleaning of the resins to maintain system efficiency. While effective in reducing water hardness and removing specific contaminants, careful maintenance and renewal are necessary, which can incur additional costs. It may not be effective for high-salinity water sources[13-14].

4.Results and Discussions

Desalination methods for converting saline water into fresh water have become increasingly crucial in addressing global challenges like water scarcity and climate change. The most widely employed desalination methods today are reverse osmosis, distillation, and electrodialysis, all of which have demonstrated effectiveness in producing fresh water from seawater and brackish water sources. However, the significant energy consumption, cost, and environmental impact

associated with these methods introduce certain challenges from a sustainability perspective. Notably, the discharge of saline waste during desalination processes can adversely impact marine ecosystems, underlining the need to carefully assess and mitigate the environmental implications of these technologies.

To overcome these challenges, it is essential to develop innovative and environmentally friendly technologies in the future. In Mersin, where desalination can play a pivotal role in addressing regional water security, integrating renewable energy sources—such as solar or wind power—into desalination plants could substantially reduce energy costs and enhance the sustainability of desalination practices. This approach not only mitigates the environmental footprint of desalination but also aligns with global sustainability and renewable energy goals.

In addition to technological advancements, research and development activities supported by public policy and partnerships with the private sector can further improve the efficiency and sustainability of desalination processes. Mersin's unique coastal geography and growing water demands make it an ideal candidate for pilot projects that explore renewable energy-powered desalination systems, which could serve as a model for other regions facing similar water security issues.

To successfully implement these advancements, a multidisciplinary approach is essential. Collaboration among engineers, environmental scientists, economists, and policymakers is critical to optimizing desalination systems and ensuring their economic viability. Public awareness and community engagement initiatives are also crucial in fostering a better understanding of desalination's benefits and environmental considerations, helping to build broader support for sustainable water resource management.

In conclusion, desalination technologies offer a vital solution for achieving water security and supporting sustainable development in Mersin. However, for these processes to be adopted on a larger scale, it is critical to promote technological innovation, adopt renewable energy integration, and foster community awareness. By following this comprehensive strategy, Mersin can pave the way for effective and sustainable water management solutions that address both current and future challenges.

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WAVE ENERGY AND TURKEY: POTENTIAL, APPLICATIONS, AND FUTURE

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Abstract

Wave energy refers to the process of converting the kinetic energy of waves on the surface of seas and oceans into electrical energy. Waves are generated by the influence of wind on the sea surface, carrying kinetic energy. This energy source stands out due to its renewable nature, environmentally friendly characteristics, and capacity for continuous replenishment. Considering the limited resources and environmental impacts of fossil fuels, wave energy presents an important alternative among sustainable energy solutions. Establishing wave energy plants in coastal areas where waves are prevalent is an effective method to harness this potential. This report provides a comprehensive assessment of the advantages, disadvantages, applications, global potential, and the current situation of wave energy in Turkey, highlighting its future role.

Keywords: Wave Energy, Renewable Energy, Sustainability, Energy Potential

Özet

Dalga enerjisi, deniz ve okyanus yüzeyindeki dalgaların hareket enerjisinin elektrik enerjisine dönüştürülmesi sürecini ifade eder. Dalgalar, rüzgârın deniz yüzeyindeki etkisiyle oluşarak hareket enerjisi taşır. Bu enerji kaynağı, yenilenebilir olması, çevre dostu özellikleri ve sürekli yenilenme kapasitesi ile dikkat çekmektedir. Fosil yakıtların sınırlı kaynakları ve çevresel etkileri göz önüne alındığında, dalga enerjisi, sürdürülebilir enerji çözümleri arasında önemli bir alternatif sunmaktadır. Özellikle dalgaların yoğun olduğu kıyı bölgelerinde dalga enerjisi santralleri kurmak, bu potansiyeli değerlendirmek için etkili bir yöntemdir. Bu rapor, dalga enerjisinin avantajları, dezavantajları, kullanım alanları, dünya genelindeki potansiyeli ve Türkiye'deki durumu hakkında kapsamlı bir değerlendirme sunarak, dalga enerjisinin gelecekteki rolünü gözler önüne sermektedir.

Anahtar Kelimeler: Dalga Enerjisi, Yenilenebilir Enerji, Sürdürülebilirlik, Enerji Potansiyeli

1.Introduction

Wave energy stands out as a renewable energy source due to its environmentally friendly characteristics and continuous renewability. The movement of waves provides a steady and predictable form of energy production based on wind conditions, offering a significant contribution to the fight against climate change as it produces no carbon dioxide emissions,

unlike fossil fuels. Additionally, the density of waves enhances energy potential, making wave energy an attractive alternative for coastal regions. However, the use of wave energy also involves certain challenges and drawbacks. Initial high installation costs, the technology's relative immaturity, and variability in wave conditions may pose obstacles for investors. Furthermore, potential negative impacts of wave energy systems on marine ecosystems should be considered. Wave energy has various applications, including electricity generation, water heating, hydrogen production, and coastal protection. Electricity generation is the most common use of wave energy, achieved by converting wave motion into electrical energy through turbines. Additionally, wave energy can be utilized for hot water supply, desalination, and aquaculture applications. Globally, the potential for wave energy is high, especially along oceanic coastlines; however, many countries have yet to fully realize this potential. While countries like the United Kingdom, Portugal, and Australia are leading in wave energy projects, their contributions to total energy production remain limited. Turkey, surrounded by seas on three sides, also possesses significant wave energy potential. The Aegean Sea, with its high wave activity, is particularly promising, and Turkey's growing energy demand necessitates the exploration and development of renewable energy sources. In Turkey, ongoing research and pilot projects in wave energy aim to lay the groundwork for future commercial-scale applications. Moreover, efforts to develop domestic technology seek to enhance Turkey's ability to produce and utilize wave energy systems. However, high installation costs and technological development challenges may limit rapid progress in this field [1-4].

2. Wave Energy

Wave energy is a form of energy derived from the motion of waves on the surface of seas or oceans, harnessed to generate other forms of energy, most commonly electricity. Waves are created by the friction and movement generated by wind passing over the surface of the water. This energy is collected by wave energy systems and converted into electrical power. As a renewable energy source, wave energy presents an environmentally friendly alternative to fossil fuels. The continuous and predictable nature of wave formation enhances its potential as an energy resource, especially in coastal areas where wave energy facilities can be effectively established [5].

In the case of solar energy, surface area requirements are significant. For instance, under ideal conditions, generating 1 kW of electricity requires approximately 10 m² of space for solar energy systems, around 2 m² for wind energy, and only 1 m² for wave energy systems. Additionally, it is estimated that even just one percent of the wave energy present in the world's oceans could exceed the current global energy demand by five times[6].

Wave energy is a sustainable form of power generation as it relies on a constantly renewable source, the movement of waves. Unlike fossil fuels, wave energy does not produce carbon dioxide or other harmful emissions during electricity generation, which makes it an environmentally friendly option. Additionally, waves are a denser energy source compared to wind, giving wave energy systems the potential to generate more power. The movement of waves is also more predictable than wind conditions, simplifying energy production planning and making wave energy a more reliable source. Wave energy systems provide additional

benefits beyond electricity generation. They can reduce wave erosion in coastal areas, offering a natural form of coastal protection. The establishment of wave energy projects can also stimulate local employment and contribute to the regional economy. Moreover, wave energy is versatile and can be used not only for generating electricity but also for applications like desalination and seawater heating. Despite its advantages, wave energy comes with some challenges. The initial installation costs for wave energy systems can be relatively high, which might deter potential investors. As an emerging technology, wave energy is still developing, and it may take time to optimize existing systems and create new advancements. Additionally, wave energy production can be unstable due to varying weather conditions, which may lead to inconsistent energy output. Environmental concerns also arise, as wave energy systems could have potential impacts on local marine ecosystems, affecting both fauna and flora. Since wave energy plants must be located near coastlines, integrating them with existing energy infrastructure can be challenging. Furthermore, the most effective wave energy sites are limited and often overlap with other valuable coastal uses, such as fishing and tourism. Finally, wave energy projects typically have long payback periods, which could pose financial risks for investors. Wave energy can be applied in several areas beyond electricity generation. For example, wave energy systems can provide hot water by heating seawater, which can then be used for residential or industrial heating. Some systems even exploit ocean temperature differences for temperature regulation. Wave energy can also be used for hydrogen production by providing electricity for water electrolysis, offering a clean source of hydrogen fuel. Additionally, wave energy systems can contribute to coastal protection by reducing erosion and supporting aquaculture operations by improving water circulation, which benefits nutrient distribution in fish farms. Another important application is water desalination. Wave energy can be used as a power source for desalination processes, helping produce freshwater from seawater, which is especially valuable in areas with limited freshwater resources. Onboard ships and wave energy systems can also be used to generate electricity, reduce fuel consumption, and support marine energy needs. For remote and coastal areas, mobile wave energy systems offer a portable energy solution to meet local power demands. Several systems are used in wave energy production, each with a unique mechanism for harnessing energy from wave motion. The Oscillating Water Column (OWC) system, for instance, uses wave movements to drive a water column up and down, which in turn rotates a turbine to produce electricity. The Tapchan (Tapered Channel) system collects wave energy in a tapered channel that elevates water to a level where it can drive a turbine. The Wave Dragon system is a floating structure that channels waves into a reservoir, from which the stored water flows through turbines to generate power. Other systems like the Osprey Wave Energy Converter use specially designed mechanical structures to convert wave motion into mechanical energy that drives turbines. The McCabe Wave Pump channels wave motion to pump water into a storage reservoir, where it can be released to generate electricity. The Searaser system utilizes wave motion to raise and store water, which can later flow through turbines to produce energy. The Pelamis system is a floating mechanism that converts wave motion into electricity by leveraging the movement of different sections of the device relative to each other. The Pendular system, on the other hand, uses a pendulum mechanism to harness the up-and-down motion of waves, transforming this

movement into power. These systems represent some of the innovative ways wave energy can be captured and utilized for sustainable energy production[5-11].

3. Wave Energy Calculations

The calculation of wave energy is based on the fundamental physical characteristics of waves. These calculations consider parameters such as wave height, period, and wavelength, which are essential for estimating the potential of wave energy production. Accurate measurements and analysis of wave data are crucial to obtaining reliable results. Typically, wave measurements include data on wavelength, height, and period. Additionally, the parameters used in wave energy calculations can vary depending on local sea and wave conditions. Therefore, it is essential to base these calculations on data specific to the targeted region. Generally, wave energy can be calculated using the following formula[12]:

$$E = \frac{1}{8} \times \rho \times g \times H^2 \times T \tag{1}$$

Wave energy (E) is calculated in joules per cubic meter (J/m³) and depends on several key parameters: the water density (ρ), typically around 1000 kg/m³; gravitational acceleration (g), with an average value of 9.81 m/s²; wave height (H) in meters; and wave period (T) in seconds.

Wave power determines how efficiently wave energy can be utilized in a given area. It is generally calculated using the following formula [13]:

$$P = \frac{1}{16} \times \rho \times g \times H^2 \times C_g \tag{2}$$

The wave power P represents the amount of energy available per meter of wave front, often expressed in watts per meter (W/m). A key factor in calculating wave power is the group velocity, C_g, which is dependent on the wavelength of the waves. This group velocity influences how efficiently energy is transferred within the wave system, impacting the potential energy capture for energy generation purposes.

$$C_g = \frac{g}{2\pi} \times T \tag{3}$$

The group velocity defines the rate at which wave energy is transported across the water. This velocity, often symbolized as C_g , is calculated based on the wavelength λ of the wave. The relationship between group velocity and wavelength helps determine the efficiency of energy transfer within the wave system, which is essential for accurately assessing wave energy potential.

To calculate the efficiency of wave energy systems, the produced electrical energy can be expressed as a ratio of the wave energy. The efficiency ratio is defined by the following formula[14]:

$$\eta = \frac{P_{elec}}{P_{wave}} \tag{4}$$

The efficiency ratio (η) of wave energy systems is calculated by comparing the produced electrical power (P_{elec}) to the wave power (P_{wave}). Here, P_{elec} represents the electrical power generated in watts (W), while P_{wave} denotes the wave power in watts per meter (W/m). This ratio provides insight into how effectively the wave energy is being converted into usable electrical energy.

The kinetic energy of waves is determined by their speed and mass. The formula for calculating this energy can be expressed as follows:

$$KE = \frac{1}{2} \times m \times V^2 \tag{5}$$

The kinetic energy (KE) of waves is defined in joules and is dependent on the mass (m) of the moving water associated with the waves, measured in kilograms, and the velocity (v) of the waves, expressed in meters per second. As waves propagate, water particles move up and down, carrying a certain amount of energy. The height of the waves and the wavelength influence this kinetic energy. Taller waves generally possess greater kinetic energy due to the increased vertical displacement of the water particles, which contributes to the overall energy transmitted by the wave. Additionally, the wavelength, defined as the distance between consecutive wave crests, affects the dynamics of the energy within the wave motion. These characteristics collectively determine the amount of energy available for conversion into useful forms, such as electricity.

The potential energy of waves is dependent on their height. This relationship can be expressed with the formula for potential energy (PE),

$$PE = m \times g \times h \tag{6}$$

where PE is measured in joules, m represents the mass of the water (kg), g is the acceleration due to gravity (approximately 9.81 m/s²), and h is the height of the waves (m). As waves rise and fall on the water's surface, they store potential energy, with the maximum potential energy occurring at the crest of the wave. At this peak point, the height of the wave is greatest, resulting in a higher potential energy compared to other positions within the wave cycle. This stored potential energy plays a crucial role in the energy dynamics of wave motion and can be harnessed for various applications.

4. The Role of Wave Energy in Turkey

Wave energy in Turkey has significant potential to become an important energy source in the future; however, further research, development, and investment are necessary to effectively assess this potential. As a country surrounded by the Aegean, Mediterranean, and Black Seas, Turkey boasts a high capacity for wave energy, particularly in the Aegean Sea, where intense wave activity occurs. The increasing energy demand in Turkey necessitates the exploration and

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development of renewable energy sources, and wave energy is viewed as a viable alternative to meet this need. Various universities and research institutions, including Bogazici University and Istanbul Technical University, are conducting research and developing projects related to wave energy systems and technologies. Currently, there are a limited number of pilot projects in Turkey's wave energy sector aimed at testing its potential and laying the groundwork for commercial-scale applications. Furthermore, Turkey has established laws and policies to promote renewable energy sources, which support the development of alternatives like wave energy. Local technology development efforts seek to enhance Turkey's ability to produce and utilize wave energy systems, which is crucial for both economic and environmental sustainability. However, the installation costs of these systems and challenges in technological development may limit progress, highlighting the need for adequate infrastructure to support wave energy initiatives. The renewable energy production of Turkey by year is presented in Figure 1.

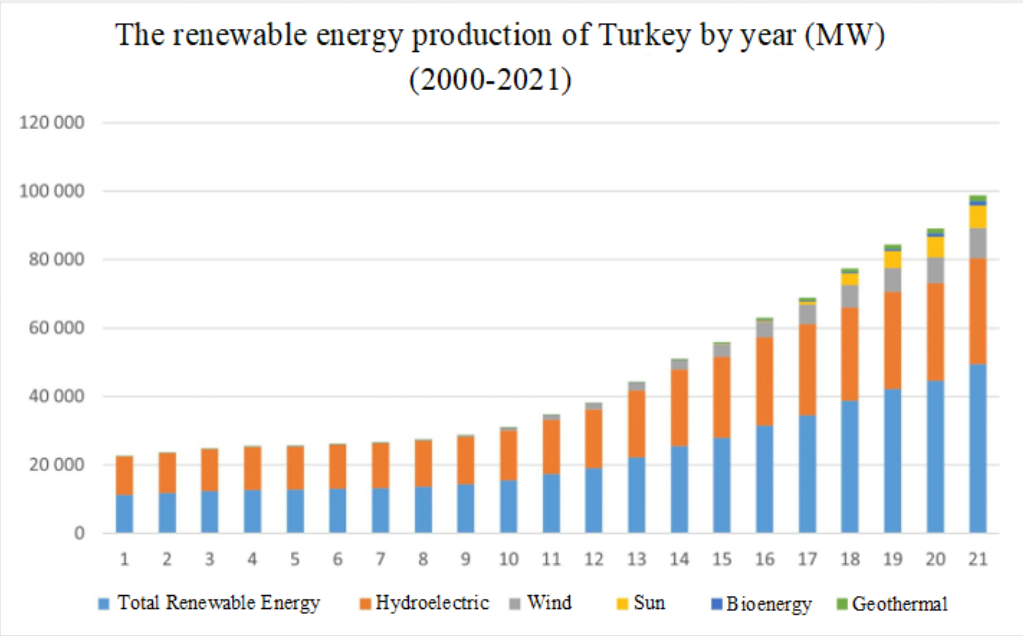

Figure 1. The renewable energy production of Turkey by year (MW) (2000-2021) [15].

Wave energy is a significant energy resource for Turkey, which is surrounded by seas on three sides. The country possesses a wave energy potential with an approximate coastline of 8,200 kilometers, particularly excluding the Sea of Marmara. Outside of oceans, wave power ranges between 10 and 40 kW/m, while measurements along the Mediterranean coast have shown an average value of around 13 kW/m. Observations in the Mediterranean indicate that wave power can fluctuate between 8.4 and 15.5 kW/m throughout the year [16].

Current wind data allows for the estimation of wave height and the calculation of potential wave energy, adjusted to sea level. For instance, studies conducted in Cesme have determined the average wave power to be 14.84 kW/m, indicating that Turkey's wave energy potential is competitive on an international scale. However, data on wave energy measurements in Turkey is limited. While it may not be possible to harness wave energy uniformly from all coasts, the

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significance of open coastline reduces as sea wave converters are not arranged in a single line. Even if only one-fifth of Turkey's coast is utilized, the technically recoverable wave energy potential is estimated to be around 18.5 billion kWh [17].

Figure 1. Wave height and power density map for Turkey[18].

According to the map generated using NATO TU-WAVES project data, the suitable marine areas and wave energy potential in Turkey are ranked as follows: the İzmir-Antalya region exhibits a wave energy potential ranging from 3.91 to 12.05 kWh/m, while in the Aegean Sea, this value is determined to be between 2.86 and 8.75 kWh/m. The potential along the Mediterranean coast varies from 2.59 to 8.26 kWh/m, whereas the Black Sea shows a range of 1.96 to 4.22 kWh/m. In the Sea of Marmara, the wave energy potential is considerably lower, falling between 0.31 and 0.69 kWh/m. These data are crucial for assessing the potential of wave energy and identifying suitable locations for energy production. Utilizing these natural resources is not only essential for increasing energy diversity in Turkey but also represents a significant step towards achieving sustainable energy goals. Strategically evaluating the country's coastal regions can support the integration of renewable energy sources, enhance energy security, and promote environmental sustainability. In this context, wave energy emerges as a potential source that is expected to play an important role in Turkey's energy future[10].

The development of wave energy presents significant opportunities for enhancing Turkey’s renewable energy portfolio. The following recommendations are proposed to facilitate the advancement of wave energy in the country:

1. **Investment in Research and Development:** Increased investments in research and development (R&D) activities are essential to improve the efficiency of wave energy technologies. This includes the design of new wave energy converters and the enhancement of existing systems to optimize performance.

2. **Implementation of Pilot Projects:** The establishment of pilot projects along Turkey's coastal regions is crucial for demonstrating the viability of wave energy potential. These projects can serve as test beds for evaluating the feasibility and economic impact of wave energy systems in real-world conditions.
3. **Data Collection and Analysis:** There is a pressing need for comprehensive data collection related to wave energy. Long-term measurements of wave power variations are necessary to understand performance under diverse environmental conditions, aiding in the optimization of energy production.
4. **International Collaboration:** Turkey should engage in international collaborations to exchange knowledge and experiences in wave energy technologies. Such partnerships can facilitate the development of innovative solutions and best practices in the field.
5. **Legal and Regulatory Framework:** A supportive legal and regulatory framework is vital for the advancement of wave energy projects. Establishing clear policies will enhance investor confidence and streamline the implementation of wave energy initiatives.
6. **Environmental Impact Assessment:** Comprehensive environmental impact assessments should be conducted for wave energy projects. A sustainable approach is required to minimize adverse effects on marine ecosystems, ensuring the protection of biodiversity.
7. **Financial Support and Incentives:** The creation of financial support mechanisms and incentive programs can encourage investments in wave energy. Attracting both domestic and foreign investors is crucial for the growth of this sector.
8. **Education and Awareness Raising:** Educational programs aimed at raising public awareness about wave energy should be developed. Increasing societal understanding and support for wave energy initiatives is essential for fostering a conducive environment for investment and development.

These recommendations aim to enable Turkey to effectively harness its wave energy potential, contributing to the country's sustainable energy objectives and fostering economic growth through innovative renewable energy solutions.

5.Results and Discussions

Wave energy holds significant potential among renewable energy sources worldwide, particularly in Turkey. Its continuously renewable nature, environmentally friendly characteristics, and the predictability it offers in energy production make wave energy an effective alternative to the adverse impacts of fossil fuels. However, to realize this potential, it is essential to overcome several existing challenges. High initial costs, the relative immaturity of the technology, and potential environmental impacts present substantial barriers for investors and researchers.

Several countries have made considerable progress in the wave energy sector by implementing significant projects and advancing the use of this energy source. Given Turkey's geographic positioning as a nation surrounded by seas on three sides, it is imperative to conduct further research and investment to evaluate the wave energy potential. The Aegean Sea, particularly areas with high wave activity, presents significant opportunities to enhance Turkey's wave energy capacity.

Pilot projects related to wave energy in Turkey play a critical role in testing this sector's potential and establishing the necessary infrastructure for commercial applications. Domestic technology development efforts not only promote energy independence but can also contribute to economic growth.

In conclusion, wave energy has the potential to occupy a vital role within Turkey's energy strategies. Harnessing this energy source could significantly contribute to environmental sustainability and energy diversity, thus addressing the country's future energy needs. Therefore, supporting and advancing wave energy projects will be a crucial step in achieving Turkey's renewable energy goals.

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NUMERICAL MODELLING OF PHOTOVOLTAIC PANELS BY USING MATLAB-SIMULINK

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ABSTRACT

Photovoltaic (PV) panels harvest the incident solar irradiation to convert it into electricity by the help of solar cells. Numerical modelling of these PV units is crucial to observe the system performance under various environmental conditions. In this study, we modelled the PV panel system by using MATLAB/Simulink. Influences of irradiation and ambient temperature levels on solar panel performance were investigated for the levels of 500 W/m^2, 750 W/m^2, and 1000 W/m^2 irradiance and 25°C - 39°C ambient temperatures. Furthermore, impact of the material permeability was numerically investigated to provide a comprehensive demonstration of how these materials affect solar panel performance. This findings show that the PV panel performance can be increased up to 9.55% by operating at optimal thermal conditions.

Keywords: Solar panels, solar irradiance, numerical PV model, operating temperature.

1. INTRODUCTION

Solar energy stands for making clean power supply by the help of sustainable and affordable photovoltaic (PV) systems. PV technology has been used in diverse application fields such as battery charging, water heating, satellite power systems, and marine technologies [1-3]. While only confined to the theory of researchers a few years ago, now developers increasingly describe solar energy as a promising and sustainable energy solution. Solar energy is an attractive primary source of power for its potential to reduce the need for grid electricity and associated expenses on the individual level [4, 5].

Excessive energy intensity of the sun at 1.35 kW per square meter (solar flux) contributes to global energy potential substantially. Furthermore, Earth-wide band is about 1.78 x 10^8 MW. The incoming total solar radiation that reaches the Earth surface annually is equivalent to be 1.22 x 10^{14} TCE (tons of coal equivalent) = 0.814 x 10^{14} TOE (tons of oil equivalent). The Earth gets 800x as much solar energy each year as there is proven oil reserves [6]. The use of solar energy for the aim of electricity generation can be possible via photovoltaic systems [7, 8]. A global attention was paid to PV systems due to the reductions in fuel reserves of traditional

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fossil fuels and environmental developments [9]. Photovoltaics is now a global market, manufacturing gigawatts of new installations each year [10]. Record solar PV installations 20% up on 2008. At 7.3 GW, global installed solar PV capacity set a new annual record in 2009. This compares to a global PV industry revenue in the same year at $38.5 billion with over $13.5 billion raised in equity and debt, an increase of 8% from the previous year [11].

A solar cell consists of a semiconductor wafer with p-n junctions, where p (positive) and n (negative) regions create an electric field. Light causes free electrons to move to the n side and holes to the p side, generating current and voltage through metal contacts, as long as the cell is part of a connected circuit [12]. In this numerical work, we simulate photovoltaic panel physics to investigate solar energy harvested electricity generation. MATLAB/Simulink software has been utilized to investigate the impact of irradiation and transmittance on PV system performance. Irradiance level of 500 W/m^2, 750 W/m^2, and 1000 W/m^2 were numerically applied the PV physics. Furthermore, the ambient temperature was varied from 25°C to 39°C to observe the possible environmental thermal effects.

2. METHODOLOGY

Photovoltaic system modelling has been conducted via MATLAB/Simulink software to examine the impact of irradiance, ambient temperature, and solar transmittance on the solar panel efficiency. In this work, we determined three scenarios in the transmittance investigation: no covering, low-transmission plastic, and high-transmission plastic. The simulations aim to document a comprehensive comparison for the solar panel performance under the irradiance levels of 1000 W/m², 750 W/m², and 500 W/m². Figure 1 presents the block diagram sample modelled in MATLAB interface.

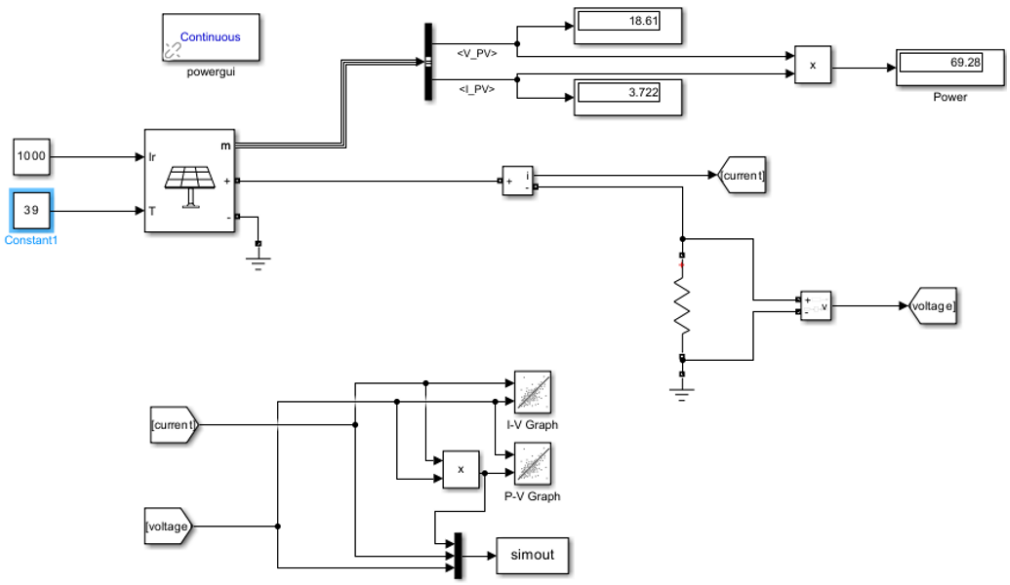

Fig. 1. Block diagram of solar modules without covering under 1000 W/m² irradiance.

Note that the photovoltaic demonstration represents a mathematical model that calculates the electrical response of a PV system under pre-determined operating conditions, i.e.,

incident irradiance, transmittance, and cell temperature. The single diode model is the most widely utilized model, and it gives generally accurate and reasonable outputs. Furthermore, this model can be applied not only into PV cells but also to modules, strings and arrays operating in uniform conditions. Figure 2 presents the main schematics of single-diode model of a solar cell [12].

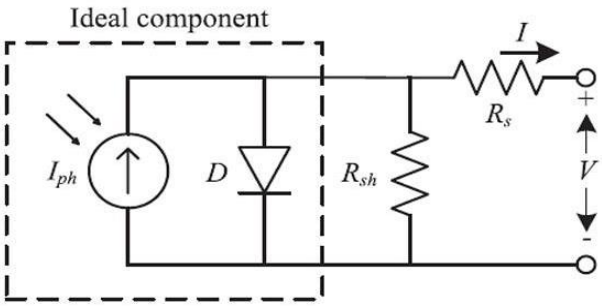

Fig. 2. Main circuit of single-diode model of a solar cell [13]

This model consists in a current source. I_{ph} , a diode saturation current Is, a modified diode ideality factor n, a series resistance Rs and a shunt resistance R_{sh}. The shunt and series resistance have an important impact in the efficiency of the solar cells [14]. On the other hand, current-voltage (I-V) curve of a PV cell is a crucial characteristic of these systems. It appears in most of the PV modules datasheets and represents all the possible combinations of current and voltage that a PV module can be operated or loaded according to the existing conditions of irradiance and temperature.

In a typical I-V curve, the maximum power point (MPP) corresponds to the point where the array produces maximum electrical power. This point is represented by the highest value obtained by multiplying current with voltage. Furthermore, The fill factor (FF) serves as a measure of solar cell quality, comparing the maximum power of an ideal cell to that of a real one [13].

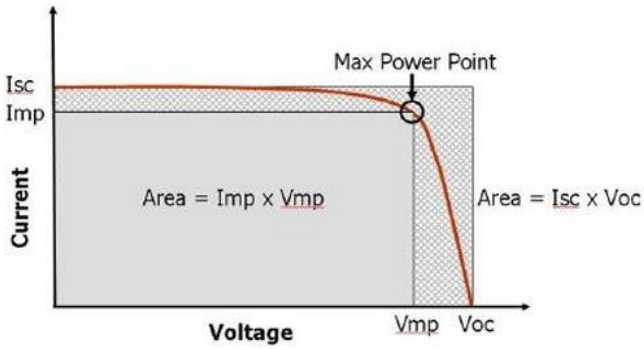

Fig. 3. MPP and FF relationship [13, 14].

3. RESULTS AND DISCUSSION

In the first simulation, we examined the base scenario of no-covering case with an irradiance level of 1000 W/m². The modelled PV panel produced a current of 3.72 A, a voltage of 18.61

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V corresponding to a power output of 69.28 W. Note that the results show high efficiency due to direct sunlight exposure compared to the other scenarios.

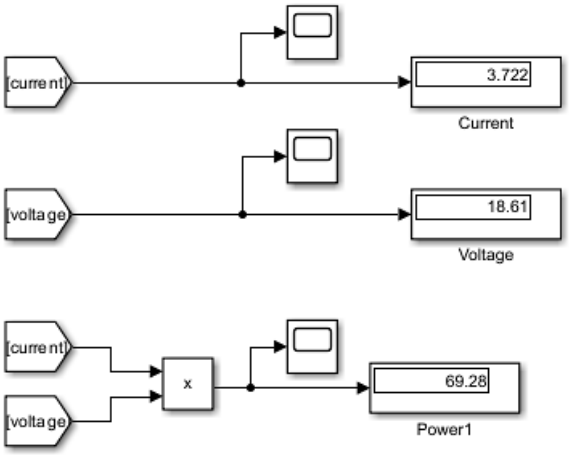

Fig. 4. Outputs for the no-covering case with an irradiance level of 1000 W/m².

Figure 4 shows the MATLAB interface for the outputs of the base scenario. Next, the simulation with high-transmittance plastic covering and an irradiance of 750 W/m² was performed. In this scenario, PV panel was exposed to higher resistance to mimic the real-case application containing shading effects. The results indicate that the produced current is about 3.49 A with a voltage level of 17.44 V. As given in Fig. 5, the power output is about 60.85 W.

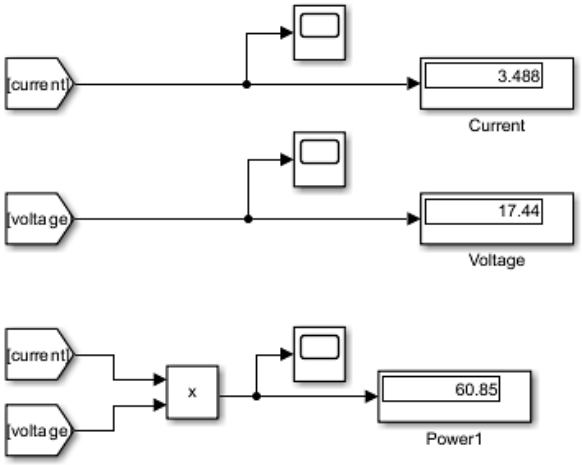

Fig. 5. High-transmittance plastic covering at 750 W/m² irradiance level.

We ran another transmittance level in the lowest irradiance level to compare the power outputs, voltage and current levels. In the simulation with low-transmittance plastic and 500 W/m² irradiance, the panels produced a current of 2.58 A, a voltage of 12.9 V, and a power output of 33.29 W. This demonstrates that low-transmittance plastic significantly reduces energy harvesting efficiency by limiting irradiance reaching the solar cells. In addition to the transmittance levels, the I-V and P-V curves at different solar irradiation levels (1000 W/m², 750 W/m², and 500 W/m²) at a constant temperature of 39°C were simulated. Figures 6a and 6b show the I-V and P-V curves at three different irradiance levels at 25°C. The findings

indicate that higher irradiance levels yield maximum voltage, current, and power output, while lower irradiance levels lead to decreased performance.

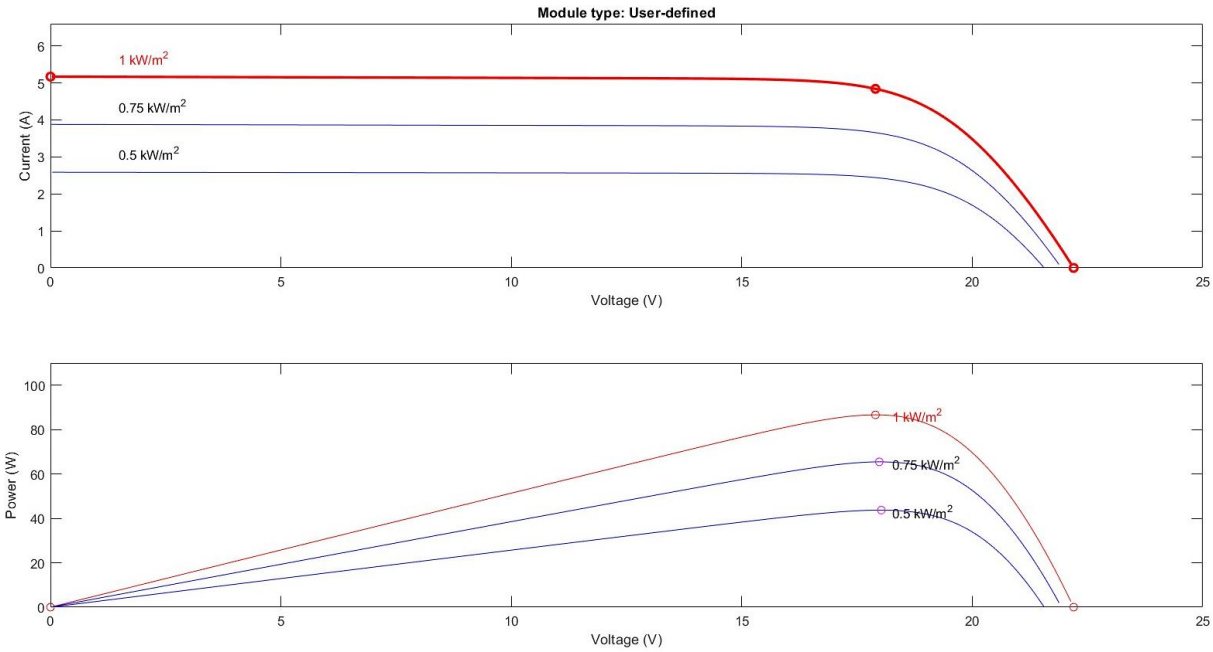

Fig. 6. a) I-V curves and b) P-V curves at various irradiance levels at 25°C temperature.

As it seen in Fig. 6, temperature level and irradiation significantly affect PV module performance. Typically, PV panels have an efficiency of 10% to 22%, converting only a fraction of incident sunlight into electricity, with the rest becoming heat. Table 1 shows the relation among the PV panel temperature, irradiance level, and electrical outputs.

Table 1: Solar panel performance for distinct temperature and irradiance levels.

Temperature (°C)	Irradiance (W/m²)	Voltage (V)	Current (A)	Power Output (W)
25	1000	19.57	3.914	76.60
25	750	18.09	3.618	65.45
25	500	12.82	2.565	32.88
39	1000	18.61	3.722	69.28
39	750	17.44	3.488	60.85
39	500	12.09	2.58	33.29

4. CONCLUSION

This study numerically presents the effects of irradiance, panel temperature, and panel transmittance (shading effects) on PV panel electrical outputs. The numerical model has been created into MATLAB/Simulink interface under realistic initial and boundary conditions. Influences of irradiation and ambient temperature levels on solar panel performance were investigated for the levels of 500 W/m^2, 750 W/m^2, and 1000 W/m^2 irradiance and 25°C - 39°C ambient temperatures. The main conclusions are as follows:

- The uncovered scenario with 1000 W/m^2 irradiance provide the improved electrical outputs under each thermal conditions. The maximum power output of 76.60 W was obtained 25 °C, and it decreases by 9.55% when the temperature rises to 39 °C.
- The power output decreases by 14.5% and 57.1% when the irradiance level goes 750 W/m^2 and 500 W/m^2, respectively.
- The minimum voltage output is obtained at 39 °C when the irradiance level is 500 W/m^2.
- Transmittance is a dominant parameter affecting the solar panel performance as the coverings behave like a radiative barrier between the PV system and incident radiation.

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AN EXPERIMENTAL INVESTIGATION ON THE RELATIONSHIP BETWEEN TRANSMITTANCE AND PV PANEL PERFORMANCE

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ABSTRACT

This study focuses on the impacts of plastic and thin fabric material usage on the surface of a solar panel, and how the transmittance of these materials affect the photovoltaic panel's efficiency. The experiments has been initiated by measuring the open-circuit voltage (V_{OC}) and short-circuit current (I_{SC}) of a small solar panel in full sunlight. Two different plastic materials with different transparencies are consecutively placed on the solar panel, and measurements of open-circuit voltage (V_{OC}) and short-circuit current (I_{SC}) are collected for each material. The data gathered is examined to compare how different materials affect light transmission and efficiency. This study gives useful insights into material selection for photovoltaic system design, resulting in more efficient solar energy utilization through innovative material uses.

Keywords: Solar irradiation, Transmittance, PV panel, Solar performance

4.INTRODUCTION

The World Energy Forum has estimated that fossil fuel resources (oil, coal and gas) will be exhausted over the next 100 years. Today, 79% of the world's primary energy consumption comes from fossil fuels, with a full 57.7% being spent on transportation. Recently, it is increasingly being appreciated that renewable energy (energy derived from resources which are regenerative and naturally replenished) may be a solution to these problem [1]. Over the past several years, there has been a rising interest in design of renewable energy applications and integration into education [2-4].

The sun is considered a promising source of energy due to its consistency and cleanliness, unlike other forms of energy that pollute the atmosphere and the environment. Most scientists emphasize the importance of solar energy due to the availability of sunlight that can meet our energy needs in the future. [5]. Solar energy obviously environmentally friendly compared to every other renewable energy source, and it is the cornerstone of any real sustainable development program. [6]. The key benefits of this technology towards sustainable development are zero (or mitigate) pollutant emissions (i.e. no greenhouse gas formers especially CO2 and NOx, no toxics such as SO2 or particulates), restoration of devastated lands, reduction in transmission requirements for electricity, increased regional and national energy

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sufficiency (versus food self-sufficiency), diversification and security of local fuel supplies, as well as contributions to rural electrification especially in developing countries [7].

The use of solar energy can be active via photovoltaic systems. A solar cell consists of a semiconductor wafer with p-n junctions, where p (positive) and n (negative) regions create an electric field. A global attention has been paid to PV systems due to the reductions in fuel reserves of traditional fossil fuels and environmental developments [8-10]. Photovoltaics is now a global market, manufacturing gigawatts of new installations each year [11]. Record solar PV installations 20% up on 2008. At 7.3 GW, global installed solar PV capacity set a new annual record in 2009. This compares to a global PV industry revenue in the same year at $38.5 billion with over $13.5 billion raised in equity and debt, an increase of 8% from the previous year [12].

This study focuses on the experimental performance of an 85 Wp monocrystalline PV under various transmittance scenario. An experimental setup (Labvolt-Solar Training System) was utilized to conduct the experiments with/out coverings on the solar panel top. The measurements indicate that shading effects dominantly decreases the electrical performance of photovoltaic systems.

5. METHODOLOGY

This study examines three different scenarios of without covering, low-transmittance plastic, and high-transmittance plastic to document the effects of shading/transmittance on solar panel efficiency. Effects of coverings on irradiance and overall solar panel performance were investigated to understand the relation between material transmittance and power generation. The experiments were carried out with the 'Solar/Wind Energy Training System 580183 (46120-05) LabVolt - Festo' setup that we had in our laboratory. Figure 1 presents the experimental set-up.

Fig. 1. LabVolt Solar/Wind Energy Training System.

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The experimental configuration has a solar array junction box, stop switch, ammeter, DC circuit breaker, solar charge controller, power busbar, invertor, AC circuit breaker box, battery bank and junction box, and AC-DC outlets. Figure 2 shows the schematic for the investigated system [13].

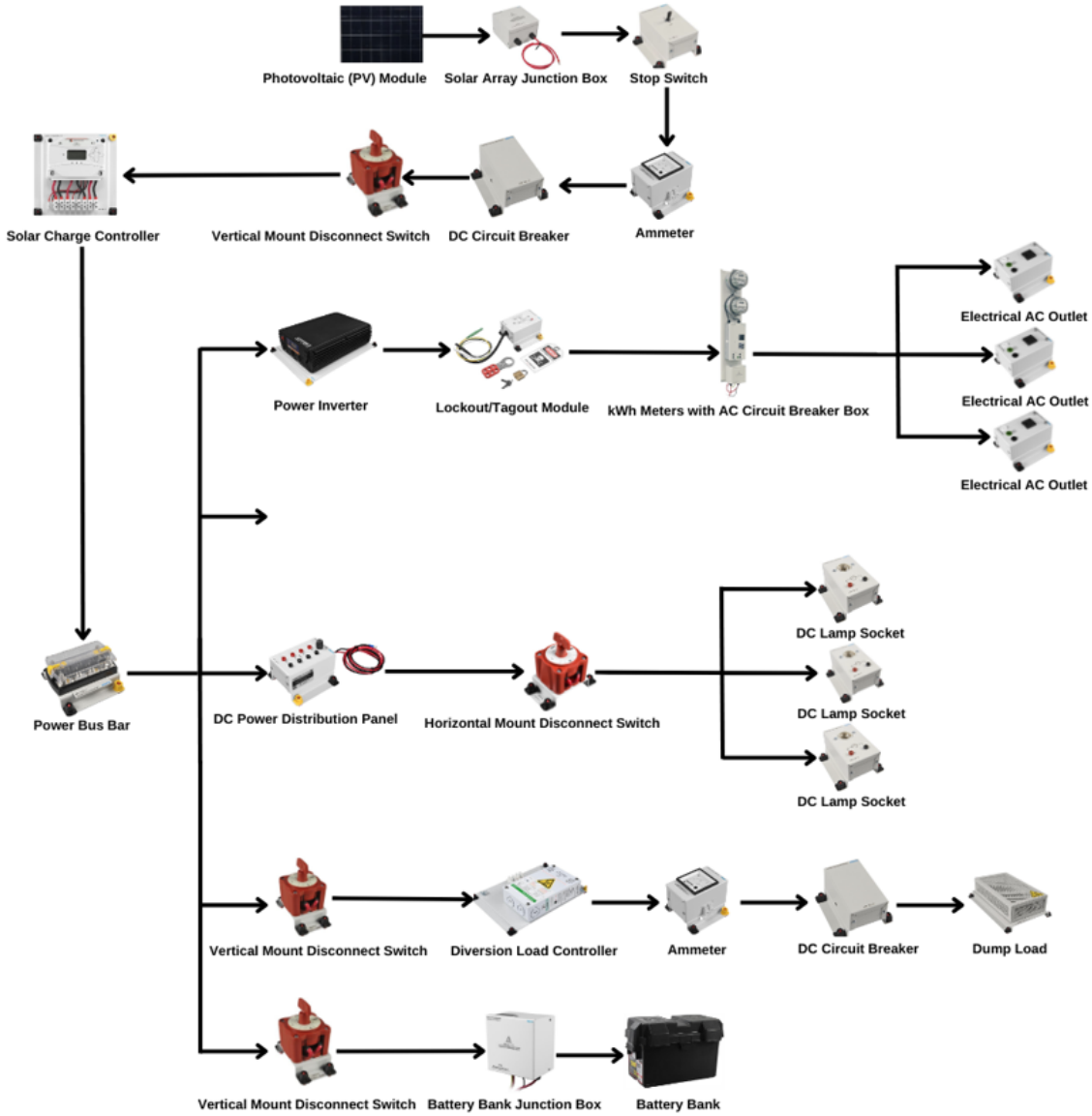

Fig. 2. Schematic of Solar/Wind Energy Training System 580183 LabVolt Series

The I-V curve of a PV cell, string, or array is an important characteristic of this system. It appears in most PV module datasheets and represents all of the possible current and voltage combinations with which a PV module can be operated or loaded based on the current irradiance and temperature conditions. Furthermore, connected with this curve is typically the P-V curve, which provides essential data regarding the performance of the PV module, such as the power output.

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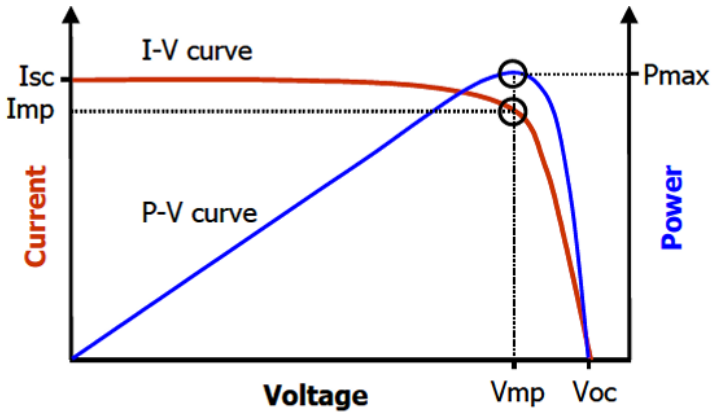

Fig. 3. I-V and P-V curve of a photovoltaic device [14]

In Fig. 3, a typical I-V and P-V curve of a PV device has been represented with the main parameters which characterizes it. The short-circuit current I_{sc} represents the current flowing through a solar cell when its voltage is zero.

$$I_{sc} = I_{ph} - I_s\left(e^{\alpha\frac{q(I_{sc}\,R_S)}{nK_BT}-1}\right) - \frac{IR_s}{R_{sh}} \qquad (1)$$

In an ideal solar cell, the short-circuit current (I_{sc}) and the light-generated current (I_{pv}) are almost identical since there is no resistance that affects performance. The open-circuit voltage (V_{oc}) is the maximum voltage that a cell can generate when no current flows.

$$V_{oc} = \frac{nK_bT}{q} * Ln\left(\frac{I_{pv}}{I_s} + 1\right) \qquad (2)$$

The fill factor (FF) needs to be emphasized. FF serves as a measure of solar cell quality, comparing the maximum power of an ideal cell to that of a real one. FF can be calculated as follows:

$$FF = \frac{I_{MP}*V_{MP}}{I_{SC}*V_{oc}} \qquad (3)$$

PV modules of the same model should have similar fill factors under identical conditions, influenced significantly by module technology and design. Generally, amorphous silicon modules have lower fill factors compared to crystalline silicon due to differences in material properties. The fill factor is crucial for assessing material impacts on solar panel efficiency and optimizing solar energy systems [15].

6. RESULTS and DISCUSSION

In this study, we investigate an 85 Wp PV panel performance under various transmittance scenarios to uncover the impact of shading effects on the photovoltaic unit efficiency. Solar panel without any covering effectively harvests the direct sunlight. This results in maximum efficiency, consistent power output, and eliminated risk of hotspots. Exposed solar panels offer

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direct access to sunlight and simplify performance monitoring. Furthermore, these systems enable easier tracking of voltage, current, and power output. This leads to greater efficiency and consistent power generation. As shown in Fig. 4, the uncovered panel provides a potential difference output of 20.09 V.

Fig. 4. Solar panel potential without any cover

The next scenario is the high transmittance (solar permeability is about 0.85) case that is conducted via a plastic layer. When we covered the PV panel top surface with high transmittance plastic material, the voltage decreased marginally to 20.02 V. The plastic covering permits the majority of irradiance to reach the cells, sustaining strong energy absorption and steady system functioning. Figure 5 presents the experimental setup and measurement results.

Fig. 5. PV panel experiment with high transmittance covering.

The last scenario has been conducted via the low transmittance thin film covering (see Fig. 6) with a solar permeability of about 0.3. In this experiment, the voltage output dropped significantly to 10.15 volts due to reduced irradiance caused by low transmittance plastic covering. The findings indicate a lower energy absorption, unstable performance, decreased efficiency, and problems like hotspots and bypass diode activation.

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Fig. 6. Solar panel with low transmittance thin plastic layer.

5. CONCLUSION

In this study, we experimentally examine an 85 Wp PV panel performance under various transmittance scenarios to uncover the impact of shading effects on the photovoltaic unit efficiency. The experimental configuration (LabVolt – Solar/Wind Energy System) has a solar array junction box, stop switch, ammeter, DC circuit breaker, solar charge controller, power busbar, invertor, AC circuit breaker box, battery bank and junction box, and AC-DC outlets. The experiments have been conducted for uncovered, low-transmittance, and high transmittance cases. The main findings are as follows:

- In the PV panel characteristic sheet, the investigated solar panel has a nominal voltage output of 21.6 V, and we measured 20.09 V maximum voltage in the horizontal orientation when the local time is about 1:00 pm (June).
- The high transmittance scenario provides a similar potential difference level of 20.02 V as the permeable plastic covering (solar permeability is about 0.85) permits the majority of irradiance to reach the cells.
- As expected, the voltage output dropped significantly to 10.15 V in the low transmittance thin film covering (solar permeability is about 0.3) scenario due to the minimized irradiance.

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TEKİL İKİ-ARALIKLI STURM-LİOUVİLLE PROBLEMLERİNİN ÖZDEĞERLERİNİN POZİTİFLİĞİ

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ÖZET

Sturm-Liouville problemleri, çeşitli fiziksel problemler için Schrödinger denkleminin çözümünde esastır. Bu problemin özdeğerleri, kuantum sistemlerinin enerji seviyelerini temsil eder ve özfonksiyonlar ise parçacıkların durum fonksiyonlarına karşılık gelir. Bu sebeple Sturm-Liouville teorisi kuantum teorisinin gelişimi ve atomik, moleküler ve katı hal fiziğindeki uygulamaları için çok önemlidir. Benzer şekilde telin, zarların titreşimi ve elektromanyetik dalgaların yayılması dahil olmak üzere dalga mekaniğindeki birçok problem Sturm-Liouville problemleri olarak formüle edilebilir. Bu çalışmanın esas amacı yeni bir Sturm-Liouville probleminin özdeğerlerini incelenmektir. Araştırdığımız problem klasik Sturm-Liouville problemlerinden bir çok açıdan farklıdır. İnceleme altında olan problemin diferansiyel denklemi tek aralıkta değil ortak uç noktaları olan iki ayrık aralıkta tanımlıdır. Problemimiz sınır şartlarının yanısıra iletim noktasında ek geçiş şartları da içermektedir. Ayrıca diferensiyel denklem esas aralığın sınır noktalarının birinde veya her ikisinde singülerliğe (tekilliğe) sahip olabilir. Problemimizde elde edilen sonuçlar uygun klasik sonuçları genelleştirmektedir.
Keywords: İki-aralıklı tekil Sturm-Liouville problemi, pozitif özdeğer, özfonksiyon.

1. GİRİŞ

Sturm-Liouville teorisi 19. yüzyılın ortalarından başlayarak günümüze kadar hem güncelliğini korumuştur hem de analiz ve uygulamalı matematiğin yeni dallarının oluşumu için temel teşkil etmiştir. Özellikle de Hilbert uzaylarında kendine eşlenik olan diferansiyel operatörler teorisinin neredeyse tüm kavram ve özellikleri Sturm-Liouville teorisi çerçevesinde oluşmuş ve gelişmiştir. Bilindiği gibi Sturm-Liouville problemleri matematiksel fiziğin bir çok somut probleminin Fourier yöntemi ile çözümünde ortaya çıkmaktadır. Bu nedenle fizikte ve başka doğa bilimlerinde ortaya çıkan yeni problemler Sturm- Liouville teorisinin farklı yönlerde gelişmesi ihtiyacını da ortaya çıkarmaktadır. Matematiksel fiziğin farklı problemlerinin analitik veya seri biçiminde çözümlerinin elde edilmesi, bu mümkün olmadığı durumlarda ise çözümlerin nitel özelliklerinin bulunması için uygun Sturm-Liouville problemlerinin aşağıdaki önemli özelliklerin incelenmesi gerekir.

1. Özdeğerlerin reel olması

2. Sayılabilir sonsuz sayıda özdeğerin mevcutluğunun ispatı

3. Özdeğerler dizisinin analitik veya asimptotik ifadelerinin bulunması

4. Özfonksiyonlar sisteminin bulunması ve uygun Hilbert uzayında baz oluşturması

5. Özfonksiyon açılımının trigonometrik Fourier serileri ile eşyakınsaklığı

Yukarıda sıraladığımız bu özelliklerin sağlanması genel olarak sınır şartlarına bağlıdır. Bazı sınır şartları için bu özellikler sağlanabilir, bazılar için ise sağlanmayabilir. Bizim bu çalışmamızda incelediğimiz Sturm-Liouville problemlerinin hem diferansiyel denklemleri hem de sınır şartları klasik Sturm-Liouville problemlerimden farklıdır. Esas farklılıklar aşağıdaki gibidir. İncelediğimiz diferansiyel denklem tek bir aralıkta değil, ortak uç noktası (bu noktaya iletim noktası veya geçiş noktası denir) olan iki ayrık aralıkta verilmiştir. Diferansiyel denklemimiz sol aralığın sol uç noktasında ve/veya sag aralığın sağ uç noktasında singülerliğe (tekilliğe) sahiptir. Ayrıca iletim noktalarında ek geçiş şartları verilmiştir. Matematiksel fiziğin bir çok problemleri için uygulanan Fourier yöntemi sonucu bu tür Sturm- Liouville problemleri ile karşılaşıyoruz (bak, mesela [1], [3], [6], [7], kaynaklarına ve bu kaynaklara yapılan atıflara). Bu nedenle incelediğimiz sınır-değer-geçiş problemi hem teorik açıdan hem de matematiksel fizik açısından önemlidir. Son yıllarda bu ve benzeri türden klasik olmayan Sturm- Liouville problemlerine ilgi daha da artmıştır ve bu alanda önemli sonuçlar elde edilmiştir (bak, mesela [2], [4], [5], [8], [9]).

2. ESAS SONUÇLAR

Bu çalışmada ortak $x = c$ uç noktası olan iki ayrık $[a, c)$ ve $(c, b]$ aralıklarında tanımlı o olan ve $x = a$ ve $x = b$ sınır noktalarının en az birinde tekilliğe (singülerliğe) sahip olan

$$-(k(x)y')' + g(x)y = \lambda y(x)\,, \quad x \in [a, c) \cup (c, b] \tag{1}$$

diferansiyel denklemi için aşağıdaki sınır-değer-geçiş probleminin bazı spektral özelliklerini inceleyeceğiz. Burada k ve g fonksiyonları $[a, c)$ ve $(c, b]$ aralıklarının her ikisinde de süreklidirler ve sonlu $k(c \pm 0)$ ve $g(c \pm 0)$ limit değerleri mevcuttur (burada $f(c \pm 0) := \lim_{x \to c \pm 0} f(x)$ gösteriminden yararlanılmıştır). Ayrıca $k(x)$ fonksiyonunun (a, c) ve (c, b) aralıklarının her ikisinde de sürekli diferansiyellenebilir olduğunu, $\forall x \in (a, c) \cup (c, b)$ için $\mathcal{K}(x) > 0$ sağlandığını kabul edeceğiz. (1) nolu iki-aralıklı Sturm-Liouville denkleminin $[a, c)$ aralığında tanımlı olan çözümü ile (bu çözüme sol çözüm denir) ve $(c, b]$ aralığında tanımlı olan çözümü (bu çözüme sağ çözüm denir) arasında

$$y(c + 0) = \gamma y(c - 0) \tag{2}$$

$$y'(c + 0) = \gamma' y'(c - 0) \tag{3}$$

geçis şartlarının sağlandığını kabul edeceğiz; burada γ ve γ' sıfırdan farklı reel sayılardır.

Durum1. $\mathcal{K}(a) > 0$ ve $\mathcal{K}(b) > 0$ olduğu durumda (1) denkleminin

$$\cos\alpha\, y(a) + \sin\alpha\, y'(a) = 0 \tag{4}$$

$$\cos\beta\, y(b) + \sin\beta\, y'(b) = 0 \tag{5}$$

sınır şartlarını sağladığını

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Durum 2: $k(a) > 0, k(b) = 0$ olduğu durumda (1) denkleminin sadece (4) sınır şartını sağladığını ve

Durum 3. $k(a) = 0, k(b) > 0$ olduğu durumda ise (1) denkleminin sadece (5) sınır şartını sağladığını kabul edeceğiz. Burada $\alpha, \beta \in [0, \pi)$ keyfi reel sayılardır.

Teorem 1. Aşağıdaki şartların sağlandığını kabul edelim.

1) $g(x) \geq 0, \forall x \in [a, c) \cup (c, b]$
2) $k(a) > 0$ ise $\sin(2\alpha) < 0$ şartı sağlanır, $k(b) > 0$ ise $\sin(2\beta) > 0$ şartı sağlanır.
3) $k(c+0) = \frac{1}{\gamma\gamma'} k(c-0)$

O halde verilmiş iki-aralıklı tekil Sturm-Liouville probleminin her bir λ özdeğeri için $\lambda \geq 0$ dir, yani bu problemin negatif özdeğeri mevcut değildir.

İspat. λ bir özdeğer, $y(x, \lambda)$ ise bu özdeğere uygun özfonksiyon olsun.

0 halde

$$-(k(x)y'(x,\lambda))' + g(x)y(x,\lambda) = \lambda y(x,\lambda), \quad x \in [a, c) \cup (c, b] \tag{6}$$

eşitliğinin her iki tarafını $y(x,\lambda)$ ile carpalım.

O halde

$$\lambda y^2(x,\lambda) = g(x)y^2(x,\lambda) - (k(x)y'(x,\lambda))'y(x,\lambda) \tag{7}$$

özdeşliği bulunur. Bu esitliğin her iki tarafını $[a, c)$ ve $(c, b]$ aralıklarında integralledikten sonra taraf-tarafa toplayarak ve kısmi integrasyon yöntemini uygulayarak

$$\lambda\left(\int_a^{c-0} y^2(x,\lambda)dx + \int_{c+0}^{b} y^2(x,\lambda)dx\right) = \left(\int_a^{c-0} g(x)y^2(x,\lambda)dx + \int_{c+0}^{b} g(x)y^2(x,\lambda)dx\right)$$

$$= \left(\int_a^{c-0} k(x)(y'(x,\lambda))^2dx + \int_{c+0}^{b} k(x)(y'(x,\lambda))^2dx\right)$$

$$- k(b)y'(b,\lambda)y(b,\lambda) + k(a)y'(a,\lambda)y(a,\lambda)$$

$$- k(c+0)y'(c+0,\lambda)y(c+0,\lambda)$$

$$+ k(c-0)y'(c-0,\lambda)y(c-0,\lambda) \tag{8}$$

esitliğini elde ederiz. Diğer taraftan $\cos\alpha\, y(a,\lambda) + \sin\alpha\, y'(a,\lambda) = 0$ olduğu için

$$-\cos\alpha \sin\alpha\, y(a,\lambda)y'(a,\lambda) = (\sin\alpha\, y'(a,\lambda))^2 \geq 0 \tag{9}$$

eşitsizliği elde edilir. $\sin(2\alpha) < 0$ şartı sağlandığı için (9) eşitsizliğinden

$$y(a,\lambda)y'(a,\lambda) \geq 0 \tag{10}$$

eşitsizliği bulunur. Benzer biçimde $\cos\beta\, y(b,\lambda) + \sin\beta\, y'(b,\lambda) = 0$ eşitliğinden

$$y(\beta,\lambda)y'(\beta,\lambda) \leq 0 \tag{11}$$

eşitsizliği elde edilir. $y(x,\lambda)$ özfonksiyonu (2), (3) geçiş şartlarını sağladığı için

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$$\hbar(c+0)\mathcal{y}'(c+0,\lambda)\mathcal{y}(c+0,\lambda) - \hbar(c-0)\mathcal{y}'(c-0,\lambda)y(c-0,\lambda)$$

$$= (\hbar(c+0)\gamma\gamma' - \hbar(c-0))\,\mathcal{y}'(c-0,\lambda)y(c-0,\lambda)$$

$$= 0$$

(12)

eşitlikleri geçerlidir. (10), (11) ve (12) eşitlikleri (8) eşitliğinde yerine yazılırsa $\hbar(b) > 0$, $\hbar(x) \geq 0$ ve $\mathcal{g}(x) \geq 0$ şartlarının da sağlandığını dikkate alınırsa (8) eşitliğinin sağ tarafında yer alan her bir terimin negatif olmadığı görülür.O halde (8) eşitliğinin sol tarafı da negatif değildir. Dolayısıyla $\lambda \geq 0$ sonucu elde edilir. İspat bitti.

Teorem 2. Kabul edelim ki Teorem 1 in tüm şartları sağlansın. Bu şartlara ilave olarak $\mathcal{g}(x) \not\equiv 0$ şartını (yani en az bir $x_0 \in [a,c) \cup (c,b]$ için $\mathcal{g}(x_0) > 0$ şartının) da sağlandığını kabul edelim. O halde verilmiş iki-aralıklı tekil Sturm- Liouville probleminin tüm özdeğerleri pozitiftir.

İspat. $\mathcal{g}(x_0) > 0$ ve $\mathcal{g}(x)$ fonksiyonu $[a,c) \cup (c,b]$ de sürekli olduğu için öyle $\delta_0 > 0$ sayısı vardır ki, $\forall x \in [x_0 - \delta_0, x_0 - \delta_0] \cap ([a,c) \cup (c,b])$ için $\mathcal{g}(x) > 0$ sağlanır. Sonlu $\mathcal{g}(c \pm 0)$ değerleri mevcut olduğu için öyle bir $\mathcal{K}_0 > 0$ sayısı mevcuttur ki $\forall x \in [x_0 - \delta_0, x_0 - \delta_0] \cap ([a,c) \cup (c,b])$ için $\mathcal{g}(x) \geq \mathcal{K}_0$ sağlanır.

$$M_0 := \int_a^{c-0} \mathcal{y}^2(x,\lambda)\mathrm{dx} + \int_{c+0}^{b} \mathcal{y}^2(x,\lambda)\mathrm{dx} \tag{13}$$

gösterelim. $\mathcal{y}(\mathrm{x},\lambda)$ özfonksiyon olduğu için $M_0 > 0$ olur. İlk önce $x_0 \in [a,c)$ durumunu araştıralım. $\delta_0 > 0$ sayısı istenilen kadar küçük alınabileceği için $\delta_0 \leq min\{x_0 - a, c - x_0\}$ olacak biçimde seçilebilir. Bu durumda

$$\int_a^{c-0} \mathcal{g}(x)\mathcal{y}^2(x,\lambda)dx + \int_{c+0}^{b} \mathcal{g}(x)\mathcal{y}^2(x,\lambda)dx \geq \int_a^{c-0} \mathcal{g}(x)\mathcal{y}^2(x,\lambda)dx$$

$$\geq \int_{x_0}^{x_0+\delta_0} \mathcal{g}(x)\mathcal{y}^2(x,\lambda)dx \tag{14}$$

eşitsizliği geçerli olur. Şimdi

$$m_0 := \int_{x_0}^{x_0+\delta_0} \mathcal{y}^2(x,\lambda)\mathrm{dx} \tag{15}$$

gösterilirse ve özfonksiyonların hiç bir pozitif ölçümlü aralıkta özdeş olarak sıfır olmayacağı dikkate alınırsa $m_0 > 0$ olduğu kolayca anlaşılır. O halde (14) eşitsizliğinden

$$\int_a^{c-0} \mathcal{g}(x)\mathcal{y}^2(x,\lambda)dx + \int_{c+0}^{b} \mathcal{g}(x)\mathcal{y}^2(x,\lambda)dx > \frac{1}{2}\mathcal{K}_0\, m_0 \tag{16}$$

eşitsizliği elde edilir. O halde (10), (11), (12) ve (16) bağıntılarını (8) eşitliğinde dikkate alınırsa

$$\lambda\ M_0 = \lambda\left(\int_a^{c-0} \mathcal{y}^2(x,\lambda)dx + \int_{c+0}^{b} \mathcal{y}^2(x,\lambda)dx\right) > \frac{1}{2}\mathcal{K}_0 m_0 > 0 \tag{17}$$

elde edilir. Buradan, $M_0 > 0$ olduğu için $\lambda > 0$ sonucu elde edilir. İspat bitti.

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Teorem 3. Kabul edelim ki Teorem 1 in tüm şartları sağlansın. Bu durumda λ=0 iki-aralıklı tekil Sturm-Liouville probleminin özdeğeri ise, $g(x)\equiv 0$ (yani $\forall x \in [a,c) \cup (c,b]$ için $g(x) = 0$) olur. Ayrıca bu durumda λ_0 özdeğerine karşılık gelen her özfonksiyon sabit fonksiyondur.

İspat. Kabul edelim ki $y = y_0(x)$ fonksiyonu λ=0 özdeğerine karşılık gelen özfonksiyondur. O halde (8) eşitliği ve (16) eşitsizliği gereği

$$\int_a^{c-0} g(x)y_0^2(x,\lambda)dx + \int_{c+0}^{b} g(x)y_0^2(x,\lambda)dx = \int_a^{c-0} k(x)(y_0'(x,\lambda))^2dx + \int_{c+0}^{b} k(x)(y_0'(x,\lambda))^2dx) - k(b)y_0'(b,\lambda)y_0(b,\lambda) + k(a)y_0'(a,\lambda)y_0(a,\lambda) \tag{18}$$

eşitliği sağlanır. (10) ve (11) eşitsizlikleri gereği (18) eşitliğinden

$$\int_a^{c-0} g(x)y_0^2(x,\lambda)dx + \int_{c+0}^{b} g(x)y_0^2(x,\lambda)dx \le 0 \tag{19}$$

eşitsizliği elde edilir. Son eşitsizlikten kolayca $g(x) \le 0$ olduğu elde edilir. Teoremin şartı gereği $g(x) \ge 0$ olduğu için $g(x)\equiv 0$ sağlanır. Şimdi λ=0 özdeğerine karşılık gelen her özfonksiyonun sabit fonksiyon olduğunu gösterelim. (8) eşitliğini λ=0 ve $g(x)\equiv 0$ için yazarsak,

$$\int_a^{c-0} k(x)(y_0'(x,\lambda))^2dx + \int_{c+0}^{b} k(x)(y_0'(x,\lambda))^2dx) = k(b)y_0'(b)y_0(b) + k(a)y_0'(a)y_0(a) - k(c+0)y_0'(c+0)y_0(c+0) + k(c-0)y_0'(c-0)y_0(c-0) \tag{20}$$

eşitliğini elde edilir. O halde (10) ve (11) gereği

$$\int_a^{c-0} k(x)(y_0'(x,\lambda))^2dx + \int_{c+0}^{b} k(x)(y_0'(x,\lambda))^2dx \le 0 \tag{21}$$

elde edilir. Bu eşitsizlikten ise teoremin şartları gereği $\forall x \in [a,c) \cup (c,b]$

$$k(x)(y_0'(x,\lambda))^2 \equiv 0 \tag{22}$$

elde edilir. $\forall x \in (a,c) \cup (c,b)$ için $k(x) > 0$ olduğundan (22) bağıntısı ancak ve ancak $y_0'(x,\lambda) \equiv 0$, yani $y_0(x)$=const olduğu durumda geçerli olur. İspat bitti.

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Teorem 4. Kabul edelim ki Teoremin 1 in tüm şartları ve ilaveten

i) $g(x) \equiv 0$
ii) $k(a)\cos\alpha = 0$, $k(b)\cos\beta = 0$
iii) $\gamma = 1$

şartları sağlansın. O halde λ=0 özdeğerdir.

İspat. Aşağıdaki üç durumu ayrı ayrılıkta inceleyelim.

Durum 1. $k(a) > 0$ ve $k(b) > 0$

Durum 2. $k(a) = 0$ ve $k(b) > 0$

Durum 3. $k(a) > 0$ ve $k(b) = 0$

Durum 1 de teoremin şartları gereği cos α $=\cos\beta = 0$ elde edilir. Bu durumda verilmiş iki-aralıklı tekil Sturm- Liouville problemi

$$-(k(x)y')' = \lambda y, \quad x \in [a, c) \cup (c, b] \tag{23}$$

$$y'(a) = y'(b) = 0 \tag{24}$$

$$y(c+0) = y(c-0), \quad y'(c+0) = \gamma' y'(c-0) \tag{25}$$

biçimine indirgenmiş olur. λ=0 sayısının (23)- (25) probleminin bir özdeğeri olduğu ve her bir sabit fonksiyonun bu özdeğere uygun özfonksiyon olduğu açıktır. Böylece Durum 1 için ispat tamamlanmış olur.

Durum 2. $k(a) = 0$ *ve* $k(b) > 0$ durumunda verilmiş iki-aralıklı tekil Sturm- Liouville problemi

$$-(k(x)y')' = \lambda y, \quad x \in [a, c) \cup (c, b] \tag{26}$$

$$y'(b) = 0 \tag{27}$$

$$y(c+0) = y(c-0), \quad y'(c+0) = \gamma' y'(c-0) \tag{28}$$

biçimine indirgenmiş olur. λ=0 değeri için her bir sabit fonksiyonun (26)- (28) problemini sağladığı açıktır. Yani λ=0 özdeğerdir ve her bir sabit fonksiyon bu özdeğere uygun özfonksiyondur. Durum 2 için de ispat tamamlanmış oldu. Durum 3 için ispat Durum 2-nin ispatına tamamen benzer biçimde yapılır. İspat bitti.

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THE RAYLEIGH QUOTIENT FOR ONE SINGULAR STURM-LIOUVILLE PROBLEM

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ABSTRACT

One of the important methods of mathematical physics is the separation of variables method, which leads to Sturm-Liouville type eigenvalue problems and then to representations of functions from certain functional spaces in terms of eigenfunctions of these Sturm-Liouville problems. Namely after applying this method a large number of physical problems lead to a homogeneous second-order linear ordinary differential equation of the form

$$\frac{d}{dx}\left(p(x)\frac{d}{dx}t\right) + q(x)t + \lambda w(x)t = 0, \quad a < x < b$$

together with appropriate boundary conditions. Many methods have been developed in classical Sturm-Liouville theory. One of the most effective methods applied to investigate the qualitative properties of eigenvalues and the corresponding eigenfunctions of Sturm-Liouville problems is the Rayleigh quotient and the methods of variational analysis based on this quotient. In this work, a new generalization of the Rayleigh quotient will be developed and the eigenvalues and eigenfunctions of two-interval Sturm-Liouville problems will be investigated. In particular, we found sufficient conditions on the coefficients of the Sturm-Liouville problem under consideration that guarantee the reality, simplicity and non-negativity of the eigenvalues.

Keywords: Singular two-interval Sturm-Liouville problem, Rayleigh quotient, eigenvalue.

1. INTRODUCTION

There is now a large literature on Sturm-Liouville type problems. These works are almost exclusively concerned with completeness and expansion in series of the system of eigenfunctions in the Hilbert space L_2. In recent years, the study of eigenvalues of a non-classical

Sturm-Liouville problems has been extended in various aspects (see, for example, [2], [3], [4]). The literature on self-adjoint Sturm-Liouville equations with additional interface conditions has garnered particular attention recently. These conditions go by a number of names, such as transmission conditions, interface conditions, jump conditions, multi-point conditions, discontinuous conditions, point interactions, etc. defined at some interior points of the base interval (see, [1], [5], [6], [7], [8], [9]). Such problems are not covered by classical Sturm-Liouville theory, since the interface conditions implies that the eigenfunctions and derivatives are not continuous at all interior points of singularity. Finite or infinite jump discontinuities may be included in the interface conditions, which can be defined at regular or singular interior points. Establishing some qualitative characteristics of the eigenvalues and associated eigenfunctions of one non-classical Sturm-Liouville problem with additional interface conditions is the main goal of this study.

2. MAIN RESEARCH

Consider a parameter-dependent differential equation defined on two non-intersecting intervals $[-1,0)$ and $(0,1]$ given by

$$\mathfrak{I}\vartheta := -\vartheta'' + \mathcal{K}(x)\vartheta = \lambda\,\vartheta,\ x\epsilon\,[-1,0)\cup(0,1] \qquad (1)$$

along with the boundary conditions, given by

$$\vartheta(-1) = a\vartheta(1) \qquad (2)$$

$$\vartheta'(-1) = \vartheta'(1) \qquad (3)$$

and with the interface conditions, given by

$$\vartheta'(-0) = b\,\vartheta(-0) \qquad (4)$$

$$\vartheta(+0) = b\,\vartheta'(+0) \qquad (5)$$

where $\mathcal{K}(x)$ is a real-valued function that is continuous on $[-1,0)\cup(0,1]$ and has finite limits on left and right sides $\mathcal{K}(\pm 0) = \lim_{x\to 0^{\pm}} \mathcal{K}(x)$, λ is a complex parameter (the so-called spectral parameter), a and b are real coefficients.

Definition. A complex number λ is said to be an eigenvalue for the boundary value transmission problem (1)-(5) if there exists a function $u\,\epsilon\,(C^2(-1,0)\oplus C^2(0,1))\cap(C^1[-1,0)\oplus C^1(0,1])$ such that u has finite left and right hand side limit values $t(\pm 0)$ and $t'(\pm 0)$ and satisfies the two-interval differential equation (1), the boundary conditions (2), (3) and the interface conditions (4), (5). The solution $t(x,\lambda)$ is called an eigenfunction belonging to the eigenvalue λ and the pair $(\lambda, t(x,\lambda))$ is called an eigen-pair for the boundary value transmission conditions (1)- (5).

Theorem. If $(\lambda, t(x,\lambda))$ is an eigen-pair for the boundary value transmission conditions (1)-(5) then λ is real.

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Proof. Since $\mathcal{K}(x)$ is-real valued function and $a,\ b$ are real parameters we get upon the complex conjugate of (1)-(5) that the pair $(\overline{\lambda}, \overline{t(x,\lambda)})$ is also an eigenpair for the same problem (1)-(5). By the Green's second identity we have

$$\int_{-1}^{-0} \left(t\Im(\bar{t}) - \bar{t}\Im(t)\right)\mathrm{dx} + \int_{+0}^{1} \left(t\Im(\bar{t}) - \bar{t}\Im(t)\right)\mathrm{dx}$$

$$= (\overline{\lambda} - \lambda)\left[\int_{-1}^{-0} |t|^2 dx \ + \int_{+0}^{1} |t|^2 dx\ \right] \qquad (6)$$

The left hand side of this equality takes the form

$$-\int_{-1}^{-0} (t\bar{t}'' - \bar{t}t'')\mathrm{dx} - \int_{+0}^{1} (t\bar{t}'' - \bar{t}t'')\mathrm{dx}$$

$$= -\int_{-1}^{-0} \frac{d}{dx} w(t,\bar{t})dx \ - \int_{+0}^{1} \frac{d}{dx} w(t,\bar{t})\, dx$$

$$= w(t,\bar{t};-1) - w(t,\bar{t};-0) - \ w(t,\bar{t};1) + w(t,\bar{t};+0) \qquad (7)$$

Using the boundary conditions (2)-(3), we get

$$w(t,\bar{t};-1) = t(-1)\bar{t}'(-1) - t'(-1)\bar{t}(-1)$$

$$= \left(\ a\ t(1)\right)\left(\tfrac{1}{a}\bar{t}'(1)\right) - \left(\tfrac{1}{a} t'(1) a\ \bar{t}(1)\right)$$

$$= w(t,\bar{t};1) \qquad (8)$$

Now using the interface conditions (4)-(5), we obtain

$$w(t,\bar{t};-0) = t(-0)\bar{t}'(-0) - t'(-0)\bar{t}(-0)$$

$$= t(-0)\ b\ \bar{t}(-0) - bt(-0)\bar{t}(-0)$$

$$= 0 \qquad (9)$$

Similaryl we have

$$w(t,\bar{t};+0) = t(+0)\bar{t}'(+0) - t'(+0)\bar{t}(+0)$$

$$= b\ t'(+0)\ \ \bar{t}'(+0) - \ t'(+0) b\ \bar{t}'(+0)$$

$$= 0 \qquad (10)$$

Substituting the equalities (8)-(10) into (6), yields

$$(\overline{\lambda} - \lambda)\left[\int_{-1}^{-0} |t|^2 dx \ + \int_{+0}^{1} |t(x)|^2 dx\ \right] = 0 \qquad (11)$$

Since u is not identically equal to zero, this means that $\overline{\lambda} - \lambda = 0$, i.e. the eigenvalue λ is real. The proof is complete.

Theorem. The eigenvalues of the two-interval boundary-transmission problem (1)-(5) are simple, i.e. an eigenfunction corresponding to an eigenvalue is unique up to a constant multiple.

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Proof. Suppose to the contrary that there are two linearly independent eigenfunctions u_0 and w_0 belonging to the same eigenvalue λ_0. The Wronskian of these two solutions is defined as follows

$$w(u_0, w_0; x) = u_0(x)w_0'(x) - u_0'(x)w_0(x)$$

Since

$$0= u_0\Im(w_0) - w_0\Im(u_0) = -u_0w_0'' + w_0u_0''=-(u_0w_0' - u_0'w_0)'=-\frac{d}{dx}w(u_0, w_0; x)$$

we have that the wronskian $w(u_0, w_0; x)$ is constant on each of the intervals $[-1,0)$ and $(0,1]$

.

Let

$$w(u_0, w_0; x) = \begin{cases} A, & for\ x \in [-1,0) \\ B, & for\ x \in (0,1] \end{cases}$$

where A and B are constants. By using the first interface condition (4) we have

$$\begin{aligned} A = w(u_0, w_0; -0) &= u_0(-0)w_0'(-0) - u_0'(-0)w_0(-0) \\ &= (\tfrac{1}{b}u_0'(-0))\, w_0'(-0) - u_0'(-0)(\tfrac{1}{b}w_0'(-0)) \\ &= 0 \qquad (12) \end{aligned}$$

Similaryl we have

$$\begin{aligned} B = w(u_0, w_0; +0) &= u_0(+0)w_0'(+0) - u_0'(+0)w_0(+0) \\ &= (b\, u_0'(+0))\ w_0'(+0) - u_0'(+0)(b\, w_0'(+0)) \\ &= 0 \qquad (13) \end{aligned}$$

Therefore the eigenfunctions $u_0(x)$ and $w_0(x)$ are linearly dependent on each of the intervals $[-1,0)$ and $(0,1]$. Consequently the are constants C$\neq 0$ and D$\neq 0$ such that

$$w_0(x) = \begin{cases} Cu_0(x), & for\ x \in [-1,0) \\ Du_0(x), & for\ x \in [0,1] \end{cases} \qquad (14)$$

Since both u_0 and v_0 satisfy the boundary conditions (2)-(3) we have

$$w_0(-1) = Cu_0(-1) = a\, C\, u_0(1) \qquad (15)$$

$$w_0(1) = Du_0(1) = \frac{D}{a}\, u_0(-1) \qquad (16)$$

Putting these equalities into the first boundary condition $w_0(-1) = aw_0(1)$ we get

$$a\, C\, u_0(1) = a\frac{D}{a}\, u_0(-1) = Dau_0(1)$$

That is

$$(C - D)u_0(1) = 0 \qquad (17)$$

Similarly we get

$$w_0'(-1) = C\, u_0'(-1) = \frac{C}{a}u_0'(1)$$

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and

$$w_0'(1) = Du_0'(1) = Dau_0'(-1)$$

Putting these equations in the second boundary condition

$aw_0'(-1) = w_0'(1)$

we get

$Cu_0'(1) = Dau_0'(-1) = Du_0'(1)$

That is

$$(C - D)u_0'(1) = 0 \qquad (18)$$

Since at least one of the values $u_0(1)$ and $u_0'(1)$ is not zero we have $C = D$, i.e. the eigenfunctions u_0 and w_0 are linearly dependent on whole $[-1,0) \cup (0,1]$. Thus we arrive at contradiction which completess the proof.

Theorem. Each eigenvalue of the boundary value transmission problem (1)- (5) has a real-valued eigenfunction.

Proof. If $(\lambda, u(x))$ is an eigen-pair then so is $(\bar{\lambda}, \overline{u(x)}) = (\lambda, \overline{u(x)})$. Therefore both real-valued functions $Reu = \frac{1}{2}(u + \bar{u})$ and $Imu = \frac{1}{2i}(u\text{-}\bar{u})$ satisfiy the problem (1-(5). At least one of the real-valued functions Reu and Imu is not idetically equal to zero and, therefore, is a real-valued eigenfunction. The proof is complete.

The Rayleigh quotient for the problem (1)- (5)

Theorem. If $b \leq 0$ and $\mathcal{K}(x) \geq 0$ then all eigenvalues of the boundary value transmission problem (1)- (5) are nonnegative.

Proof. Let $(\lambda_0, u_0(x))$ be any eigen-pair of the problem (1-(5). By multiplying the equation

$$-u_0'' + \mathcal{K}(x)u_0 = \lambda_0 u_0 \qquad (19)$$

by $u_0(x)$ and integrating over $[-1,0)$ and $(0,1]$ we have

$$\int_{-1}^{-0} (-u_0u_0'' + \mathcal{K}(x){u_0}^2)dx + \int_{+0}^{1} (-u_0u_0'' + \mathcal{K}(x){u_0}^2)dx$$
$$= \lambda_0 \left(\int_{-1}^{-0} {u_0}^2 dx + \int_{+0}^{1} {u_0}^2 dx \right) \qquad (20)$$

One can rewrite this equality by performing an integration by parts in the following form

$$-u_0u_0'|_{-1}^{0} - u_0u_0'|_{+0}^{1} + \int_{-1}^{-0} ({u_0}'^2 + \mathcal{K}(x){u_0}^2)dx + \int_{+0}^{1} ({u_0}'^2 + \mathcal{K}(x){u_0}^2)dx$$
$$= \lambda_0 \left(\int_{-1}^{-0} {u_0}^2 dx + \int_{+0}^{1} {u_0}^2 dx \right) \qquad (21)$$

By using the boundary conditions (2) and (3) we have

$$u_0(-1)u_0'(-1) = (a\, u_0(1))\left(\frac{1}{a} u_0'(1)\right) = u_0(1)u_0'(1) \qquad (22)$$

Now using the interface conditions (3)-(4) we have

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$$u_0(-0)u_0'(-0) = b\,(u_0(-0))^2 \qquad (23)$$

and

$$u_0(+0)u_0'(+0) = b\,(u_0(+0))^2 \qquad (24)$$

Putting these equalities into (21) we get the following Rayleigh quotient for the problem (1)-(5)

$$\lambda_0 = \frac{-b\left(u_0{}^2(-0) + u_0{}'^2(+0)\right) + \int_{-1}^{-0}(u_0{}'^2 + \mathcal{K}(x)u_0{}^2)dx + \int_{+0}^{1}(u_0{}'^2 + \mathcal{K}(x)u_0{}^2)dx}{\int_{-1}^{-0} u_0{}^2 dx + \int_{+0}^{1} u_0{}^2 dx}$$

Since $b \leq 0$ and $\mathcal{K}(x) \geq 0$, it follows from this Rayleigh quotient that $\lambda_0 \geq 0$. The proof is complete.

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DEVELOPMENT OF STATISTICS AND MACHINE LEARNING BASED CASH FORECASTING MODELS FOR AN ELECTRONIC PAYMENT COMPANY

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ABSTRACT

Digital banks are modern platforms that extend the reach of traditional banking services by offering financial services over the Internet. These platforms provide significant convenience in payment and money transfer transactions. With technological advancements, integrations such as Electronic Fund Transfer (EFT) and Instant and Continuous Transfer of Funds (FAST) have become integral to digital banking. EFT and FAST are notable for their high transaction volumes in money transfers. However, manual management of funds during the use of these integrations result in financial losses when there is an excess of money in the account, and customer dissatisfaction when funds are insufficient. The aim of this study is to predict how much cash should be held at which bank for an electronic payment company. To achieve this, forecasting models have been developed using Long Short-Term Memory (LSTM), Multi-Horizon Quantile Recurrent Forecaster (MQRNN), Multi-Layer Perceptron (MLP), Auto-Regressive Integrated Moving Average (ARIMA) and Seasonal AutoRegressive Integrated Moving Average (SARIMA). Data have been collected for two different banks from United Payment. Weekly forecasting models have been developed for each bank. The performance of the models has been evaluated using Mean Absolute Percentage Error (MAPE). The results obtained with the prediction models show that MLP demonstrates superior performance by providing the most accurate forecast results for both banks.

Keywords: Cash Forecasting, Fund Management, Machine Learning

1. INTRODUCTION

Digital banking platforms expand the scope of traditional banking by facilitating financial services online. These platforms, which have been rapidly evolving with dynamic momentum in recent times, eliminate the need to visit physical branches, enabling essential services to be conducted through mobile apps or web-based platforms. In this context, transactions such as bill payments, foreign exchange operations, tax payments, stock trading, and money transfers are completed quickly and easily.

Money transfers are one of the most popular transactions in the banking sector. Traditionally, domestic money transfers were typically carried out by visiting bank branches in person or through third-party intermediary institutions. In contrast, digital banking now allows for much more secure, fast, and convenient money transfers. However, while digital banking offers numerous advantages, current domestic money transfer methods still have certain limitations, making them inadequate in some respects. Popular methods such as wire transfers, EFT, and FAST, despite technological advancements, do not fully meet the evolving needs of users. Wire transfers can only be performed between accounts within the same bank, EFT is not available 24/7, and FAST incurs high transaction fees and has low transfer limits, all of which highlight the need for a new and improved money transfer method. The manual management of funds in these systems lead to financial losses when there is excess money in the account or payment delays when there are insufficient funds, ultimately causing customer dissatisfaction. Additionally, manual fund management lead to various operational problems.

Cash forecasting is a strategic and analytical process designed to optimize the bank's finances and predict future performance. Effective management of this process helps banks plan for both their short- and long-term financial needs, promoting sustainable growth and development. By keeping bank account balances at optimal levels, the bank's financial stability is safeguarded, and liquidity is efficiently managed. Accurate cash forecasting also enables banks to make well-informed decisions, increases operational efficiency, and strengthens their capacity to seize investment opportunities and overcome financial challenges.

Accurately forecasting how much cash should be held in each bank is crucial for customer satisfaction, control of operational costs, and security. Insufficient cash holdings can result in negative outcomes, such as failure to meet customer demands and loss of trust, while holding excessive cash ties up capital and increases costs. Additionally, factors such as regional economic differences and fluctuations in foreign exchange and interest rates can directly influence cash needs. Therefore, accurate cash forecasts allow banks to optimize costs by accounting for these variables, comply with regulatory requirements, and manage resources more effectively.

The aim of this study is to predict how much cash should be held at which bank for an electronic payment company. To achieve this, forecasting models have been developed using LSTM, MQRNN, MLP, ARIMA, and SARIMA.

This study is organized as follows: Section 2 includes relevant literature. The dataset has been described in Section 3. The methodology is presented in Section 4. Section 5 presents results and discussion. Section 6 concludes the paper.

2. LITERATURE REVIEW

(Kozo Ueda, 2024) examined the impact of a retroregression event that provides convenience for bank users on cash demand, treating it as an experiment. Using bank account transaction

data, it was observed that branch and Automatic Teller Machine (ATM) consolidations not only reduced the amount of cash withdrawals made by previous users but also decreased total spending and cash transaction entries by the same amount. (Vangala Sarveswararao et al., 2023) aimed to use deep learning methods to forecast ATM cash withdrawal transactions for an Indian commercial bank. In this context, methods such as ARIMA, Random Forest (RF), Support Vector Regression (SVR), and MLP were used to develop forecasting models. The results indicated that RF had the lowest error rate. (Alireza Fallahtafti et al., 2022) aimed to forecast ATM cash demand for the periods before and during the COVID-19 pandemic. In this study, ATMs were categorized based on environmental factors affecting accessibility and cash withdrawal patterns. It was found that the statistical models ARIMA and SARIMA, analyzed using grid search and k-fold cross-validation techniques, generally provided more accurate forecasts. (Chattriya Jariyavajee et al., 2022) presented forecasting models for cash inventory in bank branches using deep learning techniques. In this study, data preparation and feature selection were performed to identify key attributes from bank branch data. In the forecasting process, Recurrent Neural Networks (RNN), LSTM, and Gated Recurrent Units methods were compared. According to the bank in this study, the proposed strategies had the potential to reduce cash inventory levels by more than the initial target of 10%. (Dimitrios Kotios et al., 2022) proposed a hybrid transaction classification model that is interconnected, intelligent, and personalized, along with a cash flow forecasting model based on RNN. The proposed model demonstrated promising results when tested in a real-world banking scenario. (Aleksei Riabykh et al., 2022) proposed a data preprocessing pipeline to forecast customer cash demand, a key component of ATM optimization systems. New forecasting methods were introduced for both local and global model paradigms. It was observed that these methods achieved more successful results compared to existing approaches for cash demand forecasting problems. (Vlad-Marius Griguta et al., 2021) presented a forecasting approach that systematically predicts future cash flows in different bank accounts by utilizing historical cash balance data collected from bank account statements. This study aimed to examine the challenges of data extraction, enhancement, and preprocessing from sources such as digital bank account statements. Experiments using both traditional and machine learning approaches for forecasting cash balances were reported. (Wilson Aggrey Ogama Kitere, 2021) aimed to analyze the impact of cash forecasting applications on the performance of commercial banks in Kenya. The results showed that commercial banks in Kenya implemented cash forecasting applications, and that inflation rates influenced interest rates. (Muhammad Rafi et al., 2021) presented a time series model based on the ARIMA technique for estimating the optimal cash amount to be held in ATMs for six different organizations in Pakistan. The proposed model was compared with RNN, and MAPE and Symmetric Mean Absolute Percentage Error (SMAPE) were used to evaluate the forecasting models. The results indicated that the proposed model performed better than the other models. (Muhammad Asad et al., 2020) proposed a data-driven approach using an LSTM-based model for accurately forecasting the cash amount for each ATM or groups of ATMs. The dataset was created using ATM data from six different banks in Pakistan, and the proposed model achieved a Root Mean Squared Error (RMSE) of 132.53. (Dursun Ece Gokcay, 2020) proposed a cash forecasting system using machine learning approaches such as Linear Regression (LR), Support Vector Machine, LSTM, and statistical methods like ARIMA on the

same ATM data. The results showed that machine learning methods, particularly LSTM, were more successful. (Muhammad Rafi et al., 2020) proposed the Vector Auto Regressive Moving Average with Exogenous Variables model for forecasting ATM cash demands. The proposed model was compared with LSTM and RNN models and achieved a lower SMAPE. (Sefik İlkin Serengil and Alper Ozpinar, 2019) proposed a cost function for replenishment optimization by stating that daily cash withdrawals are predictable. The experiments revealed that the proposed model significantly reduced empty balances. (Sefa Erbas, 2018) aimed to forecast branch end-of-day balances using different regression methods. A daily forecasting method was chosen to reduce the variance caused by the absence of any amount limitations in branch transactions. For each branch, a model was developed to forecast afternoon cash movements based on transactions completed by noon. (Pankaj Kumar Jadwal et al., 2017) aimed to forecast cash demand using Neural Networks (NN) with the NN5 time series data. RMSE was calculated for clustered ATM groups and averaged. The results indicated an increase in the accuracy of the ATM cash deposit system.

3. DATASET

The weekly dataset encompassing the cash amounts held by United Payment for its On-Duty Transfer product in two different bank accounts, A and B, from 29.11.2018 to 10.05.2024 has been created. The forecasting models have been developed for the weeks of 08.03.2024 to 18.03.2024 for Bank A, and 01.03.2024 to 08.03.2024 for bank B. The attributes and descriptions of the dataset are listed in Table 1. The minimum, maximum, average, and standard deviation values of the cash amounts in the dataset are detailed by bank in Table 2.

Table 1. Attributes in the dataset

Attribute Name	Description
Loading Date	Transaction date
Number of Days Passed	Number of days passed since last loading
Number of Expenditures Until Next Loading	Total number of transactions made from previous loading to current transaction
Balance Before Loading	Balance in account before loading
Year	Year
Month	Month
Quarter	Quarter of the year
Weekday	Day of the week
Weekend	Weekend
Closing_USD	USD closing value
Opening_USD_opening	USD opening value
High_USD	Highest value of USD
Low_USD	Lowest value of USD
Closing_EURO	Euro closing value
Opening_EURO	Euro opening value
High_EURO	Highest value of Euro
Low_EURO	Lowest value of Euro
Total_Recovered	Total number of COVID-19 recoveries

Table 2. The minimum, maximum, average, and standard deviation of cash amount

Cash Amount	Minimum	Maximum	Average	Standart Deviation Values
Bank A	10	85000000	5062511	7298850
Bank B	22	10000000	1361430	1584407

4. METHODOLOGY

4.1 Long Short Term Memory

One of the recurrent deep learning algorithms is called LSTM. The control flow of an LSTM is comparable to that of an RNN. It manages the processes of forward propagating information and data processing. Unlike traditional recurrent networks, the feedback loop in an LSTM network allows for the processing of both individual data points and entire sequences. Therefore, LSTM networks are used for time series data processing, classification, and prediction (Anna Manowska et al., 2020).

4.2 Multi-Horizon Quantile Recurrent Forecaster

MLP in MQRNN takes the context vectors generated by LSTM, which acts as a convolutional encoder for each horizon. The Seq2SeqC architecture is used in this technique. There are three main parts of this architecture:

1. Encoder: It creates a feature vector to represent the input time series. Patterns in the time series are discovered and extracted using these vectors. This process is usually performed by a CNN or a recurrent neural network, which may have one or more layers.
2. The feature vector obtained in the encoder step is called the encoder or context (intermediate vector). The decoder step uses this vector to represent the input time series.
3. Decoder: Typically, an RNN or a similar model consists of one or more layers. It takes the feature vector from the encoder and uses this information to generate predictions at subsequent time steps. It is generally trained to predict a certain percentile and can model a given time series distribution using various techniques for this purpose. Therefore, it utilizes the encoder's feature vector to predict values at subsequent time steps (Xiao-Yu Zhang et al., 2022).

4.3 Multi Layer Perceptron

Many different types of neural networks have been proposed previously. However, MLP has received the most attention due to its usefulness in various fields and its relative ease of use. MLP employs a backpropagation method based on the steepest gradient descent technique, which adjusts the connection weights to minimize the network's target function during training. Nevertheless, this strategy has several shortcomings, including sensitivity to the learning rate, reliance on linear search, slow convergence, a tendency to get stuck in local minima, and possible oscillations during the search. The gradient descent strategy aims to alleviate these problems by utilizing more powerful nonlinear optimization techniques, such as conjugate gradient and Levenberg-Marquardt. A different topology is applied to the MLP structure for

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each experimental run, and only the connection weights change during the training process. After an experimental run, the modeler can explore the behavior of variously constructed neural networks by adjusting specific topological elements. Several tests are necessary to find the most suitable neural network architecture. To avoid getting stuck in local minima, multiple experiments with the same architecture but different initial weights should be conducted. In summary, MLP neural networks require significant human intervention and trial-and-error during the training phase to be effective. While there are several guidelines that can assist in the construction of MLP designs, no single guideline is universally acknowledged as the best by scholars. Therefore, using empirical methodologies is the most effective approach to addressing this issue (Serkan Aras et al., 2017).

4.4 Auto-Regressive Integrated Moving Average

The three basic components of the autoregressive integrated moving average, better known as ARIMA, are moving average, integration, and autoregression. Box and Jenkins developed the ARIMA model around 1970. ARIMA is one of the models that best fits short-term forecasts, serving as an active predictor that connects past, present, and future forecasts. Many micro and macro dynamic tests have been conducted using the ARIMA model (Hamzeh F. Assous et al., 2020).

4.5 Seasonal Auto-Regressive Integrated Moving Average

The SARIMA model is constructed by adding a seasonal component to the ARIMA model. The standard notation for this model is SARIMA(p, d, q)(P, D, Q)(s). In this notation, p represents the order of the AR model, P denotes the order of the seasonal AR model, d indicates the degree of differencing, D signifies the seasonal degree of differencing, q is the order of the Moving Average (MA) model, Q is the order of the seasonal MA model, and s represents the length of the seasonal period (Agaraoli Aravazhi, 2021).

5. RESULTS AND DISCUSSION

MAPE values for the LSTM, MQRNN, MLP, ARIMA, and SARIMA-based forecasting models developed for A and B banks are shown in Table 3.

Table 3. MAPE values of the developed models

MAPE (%)	LSTM	MQRNN	MLP	ARIMA	SARIMA
Bank A	56.37	21.41	19.59	39.07	34.89
Bank B	17.23	23.62	12.87	23.96	17.84

- For Bank A, the lowest MAPE has been achieved with MLP (19.59%), while the highest MAPE has been observed with LSTM (56.37%).
- The forecast models developed for Bank B produced more successful results compared to those developed for Bank A.

- For the prediction models developed for Bank B, LSTM, MLP, and SARIMA provided more successful results than other methods, with MLP (12.87%) demonstrating the best predictive performance.
- When examining the results for both banks, it has been evident that MLP provided superior forecasting performance.

6. CONCLUSION

Money transfers are one of the most preferred banking transactions that digital banking has made effortless. However, the various existing methods for this service do not fully meet people's needs. The manual management of funds in banks with the currently used methods leads to customer dissatisfaction and financial losses. In this context, cash forecasting stands out as an important strategic action. In this study, cash forecasting models using time series-based LSTM, MQRNN, MLP, ARIMA, and SARIMA have been developed to control cash management in bank accounts The prediction models have been evaluated using the MAPE metric. The results obtained from the developed prediction models showed that the MLP method demonstrated superior forecasting performance.

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DEVELOPMENT OF A DIGITAL HOUSEKEEPING SYSTEM TO OPTIMIZE MEZZANINE LOCATIONS IN A WAREHOUSE

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ABSTRACT

In today's rapidly evolving world, e-commerce marketplaces are experiencing significant and dynamic growth. To remain competitive and deliver superior customer service, e-commerce businesses must implement various strategic measures. Efficient warehouse management and process acceleration are critical factors in gaining a competitive edge, as they enable businesses to respond swiftly to customer demands. Inefficient warehouse and location management result in time and cost inefficiencies, leading to wasted company resources. Therefore, automating warehouse management holds substantial importance for e-commerce operations. This study aims to transform manually managed housekeeping processes within Trendyol warehouses into a systematic structure, thereby enhancing both personnel and process efficiency. For this purpose, a system has been developed that allows products with the same barcode distributed across different mezzanine locations to be collected in a planned manner and these products to be addressed to a single location, creating locations with the same barcode. The plan management page has been created on the VENA program and collection algorithm scenarios have been developed in line with this page. With the developed system, mono locations where the same type of products are located together have been created in order to increase picking efficiency and 100% tracking of location occupancy has been ensured.

Keywords: Housekeeping, Automatic Plan Creating, Location Organizing System

1. INTRODUCTION

The increasing demand for the e-commerce sector intensifies the competitive environment, and in this context, the necessity of businesses to effectively manage high business volumes becomes the key to gaining competitive advantage. One of the most critical elements for successfully managing this business volume is smooth and efficient warehouse management. E-commerce warehouses experience high product mobility and heavy traffic, necessitating the careful coordination of warehouse operations.

In Trendyol warehouses, products are stored in mezzanines, which are multi-storey shelving systems. These shelves consist of boxes referred to as "locations" in the system, each containing different products. Each product is labeled with a barcode, ensuring accurate tracking and

management. This system enables the quick fulfillment of customer demands, which is a key factor in maximizing customer satisfaction. However, in the current operational process, identifying and collecting products with the same barcode scattered across different mezzanine locations leads to time loss, and manual processes introduce operational errors. These inefficiencies cause delays in fulfilling customer demands. Additionally, this situation can lead to complications in stock management and supply chain disruptions. Also in the current system, business plans can only be created for customer orders, but the lack of planning to maintain order within mezzanine locations creates operational challenges in warehouse management. To enhance picking efficiency and facilitate faster, error-free order preparation, it is necessary to create "mono locations," where products of the same type are grouped together. Particularly during year-end inventories, tracking the distribution of the top 100 barcodes in mezzanine locations using manual forms results in significant time and labor losses. Digitalizing these processes greatly improve efficiency during inventory counts and allow for more accurate and faster management of operational workflows. Furthermore, the more effective use of location capacities and the enhancement of operational efficiency are strategic steps that will not only optimize performance but also strengthen the brand image by maximizing customer satisfaction.

This study aims to develop the housekeeping system that systematically consolidates products with the same barcode into a single location, reducing the workload of warehouse employees and increasing the efficiency of operational processes. This system aims to improve warehouse efficiency by minimizing operational errors and saving time and costs through the optimization of order-picking processes.

This study is organized as follows: Section 2 includes relevant literature. Details of the digital housekeeping system is presented in Section 3. Section 4 presents results of the study. Section 5 concludes the paper.

2. LITERATURE REVIEW

(Stanisław Ambroszkiewicz and Stanisław Bylka, 2023) aimed to examine the coordination between a single supplier and a single retailer, focusing on the common economic lot sizing problem in a two-stage supply chain. In this context, Stock Management-variant (SM-v) policies were compared to scenarios where the maximum supplier inventory level was equal to the space constraint. The results showed that SM-v policies performed better. (Veronika Lesch et al., 2023) aimed optimize the assignment and order-picking problem in a mezzanine warehouse. In this study, a specialized version of the Non-dominated Sorting Genetic Algorithm II and the Ant Colony Optimization algorithm was proposed. The findings indicated that the two proposed algorithms produced better outcomes when hybridized. (Stanisław Ambroszkiewicz and Stanisław Bylka, 2021) presented a numerical counterexample to demonstrate that the warehouse space capacity constraint was incorrect for managing inventory levels. The model was reformulated, and suitable conditions for an optimal Consignment Stock Policy were proposed. (Akhila Mukunda et al., 2021) proposed an optimal storage solution for small-scale industries, considering constraints. Various vertical storage solution models were evaluated based on selected criteria to ensure the efficient use of storage areas. The results indicated that mezzanine storage was the most effective solution. (Andreia M. Freitas et al.,

2020) aimed to enhance the efficiency of a hybrid warehouse in a bus manufacturing organization. In this study, logistical issues were identified, and a combination of lean tools was applied. The results showed a reduction in control and picking times, along with improved working conditions for employees. (Monika Kofler et al., 2011) proposed implementing daily warehouse improvement activities to achieve effective warehouse allocation. The impact of these daily improvement tasks on warehouse assignment was examined, with the results showing the approach was successful.

3. DETAILS OF THE DIGITAL HOUSEKEEPING SYSTEM

3.1 Current Status Operational Flow

The top floors of mezzanine locations are the location types where single-type or mono products are located and different barcodes cannot be systematically assigned to these locations; therefore, such locations are referred to as mono locations. While the average product finding time in mono locations is 3 seconds, this time is 5.4 seconds in mix locations. However, when the number of products in mono locations decreases, an inefficient location capacity management occurs. To prevent this situation, the operations teams manually determine the locations with low quantities and direct the products on the top floor to the mix locations on the lower floor. The visual of the warehouse is presented in Figure 1.

Figure 1. Visual of the warehouse

In order to increase the number of mono locations, the “X” barcode distributed among the mezzanine locations is manually determined by the operation from the locations with low quantities. Products are collected from locations with 1, 2 or 3 products left in quantity and transferred to a basket. Barcodes seen as residue are combined and transferred to an empty location to obtain a mono location. This process is showed in Figures 2 and 3.

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Lokasyon	Barkod	Adet	ZONE
3B.20.14.01D	8682582368031	19	3B
3B.21.18.01A	8682582368031	15	3B
3B.25.23.01E	8682582368031	18	3B
3B.25.34.01E	8682582368031	14	3B
3B.26.26.01A	8682582368031	20	3B
3B.29.31.01A	8682582368031	20	3B
3B.31.23.01B	8682582368031	20	3B
3B.32.27.01A	8682582368031	20	3B
3B.33.15.05D	8682582368031	20	3B
3B.39.26.01C	8682582368031	17	3B
3B.47.23.01C	8682582368031	1	3B
3B.55.10.01C	8682582368031	10	3B
3B.59.19.01C	8682582368031	1	3B
4A.09.27.02B	8682582368031	11	4A
4B.02.02.03C	8682582368031	1	4B
4B.05.24.03D	8682582368031	11	4B
4B.10.22.01E	8682582368031	23	4B
4B.11.38.01B	8682582368031	17	4B
4B.27.11.01A	8682582368031	16	4B
4B.45.22.01D	8682582368031	1	4B
5A.35.32.01C	8682582368031	21	5A
5A.37.27.01E	8682582368031	1	5A
5A.38.17.01B	8682582368031	21	5A
5A.41.16.01D	8682582368031	19	5A
5A.41.21.01D	8682582368031	21	5A
5A.44.30.02G	8682582368031	22	5A
5A.56.32.01E	8682582368031	11	5A
5A.60.24.01D	8682582368031	12	5A
5B.24.36.05A	8682582368031	1	5B
5B.47.29.02B	8682582368031	5	5B

Figure 2. Location determination

Lokasyon	Barkod	Adet	ZONE
3B.47.23.01C	8682582368031	1	3B
3B.59.19.01C	8682582368031	1	3B
4B.02.02.03C	8682582368031	1	4B
4B.45.22.01D	8682582368031	1	4B
5A.37.27.01E	8682582368031	1	5A
5B.24.36.05A	8682582368031	1	5B
5B.47.29.02B	8682582368031	5	5B

Figure 3. Location determination

3.2 Digital Housekeeping System

The working principles of the picking algorithm have been established. A "Create Plan" page has been developed for the processes where the picking plan would be created, and this page has been integrated into the existing Vena program. Additionally, picking algorithm scenarios have been created. The design of the plan creation and results page structure and the required result titles have been determined. The results page structure and the required result title are shown in Figure 4.

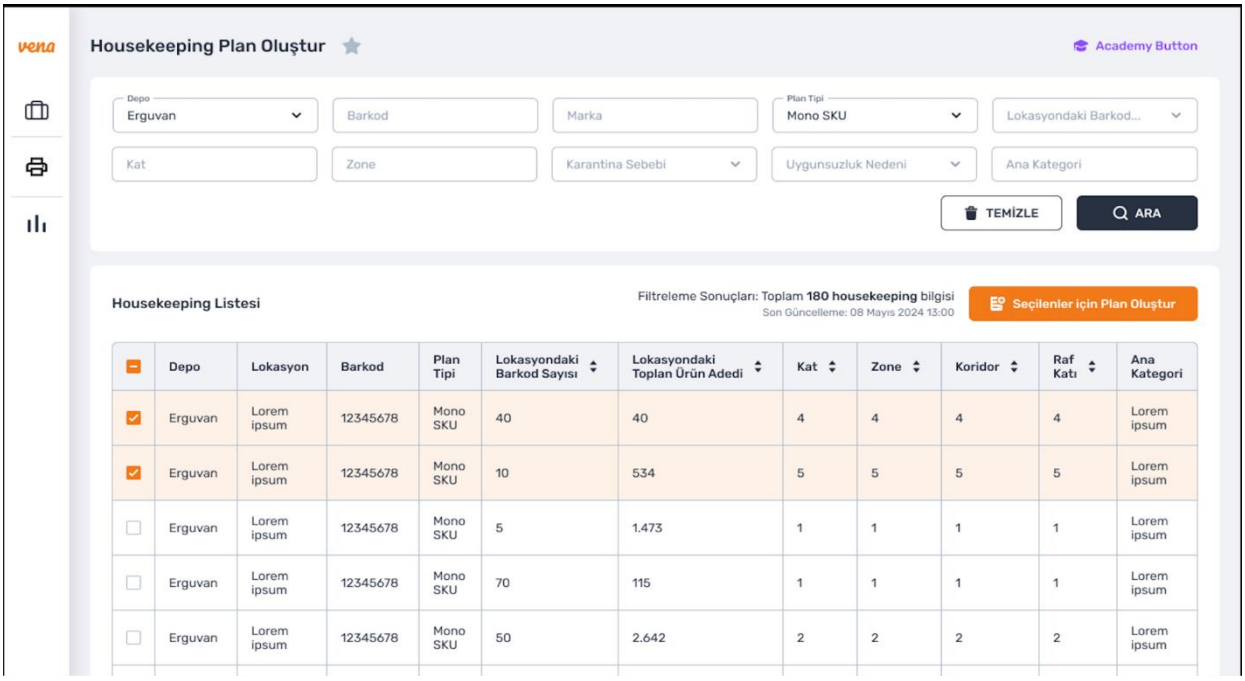

Figure 4. Results page structure and the required result title

4. RESULTS OF THE STUDY

With the developed system,

— Location occupancy has been monitored at a rate of 100%.
— The time required for the manual process counting has been completely eliminated.
— Delivery times given for container compression in the year-end count have decreased by 100%.
— The number of existing mono locations in the mezzanine has been increased and thus the picking efficiency has been increased with the mono locations obtained.

5. CONCLUSION

Warehouse management is a process that plays a critical role in a company's logistics operations, involving the planning and execution of product storage, tracking, and distribution. Efficiently managed warehouse operations help minimize costs and improve customer satisfaction. However, maintaining these processes manually leads to the loss of time and effort. In this study, the manual processes carried out by the operations teams to improve the efficiency of mezzanine locations have been transformed into a digitally controlled smart system. As a result of this study, the time required for manual counting processes has been completely eliminated.

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TIME SERIES BASED FINANCIAL COMPONENT FORECASTING MODELS FOR THE E-COMMERCE SECTOR

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ABSTRACT

The contemporary e-commerce sector is evolving with dynamic momentum. This growth requires e-commerce companies offering a wide range of services to take various strategic steps. To differentiate themselves in a competitive market, these companies must prioritize effective cost optimization. Financial forecasting emerges as a crucial tool that enables companies to execute cost optimizations effectively. In this regard, accurate financial component forecasts (such as income/expense, cash/credit card/promissory note collections, invoice amounts, etc.) are essential for predicting future financial performance and guiding strategic decision-making. The aim of this study is to develop financial component forecasting models for e-commerce sector. To achieve this, financial forecasting models have been developed using Long Short-Term Memory (LSTM), Bi-Directional Long Short-Term Memory (Bi-LSTM), Convolutional Long Short-Term Memory (ConvLSTM), and Auto-Regressive Integrated Moving Average (ARIMA). The weekly dataset encompassing card collections, cash collections, and cash payments for the period from January 1, 2017, to July 24, 2022, has been created. Financial forecasting models have been developed for the months March and July. The performance of the models has been evaluated using Mean Absolute Percentage Error (MAPE). Among the models developed for July, the superior performance has been provided by the ARIMA model for the cash collection. When the forecasting models developed for March have been examined, it has been observed that the model with the lowest MAPE has been obtained with the ConvLSTM model developed for card collection.

Keywords: Financial Forecasting, Times Series, Machine Learning, E-Commerce

1. INTRODUCTION

The e-commerce sector has undergone a radical transformation due to the widespread use of the internet and rapid advances in digital technologies, becoming one of the most dynamic and rapidly growing areas of the global economy. This transformation has largely replaced traditional retail shopping with online shopping, thereby intensifying the competitive environment. The competitive nature of e-commerce has necessitated that companies take various strategic actions to stand out. In this context, ensuring accurate cost optimization has become critically important for companies.

Cost optimization is crucial for e-commerce companies in terms of maintaining a competitive advantage, increasing profitability, and ensuring operational efficiency. Intense competition and shrinking profit margins in the sector force companies to minimize their costs. Cost optimization reduces expenses in areas such as storage, logistics, and marketing, allowing the company to use its resources more efficiently. This enables companies to keep their prices competitive, increase customer satisfaction, and develop long-term sustainable growth strategies.

Financial forecasting is a comprehensive and analytical process conducted to ensure a business's cost optimization and predict its future financial performance. This process involves systematically analyzing past and current financial data, as well as economic indicators and market conditions. Based on these analyses, predictions are made regarding the company's future revenues, profit margins, cash flows, capital requirements, and other financial outcomes. Financial component forecasting enables e-commerce companies to accurately and reliably predict the future performance of their financial components. These predictions allow companies to forecast profit margins, cash flows, and other key financial indicators, thereby minimizing financial risks and enhancing strategic planning. Accurate financial forecasts not only optimize the financial performance of e-commerce companies but also improve their operational decision-making processes. Companies that apply accurate financial forecasting models in critical operational areas such as inventory management, production planning, and sales and marketing strategies can use their resources more efficiently and respond quickly and flexibly to customer demands. This helps companies develop sustainable growth strategies, gain a competitive advantage, and achieve a leading position in the sector.

The purpose of this study is to develop financial component forecasting models for the e-commerce sector. To achieve this, financial forecasting models were developed using LSTM, Bi-LSTM, ConvLSTM, and ARIMA.

This study is organized as follows: Section 2 covers relevant literature. The dataset has been described in Section 3. The methodology is presented in Section 4. Section 5 presents results and discussion. Section 6 concludes the paper.

2. LITERATURE REVIEW

(Aleem Khan, 2024) examined the application, potential, challenges, and future prospects of machine learning in financial forecasting. He explained how machine learning can be used to make more accurate financial predictions, particularly highlighting the effectiveness of the Recurrent Neural Network algorithm in predicting stock prices and exchange rates. (Mohamed Amine Ben Rabia and Adil Bellabdaoui, 2023) proposed an analytical framework for bus route revenue forecasting using Multiple Linear Regression and Seasonal AutoRegressive Integrated Moving Average with eXogenous variables (SARIMAX). The framework's robustness and applicability were validated using real data, with the goal of comparing the two methods to identify the one with the best performance. (Jasmin Praful Bharadiya, 2023) explained how machine learning algorithms, combined with the analysis of large amounts of historical data, can make accurate predictions about a business's future state. The study noted that technologies such as automated data analysis, dynamic pricing, and anomaly detection help businesses optimize processes, reduce costs, and identify new revenue streams. (Rimo Das et al., 2023)

aimed to develop a framework capable of forecasting aggregate and segmented market demand by leveraging data from various sources. Several machine learning algorithms were explored to understand passengers' booking patterns and the latent progression of the booking curve. (Yu Du et al., 2023) proposed a machine learning and deep learning-based quarterly revenue forecasting model for automobile manufacturing companies. It has been used that the Random Forest and SARIMA algorithms in the first part, while a Convolutional Neural Network (CNN) algorithm-based model was employed in the second part. The results demonstrated the model's success in revenue forecasting. (Nitin Gautam et al., 2023) discussed data sources that airlines can use for future competitive scheduling, market size estimation, and market share forecasting. They explained methodologies based on machine learning algorithms for estimating quantities and how these methods can improve pricing and revenue management applications. (Harikumar Pallathadka et al., 2023) explained the applications of machine learning and artificial intelligence in e-commerce, corporate governance, and finance. Key topics included sales growth, profit maximization, sales forecasting, inventory management, security, fraud detection, and portfolio management. (Yashasvi Roy and Sanmukh Kaur, 2023) analyzed a company's financial data with different values and categories for financial forecasting. All categorical data were encoded for machine learning algorithm processing. The data was then processed through various machine learning algorithms to ensure maximum accuracy and identify the most suitable one. The Gradient Boosting and multiple machine learning combinations provided the most optimal outcomes for financial forecasting. (Helmut Wasserbacher and Martin Spindler, 2022) explained the machine learning with a focus on financial forecasting, planning, and analysis. They suggested using machine learning not only for traditional forecasting but also for causal inference. A review of current literature on machine learning in financial forecasting, planning, and analysis was conducted, and a simulation study demonstrated its application. (Harya Widiputra et al., 2021) proposed creating a forecasting model that incorporates the best features of time series data analysis models to predict different stock market indices. The developed hybrid ensemble model, named CNN-LSTM, combined components from CNN and LSTM models. The results indicated that the multivariate CNN-LSTM model offered the highest statistical accuracy and reliability. (Philip Ndikum, 2020) examined the performance of machine learning algorithms and techniques for forecasting financial asset prices. The study compared the applications of modern machine learning algorithms on high-performance computing infrastructures with the traditional and widely-used Capital Asset Pricing Model (CAPM), finding that the machine learning algorithms outperformed the CAPM. (Omer Berat Sezer et al., 2020) aimed to provide a comprehensive literature review of deep learning studies on financial time series forecasting applications. It also suggested categorizing the studies based on indices, currencies, and model selections, including CNNs, Deep Belief Networks (DBNs), and LSTM networks.

3. DATASET

The weekly dataset encompassing card collections, cash collections, and cash payments for the period from January 1, 2017, to July 24, 2022, has been created. The attributes and descriptions of the dataset are listed in Table 1. Minimum, maximum, average and standard deviation values in the data set are listed in Table 2.

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Table 1. Attributes in the dataset

Attribute Name	Description
Date	Date
Sales	Amount of sales made by the company (TRY)
Cash_collection	Amount of cash collection made by the company (TRY)
Check_entry	Amount of checks issued to the company (TRY)
Promissory_note_entry	Amount of promissory notes issued to the company (TRY)
Card_collection	Amount of card collection made by the company (TRY)
Purchase	Amount of purchases made by the company (TRY)
Cash_payment	Amount of cash payments made by the company (TRY)
Check_exit	Amount of checks issued by the company (TRY)
Promissory_note_exit	Amount of promissory notes issued by the company (TRY)
Year	Year
Month	Month
Quarter	Quarter of the year
USD_close	USD closing value
USD_open	USD opening value
USD_maximum	Highest value of USD
USD_minimum	Lowest value of USD
Euro_close	Euro closing value
Euro_open	Euro opening value
Euro_maximum	Highest value of Euro
Euro_minimum	Lowest value of Euro
Bist100_close	Closing value of Borsa Istanbul 100
Bist100_open	Opening value of Borsa Istanbul 100
Bist30_close	Closing value of Borsa Istanbul 30
Bist30_open	Opening value of Borsa Istanbul 30
New_cases	Number of new COVID-19 cases
Total_cases	Total number of COVID-19 cases
New_deaths	Number of new COVID-19 deaths
Total_deaths	Total number of COVID-19 deaths
New_recoveries	Number of new COVID-19 recoveries
Total_recoveries	Total number of COVID-19 recoveries

Table 2. Statistics of target variables

Financial Components	Minimum	Maximum	Average	Standart Deviation Values
Card Collection	12035	35397759,3	3469189,15	2427987,9
Cash Collection	0	526244	325777,55	90538,53
Cash Payment	0	56689,46	9435,68	8749,09

4. METHODOLOGY

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This study utilized the Python programming language to achieve significant analytical advancements. For model development; TensorFlow, Keras, Pandas, Scikit-learn, Numpy, and Statsmodels libraries have been used. For the development of an interface with hyperparameter flexibility, the Tkinter, Pandastable, Matplotlib, and Streamlit libraries have been used.

4.1 Long-Short Term Memory

LSTM, a deep learning model, is a prediction technique that is better suited for time series data since it can tap into its intrinsic laws and capture the long-distance dependence between output and input with a high predictive capacity. LSTM has seen significant application in natural language processing, economics, energy power, and transportation forecasting in recent years (Xiangzhou Chen and Zhi Long, 2023).

4.2 Bi-Directional Long-Short Term Memory

In order to incorporate context information from the past and future, the Bi-LSTM neural network is made up of LSTM units that operate in both directions. Without keeping redundant context data, Bi-LSTM is able to learn long-term dependencies. It is therefore extensively used for text classification and has proven to perform exceptionally well for sequential modeling problems. To capture dependencies in two contexts, the Bi-LSTM network, in contrast to the LSTM network, consists of two parallel layers that propagate in two directions with forward and reverse passes (Beakcheol Jang et al., 2020).

4.3 Convolutional Long-Short Term Memory

With their ability to handle spatiotemporal data, Conv-LSTM networks have become a cutting-edge deep learning architecture. Conv-LSTM expands on this idea by fusing convolutional operations straight into the recurrent gates of LSTMs. Its foundation lies in the hybridization of CNNs and LSTMs. This has significant ramifications for biological signal processing, especially in the context of electrocardiogram analysis because of the complex interactions between temporal and spatial data (Alisher Mukhametkaly et al., 2023).

4.4 Auto-Regressive Integrated Moving Average

Moving average, integration, and autoregression are the three ideas that make up autoregressive integrated moving average, or ARIMA as it is commonly known. By 1970, Box and Jenkin had developed ARIMA. As an active predictor that links past and present with future estimates, ARIMA is among the models that fit short-term forecasts the best. The ARIMA model has been used to test numerous isolated micro and macrodynamics (Hamzeh F. Assous et al., 2020).

5. RESULTS AND DISCUSSION

In this study, forecasting models for financial components have been developed using time series-based methods. Financial forecasting models have been developed using LSTM, Bi-LSTM, ConvLSTM, and ARIMA with data on card collections, cash collections, and cash payments. Using a weekly dataset, forecasts have been generated for the months of March and July. The performance of the developed models has been evaluated using MAPE. The results obtained with the developed prediction models for march are given in Table 3 through Table 5.

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Table 3. MAPE values of the prediction models developed for card collection

Method	MAPE (%)
LSTM	8.27
Bi-LSTM	9.68
ConvLSTM	5.47
ARIMA	22.92

Table 4. MAPE values of the prediction models developed for cash collection

Method	MAPE (%)
LSTM	16.03
Bi-LSTM	26.78
ConvLSTM	18.82
ARIMA	28.24

Table 5. MAPE values of the prediction models developed for cash payment

Method	MAPE (%)
LSTM	22.95
Bi-LSTM	17.64
ConvLSTM	27.7
ARIMA	24.61

The results obtained with the developed prediction models for July are given in Table 6 through Table 8.

Table 6. MAPE values of the prediction models developed for card collection

Method	MAPE (%)
LSTM	10.78
Bi-LSTM	14.33
ConvLSTM	5.91
ARIMA	10.59

Table 7. MAPE values of the prediction models developed for cash collection

Method	MAPE (%)
LSTM	2.37
Bi-LSTM	4.91
ConvLSTM	3.65
ARIMA	1.57

Table 8. MAPE values of the prediction models developed for cash payment

Method	MAPE (%)
LSTM	9.63
Bi-LSTM	14.29
ConvLSTM	10.7
ARIMA	19.75

Based on the results:

- Among the forecast models developed for March, the most successful results for the card collection have been achieved with ConvLSTM (5.47%); for cash collection with LSTM (16.03%); and for cash payment with Bi-LSTM (17.64%).
- When the forecasting models developed for March have been examined, it has been observed that the model with the lowest MAPE has been obtained with the ConvLSTM model developed for card collection.
- When the results obtained for July have been examined, the most successful prediction performance has been achieved with ConvLSTM (5.91%) for card collection; ARIMA (1.57%) for cash collection and LSTM (9.63%) for cash payment.
- Among the models developed for July, the superior performance has been provided by the ARIMA model for the cash collection.

6. CONCLUSION

The e-commerce sector has gained significant momentum with the transformation brought about by the digital age and has become a major trading platform. E-commerce companies place great importance on financial component forecasts to maintain their positions in the dynamic market. Businesses with accurate financial forecasts gain a competitive advantage by basing their strategic planning on these estimates. In this study, financial forecasting models based on LSTM, Bi-LSTM, ConvLSTM, and ARIMA were developed for the e-commerce sector. The performance of forecasting models has been evaluated using the MAPE. The results indicated that the most successful forecasts have been achieved with ConvLSTM for March and ARIMA for July.

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DETECTION OF FIELD INVENTORIES IN ENERGY SERVICE COMPANIES USING IMAGE PROCESSING AND DEEP LEARNING

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ABSTRACT

This study aims to address the challenges encountered in managing inventory photos in the energy sector, particularly within energy service companies. The capture and upload of photos without content analysis make it difficult to identify the desired inventory photos and extract relevant data. To overcome this issue, the study proposes the development of algorithms based on image processing and deep learning to recognize inventory photos and classify them into specific categories. The research involves the classification of six distinct inventory categories: lighting panel, transformer, lighting pole, cell, building, and distribution network. A comprehensive dataset obtained from EnerjiSA has been utilized in this study, and classification models have been developed using Convolutional Neural Network (CNN)-Adam Optimization and You Only Look Once (YOLO) (versions 3 and 5) algorithms. The performance of the developed models has been evaluated using accuracy and F-score metrics. The results demonstrate the high effectiveness of the proposed algorithms in distinguishing inventory photos within the energy sector. The application of these algorithms can reduce photographic clutter, improve inventory management processes, and provide real-time feedback on photo quality, helping users to achieve more accurate and standard-compliant photos.

Keywords: Computer Vision, Deep Learning, Energy Sector, Inventory Photographs

1. INTRODUCTION

Energy service providers conduct field maintenance and inspection activities to ensure the quality and continuity of their services. As part of these processes, field teams periodically capture photos of work sites and upload them to the server. Since these photos are stored directly in the database without any control process, they contribute to data clutter. The analysis of the stored photos is typically conducted manually by personnel, which not only slows down the process but also poses potential eye strain issues due to prolonged screen exposure. Therefore, automating the identification of inventory items in photos can accelerate these processes and help prevent data clutter, thereby easing the workload of field teams.

In this study, a solution based on image processing and deep learning techniques is proposed. Algorithms have been developed to recognize and categorize inventory photos, aiming to classify images into six main categories commonly encountered in the energy sector: lighting panel, transformer, lighting pole, cell, building, and distribution network. Each category represents a specific type of asset, facilitating faster and more organized access to visual data based on this classification.

The implementation of these algorithms can reduce the accumulation of unnecessary or duplicate photos, streamline inventory management processes, and provide real-time feedback on photo quality, helping users capture images that are more accurate, consistent, and compliant with standards. The adoption of this approach may enhance efficiency, accuracy, and cost savings for energy service companies, enabling better management of field assets and more responsive handling of operational needs.

This paper is organized as follows: Section 2 presents related literature. Section 3 provides details on dataset generation. Methodology and details of the prediction models are given in Section 4. Results and discussion are presented in Section 5. Section 6 concludes the paper.

2. LITERATURE REVIEW

In recent years, numerous studies have been conducted in various fields, particularly in the energy sector, utilizing machine learning and deep learning algorithms. [1] proposed a model based on RT-DETR, offering adaptable improvements for detecting small targets in drone aerial photography, addressing complex backgrounds and the limitations of traditional CNN models. The study emphasizes the effectiveness of drone technology in tasks such as solar panel detection and its potential in the field of sustainable energy. [2] examined and categorized publicly available datasets for predictive maintenance across five subfields of the energy sector (wind, solar, oil and gas, diesel and thermal, and electricity grid). This work classifies the features of these datasets based on objective criteria within data repositories such as IEEE DataPort, UCI, Kaggle, EDP, and Mendeley Data, while also providing references to significant research studies. [3] addresses the importance and development of object detection systems used in applications like scene understanding, video surveillance, robotics, and autonomous driving. The success of deep learning and convolutional neural networks in this domain is particularly highlighted. The paper introduces existing deep learning frameworks and services for object detection, examining techniques that enhance the performance of state-of-the-art object detection systems. [4] comprehensively investigates the role of non-destructive testing (NDT) techniques in assessing the safety of pressurized equipment and the applications of object detection algorithms in this field. The integration of object detection techniques into the analysis of NDT data and the results obtained, as well as developmental trends, are emphasized. Additionally, the potential of methods such as GAN-based data augmentation and unsupervised learning to improve intelligent applications and performance of object detection in NDT is explored, alongside discussions on techniques to enhance the interpretability of deep learning models. [5] provides an in-depth examination of the application of YOLOv5 in the field of

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object detection, which holds significant importance in computer vision. Due to the impact of YOLO technology on real-time object identification and the flexibility and computational efficiency offered by the YOLOv5 architecture, there is substantial demand for its implementation. The research details the architectural improvements and design elements that differentiate YOLOv5 from its predecessors, as well as the training process and the effectiveness of transfer learning techniques. [6] aims to recognize vehicles in aerial images using CNN, achieving a maximum accuracy of 68.42% with a dataset divided into 60% training and 40% test sets, optimized using Adam. [7] discusses the necessity of maintaining knowledge of classical computer vision techniques by comparing deep learning and traditional computer vision approaches. Several studies have been conducted to facilitate operations in the energy sector. [8] utilized CNN and Support Vector Machine (SVM) algorithms for the detection and recognition of hazard signals in a transformer station. [9] introduced the OSLPNet model to extract street lamp poles from street view images. To reduce the issue of inadequate segmentation of various street lighting poles in images, a multi-scale phased controller (MPC) with multi-level receptive fields is proposed. [10] presents an autonomous risk classification model for detecting potential anomalies in electricity poles. By collecting 8,775 images of electricity poles using UAVs and integrating a Faster R-CNN object detector, the study accurately identifies steel, concrete, and wooden poles. Image processing techniques are employed to calculate the tilt angles of the poles, which are then classified as "risky" or "not risky" based on these angles.

3. DATASET GENERATION

The dataset used in this study has been obtained from EnerjiSA. It consists of an extensive collection of photos representing various inventory items commonly used in the energy sector. The dataset includes six distinct inventory categories:

- Lighting Panel
- Transformer
- Lighting Pole
- Cell
- Building
- Distribution Network

There are a total of 565 photographs in the data set. Data augmentation operations have been carried out to increase the success performance of the developed models.

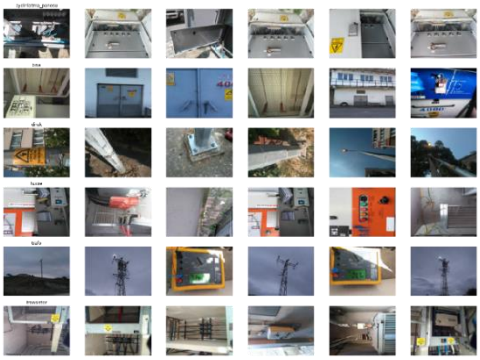

Figure 1. Dataset

4. METHODOLOGY

In this study, an image processing and deep learning-based approach has been used to recognize and classify inventory photos in the energy sector. Primarily, the CNN-Adam Optimization and YOLO (versions 3 and 5) algorithms have been employed to categorize inventory photos into specific classes. The performance of the developed models has been evaluated using accuracy metric.

4.1. Convolutional Neural Network (CNN)-Adam Optimization

Convolutional Neural Network (CNN) is a deep learning architecture that can effectively perform feature extraction, especially on image data, and is successfully used in tasks such as image classification and object recognition. Adam optimization (Adaptive Moment Estimation) is an optimization algorithm used during the training process of deep networks like CNNs. Adam provides faster and more stable learning by adaptively adjusting the learning rate at each step.

4.2. You Only Look Once (YOLO)

YOLO is an object detection algorithm using CNN. It runs faster than other algorithms because it passes the entire image through a neural network at once. YOLO surrounds the objects it detects in the images with a bounding box and divides the given image into NxN grids. Each grid checks whether there is an object in it and if it thinks the object exists, whether the center point is in its own area. If it is determined that the object has a center point, the grid determines the class, height and width of the object and draws a bounding box. Each bounding box has a confidence score. Depending on which class has the highest confidence score, that frame determines the class [11].

5. RESULTS AND DISCUSSION

The performance metrics of three object detection algorithms, YOLOv3, YOLOv5, and CNN-Adam Optimization, have been evaluated. The performance of the models are shown in Table 1.

Table 1. Results of the model

Algorithm / Metric	Yolov3	Yolov5	CNN-Adam Optimization
Accuracy	% 71.1	% 76	% 70

- YOLOv5 achieved the highest accuracy of 76%, followed by YOLOv3 at 71.1% and CNN-Adam Optimization at 70%.
- Overall, YOLOv5 outperformed the other algorithms in terms of accuracy.
- YOLOv5 demonstrated its effectiveness for the given task, suggesting potential areas for further improvement in object detection algorithms.

CONCLUSION

Object detection algorithms have the potential to revolutionize inventory management by enabling the accurate and efficient detection of inventory items across various sectors. This study proposes the implementation of image processing and deep learning algorithms to address the challenges of inventory photo management in the energy sector. Specifically, the performance of three widely used object detection algorithms YOLOv3, YOLOv5, and CNN with Adam Optimization is evaluated. Among the assessed algorithms, YOLOv5 demonstrates

superior performance, achieving the highest accuracy rate of 76%. These findings underscore the potential of object detection algorithms to significantly enhance inventory management practices by ensuring the reliable and efficient tracking of inventory items.

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SYNTHETIC DATA GENERATION WITH LARGE LANGUAGE MODELS TO EVALUATE ENSEMBLE REGRESSION ALGORITHMS

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ABSTRACT

In the realm of real estate price prediction, synthetic data generation using Large Language Models (LLMs) has emerged as a valuable approach to evaluate and compare ensemble regression algorithms. This study explores the effectiveness of various ensemble techniques in predicting real estate prices by leveraging a synthetic dataset designed to simulate real-world scenarios. The dataset includes diverse property features and pricing factors, providing a robust foundation for testing the predictive performance of the algorithms. We evaluated several ensemble regression algorithms, including Ridge, Voting, Gradient Boosting, Extra Trees, Random Forest, Bagging, AdaBoost, Decision Tree, SVR, and a hybrid model combining Bagging and SVR. The performance of these algorithms was assessed based on their Root Mean Square Error (RMSE) values, revealing notable differences in predictive accuracy. Ridge Regression emerged as the most effective algorithm, achieving the lowest RMSE of 24,885. In contrast, the SVR algorithm exhibited the highest RMSE of 170,548, indicating substantial deviation from actual values. The Bagging + SVR combination also performed poorly with an RMSE of 170,806. The results highlight the varying degrees of effectiveness among the evaluated algorithms, with Ridge Regression, Voting, and Gradient Boosting showing superior performance compared to others. This analysis underscores the potential of synthetic data generation in assessing and refining ensemble regression methods, offering valuable insights for improving real estate price prediction models. The findings contribute to a broader understanding of ensemble learning techniques and their application in predictive analytics.

Keywords: Ensemble Regression Algorithms, House Price Prediction, Large Language Models.

1. INTRODUCTION

The use of ensemble regression algorithms has gained significant attention in predictive modeling due to their ability to improve accuracy and robustness by combining multiple models. Real estate price prediction, in particular, presents a complex challenge due to the multifaceted nature of property features and market dynamics. To address this, researchers have

increasingly turned to synthetic data generation as a means of evaluating and refining these algorithms. This approach allows for the creation of diverse and controlled datasets that simulate real-world conditions, offering valuable insights into the performance of various ensemble techniques.

Synthetic data generation involves using computational models, such as Large Language Models (LLMs), to create datasets that mimic real-world scenarios. This method offers several advantages, including the ability to generate large volumes of data and control specific features and variables. By employing LLMs, researchers can create comprehensive datasets tailored to the specific needs of their study, thereby enhancing the reliability and validity of their findings [1][2].

Ensemble learning methods, which combine predictions from multiple models to improve overall performance, have been widely applied in regression tasks. These methods include algorithms such as Ridge Regression, Voting, Gradient Boosting, Extra Trees, Random Forest, Bagging, AdaBoost, and Decision Trees. Each of these algorithms has unique characteristics and mechanisms for aggregating predictions, which can lead to varying degrees of accuracy in predicting real estate prices [3][4]. For instance, Ridge Regression is known for its ability to handle multicollinearity and provide stable estimates, while Gradient Boosting and Random Forests are praised for their high predictive accuracy and ability to handle complex interactions among features [5][6].

The effectiveness of these ensemble algorithms can be evaluated using metrics such as Root Mean Square Error (RMSE), which provides a measure of the prediction error by comparing predicted values to actual values. Recent studies have demonstrated that different ensemble techniques exhibit varying levels of performance in real estate price prediction tasks. For example, Ridge Regression has shown superior performance with the lowest RMSE, while Support Vector Regression (SVR) and its combination with Bagging have yielded higher RMSE values, indicating less accurate predictions [7][8].

In this study, we leverage synthetic data generated through LLMs to evaluate the performance of several ensemble regression algorithms in the context of real estate price prediction. By examining the RMSE values associated with each algorithm, we aim to provide a comprehensive analysis of their effectiveness and identify the most promising methods for improving prediction accuracy. This approach not only contributes to the understanding of ensemble learning techniques but also highlights the potential of synthetic data in enhancing predictive modeling practices [9][10].

2. EVALUATION METRICS AND SYNTHETIC PREDICTION DATASET

In predictive modeling, selecting appropriate evaluation metrics is crucial for assessing the performance of various algorithms. In this study, we focus on Root Mean Square Error (RMSE) as the primary metric for evaluating the effectiveness of ensemble regression algorithms in predicting house prices. RMSE is a widely used metric that quantifies the average magnitude of prediction errors by calculating the square root of the average squared differences between

predicted and actual values. It provides a clear indication of the model's accuracy, with lower RMSE values indicating better performance [11].

To conduct this evaluation, we utilized a synthetic house price prediction dataset generated using a Large Language Model (LLM). This dataset consists of 1,000 examples, each representing various attributes relevant to house pricing. The dataset includes the following columns:

- ***metrekare:*** Represents the area of the house in square meters.
- ***oda_sayisi:*** Denotes the number of rooms in the house.
- ***bina_yasi:*** Indicates the age of the building.
- ***kat:*** Specifies the floor on which the house is located.
- ***sehir_merkezine_uzaklik:*** Measures the distance from the house to the city center.
- ***garaj_var_mi:*** Indicates whether the house has a garage (1 for yes, 0 for no).
- ***asansor_var_mi:*** Shows whether the building has an elevator (1 for yes, 0 for no).
- ***fiyat:*** Represents the house price, which is the target variable we aim to predict.

The synthetic dataset was created to replicate real-world scenarios by integrating various property features and pricing variables. This methodology facilitates a thorough evaluation of ensemble regression algorithms by offering a controlled environment in which the data characteristics can be accurately managed and adjusted.

The choice of RMSE as the evaluation metric stems from its effectiveness in reflecting prediction accuracy. RMSE is particularly useful because it penalizes larger errors more severely than Mean Absolute Error (MAE), making it effective in identifying models that produce substantial deviations from actual values [12]. The RMSE formula is given by:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

where y_i represents the actual values, $\hat{y}_i$ denotes the predicted values, and n is the number of observations.

In conclusion, the combination of the synthetic dataset and RMSE as an evaluation metric offers a strong foundation for evaluating the effectiveness of ensemble regression algorithms. This method supports an in-depth analysis of model performance, helping to pinpoint the most effective techniques for house price prediction and improving accuracy in real estate analytics.

3. HOUSE PRICE PREDICTION WITH ENSEMBLE REGRESSORS

Predicting house prices is a complex task that significantly impacts real estate markets, investment strategies, and home-buying decisions. Ensemble regression methods are increasingly employed to tackle this challenge due to their ability to combine multiple models and improve predictive accuracy. This section explores the application of various ensemble

regression algorithms for house price prediction, evaluating their performance and effectiveness.

Ensemble regressors leverage the strengths of different algorithms to enhance overall prediction quality. One of the primary methods used is Ridge Regression, which incorporates L2 regularization to handle multicollinearity and stabilize predictions. By penalizing large coefficients, Ridge Regression reduces the risk of overfitting and provides more reliable estimates of house prices [13].

Another widely used technique is the Voting Regressor, which aggregates predictions from multiple models to produce a final estimate. This approach combines the predictions of various algorithms, aiming to reduce variance and improve the robustness of the predictions [14]. Gradient Boosting is also a popular choice, known for its ability to sequentially build models that correct the errors of previous ones. This iterative process captures complex patterns in the data and often results in high predictive accuracy [15].

Extra Trees, or Extremely Randomized Trees, is another effective ensemble method. It constructs multiple decision trees using random subsets of features and training samples, increasing model diversity and reducing overfitting [16]. Random Forests extend this concept by aggregating predictions from many decision trees, each trained on different data subsets. This technique enhances stability and performance by averaging the predictions of numerous trees [17].

Bagging, or Bootstrap Aggregating, trains multiple instances of a model on various bootstrap samples of the data. By averaging the predictions from these models, Bagging helps to reduce variance and improve accuracy [18]. AdaBoost, or Adaptive Boosting, combines several weak learners into a strong learner by focusing on misclassified examples in each iteration. This method improves model accuracy and robustness [19].

Decision Trees model decisions through a tree-like structure, where each internal node represents a feature, and each leaf node represents an outcome. While Decision Trees are simple and interpretable, they are prone to overfitting, which can be mitigated by combining them with other methods [20]. Support Vector Regression (SVR) employs support vector machines for regression tasks, aiming to find a function that deviates from actual values by a margin no greater than a specified threshold. SVR is effective in high-dimensional spaces but can be computationally intensive [21].

Combining Bagging with SVR, known as Bagging + SVR, leverages the strengths of both techniques to improve prediction stability and accuracy. Bagging reduces variance by aggregating multiple SVR models, potentially enhancing overall performance [22].

To evaluate the performance of these ensemble regressors, Root Mean Square Error (RMSE) is used as the primary metric. RMSE measures the average magnitude of prediction errors by calculating the square root of the average squared differences between predicted and actual values. It provides a clear indication of model accuracy, with lower RMSE values reflecting better performance [23].

In conclusion, each ensemble regressor offers unique advantages for house price prediction. Techniques such as Gradient Boosting and Random Forests are noted for their high accuracy, while Bagging and AdaBoost provide improvements in stability and robustness. By analyzing the performance of these algorithms using RMSE, we can identify the most effective models for predicting house prices and gain valuable insights into real estate analytics. The performances of the algorithms with an 80%-20% split are provided in Table 1, based on RMSE errors.

Table 1. Performance values of ensemble regression algorithms in terms of RMSE

Algorithm	RMSE
Ridge	24,885
Voting	25,471
Gradient Boosting	26,213
Extra Trees	26,977
Random Forest	28,435
Bagging	28,500
AdaBoost	31,857
Decision Tree	35,971
SVR	170,548
Bagging + SVR	170,806

As seen in Table 1, among various ensemble regression algorithms, the best performance, with the lowest RMSE value of 24,885, was achieved by the Ridge algorithm. This result shows that optimizing the parameters of the Ridge algorithm can improve prediction performance in forecasting house prices.

4. CONCLUSION

In our synthetic house price prediction study, we evaluated several ensemble regression algorithms based on their RMSE values. Ridge Regression achieved the best performance with the lowest RMSE of 24,885, closely followed by the Voting Regressor, which had an RMSE of 25,652. Gradient Boosting recorded an RMSE of 26,213, while Extra Trees achieved an RMSE of 26,977. Random Forest produced an RMSE of 28,435, and Bagging had an RMSE of 28,500. AdaBoost's performance yielded an RMSE of 31,857, with the Decision Tree algorithm performing the worst among the ensemble methods at 35,971. Both Support Vector Regression (SVR) and the combination of Bagging + SVR exhibited significantly higher RMSE values of 170,548 and 170,806, respectively. This analysis highlights that Ridge Regression, Voting Regressor, and Gradient Boosting were the most effective algorithms for predicting house prices, whereas SVR and its combination with Bagging proved to be less effective.

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RIDGE REGRESSION PARAMETER OPTIMIZATION IN HOUSE PRICE PREDICTION

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ABSTRACT

In this study, we explore the optimization of Ridge Regression for house price prediction by fine-tuning its regularization parameter, alpha. Ridge regression, a technique that introduces a penalty term to the linear regression model, helps mitigate issues of multicollinearity and overfitting by shrinking the coefficients of less relevant features. The regularization parameter alpha controls the strength of this penalty, and selecting an optimal value is crucial for enhancing model performance. To identify the best alpha value for our model, we employed Grid Search with cross-validation. This approach systematically evaluates a range of alpha values to determine which provides the best balance between model complexity and prediction accuracy. Our parameter search was conducted over a logarithmic scale of alpha values, ranging from 10^{-4} to 10^{4}, ensuring a comprehensive exploration of potential regularization strengths. The Grid Search procedure yielded an optimal alpha value of approximately 1.6238. This parameter value was found to significantly improve the Ridge Regressor's performance, resulting in an impressive Root Mean Square Error (RMSE) of 24,275 on the validation set. The RMSE metric, which measures the average magnitude of prediction errors, is crucial in evaluating the model's accuracy. A lower RMSE indicates better predictive performance, and our optimized model achieved a competitive RMSE, demonstrating its efficacy in handling house price prediction tasks. The results highlight the importance of parameter tuning in machine learning models, particularly in regression tasks where regularization can dramatically influence performance. The successful optimization of the alpha parameter underscores the potential of Ridge Regression in providing reliable and accurate predictions for real estate pricing. This study contributes to the broader understanding of parameter optimization techniques and their impact on model accuracy in the domain of predictive analytics.

Keywords: Ridge Regression Algorithms, House Price Prediction, Grid Search, Alpha Value, Regression.

1. INTRODUCTION

House price prediction is a critical and complex problem in the field of real estate analytics. Accurate prediction of house prices can provide significant insights for buyers, sellers, and investors, facilitating informed decision-making and strategic planning. Among the various statistical and machine learning methods used for this purpose, Ridge Regression has gained prominence due to its effectiveness in handling issues related to multicollinearity and overfitting in regression models [1].

Ridge Regression, also known as Tikhonov regularization, is an extension of ordinary least squares regression. It incorporates a penalty term into the cost function, which discourages large coefficients for the features. This penalty, controlled by the regularization parameter alpha, helps stabilize the regression estimates by reducing the impact of multicollinearity. Multicollinearity arises when predictor variables are strongly correlated, resulting in increased variance in the coefficient estimates and unstable predictions. By applying a penalty proportional to the square of the magnitude of the coefficients, Ridge Regression addresses these issues, resulting in a more reliable model [2].

The alpha parameter plays a crucial role in Ridge Regression, as it dictates the strength of the regularization applied. A higher alpha value increases the penalty, resulting in smaller coefficient estimates and a more regularized model. Conversely, a lower alpha value reduces the regularization effect, allowing the model to fit the training data more closely. Thus, the choice of alpha is vital for balancing the trade-off between bias and variance, impacting the model's ability to generalize well to new data [3, 4].

To identify the optimal alpha value, Grid Search with cross-validation is often employed. This technique involves systematically evaluating a range of alpha values to determine which one minimizes the Root Mean Square Error (RMSE) on the validation set. By conducting a grid search over a logarithmic scale of alpha values, ranging from 10^{-4} to 10^{4}, one can ensure a thorough exploration of potential regularization strengths [5]. This approach helps in finding the alpha that provides the best performance in terms of predictive accuracy and model stability.

In this study, we applied Ridge Regression to house price prediction and optimized the alpha parameter using Grid Search. The search revealed an optimal alpha value of approximately 1.6238, which resulted in an RMSE of 24,275. This finding underscores the effectiveness of Ridge Regression in handling real estate data and highlights the importance of parameter tuning in enhancing model performance. By optimizing the alpha parameter, the Ridge Regressor achieved a better balance between fitting the training data and generalizing to unseen data, demonstrating its potential for accurate and reliable predictions in the context of house pricing.

The results of this study contribute to the understanding of parameter optimization techniques and their impact on predictive modeling. Ridge Regression, with its regularization capabilities, offers a robust solution for house price prediction, provided that the alpha parameter is carefully selected. This work emphasizes the significance of parameter tuning in improving the accuracy and reliability of predictive models, particularly in the challenging domain of real estate analytics.

2. EVALUATION METRICS AND DATASET

In predictive modeling, selecting appropriate evaluation metrics is essential for accurately assessing the performance of various algorithms. This study focuses on RMSE as the primary metric for evaluating the effectiveness of ensemble regression algorithms in predicting house prices. RMSE is a widely recognized metric that quantifies the average magnitude of prediction errors. It is computed as the square root of the average of the squared differences between predicted and actual values. A lower RMSE signifies better model performance, as it indicates fewer discrepancies between predicted and observed values [6].

To evaluate the ensemble regression algorithms, we used a synthetic house price prediction dataset. This dataset comprises 1,000 examples, each containing several attributes relevant to house pricing. The columns in the dataset are as follows:

- ***metrekare:*** Represents the area of the house in square meters.
- ***oda_sayisi:*** Denotes the number of rooms in the house.
- ***bina_yasi:*** Indicates the age of the building.
- ***kat:*** Specifies the floor on which the house is located.
- ***sehir_merkezine_uzaklik:*** Measures the distance from the house to the city center.
- ***garaj_var_mi:*** Indicates whether the house has a garage (1 for yes, 0 for no).
- ***asansor_var_mi:*** Shows whether the building has an elevator (1 for yes, 0 for no).
- ***fiyat:*** Represents the house price, which is the target variable we aim to predict.

The synthetic dataset was created to simulate real-world scenarios by including a range of property features and pricing variables. This controlled environment allows for a detailed evaluation of ensemble regression algorithms, as the characteristics of the data can be precisely managed and varied.

The choice of RMSE as the evaluation metric stems from its effectiveness in reflecting prediction accuracy. RMSE is particularly useful because it penalizes larger errors more severely than Mean Absolute Error (MAE), making it effective in identifying models that produce substantial deviations from actual values [7]. The RMSE formula is given by:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

where y_i represents the actual values, $\hat{y}_i$ denotes the predicted values, and n is the number of observations.

In summary, the synthetic dataset and RMSE evaluation metric provide a solid framework for assessing the performance of ensemble regression algorithms. This approach ensures a comprehensive analysis of model accuracy, facilitating the identification of the most effective techniques for house price prediction and enhancing predictive accuracy in real estate analytics.

3. HOUSE PRICE PREDICTION WITH RIDGE PARAMETER OPTIMIZATION

In the realm of machine learning (ML), parameter optimization is essential for enhancing model performance. This process involves selecting the best hyperparameters to minimize prediction errors and improve the model's ability to generalize to new, unseen data. By fine-tuning parameters, models can be adjusted to better fit the data while avoiding overfitting.

Ridge Regression, a well-known algorithm for regression tasks, is particularly effective in handling multicollinearity [8]. It extends ordinary least squares regression by incorporating a regularization term into the cost function. This term, governed by the alpha parameter, penalizes large coefficients, thereby reducing model complexity and improving stability. Ridge Regression modifies the cost function of linear regression by adding a regularization term:

$$Cost\ Function = \frac{1}{2n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 + \frac{\alpha}{2}\sum_{j=1}^{p}\beta_j^2$$

where y_i represents the actual values, $\hat{y}_i$ denotes the predicted values, β_j are the coefficients, and α is the regularization parameter. This regularization term $\frac{\alpha}{2}\sum_{j=1}^{p}\beta_j^2$ helps address issues related to multicollinearity overfitting by shrinking coefficients [1][2].

The key parameter in Ridge Regression is alpha, which controls the strength of regularization. A higher alpha value increases the penalty on large coefficients, leading to more significant shrinkage, while a lower alpha reduces the regularization effect, allowing the model to fit the training data more closely. Finding the optimal alpha is crucial for balancing model bias and variance, thereby improving performance on new data.

To identify the best alpha value, Grid Search is a commonly used technique. Grid Search systematically explores a predefined range of alpha values and evaluates the performance of the Ridge model for each value. This involves training the model with various alpha values and selecting the one that minimizes an evaluation metric, such as RMSE [5].

Grid Search operates by defining a grid of possible alpha values and performing cross-validation to assess model performance for each value [9]. The process involves defining the grid, training models, evaluating performance, and selecting the optimal alpha. This approach ensures that models are well-calibrated and capable of making accurate predictions.

In summary, parameter optimization is vital for achieving high performance in Ridge Regression. By employing techniques such as Grid Search to adjust the alpha parameter, one can greatly improve model accuracy and robustness, especially in tasks like house price prediction. This approach ensures that models are well-calibrated and capable of making accurate predictions.

With alpha parameter optimization, the corresponding RMSE values for Ridge Regression are given in Table 1. As seen in Table 1, the optimal alpha value was 1.623777, and the corresponding RMSE was 24275.095904. The RMSE value in the test data set was obtained as 24,886.1550291.

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Table 1. Performance values of ensemble regression algorithms

ID	alpha parameter	RMSE values
0	0.0001	-24,275.334789
1	0.000264	-24,275.334736
2	0.000695	-24,275.334596
3	0.001833	-24,275.334226
4	0.004833	-24,275.333252
5	0.012743	-24,275.330693
6	0.033598	-24,275.324013
7	0.088587	-24,275.306868
8	0.233572	-24,275.264895
9	0.615848	-24,275.176543
10	**1.623777**	**-24,275.095904**
11	4.281332	-24,275.892084
12	11.288379	-24,284.171538
13	29.763514	-24,337.011189
14	78.475997	-24,569.227862
15	206.913808	-25,189.147626
16	545.559478	-26,187.419266
17	1438.449888	-27,443.968466
18	3792.690191	-28,819.037080
19	10000.0	-30,183.057951

As seen in Table 1, among the 20 alpha values, the lowest RMSE value of 24,275.095904 was achieved with the Ridge algorithm. This result demonstrates that optimizing the Ridge algorithm's parameters can enhance prediction performance in house price prediction.

4. CONCLUSION

In the context of optimizing Ridge Regression for house price prediction, the alpha parameter plays a crucial role in controlling the regularization strength. The primary objective was to determine the optimal alpha value that minimizes the RMSE, a metric used to quantify the model's prediction accuracy.

Grid Search was employed as the optimization technique, systematically exploring a predefined range of alpha values to identify the optimal parameter. This method involves training the Ridge Regression model with different alpha values and evaluating each model's performance through cross-validation.

Through this optimization process, it was found that the Ridge Regression model with an alpha value of 1.623777 yielded the lowest RMSE. The resulting RMSE for this optimal alpha was 24,275.095904. This outcome indicates that the model with this specific alpha value provided the most accurate house price predictions, minimizing the average magnitude of prediction errors compared to other tested alpha values. The selection of this alpha value reflects a balanced trade-off between bias and variance, achieved through regularization that effectively addresses multicollinearity while preserving model accuracy. The successful reduction of RMSE to 24,275.095904 demonstrates the effectiveness of Grid Search in optimizing the Ridge

Regression model's performance for predicting house prices, resulting in enhanced model robustness and predictive accuracy.

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ANKARA BÖLGESİNDE EN YÜKSEK DOMATES VERİMİNİ SAĞLAYAN OPTİMUM SULAMANIN DSSAT İLE MODELLENMESİ

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ÖZET

İklim değişikliği ve artan kurak dönemlerin etkisi ile sulamanın optimize edilmesi günümüzde zorunlu bir hale gelmiştir. Bu çalışma, Ankara bölgesindeki domates yetiştiriciliği için en uygun sulama stratejilerinin belirlenmesi amacıyla Decision Support System for Agrotechnology Transfer (Agroteknoloji Transferi için Karar Destek Sistemi - DSSAT) modelinin kullanılması ile bitki büyümesi ve verimin simüle edilmesini kapsamaktadır. Çalışmada, Ankara iline ait meteorolojik, toprak ve bitki verileri kullanılmıştır. FAO-56 Penman-Monteith yöntemi ile çim bitkisi esas alınarak günlük referans evapotranspirasyon hesaplanmış ve DSSAT CROPGRO-Tomato modeli kullanılarak, domates bitkisinin büyüme sezonu boyunca bitki büyümesi, toprak nem içeriği ve verim miktarı simüle edilmiştir. Çalışmada simüle edilen toplam 3258 büyüme mevsimi boyunca damla sulama yönetimi parametrelerinin alternatiflerinin kullanılması ile elde edilen simülasyon verileri ve ölçülen veriler karşılaştırılmıştır. Simüle edilen verim ile gerçek verim arasındaki fark en fazla 284.92 kg kuru madde (6.83%) iken, en düşük fark 3.5 kg kuru madde (0.09%) olarak bulunmuştur. Optimum verimin, 20 sulamada ortalama 4083.03 ± 721.64 kg/ha olacağı belirlenmiştir. Simülasyon sonuçları, sulama stratejilerinin doğru yönetimiyle domates veriminin en iyi düzeyde tutulabileceğini göstermektedir. Simüle edilen verim ile gerçek verim sonuçları karşılaştırıldığında, DSSAT modelinin kabul edilebilir hata payı ile sonuçlar ürettiği tespit edilmiştir. Çalışmanın bulguları, sulama planlamasında gelişmiş modellerin kullanımı sayesinde su tüketiminin azaltılabileceğini ve verimin korunabileceğini ortaya koymaktadır.

Anahtar Kelimeler: Sulama planlaması, optimum sulama, DSSAT, bitki büyüme modeli, su kullanım verimliliği

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1. GİRİŞ

İklim değişikliğinin etkileriyle yüzleşirken, su kaynaklarının sürdürülebilirliğini sağlamak ve tarımsal üretimde yüksek verim elde etmek giderek zorlaşmaktadır. Su kaynakları yönetiminde anahtar kavram, doğru sulama planlamasıdır. Sulama planlaması, hasat miktarını güvence altına almak ve su kısıtından kaynaklanan ürün kaybı ihtimalini azaltmak açısından büyük önem taşımaktadır. Karar vericilerin modern sulama yöntemlerini (yağmurlama ve damla sulama) teşvik etmelerine rağmen, Türkiye'de sulama amaçlı su kullanımı, tatlı su kaynaklarının %77'sini oluşturmaktadır (DSİ, 2021). Yakın gelecekte Türkiye'de yağış miktarlarında önemli bir azalma ve kuraklık koşullarında ciddi bir artış olacağı öngörülmektedir (Turkes vd., 2020). Bu nedenle, su kullanım verimliliğini artırmak büyük bir öncelik haline gelmiştir.

Sulama planlaması, geleneksel yöntemlerden gelişmiş izleme sistemleri ve kontrol stratejilerine doğru önemli bir ilerleme kaydetmiştir. Hassas sulama sistemleri, toprak nemini ölçme ve iklim modelleri yardımıyla sulama suyu ihtiyacını tahmin ederek uygulamada devrim yaratmıştır. Toprak, bitki ve iklim bazlı izleme yöntemlerinin birleştirilmesi, su kullanım etkinliğini artırma potansiyeline sahiptir (Bwambale vd., 2022). İzleme sistemleri kullanılarak sulama verimliliğinin artırılmasına rağmen, modeller kullanılarak sulama verimliliğinin artırılması büyük önem taşımaktadır. Decision Support System for Agrotechnology Transfer (Agroteknoloji Transferi için Karar Destek Sistemi - DSSAT) bitki büyüme modeli bu amaçla kullanılan bir modeldir.

Rinaldi vd. (2007), DSSAT simülasyon modelini, Güney İtalya'da domates bitkisi için kalibre etmiş ve üç bağımsız veri setiyle doğrulayarak kabul edilebilir sonuçlar elde etmiştir. Model, 53 yıllık verilerle, 23 farklı interaktif sulama ve/veya azot yönetimi senaryosunun faydalarını, risklerini ve maliyetlerini değerlendirmek amacıyla kullanılmıştır. Çalışma bulgularında modelin, çiftçilerin en uygun ürün yönetim stratejisini belirlemelerine yardımcı olacak faydalı bir karar destek sistemi olduğu vurgulanmıştır.

Abou-Shleel vd. (2011), Mısır'da iki lokasyonda (Tall Elkabeer ve Al-Khanka) üç farklı ekim tarihi ve üç farklı azotlu gübre seviyesi uygulamasının domates verimi üzerindeki etkisini değerlendirmiştir. DSSAT, iklim değişikliği koşulları altında domates verimini tahmin etmek için hava, toprak ve deneysel sonuçlara ilişkin verilerle çalıştırılmıştır. Çalışma bulgularında DSSAT'ın mevcut koşullar altında domates bitkisinin verimini gerçek verimden sadece % 0.3 ila % 0.6'lık bir farkla simüle edebildiği bildirilmiştir.

Boote vd. (2012) tarafından yapılan çalışmada, iklim değişikliği nedeniyle potansiyel sıcaklık artışlarına daha doğru yanıt verebilmek amacıyla, domates bitkisi için DSSAT modelinin sıcaklık parametreleri güncellenmiştir. Sonuç olarak, Willmott d indeksinin her zaman 0.92'nin üzerinde bulunduğu bildirilmiştir.

Elsayed vd. (2017), araştırmalarında modelini, İtalya da tarla çalışmalarından elde edilen deneysel verilerle değerlendirmişlerdir. Çalışmada, uyum indeksinin (d-Stat) 0.562 ila 0.998 arasında değiştiği bulunmuştur. Çalışmanın sonucunda, modelin bölgesel planlamalara yardımcı olacak bir karar verme aracı olarak kullanılabileceği belirtilmiştir.

Cammarano vd. (2020), Güneybatı İtalya'da yetiştirilen domatesin verim ve büyüme parametrelerini simüle etmek, öngörülen iklimin tarımsal uygulamalar üzerindeki etkilerini ölçmek ve artan CO2'nin su ve besin verimliliği üzerindeki rolünü anlamak amacıyla bir çalışma gerçekleştirmiştir. Çalışma bulgularında DSSAT modelinin, domatesin azot gübrelemesine tepkisini kabul edilebilir hata seviyeleri ile simüle ettiği rapor edilmiştir.

Shravika vd. (2021), Hindistan'da DSSAT modelinin farklı ekim tarihleri ve domates çeşitleri altında performansını değerlendirmiştir. Model, fenoloji, biyokütle, meyve verimi ve azot alımı simülasyonlarında yüksek doğrulukla performans göstermiştir.

Amankwaa-Yeboah vd. (2023), domates üretiminde besin ve su verimliliğini en üst düzeye çıkarmak amacıyla, su tasarrufu sağlayan bir strateji olarak sulama ve besin yönetiminin birleşik etkisini DSSAT yardımıyla incelemiştir. Araştırmacılar, farklı sulama ve besin yönetimi altında ölçülen ve simüle edilen verimler arasında güçlü uyum bulmuşlardır.

Bu çalışma ile domates yetiştiriciliğinde sulama planlamasında büyüme mevsimi boyunca sürekli değişen iklim parametrelerini, toprak verilerini ve bitki büyümesini modelleyebilen DSSAT gibi bir karar destek sisteminin Ankara koşullarında geçerliliği belirlenmeye çalışılacaktır.

2. MATERYAL VE METOT

2.1. Çalışma Alanı ve Veriler

Çalışma alanı, Ankara ili, İç Anadolu Bölgesi'nin kuzeybatısında yer almakta olup, deniz seviyesinden ortalama 890 metre yükseklikte yer almakta ve yarı kurak iklim özellikleri göstermektedir. İlin genel iklimi karasal iklim olarak tanımlanabilir; yazlar sıcak ve kurak, kışlar ise soğuk ve kar yağışlıdır. Ortalama yıllık sıcaklık değeri 12 °C iken aylık ortalama en yüksek sıcaklık değeri 30.5 °C ile ağustos ayında, aylık ortalama en düşük sıcaklık değeri ise -3.2 °C ile ocak ayında görülmektedir (Anonim, 2023). Ankara iline ait bazı meteorolojik parametrelerin uzun yıllar ortalaması Görsel 1'de verilmiştir.

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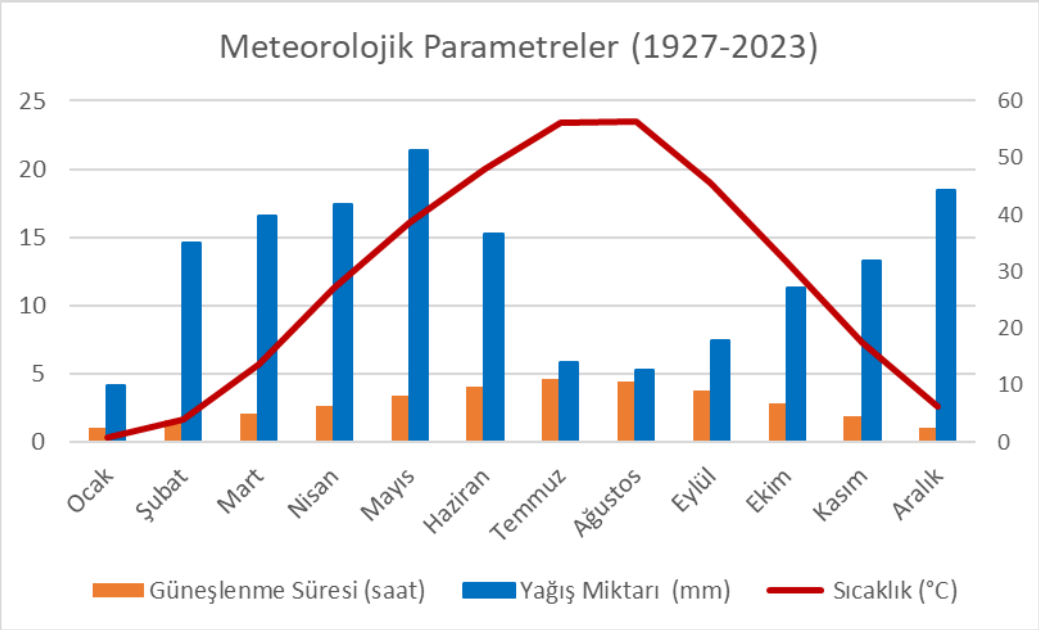

Görsel 1. Ankara iline ait bazı meteorolojik parametrelerin uzun yıllar (1927-2023) ortalaması

İklim parametrelerini temsil etmek için, çalışma alanı olan Ankara ilinde en fazla domates yetiştirilen beş ilçenin meteorolojik verileri, Meteoroloji Genel Müdürlüğü (MGM)'nden, toprak verileri önceden yapılan çalışmalardan (Kesmez, 2009; Soba vd., 2018; Taşkın vd., 2018; Anonim, 2018) temin edilmiştir. Meteorolojik veriler, günlük maksimum, minimum ve ortalama sıcaklık, maksimum, minimum ve ortalama nem, rüzgâr hızı, toplam güneş radyasyonu ve toplam yağış verileridir.

2.2. Metot

Meteoroloji, toprak ve bitki verileri kullanılarak, FAO-56 Penman-Monteith yöntemi (Allen vd., 1998) ile çim bitkisi esas alınarak günlük referans evapotranspirasyon hesaplanmıştır. Ardından Ankara bölgesine ait meteoroloji ve toprak verileri ile domates bitkisine ilişkin bitki parametreleri (Çizelge 1 ve 2) kullanılarak DSSAT modelinde bir domates yetiştirme mevsiminde bitki ve çevre koşullarının (bitki büyümesi, toprak nem içeriği vb.) değişimi ve mevsim sonunda elde edilecek verim miktarı simüle edilmiştir.

Çizelge 1. Domates bitkisine ait büyüme parametreleri

İlçe	Dikim Tarihi	Dönem Uzunluğu (gün)				kc_1	kc_3	kc_4	Başlangıç / En derin kök derinliği (m)	Mevsimlik k_y
		I	II	III	IV					
Ankara Bölge	Mayıs-II (11.05.2023)	30	30	55	30	0.53	1.17	0.81	0.15/0.90	1.05
Beypazarı						0.46	1.16	0.80		
Esenboğa						0.54	1.18	0.81		
Etimesgut						0.46	1.16	0.79		
Kızılcahamam						0.55	1.15	0.79		
Nallıhan						0.52	1.15	0.79		
Polatlı						0.52	1.18	0.81		

Çizelge 2. Domates bitkisine ait DSSAT modelinde kullanılan değerler

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Çeşit	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR
Florida	12.33	0.00	24.4	2.2	19.0	45.20	52.00	1.36	300.0
Çeşit	**SIZLF**	**XFRT**	**WTPSD**	**SFDUR**	**SDPDV**	**PODUR**	**THRSH**	**SDPRO**	**SDLIP**
Florida	300.0	0.78	.0040	26.0	300.0	55.0	8.5	.300	.050

DSSAT, 40'tan fazla bitki için üretim simülasyonu yapabilen bir yazılım olup, çevresel ve yönetim etkilerinin bitki üzerindeki etkilerini değerlendirmektedir (Jones vd., 2003; Hoogenboom vd., 2019; Hoogenboom vd., 2021). Alternatifleri değerlendirebilmek adına beş farklı ilçe yanında optimum ve kısıntılı sulama koşullarının da domates verimleri DSSAT kullanılarak simüle edilmiştir. DSSAT ile bitki büyümesinin modellenebilmesi için üç temel veri gerekmektedir (White vd., 2013; Hoogenboom vd., 2019):

- **Bitki büyüme dönemi boyunca hava durumu:** Meteoroloji istasyonu özelikleri (enlem, boylam ve deniz seviyesinden yükseklik), günlük güneş radyasyonu, maksimum ve minimum günlük hava sıcaklığı ve günlük toplam yağış miktarı.
- **Toprak yüzeyi özellikleri ve toprak profili verileri:** Horizon derinlikleri, kum, silt ve kil içeriği yüzdesi, organik karbon miktarı.
- **Yönetim ve deneysel veriler:** Ekim tarihi, başlangıç toprak durumu (su içeriği), ekim yoğunluğu, sıra aralığı, ekim derinliği, ürün çeşidi, sulama ve gübreleme uygulamaları.

Yukarıda belirtilen minimum gerekli veriler kullanılarak DSSAT'ta CROPGRO-Tomato modeli çalıştırılarak Florida çeşidi için mevsim sonunda elde edilebilecek verim miktarı ve mevsim boyunca değişen toprak su içeriği simüle edilmiştir.

2.2.1. DSSAT ile Veri Üretimi

Yeterli ve güvenilir gerçek verilere ulaşmanın zorlukları ve saha deneyleri yapmanın zaman alıcı olması sebebiyle, DSSAT simülasyon aracı kullanılarak gerçek saha koşullarını yansıtan simüle veriler elde edilmektedir. Çalışmada DSSAT modeli, sulama miktarında farklı konfigürasyonlarla verim üretmek için kullanılmıştır.

DSSAT, genetik değişikliklerden topraktaki besin ve su değişikliklerine kadar tüm değişiklikleri dikkate alan kapsamlı bir modelleme aracıdır. DSSAT'ın çalıştırılması için iklim verilerine, toprak verilerine, tarımsal uygulamalara ait bilgilere ve sulama programına ihtiyaç vardır.

Domates büyümesinin DSSAT simülasyonu için, Çizelge 3'te gösterildiği gibi ayrıntılı toprak girdileri doğru modelleme için büyük önem taşımaktadır. Toprak verileri, gri renkli ve iyi drene edilmiş koşullara sahip kil olarak tanımlanmıştır. Toprak, %1 eğim, orta derecede düşük yüzey akışı potansiyeli ve verimlilik faktörü 1 ile karakterize edilmiştir. Ayrıca, toprak farklı katmanlar halinde, her biri derinlik, kil ve silt yüzdeleri, organik karbon içeriği, pH, katyon değişim kapasitesi ve toplam azot gibi özelliklere sahip olarak ayrıntılı şekilde tanımlanmıştır. Başlangıçtaki toprak koşulları %100 kullanılabilir su ve 25 kg/ha azotu göstermektedir ve her

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katman için nem ve azotun detaylı dağılımı sağlanmaktadır. Bu veriler, Soba vd. (2015), Taşkın vd. (2018) ve Anonim (2018) araştırmalarından alınmıştır.

Çizelge 3. DSSAT toprak girdileri

Toprak Girdileri								
Toprak Bünyesi				Kil				
Renk				Gri				
Drenaj				İyi				
Eğim (%)				1				
Akış Potansiyeli				Orta derecede düşük				
Katman Bilgileri								
Derinlik	Ana Katman	Kil (%)	Silt (%)	Taş (%)	Organik Karbon	Sudaki pH	Katyon Değişimi (ds/m)	Toplam Azot
0-30 cm	-	34	40	0	2.27	8.1	13.1	0.11
30-60 cm	-	36	38	0	2.27	8.2	27.3	0.12
60-90 cm	-	36	38	0	2.33	8.6	33.1	0.12
90-120cm		36	38	0	2.33	8.2	27.7	0.12
Başlangıç Toprak Koşulları								
Su (% Kullanılabilir)				100				
Azot (kg/ha)				25				
Derinlik, Tabaka Tabanı (cm)		Hacimsel Su (cm^3)		Amonyum (NH_4) g[N] Mg^{-1}			Nitrat ($N0_3$) g[N] Mg^{-1}	
16		0.418		0.3			3	
16		0.418		0.3			3	
21		0.429		0.3			3	
58		0.431		0.3			3	

Ankara ilinde yaygın olarak domates ekimi Mayıs ayının başında hasadı ise Eylül ayında yapılmaktadır (Anonim, 2017). Ekim tarihi 2 Mayıs, hasat tarihi ise 24 Eylül'de olarak belirlenmiştir. Simülasyonda, her metrekareye bir bitki yoğunluğu hedeflenmiş ve fideler sıralar halinde düzenlenmiştir. Sıralar, 140 cm aralıklarla yerleştirilmiş, kuzey yönüne 0 derece eğimli ve 1.5 cm derinlikte dikilmiştir.

DSSAT, kapsamlı bir simülasyonu tamamlamak için birçok seçeneği göz önünde bulundurur ve örneğin evapotranspirasyonu hesaplamak için farklı yöntemler sunar. Bu nedenle, herhangi bir çalışma için simülasyon seçeneklerinin dikkatlice yapılandırılması önemlidir. Bu çalışmada, domates büyümesi için DSSAT simülasyonunda Çizelge 4'te ayrıntıları verilen belirli simülasyon seçenekleri kullanılmıştır. Simülasyon 2 Mayıs 2005 tarihinde başlamış ve 18 yıl boyunca yürütülmüştür. Su etkilerinin simülasyonu etkinleştirilmiş, diğer etkiler ise etkinleştirilmemiştir. Simülasyon verileri DSSAT yazılımının içerdiği yöntemler seçilerek elde edilmiştir. Başlangıç toprak koşulları raporlanmış ve hidroloji için Ritchie su dengesi yöntemi (Ritchie, 1972, 1998; Jones vd., 2003) seçilmiştir. Evapotranspirasyon FAO-56 yöntemi ile, toprak organik maddesi Ceres yöntemi (Ritchie, 1972; Jones vd., 2003) ile, infiltrasyon ise Soil Conservation Service yöntemi ile modellenmiştir. Toprak buharlaşması ise Ritchie-Ceres yöntemi seçilerek hesaplanmıştır. Yönetim seçeneklerinde simülasyon verileri üretme stratejisi izlenmiştir.

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Çizelge 4. DSSAT simülasyon seçenekleri

Simülasyon Seçenekleri			
Genel Bölüm			
Simülasyon başlangıç tarihi (aa/gg/yyyy)		05/02/2005	
Simülasyon çalıştırmaları		Yıl = 18	
Seçenekler Bölümü: Su etkilerinin simülasyonu etkinleştirilir, diğerleri etkinleştirilmez			
Simülasyon Yöntemleri			
Hava durumu	Ölçülen veriler (Ankara Bölgesi)	Fotosentez	Yaprak fotosentez tepki eğrisi (saatlik)
Başlangıç toprak durumu	Çizelge 3	Hidroloji	Ritchie su dengesi
Evapotranspirasyon	FAO-56	Toprak organik maddesi yöntemi	Ceres (Godwin)
İnfiltrasyon	Soil Conservation Service	Toprak buharlaşma yöntemi	Ritchie—Ceres
Yönetim seçenekleri: Simülasyon verisi oluşturma stratejisi tablosunda verilmiştir.			

Değişken sulama senaryoları altında verim ve toprak su içeriği için simüle edilmiş veriler üretmek üzere bir strateji geliştirilmiştir. Bu strateji, Çizelge 5'te görüldüğü gibi toplam 3258 simüle mevsim için damla sulamaya ilişkin sulama yönetimi parametrelerinin (derinlik, eşik, son nokta, sabit miktar ve yöntem) manipüle edilmesini içermektedir.

Çizelge 5. DSSAT simülasyon stratejisi

Meteoroloji Verileri	Sulama	Uygulama Derinliği (cm)	Eşik Seviye (mm)	Son Seviye (mm)	Sabit Miktar (mm)	Yöntem	Simülasyon Çalıştırmaları
Ankara Bölgesi	Yok	-	-	-	-	-	18
	Var	30	90	100	5	Damla sulama	3240
			20'ye ulaşana kadar 5 azalma		60'a ulaşana kadar 5'er artma		
			20		60		
Toplam Çalıştırmalar (Simüle Edilmiş Mevsim Verileri)							3258

3. SONUÇLAR VE DEĞERLENDİRME

Meteorolojik gözlemler istatistiksel olarak analiz edilmiş olup dağılımı Görsel 2'de verilmiştir. 2005-2022 yılları arasındaki sıcaklık verileri (en yüksek ve en düşük sıcaklıklar), hem kış hem de yaz aylarında belirgin bir artış eğilimi göstermiştir. Kış aylarında en yüksek sıcaklıklar sırasıyla 0.69 °C, 2.96 °C ve 1.45 °C artış gösterirken, en düşük sıcaklıklar 1.98 °C, 2.3 °C ve 2.12 °C ile daha yüksek artış göstermiştir. Bu durum, kışların zaman içinde belirgin bir şekilde daha sıcak hale geldiğini ortaya koymaktadır. Yaz aylarında ise Temmuz ayında en yüksek sıcaklık 0.08°C'lik hafif bir artış göstermiş, Haziran ve Ağustos aylarında ise en yüksek sıcaklıkta -1.05 °C'lik düşüşler meydana gelmiştir. Buna karşın, en düşük sıcaklıklar genel

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olarak yükselmiş ve daha sıcak gecelerle sonuçlanmıştır. Özellikle Eylül ayında hem en yüksek hem de en düşük sıcaklıklar sırasıyla 2.02 °C ve 1.28 °C oranında önemli artışlar kaydetmiştir. Genel olarak, veriler hem kış hem de yaz mevsimlerinin geçmişe göre daha sıcak hale geldiğini vurgulamaktadır.

Simüle edilen toplam 3258 büyüme mevsimi boyunca damla sulama yönetimi parametrelerinin alternatiflerinin kullanılması ile elde edilen simülasyon verileri ile ölçülen verilerin (Kesmez, 2009) karşılaştırması Çizelge 6'da verilmiştir. 2005 yılında simüle edilen verim ile gerçek verim arasındaki fark 284.92 kg kuru (6.83%) madde iken, 2006 yılında fark 3.5 kg kuru madde (0.09%) ile çok düşük bir seviyededir. Karşılaştırma sonucu, bu girdilerle DSSAT'ın Ankara'da yetiştirilen domates verimini simüle etmesinin kabul edilebilir düzeyde olduğunu göstermektedir.

Çizelge 6. DSSAT simülasyon bulguları

Yıl	Ölçülen (kg/ha – Kuru Madde)	Simüle edilmiş (kg/ha – Kuru Madde)	Hata (kg/ha - Kuru Madde)	Fark (%)
2005	4315.92	4031.00	284.92	6.83
2006	3921.57	3918.00	3.56	0.09

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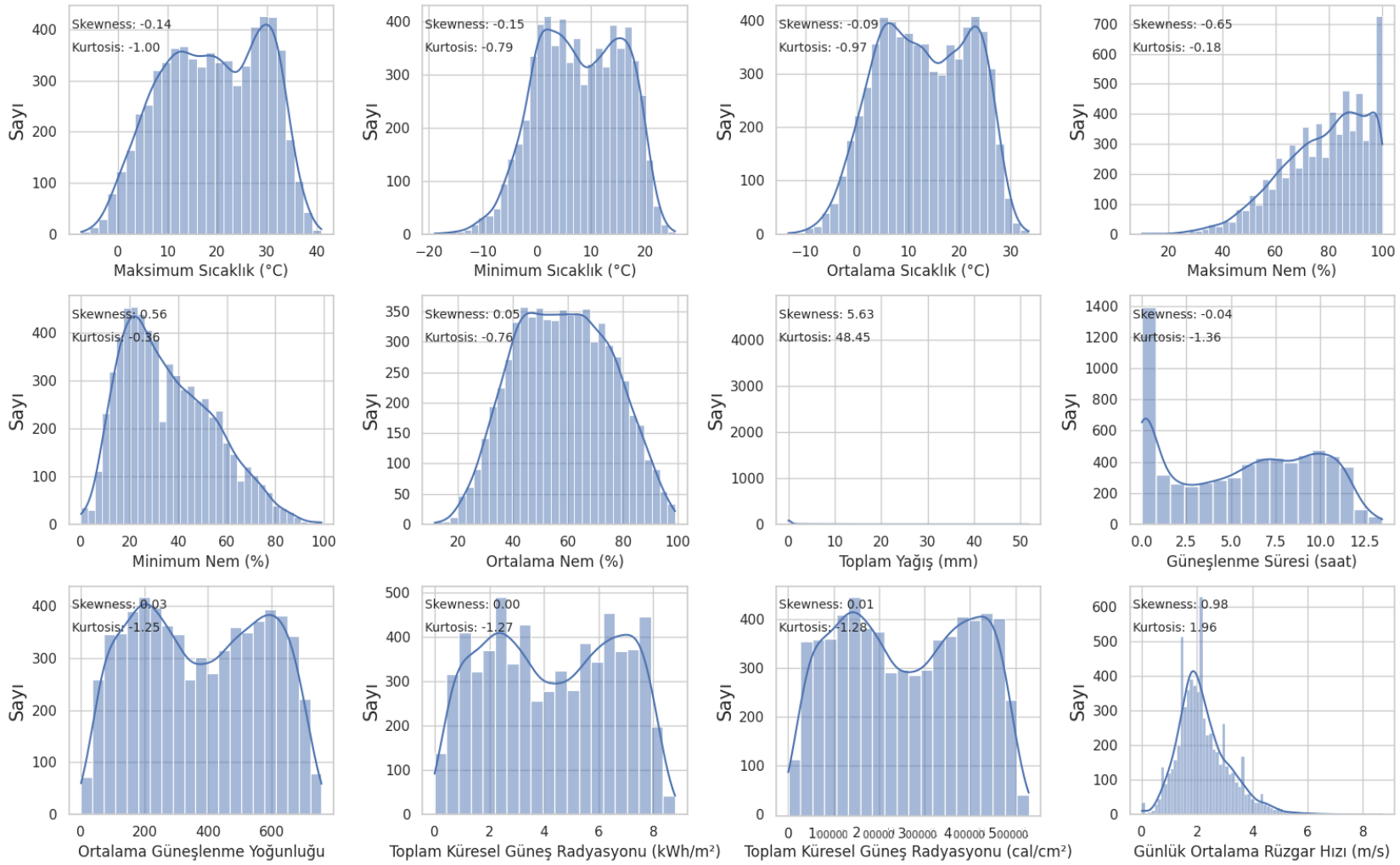

Görsel 2. Meteorolojik parametrelerin istatistiksel dağılımı (2005-2020)

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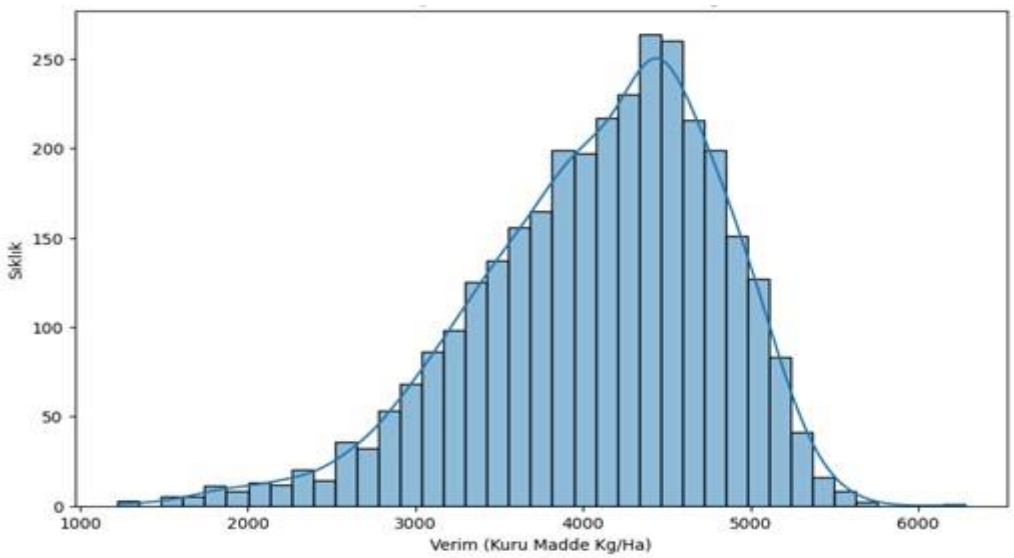
Sulama ve verim arasındaki ilişkiler hakkında bilgi sağlamak amacıyla DSSAT simülasyon verileri (verim ve toprak su içeriği) için tanımlayıcı istatistikler (ortalama, standart sapma, en düşük, en yüksek ve yüzdelik dilimler) hesaplanmıştır (Çizelge 7).

Çizelge 7. DSSAT çıktılarına ait tanımlayıcı istatistikler

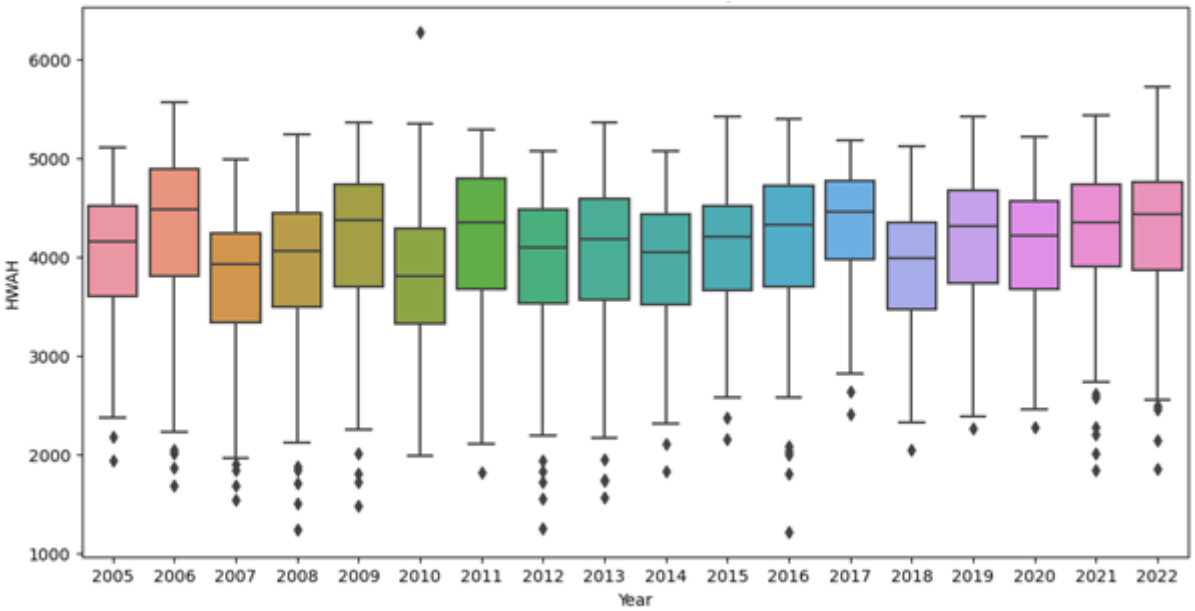
	HWAH	IR#M	IRCM	PRCM	ETCM	SWXM	ESCP	EPCP
Ortalama	4083.03	19.51	487.54	126.22	643.89	63.26	258.08	385.81
Standart sapma	721.64	15.66	404.88	47.81	129.64	22.27	60.56	96.65
En düşük	1224.00	0.00	0.00	61.00	243.00	32.00	80.87	154.82
0.25	3631.25	8.00	260.00	81.00	551.00	48.00	219.57	312.34
0.50	4186.00	14.00	365.00	121.50	649.00	58.00	251.90	393.64
0.75	4609.00	26.00	540.00	159.00	746.00	72.00	283.73	460.16
En yüksek	6276.00	93.00	2880.00	234.00	939.00	172.00	524.18	593.31

HWAH	Verim tahmini
IR#M	Sulama uygulamaları: uygulama sayısı
IRCM	Sezon uygulanan sulama (kayıplar dahil) (mm)
PRCM	Toplam sezon yağışı (mm), simülasyon - hasat
ETCM	Toplam sezon evapotranspirasyonu, simülasyon-hasat (mm)
SWXM	Hasatta toplam kullanılabilir su (mm)
ESCP	Toplam toprak buharlaşması, ekimden hasada kadar (mm)
EPCP	Toplam transpirasyon, ekimden hasada kadar (mm)

Yıllar içinde hektar başına simüle edilen verimi Görsel 3'te, verimin yıllara göre dağılımı Görsel 4'te verilmiştir. Grafikteki her kutu, belirli bir yıl için verim verilerinin çeyrekler arası aralığını (IQR) temsil etmekte, kutunun içindeki çizgi ise medyan verimi göstermektedir. Medyan verim (kutudaki orta çizgi) çoğu yıl için 4000 kg/ha civarında dalgalanmaktadır ve zaman içinde nispeten istikrarlı merkezi verim değerlerine işaret etmektedir. Görsel 4, her yıl için en yüksek verime ulaşabilecek bir sulama konfigürasyonu olduğunu göstermektedir. Genel eğilim incelendiğinde, tarımsal uygulamalarda veya elverişli iklim koşullarında olası iyileştirmeler sonucunda hafif bir artış eğilimi olduğu, ancak iklim koşullarındaki değişikliklere bağlı olarak verimde azalmalar da gözlemlendiği anlaşılmaktadır.

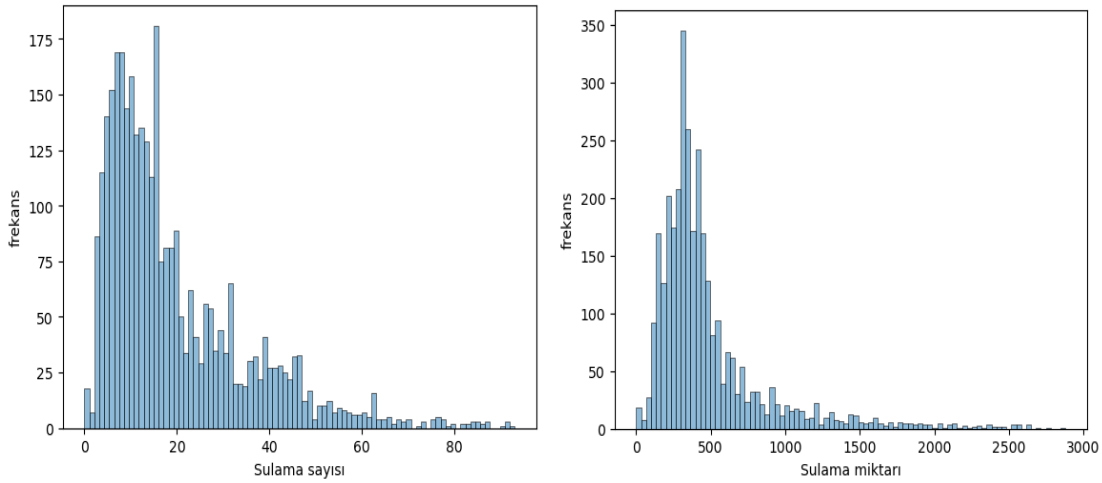


Görsel 3. DSSAT'tan elde edilen simüle edilmiş verim değerlerinin dağılımı



Görsel 4. 2005'ten 2022'ye kadar verimin (HWAH) yıllık dağılımı

Sulama sayısı ve miktarının dağılımı Görsel 5'te verilmiştir. Sulama uygulamalarının dağılımını ve uygulanan su miktarını anlamak, verimi en üst düzeye çıkarmak için en uygun sulama sıklığını tanımlamak açısından çok önemlidir. Simüle edilmiş verilerdeki sulama uygulama sayısına bakıldığında, ortalama sulama sayısı (IR#M) 19.51'dir (Çizelge 7 ve Görsel 5) ve bu ise domateste damla sulamanın genel sıklığını göstermektedir. Sulama sayısı, farklı sulama yönetimi uygulamalarını yansıtacak şekilde 0 ile 93 arasında değişen önemli farklılıklar göstermektedir. Uygulanan su miktarı yüksek değişkenliğe sahiptir. Bu ise uygulanan su miktarındaki değişime bağlı olarak verimdeki değişiklikleri gösteren sulama stratejilerinin modellenmesi ve ayrıca su kullanım verimliliğinin artırılması ve sürdürülebilir tarım uygulamalarının sağlanması için önemlidir.



Görsel 5. Sulama sayısı ve sulama miktarının dağılımı

DSSAT ile simüle edilen verilerden elde edilen gerçek evapotranspirasyon (ET_a) dağılımı Şekil Görsel 6'da verilmiştir. DSSAT, büyüme mevsimi boyunca gerçek evapotranspirasyonu (ET_a) birçok faktör ve yaprak alan indeksine bağlı olarak hesaplamaktadır. ET_a, topraktan ve bitki

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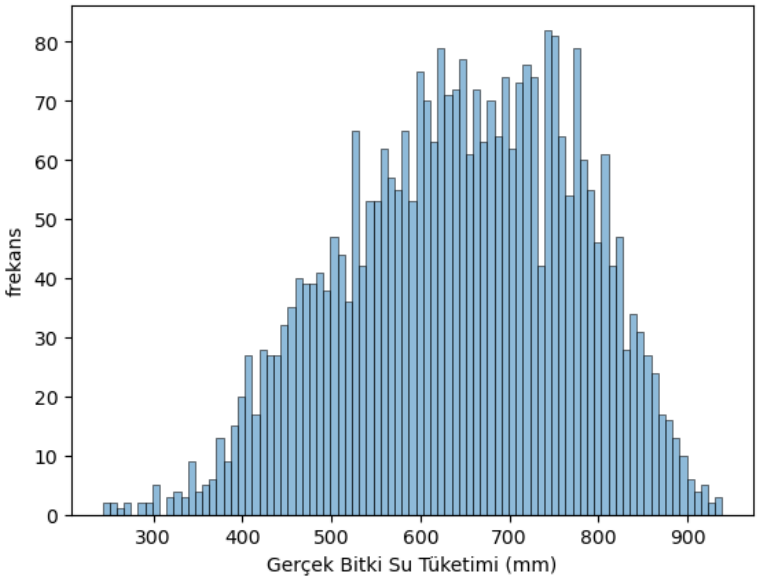
yüzeyinden su kaybını temsil ettiği için sulama programlarının planlanmasında kritik bir rol oynamaktadır.



Görsel 6. DSSAT ile simüle edilen verilerden elde edilen gerçek evapotranspirasyon dağılımı

Verim ile sulama sayısı, uygulanan sulama miktarı, gerçek evapotranspirasyon (ET_a) ve topraktaki kullanılabilir su arasındaki ilişki Görsel 7'de verilmiştir. DSSAT simülasyonu sonucu ortalama verim 4083.03 kg/ha olup bu değer tipik verimlilik seviyesini göstermektedir ve verim aralığı minimum 1224 kg/ha ile maksimum 6276 kg/ha arasında önemli ölçüde değişmekte olup farklı sulama yönetimi koşullarından kaynaklanan geniş bir varyasyon sergilemektedir. Standart sapmaya göre 721.64 kuru madde kg/ha, verim değerlerinin çoğunun 4083.03 ± 721.64 kg/ha aralığında (yani 3361.39 kg/ha ile 4804.67 kg/ha arasında) yer aldığını ve bu aralıktan daha yüksek ve daha düşük değerlerin standart sapma değerlerini artıran aykırı değerler olarak kabul edilebileceğini göstermektedir. Analizler, yüksek verimin sezonda yaklaşık 20 sulama uygulaması ile elde edildiğini ve bu aralıktaki veri noktalarının çoğunun bu bölgede yoğunlaştığını ortaya koymuştur. Sulama sayısının 20'nin üzerine çıkması, verimde azalma ve aşırı sulamanın olumsuz etkilerini göstermektedir.

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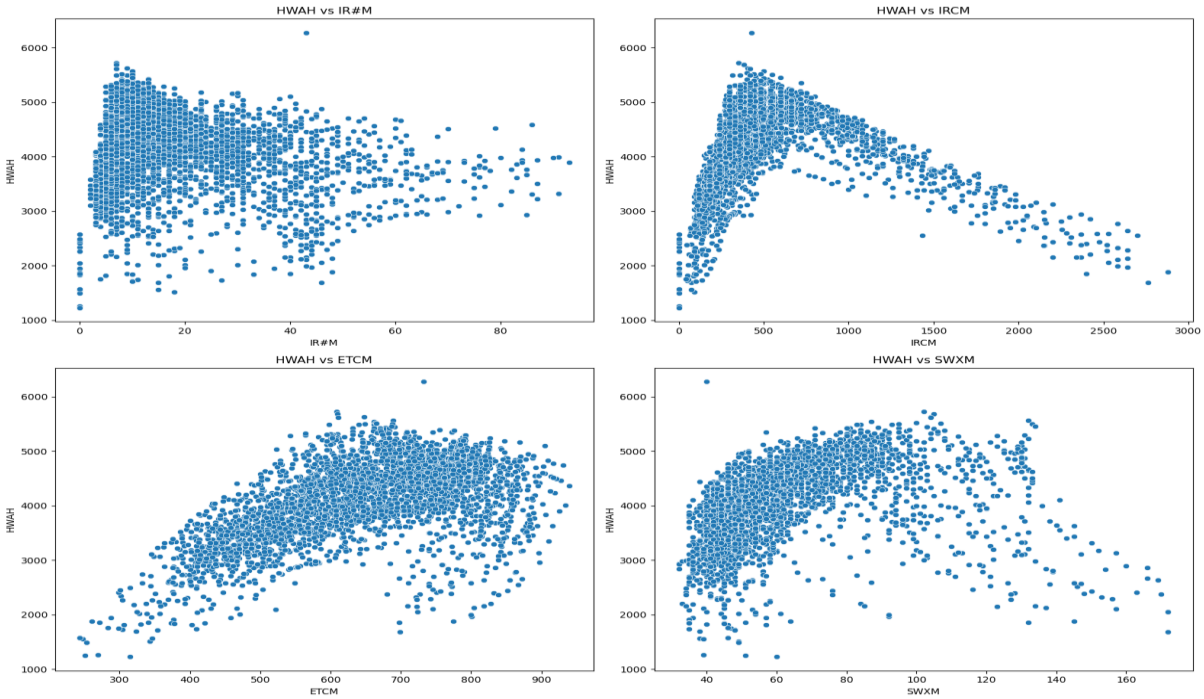

Görsel 7. Verim ile sulama sayısı, uygulanan sulama miktarı, gerçek evapotranspirasyon (ET_a) ve topraktaki kullanılabilir su arasındaki ilişki

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Bu çalışmada, Ankara bölgesinde domates yetiştiriciliğimde optimum sulama stratejilerinin belirlenmesi amacıyla DSSAT CROPGRO-Tomato modelinin kullanımı ve bu modelin sonuçları değerlendirilmiştir. Ankara'nın yarı kurak iklim koşulları, su kaynaklarının verimli kullanılmasını gerekli kılmaktadır. Bu kapsamda sulama stratejilerinin doğru planlanması büyük önem taşımaktadır. Çalışmada DSSAT modeli, bitki büyümesi ve verim simülasyonlarıyla sulama planlamasında etkili bir karar destek sistemi olarak kullanılmıştır. Model sonuçları incelendiğinde, DSSAT'ın domates verimini kabul edilebilir bir seviyede simüle ettiği belirlenmiştir. Çalışma bulguları, modelin sulama planlamasında etkili bir araç olarak kullanılabileceğini göstermektedir. Özellikle iklim değişikliğinin gelecekte bitkisel üretim üzerinde yaratabileceği olumsuz etkiler dikkate alındığında, bu tür gelişmiş modellerin kullanımı giderek daha fazla önem kazanmaktadır. DSSAT gibi simülasyon modelleri, farklı iklim senaryolarını ve sulama stratejilerini değerlendirme imkânı sunarak karar vericilere önemli bilgiler sağlamaktadır. Sonuç olarak, bu çalışma, Ankara bölgesindeki domates yetiştiriciliğinde optimum sulama stratejilerinin belirlenmesinde DSSAT modelinin etkinliğini göstermiştir. İklim değişikliği ve azalan su kaynaklarına karşı bitkisel üretimin sürdürülebilirliğini sağlamak adına DSSAT gibi karar destek sistemlerinin kullanımı büyük önem taşımaktadır.

TEŞEKKÜR: Bu çalışma, TÜBİTAK 1002A Hızlı Destek programı kapsamında 123O766 proje numarası ile desteklenmiştir. Bilimsel çalışmamıza verdiği destekten ötürü TÜBİTAK'a teşekkür ederiz.

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SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) BREEDING OBJECTIVES

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ABSTRACT

Safflower (*Carthamus tinctorius* L., 2n:24) is strong root developing, abundantly branching, oil seed crop generally up to 100 cm tall from the Compositae family. Safflower is an important crop for arid agricultural areas due to its high tolerance to cold and drought. Safflower seeds contain an average of 35-40% oil. This seed oil has properties that can be used for both food and industrial purposes. Due to the high linoleic ($C_{18}H_{32}O_2$) fatty acid content, safflower seed oil provides raw materials to many industries. Its seeds are also evaluated in animal nutrition. Carthamin, which contains a yellow-red dye, is obtained from the petals of the safflower flower. With plant breeding studies, the genetic structure of economically important plants is changed and developed within a plan according to the demands of growers and consumers. The aim of plant breeding is to contribute to agricultural production by developing high-quality and productive cultivars that are more suitable for climate and soil conditions and resistant to diseases and pests. Although safflower plants have many advantages over other oil crops, there is a need to develop high-yield hybrid cultivars for their cultivation to become widespread. Among the basic goals targeted in safflower breeding programs are “high oil content, high seed yield, resistance to diseases and spineless”. In this study, the breeding purposes, and targets of the aspirin plant for use in different areas were evaluated with current literature data.

Keywords: Seed yield, oil content, fatty acid, flower color, spiny

1. INTRODUCTION

Safflower (*Carthamus tinctorius* L., 2n:24) is an oilseed crop in the Compositae family. Today, safflower is cultivated in many countries. It has a wide range of uses (food, paint, ornamental plant, animal feed, cosmetics etc.) (Emongor, 2010). This plant has great economic value, especially in Asian countries. It is cultivated for medical purposes and biodiesel production in these countries. It is also an important food source for animal husbandry (Menegaes et al., 2021). It is an alternative product for those who produce grain. In addition, dyes are obtained from safflower leaves. Red petals are used as a spice (false saffron) (Buyukkurt et al., 2021; Özçınar, 2021)

According to FAOSTAT (2022) data, world safflower seed production increased by 36.9% compared to the previous year, reaching 995,508 tons. Kazakhstan ranked first in safflower seed production with 447,457 tons. Russia and the USA followed this country (Figure 1).

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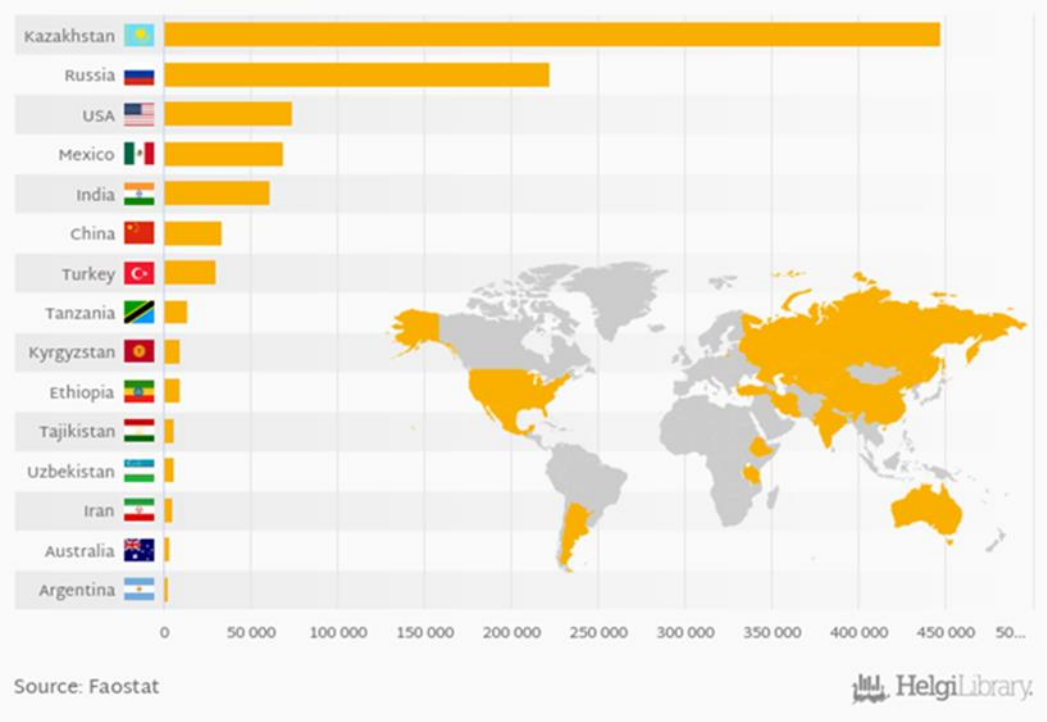

Figure 1. Global safflower seed production of countries

The USA is the leading country in safflower oil production. According to FAOSTAT 2021 data, the USA produced 21,125 tons of safflower oil. This value corresponds to approximately 35% of total production. India, the world's second largest safflower producer, produced 11,000 tons. Mexico, Argentina, Belgium, and Spain followed India with lower production.

According to TÜİK (2023) data, cultivation was conducted in 321 298 da of land in Türkiye, and 39 000 tons of production was obtained. Seed yield was 121 kg/da. The main provinces that cultivate safflower are shown in Figure 2. Seventy-two percent of the safflower produced is consumed for food purposes.

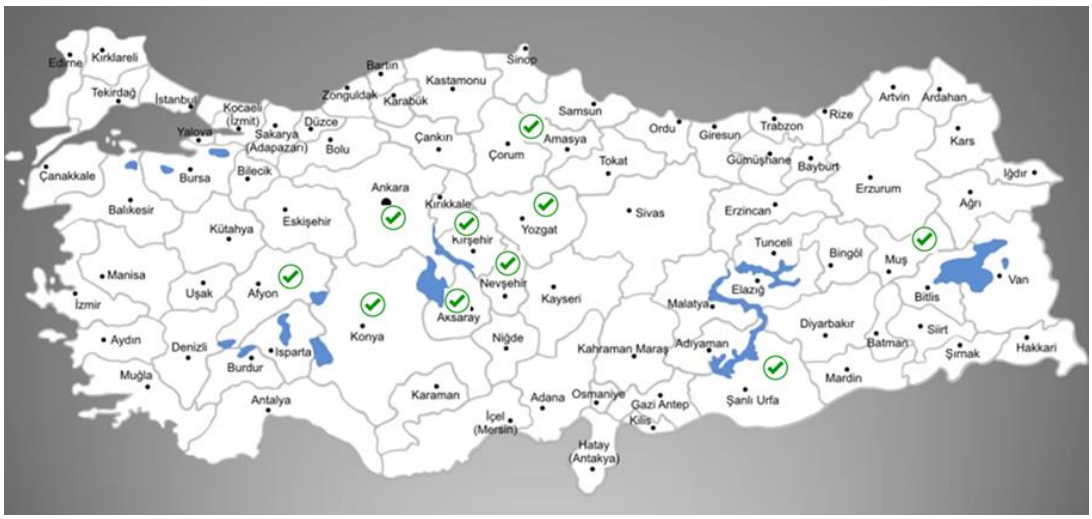

Figure 2. Main provinces that cultivate safflower in Türkiye

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2. SAFFLOWER BREEDING OBJECTIVES

There are fifteen registered safflower cultivars in Türkiye. Important properties of these cultivars are summarized in Table 1.

Table 1. Registered safflower cultivars in Türkiye and their important properties

Cultivar Name	Type (Spiny + Spineless -)	Flower color	Plant Height (cm)	Seed color	Oil content (%)	1000 seed weight (g)
Yenice 5-38	-		100-120		24-25	38-40
Dinçer (5-18-1)	-		90-110		25-28	45-49
Remzibey 05	+		60-80		35-40	46-50
Balcı	+		55-70		38-41	40-48
Linas	+		85-90		37-38	40-44
Olas	+		90-100		39-41	38-42
Göktürk	+		90-100		34-35	40-45
Asol	+		70-80		40-41	45-48
Hasankendi	+		80-90		35-36	38-45
Olein	+		70-90		31-36	34-44
Askon42	+		70-90		33-37	36-54
Yekta	+		80-100		35-37	40-50
Servetağa	+		85-90		35-40	35-40
Koç42	+		70-90		37-39	40-50
Safir	+		70-150		33-39	40-42

(SOURCE: Eryılmaz and Şahin, 2023)

Safflower is particularly well adapted to arid and semiarid regions with low rainfall. This gives hope that the plant will gain even more importance in the near future and its cultivation will develop further. On the other hand, hybrid safflower varieties should be developed so that the safflower plant can compete with sunflower, an important oil crop (Sefaoğlu and Özer, 2022).

Safflower breeding objectives:

The most important breeding criterion in safflower is seed yield. The average seed yield in Türkiye is 120 kg/da. However, sometimes this yield can be much lower. Genotype and environmental conditions are effective on seed yield. New varieties with high yield potential need to be developed (Koç, 2021). One of the most important selection criteria for earliness is

the shortness of the rosette period. Varieties with a short rosette period are not only earlier, but also have stronger competition with weeds (Baydar and Erbaş, 2014).

The fatty acid composition of safflower oil includes unsaturated fatty acids [16-20% oleic acid (C18:1) - 71-75% linoleic acid (C18:2)] and saturated fatty acids [6-8% palmitic acid (C16:0) - 2-3% stearic acid (C18:0)] (Amirkhiz et al., 2021). The amount of saturated fatty acids is 10%. It is desired for this ratio to be lower (below 4%) and for the oleic acid content to be high (90%).

Safflower oil has desirable properties in terms of health. It has ideal properties like cooking and frying oil. It is used industrially in cosmetics and skin care products. In addition, safflower oil is used in the painting sector and varnishes due to its fast drying and protective coating properties (Khalid et al., 2017).

There are spiny and spineless safflower types. Spiny is an important cultivar characteristic. Cultivars cultivated worldwide include both spiny and spineless types. In spiny cultivars, leaves and heads are covered with spines of varying temperatures and lengths (Landau et al., 2004). Spiny cultivars have higher seed yields and oil ratios than spineless ones. Spiny cultivars are more resistant to drought. Spiny cultivars are more suitable for flower production (Kayaçetin, 2022).

Safflower genotypes are morphologically grouped according to whether they are spiny or spineless and flower color. Flower color varies according to the variety. Safflower has mainly white, light yellow, light orange, yellow, red orange and yellow-orange flower colors (Erbaş and Mutlucan, 2023). However, flower color varies according to budding, flowering and maturation stages.

Safflower can be sown both in winter and summer (Coşkun, 2014). In regions with long and harsh winters: SUMMER sowing, in climate regions with mild winters: WINTER sowing is applied. The rosette stages of cold-resistant winter safflower cultivars are longer. The rosette leaves of these plants are flatter to the ground, and the base and leaves are spinier. In winter cultivars, the seed husk ratio is higher, the oil ratio is lower, and the seed yield is higher. Registered safflower cultivars in our country are not resistant to cold and frost. They are damaged in the harsh winter months of the continental climate (Naderi et al., 2015). For this reason, safflower is only grown as a summer plant outside of regions where the Mediterranean climate is effective.

3. CONCLUSION

The most important breeding objectives of the safflower plant are:
1-Increasing the yield of safflower seeds,
2-Shortening the vegetation period,
3-Reducing the amount of shell in the seed,
4-Increasing the fixed oil content in the seed,
5-Changing the composition of fatty acids according to the purpose of use,
6-Making it suitable for the mechanization used in its cultivation,
7-Providing adaptation to climatic stress conditions,
To be suitable for mechanical production, the plant height is approximately 80 cm, the maturation period is 3-5 months, the average number of branches is 7, the number of heads is 12-14 and the minimum oil content is 50%. For safflower agriculture to develop in our country,

it is primarily important to develop new productive varieties suitable for winter and usage purposes.

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EVALUATION OF RELATIONSHIPS BETWEEN SEED YIELD AND SOME AGRONOMIC CHARACTERS IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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ABSTRACT

Safflower (*Carthamus tinctorius* L.) is an important annual oil crop that has been cultivated since ancient times. The plant height is average 1-1.5 m. The plant has a main stem and many side branches attached to the main stem. The number of side branches varies between 10-30 depending on the variety, climatic conditions and cultural practices. The flower is in a small head at the end of the main stem and side branches. Seeds are in a fibrous structure made of cellulose in a head that has reached harvest maturity. Although it varies according to cultivars, thousand seed weight is between 30-45 g. Plant height, number of branches, number of head, number of seeds per head, seed yield per plant, thousand seed weight and oil ratio are the characters related to seed yield in safflower. Seed yield is a quantitative trait that is controlled by many genes and significantly affected by environmental factors. Therefore, to be successful in plant breeding programs, it is more effective to use yield elements and quality traits as selection criteria instead of yield. In this study, correlation, path and biplot analyses were performed and a heat map was created to determine the relationships between seed yield and yield components of some safflower varieties and to determine selection criteria. It was determined that plant height, number of branches, number of heads and thousand seed weight had positive effects on seed yield.

Keywords: Yield, selection, correlation, thousand seed weight

1. INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an important annual oil crop that has been cultivated since ancient times (Ekin, 2005). The plant has versatile uses. It provides raw materials for various sectors such as food, medicine, cosmetics, and paint (Emongor, 2010). Due to its deep root system, the plant's ability to benefit from moisture deep in the soil increases its resistance to drought. It has very little climate and soil selectivity (Mosupiemang et al., 2022).

For safflower production to develop and compete with other oilseed crops, high yielding cultivars are needed. To develop suitable cultivars for the purpose in safflower, it is of great importance to determine the relationships between yield-related characters to determine the selection criteria in the breeding program to be implemented (Sampaio et al., 2016).

Scientifically, the relationship between two characters is expressed by correlations. With correlation analysis, we also have information about the direction and intensity of the relationship between yield and yield components (Schober et al., 2016). When it is desired to find the parts resulting from the relationship with other variables in the correlation coefficient calculated between variables, we use path analysis. With path analysis, for example, we can determine the direct and indirect effects on seed yield. We can use the findings obtained from path analysis in selection breeding (Açıkgöz et al., 2004).

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To better emphasize the relationships between the examined characters, they are visualized in different ways. Biplot analysis is frequently used in agricultural studies to visually evaluate data. Biplot is a two-way table design. It graphically displays row and column factors. In this analysis method, both the relationships between row and column factors and their binary interactions can be visually displayed (Torres-Salinas, 2013). In addition, heat maps, which are a method of graphically representing data, are used. Heat maps make it easier to visualize complex data and understand it briefly.

In this study, to determine the relationships between seed yield and yield components of some safflower cultivars and to determine the selection criteria, correlation, path and biplot analyses were performed using MINITAB, TARIST statistical programs and EXCEL and a heat map was created.

2. MATERIAL AND METHOD

Seven different safflower cultivars were used in the studies carried out in Ankara ecological conditions and the yield and yield components explained below were determined. The data obtained were analyzed using TARIST and MINITAP package programs (Açıkgöz et al., 2004).

The yield and yield components examined (Figure 1 and Figure 2):
Plant Height (cm): Determined by measuring the level from the soil level to the tip of the plants that have reached harvest maturity.
Number of Heads per Plant: The heads of the plant were counted.
Number of Branches per Plant: All branches of the plant were counted.
Thousand Seed Weight (g): Calculated using the formula A1+A2+A3+A4 / 4 X10 [A: Weight of 100 seeds].
Seed Yield (kg/da): Yield per decare was calculated using the formula 1000 m2 x plot yield / plot area.
Oil Ratio (%): The shelled crude oil ratio of the seeds was determined by the Soxhelet device.

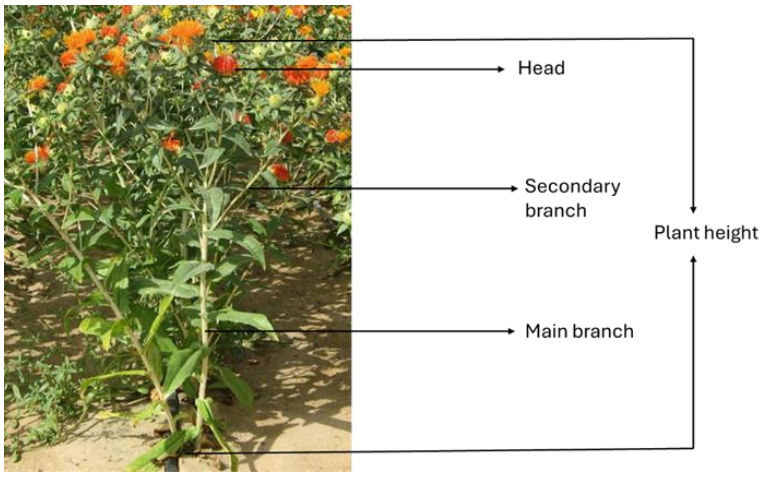

Figure 1. General view of the safflower plant and aerial parts

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Figure 2. Safflower head and seeds

3. RESULTS AND DISCUSSION

The bilateral relations between the yield and yield elements examined were examined by correlation analysis (Table 1). A heat map was created with the Excel application for the data in the analysis table.

Table 1. Correlation analysis results

	SY	PH	BN	HN	TSW
PH[2]	0,895[1]				
BN	0,828	0,789			
HN	0,891	0,856	0,926		
TSW	-0,423	-0,432	-0,548	-0,516	
OR	-0,305	-0,23	-0,369	-0,303	0,287

[1](Correlation coefficient (r) = 0.00-0.10 Insignificant correlation, r=0.40-0.69, Moderate correlation, r=0.10-0.39, Weak correlation, r=0.70-0.89, Strong correlation, r=0.90-1.00 Very strong correlation)
[2]PH: Plant Height, BN: Branch Number, HN: Head Number, TSW: Thousand Seed Weight, OR: Oil Ratio

The interpretation of the correlation analysis was made according to Schober et al., (2018). According to the correlation analysis, a very strong positive relationship was found between seed yield and plant height, branch number and head number. A negative and moderate relationship was found between seed yield and thousand seed weight. A negative but weak relationship was also recorded between seed yield and oil ratio. A very strong positive relationship was found between plant height and branch number and head number, and between branch number and head number. A negative moderate relationship was observed between head number and 1000 seed weight (Table 1). The matrix graph of each examined character is presented in Figure 3.

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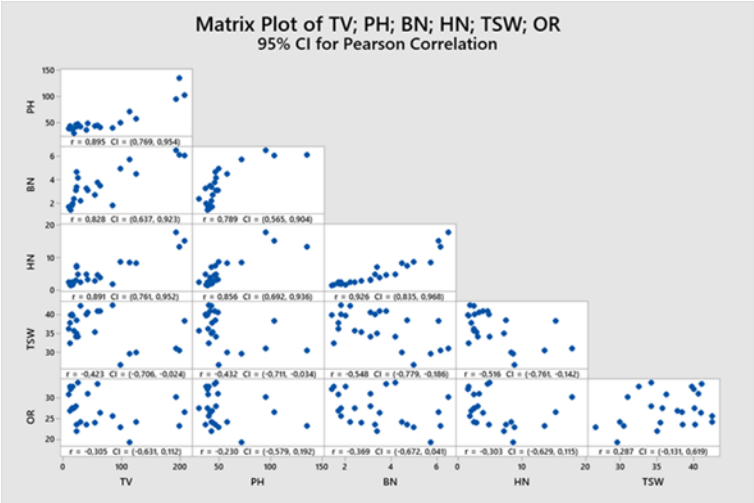

Figure 3. Matrix plot of TV, PH, BN, HN, TSW, and OR (PH: Plant Height, BN: Branch Number, HN: Head Number, TSW: Thousand Seed Weight, OR: Oil Ratio).

The path coefficients and percentage values in the analysis conducted to determine the direct and indirect effects of the examined traits on seed yield are presented in Table 2.

Table 2. Path coefficients and percentage values (%) of the characters that directly and indirectly affect seed yield (kg/da) in safflower.

Character[1]	Direct Effect	Indirect Effects				
		PH	BN	HN	TSW	OR
PH	**0.5009 (53.0429)[2]**		0.3959 (44.3426)	0.4288 (45.1279)	-0.2162 (40.1907)	-0.1052 (32.5990)
BN	**0.0228 (2.5617)**	0.0180 (1.9059)		0.0211 (2.2251)	-0.0125 (2.3258)	-0.0081 (2.5031)
HN	**0.4526 (47.6273)**	0.3874 (41.0288)	0.4193 (47.0662)		-0.2336 (43.4253)	-0.1301 (40.3075)
TSW	**0.0575 (10.6840)**	-0.0248 (1.3951)	-0.0315 (3.5373)	-0.0297 (3.1223)		0.0166 (5.1540)
OR	**-0.0627 (19.4366)**	0.0132 (1.3951)	0.0222 (2.4922)	0.0180 (1.8973)	-0.0182 (3.3741)	

[1] PH: Plant Height, BN: Branch Number, HN: Head Number, TSW: Thousand Seed Weight, OR: Oil Ratio. [2]Values in parentheses indicate path percentages.

According to Table 2, plant height (%53.0429) and head number (%47.6273) were found to be the most directly effective characters on seed yield per decare. This was followed by oil ratio (negative effect) and thousand seed weight, respectively. The highest positive indirect effect on seed yield was head number over branch number with a path coefficient of 0.4193 and the path percentage was found to be 47.0662. In addition, positive indirect effects of plant height over branch number and head number and head number over plant height were determined on seed yield. Indirect negative effects of plant height and head number over thousand seed weight were observed.

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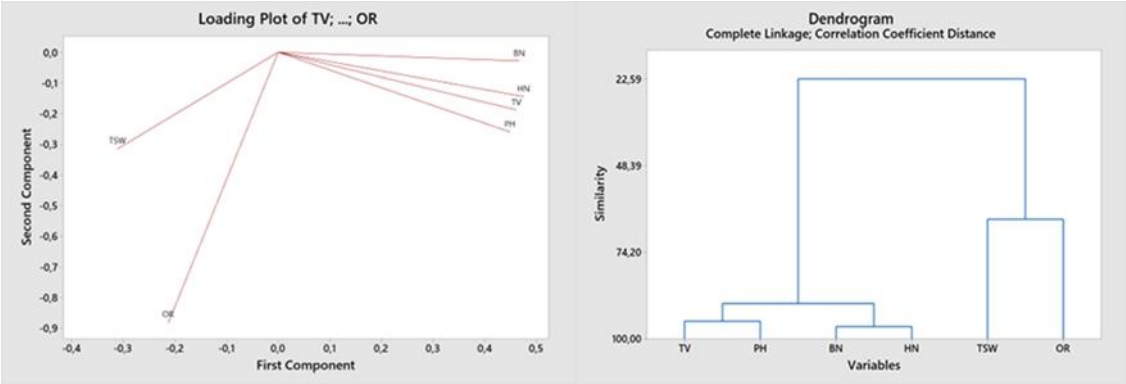

Figure 4. Biplot graph (left) and dendrogram (right) of the examined yield and yield components

When the biplot graph is examined, it is seen that thousand seed weight and oil ratio are negatively related to other yield elements. Similarly, these two characters are in a different group in the dendrogram (Figure 4).

The most important selection criteria in safflower breeding are seed yield and oil content (Koç, 2021). The main criteria for determining seed yield in safflower are the number of heads in the plant and the number of seeds in the head (Nikzad and Baydar, 2023). A negative relationship has often been observed between oil content and seed yield in safflower (Mokhtassi Bidgoli et al., 2006). It has been reported that genotypes with high oil content generally have lower seed yield. The maximum direct effect on seed yield is the number of heads in the plant and plant height. In a study conducted, a positive and significant correlation was determined with seed yield, plant height, seed yield per plant, seed weight per plant and biological yield per plant, and it was recorded that the greatest direct effect on seed yield was plant height, seed weight/head and 1000 seed weight (Köse et al., 2018; Sırel and Aytaç, 2016; El Bey and Kurt, 2023).

In line with the findings obtained from the research, it is seen that considering plant height, head number and branch number affecting yield in selection studies related to safflower breeding will make a significant contribution to increasing safflower seed yield.

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DETERMINATION OF THE SUITABILITY OF DIFFERENT WATER RESOURCES FOR IRRIGATION IN AYAŞ REGION

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ABSTRACT

The main purpose in agricultural production is to provide maximum efficiency. The most significant input in increasing agricultural productivity is irrigation. However, it is also necessary to take into consideration the effects of the solid substances dissolved in the water and given to the soil with the irrigation water. Nowadays, since it is difficult to find water in sufficient quantity and quality, low quality water is also used in agriculture. The use of these waters may cause arable lands to become saline over time and the expected yield in plant production to decrease.

In this study, the irrigation water quality of 1 dam, 2 ponds, 3 streams and 8 wells used for irrigation purposes in Ayaş district of Ankara province was examined and their suitability for the products grown in the region was discussed by evaluating them according to certain classification systems. According to the results, there is no restricting factor inhibiting the use of irrigation water samples taken from 14 source, except 3 of them. In sodium classification of water samples, it has been found that 4 samples are classified into the best quality, 8 samples are classified into good quality, and 2 samples are classified into acceptable quality. In the salinity assessment, it was determined that eight samples were in the good, i.e. medium salt water class, three samples were in the high salty water class within acceptable limits, and three samples were unusable due to very high salt content. It is clear that the use of these high salt content waters in the cultivation of plants sensitive to salinity will cause a decrease in yield. It has been revealed that some salinity management studies such as selection of irrigation method, drainage and leaching water addition should be carried out in the region to prevent yield reduction.

Key Words: Irrigation water quality, salinity, crop production

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AYAŞ YÖRESİNDEKİ FARKLI SU KAYNAKLARININ SULAMAYA UYGUNLUĞUNUN BELİRLENMESİ

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ÖZET

Tarımsal üretimde asıl amaç maksimum verimi sağlamaktır. Verim artışındaki en önemli girdi ise sulamadır. Ancak, sulama suyu ile birlikte toprağa verilen, suda erimiş halde bulunan katı maddelerin etkilerini de göz önünde tutmak gerekmektedir. Çünkü bu maddelerin miktar ve cinsleri, sulama suyunun kalitesini belirlemektedir. Günümüzde, yeterli miktar ve kalitede su bulmak zorlaştığı için, düşük kaliteli suların da tarımda kullanımı söz konusudur. Bu suların kullanımı zamanla tarım yapılabilir arazilerin tarım dışı kalmasına ve bitkisel üretimde beklenen verimin düşmesine neden olabilmektedir.

Bu çalışmada, Ankara ili Ayaş ilçesindeki sulama amaçlı kullanılan 1 baraj, 2 gölet, 3 akarsu ve 8 kuyu sularının sulama suyu yönünden kaliteleri incelenmiş ve belli sınıflandırma sistemlerine göre değerlendirilerek bölgede yetiştirilen ürünler için uygunluğu tartışılmıştır. Elde edilen bulgulara göre, seçilen 14 sulama suyu örneğinden 3'ü dışındakilerin kullanımında herhangi bir kısıtlayıcı etkene rastlanmamıştır. Su örneklerinin sodyum sınıflandırmasında; dört örneğin çok iyi kalitede sular sınıfında, sekiz örneğin iyi kalitede sular ve iki örneğin kabul edilebilir sınırlarda sular olduğu belirlenmiştir. Tuzluluk değerlendirmesinde ise sekiz örneğin iyi, yani orta tuzlu sular sınıfına girdiği, üç örneğin kabul edilebilir sınırlarda yüksek tuzlu sular sınıfında, üç örneğin ise, çok yüksek tuz içeriği ile kullanılamaz olduğu saptanmıştır. Tuzluluğa hassas bitkilerin yetiştirilmesinde bu yüksek tuz içerikli suların kullanılmasının verimde düşüşe neden olacağı açıktır. Verim azalmasını engellemek için bölgede sulama yöntemi seçimi, drenaj ve yıkama suyu ilavesi gibi bazı tuzluluk yönetimi çalışmalarının yapılması gerektiği ortaya çıkmıştır.

Anahtar Kelimeler: Sulama suyu kalitesi, tuzluluk, bitki verimi

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1. GİRİŞ

Dünya nüfusu her geçen gün artarken, temel gıda ihtiyacı da bununla birlikte artmaktadır. Gıda ihtiyacı sorunu dünyadaki en büyük sorunlardan biri olarak karşımıza çıkmaktadır. Gıda ihtiyacındaki açığın kapanmasında en etkili yol tarımsal üretimin arttırılmasıdır. Tarımsal üretimdeki artış ancak uygun olmayan şartlarda da üretim yapabilme imkanlarının araştırılmasına bağlıdır. Su kaynaklarının geliştirilmesine yönelik çalışmalarda, toprak kaynaklarının sulama için uygunluğu yanında, su kaynağının da kantite ve kalite yönünden uygun olması, sulama projelerinin başarısında oldukça önemli bir etmeni oluşturmaktadır.

Tarımda kullanılan sulama sularının tamamı saf su olmadıkları için bünyelerinde tuz içerirler. Bu tuzların konsantrasyon ve çeşitleri, suların kalitesi hakkında bilgi sağlar. Suyun kalitesi de kullanım için uygunluğu gösteren bir ölçüttür. Tarımsal yönden suların uygunluğuna karar vermede sadece iklim-toprak-bitki özellikleri değil, aynı zamanda sulama, tuzluluk ve drenaj açısından çiftçinin bilgi birikimi de önem arz etmektedir.

Sulama alanlarında yeterli miktarda ve yeterli kalitede su bulmak giderek zorlaşmaktadır. Çünkü her geçen gün su kaynaklarındaki kirlilik yükünde artışlar gözlenmektedir. Özellikle teknolojideki ilerleme, sanayi ve endüstriyel yayılımı tetiklemiş ve endüstriyel kirliliğin yaygınlaşmasına sebep olmuştur. Dünyada birçok yörede su kaynaklarındaki azalma ve kirlenmelerden dolayı, kalitesi düşük olan suların tarımsal amaçlar için kullanılması zorunluluk haline gelmiştir. Bu sebeple günümüzde yeterli kalitede olmayan suların sulamada kullanılması sonucunda ortaya çıkabilecek sorunlara ilişkin araştırmalarda artışlar meydana gelmiştir.

Bu çalışmada, Ankara ili Ayaş ilçesindeki baraj, gölet ve kuyu gibi su kaynaklarından elde edilen su örneklerinin sulamaya elverişlilik yönünden incelemesi yapılmıştır. Ankara ili Ayaş ilçesindeki DSİ tarafından işletmeye açılmış baraj ve göletler ile özel mülkiyetli kuyu sularından alınan su örneklerinin su kalitesi açısından sulamaya elverişliliği incelenmiştir. Ayrıca; sulama havzalarındaki bitki deseninin su kalitesine uygunluğu ve kullanılan suların bitkiye ve toprağa etkileri tartışılmıştır.

2. MATERYAL ve YÖNTEM

2.1. Materyal

Ayaş ilçesi, önemli miktarlarda sebze ve meyve üretimi yapılan bir yöredir. Bu yörede özellikle domates, armut, dut, havuç, elma, kiraz, biber, kavun, karpuz, gibi ürünler yaygın olarak yetiştirilmektedir.

Bu çalışmada Ankara ili Ayaş ilçesindeki; Asartepe Barajı, Bayat (Çanuh) Göleti, Kirazdibi Göleti, Ayaş Çayı, İlhan Çayı, İlhan (Çanıllı) Deresi ve çizelge 1 de belirtilen sekiz kuyudan örnekler alınmıştır. İlçe için dikkate alınan bu su kaynakları, çalışmada analiz edilerek sulamaya uygunluk yönünden değerlendirilmiştir. Böylece Ayaş ilçesi su kaynaklarının sulamaya uygunluğu hakkında değerlendirme yapılmıştır.

Çizelge 1. Su Örneklerinin Alındığı Yerler

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Örnek No	Örnek Alınan Yer	Kuyu Derinliği (m)
A1	İlhan Deresi	
A2	Asartepe Barajı	
A3	Bayat Sulama Göleti	
A4	Kirazdibi Göleti	
A5	Asartepe kenarı kuyu	130
A6	Çanıllı yakını kuyu	148
A7	Bulut Çiftliği Yakını kuyu	170
A8	Ayaş Yolu (Giriş) kuyu	
A9	Ayaş Çıkışı Domates Tarlası kuyu	17
A10	İlhan Çayı	
A11	Güneyce kuyu	12
A12	Uğur Çayırı kuyu	
A13	Ayaş Çayı	
A14	Balçiçek Çiftliği yakını kuyu	20

2.2. Yöntem

Bu bölümde araştırma materyalinin temini ve araştırma analizlerinde uygulanan yöntemler kısaca açıklanmıştır.

2.2.1. Su Örneklerinin Alınması

Çalışma alanı bölgesinde yer alan baraj, gölet ve özel mülkiyetli kuyulardan arazi sahiplerinden izin almak suretiyle su örnekleri alınmıştır.

Sulama amacıyla analiz edilecek su örneği alma ilkelerine bağlı olarak sulamada kullanılacak baraj suyunun analizi için temin edilen örnek, baraj ve göletlerin durgun olan kısmından ve su yüzeyinden 20-30 cm derinlikten alınmıştır. Dere ve çay gibi akarsulardan alınan örnekler ise akış halindeki suyun yüzeyin hemen altından olacak şekilde, kuyulardan ise pompa aracılığıyla belli bir süre akıtıldıktan sonra alınmıştır.

Örnek alırken dikkat edilecek diğer bir husus ise kabın temizliğidir. Örnek alma şişeleri, alınacak su ile 2-3 defa çalkalandıktan sonra hava almamasına özen gösterilerek ağzına kadar doldurup sıkıca kapatılmıştır. Numunenin alındığı yer, koordinatları ve özelliği gibi gerekli bilgiler etikete yazılarak örnek şişelerinin üzerine yapıştırılmıştır.

Örnekler, serin ve güneş almayacak şekilde (7-13 °C) ilgili bölüm laboratuvarına ulaştırılmış ve burada analiz edilmiştir.

2.2.2. Sulama Suyu Kalite Analizleri

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Sulama sularından alınan örneklerin kalitelerinin belirlenmesi ve sınıflandırılmasında temel kriterleri oluşturan belli başlı analizlere değinilmiştir. Bunlar; pH, EC, anyon ve katyon analizleri, SAR, %Na ve RSC' dir.

EC: Eriyebilir tuzların toplam konsantrasyonu

Sulama suyu kalitesine göre yapılan sınıflandırmada en önemli ölçüt olarak, su içerisinde erimiş halde bulunan toplam tuz iyonu konsantrasyonunu gösteren Elektriksel İletkenlik (EC) kullanılmaktadır (Anonim 2024).

Ülkemizde A.B.D. Tuzluluk Laboratuvarı Sınıflandırma Sistemi kullanılmaktadır. Bu sınıflandırma sistemine göre sulama suyu az, orta, yüksek ve çok yüksek tuzlu sular (C1, C2, C3, C4) olarak gruplandırılmaktadırlar. 25°C'de elektriksel iletkenlik (EC) değerine göre sulama suları dört sınıfta incelenmektedir.

a) C1: EC <0.25 dS/m: Farklı özelliklere sahip birçok toprakta, hemen hemen her kültür bitkisinin yetiştirilmesinde kullanılabilen sudur.
b) C2: 0.25 <EC <0.75 dS/m: Toprağa ilave yıkama suyu uygulayarak birçok bitkinin sulanmasında kullanılabilecek sudur.
c) C3: 0.75 <EC<2.25 dS/m: Toprakların drenaj koşullarının iyi olduğu koşulda, ilave yıkama suyu uygulamak şartıyla, tuzluluğa hassas olmayan tüm bitkilerin sulanmasında kullanılabilecek sudur.
d) C4: EC>2.25 dS/m: Toprakların drenaj koşullarının iyi olduğu koşulda, ilave yıkama suyu uygulamak şartıyla, tuzluluğa dayanımı yüksek bitkilerin sulanmasında kullanılabilecek sudur.

Elektriksel iletkenliklerin belirlenmesinde YSI Marka, 3200 Model EC metre kullanılmıştır.

PH

pH hidrojen iyonun aktivitesi cinsinden bir asit veya bazın derecesini ifade etme yoluyla sulama sularının asitlik bazlık durumu hakkında bilgi verir (Acatay 1996, Kaya ve Öztürk 2003).

Sulama suyunun uygun pH değeri bitkinin cinsine ve toprağın özelliklerine bağlıdır. Ayers ve Westcot (1989)'un çalışmasına göre, pH'nın sulama suyu için normal sınırları 6.5–8.4 olarak değerlendirilmiştir. Çevre ve Orman Bakanlığı, Su Kirlilik Kontrolü Yönetmeliğine göre de bu aralık, su kalite sınıflandırmasında I. ve II. sınıf sular olarak belirtilmiştir. pH değerlerine göre sınıflandırma listesi çizelge 2'de verilmiştir.

Çizelge 2. pH sınıfları

pH	Sınıflandırma
4.5	Son derece asidik su
4.6 - 5	Çok kuvvetli asidik su
5.1 - 5.5	Kuvvetli asidik su

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5.6 - 6	Orta asit su
6.1 - 6.5	Zayıf asit su
6.6-7.3	Nötr su
7.4-7.8	Hafif alkali su
7.9-8.4	Alkali su
8.5-9	Kuvvetli Alkali su
9.1	Çok kuvvetli alkali su

Anyon ve Katyon Analizleri

Anyonlar: Cl^-, SO_4^{-2}, CO_3^{-2}, HCO_3^-

Katyonlar: Na^+ , K^+, Ca^{+2}, Mg^{+2}

Analiz sonuçları, ppm ya da me/l olarak ifade edilir. Anyon ve katyon analizleri için DIONEX marka, ICS 1600 cihazı kullanılmıştır.

Klor (Cl^-)

Birçok araştırmacının çalışmasına göre, klor iyonu yüksek konsantrasyonlarda olduğunda bitkiler için toksik olup, bitki organlarına zarar verebilmektedir. Literatürde özellikle sert çekirdekli meyvelerde klorun toksik etki yaptığı, şeker pancarı, avakado, yonca, patates, asma, arpa, pamuk, soya, susam, narenciye, ayçiçeği, domates gibi pek çok bitkide yaprak adsorbsiyonu ve yapraklarda yanmalara neden olduğu ortaya konmuştur (Güngör ve Yurtseven 1991).

Sülfat (so_4^-)

Yüksek so_4^- konsantrasyonunda bitkiler Ca^{+2} İyonunu alamadıkları için Na^+ ve K^+ iyonlarının adsorbsiyonu artmaktadır ve bu sebeple konsantrasyonun fazla olduğu durumda zararlı etki nedeniyle bitki bünyesinde katyon dengesizlikleri görülebilmektedir. TSE İçme Suları Standardı'na göre doğal kaynak sularında sülfat kapsamı; 20 mg/L, içme sularında ise 200 mg/l izin verilebilir sınır olarak kabul edilmektedir (Yılmaz 2005).

Bikarbonat (HCO_3^-)

Bikarbonatın toksik etkisi bitkiden bitkiye farklılık göstermekle birlikte,bazı bitkilerde düşük konsantrasyonlarda da hasar görülebilmektedir. Yapılan çalışmalarda bikarbonat iyonunun, bitkide besin maddesi alımına ve bitki metabolizmasına etkili olduğu görülmüştür. Bikarbonat ile ilgili bir çalışmada, fasulye bitkisi bikarbonata çok duyarlı bulunmuş ancak pancar nispeten daha az duyarlılık göstermiştir (Wadleigh and Brown 1952, Woolhouse 1966).

Sodyum bikarbonat ve sodyum karbonat içeren sulama suları, sodyumun klorür ve sülfatlarını içeren sulara göre bitkilere çok daha fazla toksik etki yapabilmektedir. Özellikle sodyum karbonat bitkiler için daha fazla toksik olup, toprağın fiziksel özelliklerini, toprakta kümeleşme oluşumunu bozar, toprağı sertleştirir, permeabiliteyi azaltır (Yılmaz 2005).

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Sodyum (Na^{+})

Bitki organlarında sodyum iyonunun birikmesi ya da dışarıya atılması bitkiden bitkiye farklılık göstermektedir. Örneğin yapılan araştırmalar göstermiştir ki, bademde ve avakado da yapılan denemelerde, topraktaki yüksek Na^{+} konsantrasyonlarında bitki yaprakları zarar görmüştür. Ayrıca tuzlu sularla yapılan yağmurlama sulama sonucunda, yapraklarda Na^{+} adsorbsiyonunun artmasına bağlı zararlanmalar gözlenmiştir (Mass 1984). Aynı zamanda sodyumun yüksek konsantrasyonlarda olması toprağa da olumsuz etki yapmaktadır. Toprak gözenekleri kapanarak toprağın permeabilitesi düşmektedir. Toprak teksel yapıya dönüşerek toprakta pH değerinin aşırı seviyelere yükselmesine sebep olmaktadır (Kaya ve Öztürk 2003).

Potasyum (K^{+})

Potasyumun yüksek konsantrasyonları bitki için toksik etki gösterir. Zaten çoğu bitkinin potasyum ihtiyacı oldukça düşüktür. Potasyumun toksik etki antagonisti (Mg^{+2} olduğu gibi) Ca^{+2} konsantrasyonunun artmasına bağlı olarak dengeye getirilebilir. Potasyumun yüksek konsantrasyonları magnezyum eksikliğine ve demir klorozuna neden olabilmektedir (Walsh and Clarke 1945, Boynton and Burrell 1944).

Magnezyum (Mg^{+2})

Magnezyum katyonu bitkilerin gelişimi için önemli olup, toprağın fiziksel ve kimyasal özelliklerini düzelten bir iyondur. Toprağın permeabilitesini artırarak toprak işlemeyi kolaylaştırır. 24 mg/L' ye kadar olan magnezyum konsantrasyonunda bitkiler herhangi bir zarar görmemekle birlikte, çok yüksek konsantrasyonlar da $MgCl_2$ ve $MgSO_4$'ın fasulye başta olmak üzere birçok kültür bitkisinde toksik olduğu belirlenmiştir. Yüksek konsantrasyonlardaki Mg^{+2} tuzları nispeten yüksek konsantrasyonlardaki Ca^{+2} ile azaltılabilir. Ancak bu tuzlar bazı hallerde toksik etkide bulunurlar (Özbek 1990).

Kalsiyum (Ca^{+2})

Topraklarda permeabiliteyi artıran ve toprak işlemeyi kolaylaştıran bir iyon olan kalsiyumun belirli doza kadar sulama sularında bulunması avantajdır. Kalsiyum toprak ve bazı doğa kaynaklarının yıkanmasından veya endüstri artıklarından gelebilir (Kaya ve Öztürk 2003). Mazaewa (1948) yüksek konsantrasyonlarda ilave edilecek $CaCl_2$ tuzlarının toprağa, NaCl tuzlarından daha toksik etki yapacağını ortaya koymuştur. Sulama suyu kalitesi açısından değerlendirildiğinde, genellikle kalsiyum ve magnezyum konsantrasyonlarının ayrı ayrı değil (Ca+Mg) konsantrasyonu olarak birlikte değerlendirildiği görülmektedir.

Sodyum Adsorbsiyon Oranı (SAR)

Sodyumun olumsuz etkisinin bir kısmı kalsiyum ve magnezyum iyonları tarafından bloke edildiği için, suların sodyum içeriği yerine SAR değerinin dikkate alınması daha doğrudur.

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$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$ Şeklinde ifade edilir.

SAR değeri me/l cinsinden belirlenen Na^{+}, Ca^{+2} ve Mg^{+2} değerleri kullanılarak eşitlik yardımıyla kolayca hesaplanabilmektedir.

Kaya ve Öztürk (2003), SAR değerine göre suların çeşitli toprak tiplerinde kullanım şekillerini aşağıdaki gibi sınıflandırmıştır;

0<SAR<10, Alkaliliği düşük suyu ifade eder, toprak özelliklerine bakılmaksızın bütün bitki çeşitlerinde sulama suyu olarak kullanılabilmektedir.

10<SAR<18, Orta alkali sulardır. Ağır bünyeli topraklarda yüksek katyon değişimi nedeniyle sorun çıkarma riski olabilir. İri taneli (kumlu) topraklarda veya organik madde oranı fazla, geçirimliliği uygun topraklarda rahatlıkla kullanılabilir.

18<SAR<26, Alkaliliği yüksek sulardır. Ancak özel şartlar sağlanmış topraklarda kullanılabilirler. Toprakta jipsin fazla olması durumunda olumsuz etkileri azaltılabilir. İlave yıkama suyu uygulanarak organik madde desteğiyle toleranslı bitkilerde rahatça kullanılabilirler.

SAR>26, Yüksek alkali suyu ifade eder. Bitkiler açısından sulamaya uygun olmamakla birlikte toprak özelliklerini kötüleştirme potansiyeli nedeniyle toprak açısından da kullanılmaları sakıncalıdır. Jips ilavesi ile veya kalkerli topraklarda zorunlu kalındığında toleranslı bitki yetiştiriliyorsa özel çalışmalarla kullanılabilirler.

Sodyum İyonunun Nisbi Oranı (Sodyum Yüzdesi) % Na

Sulama suyunun kullanılması ile ilgili olarak oluşacak sodyum zararı, bu suyun katyonlarının mutlak ve nispi konsantrasyonlarına bağlı bulunmaktadır. Sodyum iyonu, toprağın fiziksel özelliklerini ve bitki gelişmesini olumsuz etkiler. Sodyum iyonunun diğer katyonlara oranla nispi miktarı yüksek olduğunda, toprak yapısı teksel bir yapıya dönüşebilmekte ve toprağın fiziksel özellikleri kötüleşebilmektedir. Kalsiyum ile magnezyum uygun oranlarda bulunması toprağı gerek yapı gerekse işleme yönünden faydalı bir duruma getirir. Potasyumun toprağa etkisi sodyuma benzese de sularda potasyum konsantrasyonu düşük olduğundan hesaplamalarda göz önüne alınmaz. Bir sulama suyunda sodyumun diğer katyonlara nispi oranı sodyum yüzdesini verir.

$$\%Na = \frac{Na^{+}}{Na^{+} + K^{+} + Ca^{+2} + Mg^{+2}}.100$$ Eşitliği ile hesaplanır.

Yüzde sodyumun bitkiye ve toprağa zararlı olmaması için 50-60'dan fazla olmaması gereklidir.

Kalıcı Sodyum Karbonat (RSC)

Yüksek RSC değerine sahip sular, toprakta sodik yapıya yani tuzluluğun artmasına ve toprağın fiziksel ve kimyasal özelliklerinin kötüleşmesine yol açtığından sulamada istenmez. Bu tür

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topraklarda sodyum oranı yükseldikçe toprağın geçirgenliği azalır ve toprağın havalanması güçleşir. Böyle bir durumda toprak ıslanınca yapışkan, kuruyunca çatlaklı ve kabuklu bir yapı kazanır (Çobanoğlu vd., 2006). Toprağın sodikleşmesi ile etkisini gösteren suyun kimyasal özellik tanımı RSC kavramı ile ifade edilmektedir.

Kalıcı Sodyum Karbonat (RSC) değerine göre sulama sınıflandırılmasında 1.25 me/L değerinden küçük olan sular 1. sınıf, 1.25-2.50 me/L arasında olanlar 2. sınıf orta kullanılabilir, 2.50 me/L den fazla ise sulama açısından uygun bulunmaktadır (Eaton 1942, Arslan vd. 2007).

RSC= (CO_3 + HCO_3) – (Ca + Mg) formülü ile hesaplanır.

3. BULGULAR VE TARTIŞMA

Araştırma kapsamında Ayaş ilçesinden 14 farklı kaynaktan alınan sular analiz edilmiş ve elde edilen sonuçlar sulama suyu kalite kriterlerine göre değerlendirilmiştir. Değerlendirmede esas alınan sulama suları için tarıma elverişli sınır değerleri Çizelge 3'de verilmiştir.

Çizelge 3. Türkiye'de Sulama Suyu Kriterleri (Su Kirliliği Kontrol Yönetmeliği Teknik Usuller Tebliği 1991)

	EC(dS/m)	**SAR**	**% Na**	**Cl (me/l)**	**SO_4 (me/l)**	**RSC (me/l)**
Çok iyi	0.25	<10	<20	4	4	<1.25
İyi	0.25-0.75	10-18	20-40	4-7	4-7	1.25-2.5
Kabul Edilebilir	0.75-2.00	18-26	40-50	7-12	7-12	>2.5
Şüpheli	2.00-3.00	>26	50-80	12-20	12-20	
Kullanılamaz	>3.00		>80	>20	>20	

Araştırmada elde edilen pH, EC, me/l cinsinden anyon ve katyon değerleri ile hesaplanan SAR, %Na ve RSC değerleri Çizelge 4'de verilmiştir.

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Çizelge 4. Su örneklerine ait kimyasal analiz ve hesaplamalara ilişkin sonuçlar

Konular	PH	EC	ANYONLAR, me/l					KATYONLAR, me/l							
		dS/m	Cl	SO4	CO3	HCO3	TOP.	Na	Ca	K	Mg	TOP.	SAR	%Na	RSC
A1	7.80	0.546	0.72	1.02	0.00	3.75	5.49	0.39	3.22	0.04	1.86	5.51	0.25	7.08	-1.33
A2	8.16	0.802	2.32	2.39	0.00	3.32	8.03	0.94	4.19	0.27	2.60	8.00	0.51	11.75	-3.47
A3	8.15	0.439	0.91	0.95	0.00	2.54	4.40	0.44	2.12	0.07	1.78	4.40	0.32	9.97	-1.36
A4	7.52	0.478	1.33	1.44	0.00	2.02	4.79	1.32	0.88	0.11	2.46	4.77	1.02	27.67	-1.32
A5	6.92	0.948	2.15	2.71	0.00	4.63	9.49	4.02	2.80	0.15	2.53	9.50	2.46	42.32	-0.7
A6	7.65	0.485	0.35	1.32	0.00	3.16	4.83	1.16	1.94	0.16	1.61	4.87	0.87	23.82	-0.39
A7	8.49	0.383	0.78	0.78	1.14	1.14	3.84	1.39	1.30	0.07	1.07	3.83	1.28	36.29	-0.09
A8	8.09	0.418	0.27	0.71	0.00	3.20	4.18	1.03	1.50	0.07	1.58	4.18	0.83	24.64	0.12
A9	7.63	1.643	2.29	6.45	0.00	7.70	16.44	1.07	12.72	0.60	1.94	16.33	0.40	6.55	-6.96
A10	8.16	0.681	1.04	3.54	0.00	2.23	6.81	1.38	2.84	0.13	2.48	6.83	0.85	20.20	-3.09
A11	7.69	0.741	1.02	4.16	0.00	2.24	7.42	1.54	3.14	0.15	2.59	7.42	0.91	20.75	-3.49
A12	7.19	5.400	5.38	47.71	0.00	0.78	53.87	11.42	14.88	0.42	27.73	54.45	2.47	20.97	-41.83
A13	7.96	4.765	11.17	35.66	0.00	0.79	47.62	16.14	11.05	0.35	20.00	47.54	4.10	33.95	-30.26
A14	7.55	3.450	1.22	32.58	0.00	0.74	34.54	17.23	7.76	0.34	9.27	34.60	5.90	49.80	-16.29

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Çizelge 4'de verilmiş olan analiz ve hesaplama sonuçları kalite sınıflandırmasına göre değerlendirildiğinde;

1) pH değerleri 7-9 aralığında olup 14 örneğin de sulamada kullanılabilir I. ve II. sınıf sular olduğu,
2) EC değerlerinin sekiz örnek için 0.25-0.75 dS/m aralığında olduğu A.B.D. Tuzluluk Laboratuvarı diyagramına göre C2 (iyi), yani orta tuzlu sular sınıfına girdiği üç örnek için 0.75-2.00 dS/m aralığında C3 yani yüksek tuzlu sular sınıfında (kabul edilebilir), üç örnek için ise (>3.00) çok yüksek tuz içerikli C4 sınıfı kullanılamaz olduğu,
3) SAR değerlerinin on bir örnek için, A.B.D. Tuzluluk Laboratuvarı diyagramına göre S1 yani düşük sodyumluluk düzeyinde çok iyi kalitede sular olduğu, iki örneğin ise S2 yani Orta Sodyumlu Sular sınıfında kaba bünyeli ve yüksek geçirgenlikteki organik topraklarda sorun oluşturmadan kullanılabilir sular olduğu, A12 örneğinin ise yüksek tuz konsantrasyonundan dolayı kullanılamaz olduğu,
4) %Na oranının dört örnek için <20 aralığında çok iyi kalitede sular sınıfında, sekiz örnek için 20-40 aralığında iyi kalitede sular ve iki örnek için 40-50 aralığında kabul edilebilir sular olduğu,
5) Cl^- İyonunun kalite standartlarına göre on iki örnek için, 4 me/l'den az, çok iyi; iki örnek için ise 7-12 me/l aralığında kabul edilebilir sınırlarda olduğu,
6) SO_4 iyonunun kalite standartlarına göre dokuz örnek için <4 aralığında çok iyi, iki örnek (A9-A11) için 4-7 aralığında iyi, üç örnek (A12-A13-A14) için >20 aralığında kullanılamaz olduğu,
7) Hesaplanan RSC değerlerinin bütün örnekler için 1.25 me/l'den düşük olduğu ve (-) değerde olması nedeniyle sulamada sorunsuzca kullanılabilir olduğu yapılmış olan analizler sonucunda ortaya konmuştur.

Çizelge 5'de alınan örneklerin ABD Tuzluluk Laboratuvarı sulama suyu sınıflandırması yapılmıştır.

Çizelge 5. Suların A.B.D. Tuzluluk Laboratuvarı Sulama suyu sınıfları (Anonymous 1954)

Konular	SAR me/l	EC dS/m	ABD Tuzluluk Lab.
A1	0.25	0.55	C2S1
A2	0.51	0.80	C3S1
A3	0.32	0.44	C2S1
A4	1.02	0.48	C2S1
A5	2.46	0.95	C3S1
A6	0.87	0.49	C2S1
A7	1.28	0.38	C2S1
A8	0.83	0.42	C2S1
A9	0.40	1.64	C3S1
A10	0.85	0.68	C2S1
A11	0.91	0.74	C2S1
A12	2.47	5.40	C4S2

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A13	4.10	4.77	C4S2
A14	5.90	3.45	C4S2

4. SONUÇ VE ÖNERİLER

Elde edilen veriler A.B.D. Tuzluluk Laboratuvarı Sınıflandırma Sistemi'ne göre değerlendirilmiş olup su örneklerinin sekiz tanesinin C2S1 sınıfına girmiş olduğu görülmektedir. Buna ilişkin, elektriksel iletkenliği belirten C2, orta tuzlu suları göstermekte olup, tuza orta derecede duyarlı bitkilerde kullanımında herhangi bir sakınca yoktur. Tuza duyarlı bitkilerde ise yıkamayla birlikte bu zarar ortadan kaldırılabilir. S1 ise, düşük sodyumlu suları göstermekte olup, her bitki ve toprak koşulunda zararsızca kullanılabilir.

Üç su örneği sınıfının C3S1 olduğu görülmekte olup, C3 sınıfının yüksek tuzlu sular sınıfını teşkil ettiği ve fazla miktarda tuz içeren bu suların, sürekli kullanılmaları halinde tuzluluk problemi yaratabilecekleri için sürekli yıkama ve özel toprak işleme uygulamalarının gerekebileceği unutulmamalıdır. Yetiştirilecek bitkilerin tuza dayanıklı olması gerekir ve özellikle drenajın yeterli olmadığı yerlerde kullanılmamalıdır.

Üç su örneği sınıfının C4S2 olduğu buna bağlı olarak da C4, çok yüksek tuzlu suları göstermektedir. Normal koşullarda bu sular sulamaya uygun değillerdir. Kullanılmaları ancak çok özel koşulları içermektedir. Örneğin tuzluluğa dayanımı yüksek bitkilerin yer aldığı drenajı iyi olan ve fazlaca yıkama suyu uygulanan alanlarda kullanılabilirler. S2, orta sodyumlu suları işaret etmekte ve kaba bünyeli, geçirgenliği yüksek topraklarda iyi bir drenaj şartıyla sorunsuzca kullanılabilmektedir. Aksi durumda, toprakta sodyum birikmesine ve zarar seviyesinin giderek artmasına ve iyileştirilemez düzeylere ulaşmasına neden olabilmektedir.

Sorunlu toprakların iyileştirilmesi, kök bölgesindeki çözünebilir tuzların yıkanarak, bitkiler için zararlı olmayan düzeylere düşürülerek, topraktan uzaklaştırılması temeline dayanır. Bu ıslah işlemi, çözünebilir tuz kapsamı, bitkilerin zarar görmeyeceği düzeye indiğinde tamamlanır. Bunun için saturasyon ekstraktı elektriksel iletkenliği (EC) 4 dS/m, sodyumluluk için değişebilir sodyum yüzdesinin ESP<15 olması gerekmektedir (Sönmez ve Yurtseven, 1995, Ekmekçi vd. 2005).

Çalışmanın yürütüldüğü Ayaş yöresinde, sulama sistemleri arasında en uygun olanlar damla ve yağmurlama sulamadır. Ağırlıklı yetiştiriciliğin sebze ve meyve olması damla sulama sistemlerinin uygunluğunu ön plana çıkarmaktadır.

Araştırma sonuçları, Ayaş İlçesinde sulama suyu amaçlı kullanılan baraj, gölet ve kuyu suyu kalitelerinin, bölgede yapılmakta olan bitkisel üretim faaliyetlerine üç örnek dışında genelde uygun olduklarını göstermektedir. Yörede yetiştiriciliği yapılan bazı bitkilerin tuz tolerans verileri dikkate alındığında; domates, biber, ıspanak, elma, üzüm, soğan, salatalık, havuç gibi bazı hassas bitkilerin yetiştiriciliğinde düşük kaliteli suların kullanımında dikkatli olunmalıdır. Özellikle kurak zamanlarda sulamalar daha sık aralıklarla ve yıkama suyu ilavesiyle yapılmalıdır. Ayrıca mevcut sularla sulandığında yörede; çavdar, kolza, kanola, arpa, şeker

pancarı, buğday, enginar, ayçiçeği verimde azalma olmaksızın yetiştirilmesinde sakınca bulunmayan bitkiler arasındadır.

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CHITOSAN NANOPARTICLES AND THEIR INFLUENCE ON GENE EXPRESSION AND SECONDARY METABOLISM IN FRUITS

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ABSTRACT
Chitosan nanoparticles (CNPs) have emerged as a promising tool in horticulture, particularly in enhancing gene expression and secondary metabolism in fruits. Their biocompatibility, biodegradability, and antimicrobial properties make them effective in improving plant growth, stress tolerance, and disease resistance. CNPs act as biostimulants, by enhancing physiological and biochemical processes such as promoting seed germination, photosynthesis, and nutrient absorption. They enhance the production of secondary metabolites, such as alkaloids and phenolic compounds, which help plants combat oxidative stress and improve tolerance to abiotic stresses like drought and salinity. Additionally, CNPs induce defense responses by upregulating defense-related genes, such as chitinase and peroxidase, which protect against fungal pathogens. Studies have demonstrated the effectiveness of CNPs in controlling diseases such as blue mold and enhancing plant defenses against pathogens, resulting in healthier and more resilient fruit crops. Furthermore, CNPs serve as innovative nanocarriers for the controlled delivery of agrochemicals, enhancing the efficiency of fertilizers, pesticides, and plant growth regulators. The ability of CNPs to mitigate stress, promote growth, and provide disease protection positions them as a valuable alternative to synthetic agrochemicals, contributing to more sustainable horticultural practices and improving the quality and yield of fruit crops. Chitosan nanoparticles (CNPs) are increasingly recognized for their potential applications in agriculture, particularly for enhancing plant growth, improving stress tolerance, and managing diseases. Their unique properties, such as biocompatibility, biodegradability, and non-toxicity, make them a promising alternative for sustainable agricultural practices.
Keywords: Chitosan, Nanoparticles, Stress, Secondary Metabolites, Nanocarrier

1. INTRODUCTION
Recently, sustainable practices in all aspects of day life, including industry and agriculture, have been of interest. Because the concerns on environmental degradation of chemical compounds as a contributing factor of climate change are increasing. Synthetic chemicals and non-biodegradable materials which are one of the main factors of pollution, soil degradation, and the accumulation of toxic residues in ecosystems lead to adverse impacts on both environmental and human health. As a result, there is an increasing need for natural, biodegradable substitutes that can provide comparable or better functions without negative side effects. Therefore, researchers have focused on natural products as alternatives to chemical inputs in sustainable agriculture to improve the yield and quality of products. Chitosan is one of these natural products that is the focus of interest.

Chitosan is a natural, nontoxic biopolymer derived by the deacetylation of chitin which is found abundantly in the exoskeletons of crustaceans and insects. Chitosan possesses remarkable antimicrobial, antifungal, and biocompatible properties (Qi et al., 2004).

Various parameters of chitosan including the degree of polymerization, molecular weight, and its other physicochemical characteristics affect its antibacterial effectiveness. Gram-positive bacteria are more susceptible to the antibacterial action of chitosan. High pH levels have an adverse impact on the antibacterial activities of chitosan; as pH increases, its antibacterial activities decrease (No et al., 2002). Chitosan is applied in agriculture and horticulture for plant defense and yield increase.

Indeed, the process by which this glucosamine polymer affects the biochemistry and molecular biology of the plant cell is the basis of its application. The anti-transpirant properties of chitosan have been proven to be effective in many agricultural products (Karimi et al., 2012). Many researchers have used chitosan to protect plants against abiotic and biotic stresses (Pirbalouti et al., 2017; Hidangmayum et al., 2019; Balusamy et al., 2022) and to stimulate plant growth (Abdel-Mawgoud et al., 2010; Mondal et al., 2011). In 1983, by inducing phytoalexin production in peas and inducing the proteinase inhibitor in tomatoes, Chitosan was initially identified as a plant elicitor (Walker-Simmons et al., 1983). Thereafter, many studies have been done on the physiological and biochemical responses of chitosan. Nanoparticles have drawn remarkable attention in agriculture due to their unique properties that increase plant health and yield. Compared to conventional bulk materials, nanoparticles have a high surface area-to-volume ratio, which increases their reactivity and facilitates cellular-level interactions with biological systems (Hassan et al., 2014; Song et al., 2016; Tokatlı & Demirdöven, 2020). The small size of nanoparticles makes it possible for active substances to transport across cell membranes efficiently, increasing bioavailability and facilitating accurate targeting throughout plant tissues (Nair et al., 2010). Due to these attributes, nanoparticles are a desirable alternative for more effective and environmentally friendly delivery of nutrients, insecticides, and other agents (Hassan et al., 2021). Among used nanoparticles in plants, chitosan nanoparticles (CSNPs) are particularly favorable, as they combine the natural antimicrobial and biocompatible properties of chitosan with the enhanced functionality of nanoparticles, promoting plant growth, improving tolerance to abiotic stresses, and enhancing crop yield and quality in ways that standard chitosan applications may not achieve (Divya & Jisha, 2018; Silveira et al., 2019; Sen et al., 2020).

The purpose of this review is to investigate the effects of chitosan nanoparticles (CNPs) on fruit crop gene expression and secondary metabolism. We will provide an overview of recent studies on how CNPs improve the synthesis of advantageous chemicals, particularly under adverse conditions. This review aims to show how CNPs can be an effective strategy for enhancing fruit quality and resilience in sustainable agriculture by highlighting the ways in which they affect plant responses.

2. CHITOSAN NANOPARTICLES (CNPS)

Chitin which is found abundantly in the exoskeletons of crustaceans and cell walls of fungi and yeasts, is composed of N-acetyl D-glucosamine repeat blocks and is a cationic amino polymer.

These repeats are joined via β-1,4 glycosidic bonds (Rinaudo, 2006). As chitin is highly hydrophobic, it remains insoluble in water and most organic solvents. Therefore, its derivatives such as chitosan are used for agricultural applications.

Chitosan is obtained by the deacetylation of chitin which is a linear heteropolysaccharide polycationic in nature and is well soluble in acidic solutions based on its deacetylation degrees (Katiyar, et al., 2014),

Chitosan exhibits various biological activities, including biocompatibility, biodegradability, and non-toxicity, as well as antimicrobial, antitumor, and immune-enhancing effects (Mi et al., 2002; Shi et al., 2006; Li et al., 2008; Zaharoff et al., 2006). These properties make chitosan an applicable compound used in medicine (Shi et al., 2006), food (Morin-Crini et al., 2019; Manigandan et al., 2018), cosmetics (Guzmán et al., 2018; Kulka and Sionkowska, 2023), and agricultural uses (Balusamy et al., 2022; Rahman et al., 2018; Singh et al., 2022).

To achieve sustainable agriculture, chitosan is preferred due to its naturally inert characteristics, making it a suitable alternative to agrochemicals. It helps enhance plant defense mechanisms against abiotic and biotic stresses which are among the most challenging issues in modern agriculture as a result of climate change (El Hadrami et al., 2010; Balusamy et al., 2022; Singh et al., 2022). It is also used to boost plant growth, promote seed germination, improve chloroplast ultrastructure and chlorophyll content, increase nitrogen fixation and nutrient uptake, and affect secondary metabolite content, such as essential oils (terpenoids) and phenolics (ALKahtani et al., 2020; Ahmed et al., 2020**;** Kahromi and Khara, 2021).

Nanotechnology involves manipulating and reorganizing matter at a scale of approximately 1–100 nm, resulting in a large surface area and enabling novel phenomena that open up new applications (Barlow et al., 2009). Nanoparticles obtained through nanotechnology have a great potential to benefit agriculture, making the agro-industry more eco-friendly with increasing growth rates every year (Pascoli et al., 2018).

Typically, nanoparticles are developed to enhance product solubility, prevent the premature degradation of bioactive components, and enable a controlled release method for agrochemicals (Wang et al., 2016). As a result, nanoparticles may enhance the effectiveness of agrochemicals, leading to better outcomes with fewer treatments and lower doses, while also reducing the risk of environmental pollution and toxicity to humans and other non-target organisms (Thirugnanasambandan al., 2014).

Chitosan nanoparticles (CNPs), obtained via nanotechnology, carry the advantages of both chitosan and nanomaterial applications in agriculture. These nanoparticles increase the effectiveness of agricultural inputs while utilizing the advantageous qualities of chitosan, such as its biodegradability and non-toxicity. Their unique characteristics allow for improved nutrient uptake, targeted delivery, and protection against environmental stresses, making them a promising solution for increasing crop productivity and sustainability in agricultural practices (Santo Pereira al., 2017). Several studies comparing the application of CNPs to the bulk form of chitosan indicate that productivity, growth, biochemical responses, and organogenesis in *in vitro* cultures are significantly enhanced when using chitosan nanoparticles (Asgari-Targhi al., 2018). Chitosan nanoparticles are superior to metal nanoparticles, as the accumulation of metal nanoparticles increases the risk of soil and water contamination, while chitosan nanoparticles can be easily degraded in the soil (Risehal., 2024).

Chitosan nanoparticles have been used in agriculture as pesticides to obtain better-quality food products with a higher yield. Many studies have focused on the application of CNPs combined with other nanoparticles to enhance their synergistic effects on yield, stress resistance, and fruit quality. For example, Cu-coated chitosan nanoparticles were applied to preserve the freshness and bioactive components of strawberries during storage (Eshghi et al., 2014).

Salinity is a significant abiotic stress factor that negatively impacts plant growth. Chitosan nanoparticles demonstrated the enhanced defense of plants under salinity stress (Balusamy et al., 2022) such as in maize (Oliveira et al., 2016) and tomato (Colman et al., 2019).

Drought stress is another abiotic factor that negatively impacts plant growth, affecting physiology, anatomy, and biochemistry, which ultimately leads to lower yields. It is known to damage chloroplasts, reducing both chlorophyll content and the activity of enzymes involved in the Calvin cycle of photosynthesis. Many studies have proven that the application of CNPs alleviates the effects of drought stress improving plant growth and yield in barley (Behboudi et al., 2018), in sugarcane plants (Priyaadharshini et al., 2019) and tomato (Mohamed et al., 2023).

Studies have shown that CNPs improve plant resistance to various diseases by enhancing defense mechanisms in plants through activation of antioxidant enzymes, accumulation of phenolic compounds, and production of reactive oxygen species. For instance, CNPs enhanced resistance against the blast disease in finger millet (Sathiyabama & Manikandan, 2016). In another study, tomato plants treated with Cu-chitosan nanoparticles showed higher antifungal efficacy against pathogens (Saharan et al., 2015). Additionally, apple fruits treated exogenously with CNPs showed increased resistance to blue mold, preserved fruit quality, and elevated defense-related gene expression (Abdel-Rahman et al., 2021).

Chitosan nanoparticles also enhance antioxidant enzymes and total phenols accumulation in bean seeds helping seeds to further tolerate oxidative stress conditions. However, identifying the optimum concentration is important for effective agricultural use (Abdel-Aziz, 2019).

3. MECHANISMS OF ACTION

Chitosan nanoparticles stimulate plant growth and significantly reduce MDA levels under stress conditions, promoting the production of secondary metabolites. This effect is linked to changes in gene expression, particularly in pathways related to secondary metabolism, especially in fruit crops (Ali et al., 2021; Abdel-Rahman et al., 2021). By acting as effective elicitors, CNPs can stimulate the biosynthesis of secondary metabolites, compounds essential for plant defense, stress tolerance, and quality enhancement (Abdel-Rahman et al., 2021). Studies indicate that CNPs influence the expression of genes involved in the synthesis of key metabolites, such as flavonoids, phenolics, and alkaloids, in various plants, which can enhance both fruit quality and resilience (Pliankong et al., 2018). Thus, CNPs offer an advanced approach to enhancing secondary metabolite production in fruits, linking biotechnological innovation with practical benefits in fruit agriculture.

Interactions with plant cell membranes are one of the main mechanisms through which CNPs act. Due to their small size and positive surface charge, CNPs can adhere to the negatively charged components of the cell membrane, enhancing their uptake into cells (Saharan et al., 2015). Compared to their bulk counterparts, CNPs can influence cellular processes in plant tissues more directly and effectively due to this surface interaction. This unique cellular contact

can activate membrane-bound receptors, initiating various downstream signaling pathways essential for plant defense (Nge et al., 2006).

CNPs are also known to act as elicitors, molecules that stimulate plant defense responses against pathogens. By interacting with the plant's immune system, CNPs can induce the synthesis of pathogenesis-related (PR) proteins, reactive oxygen species (ROS), and secondary metabolites, which are essential for fortifying plant defenses. Specifically, CNPs can activate enzymes such as catalase and peroxidase, which play roles in mitigating oxidative stress caused by ROS (Sathiyabama & Manikandan, 2016). The accumulation of ROS acts as a signaling molecule that helps mediate the expression of defense-related genes and strengthens the cell wall against pathogen entry (Choudhary et al., 2017).

Chitosan nanoparticles also demonstrate hormone-like activities, influencing processes such as root growth, shoot elongation, and cellular differentiation (Pichyangkura & Chadchawan, 2015). These effects are thought to arise from the nanoparticle's interaction with auxin-related pathways, which are critical for root development and morphogenesis. By modulating hormonal balance, CNPs promote a more robust root system and overall plant growth, enhancing the plant's ability to withstand both biotic and abiotic stressors (Saharan et al., 2016).

In addition to their direct effects on growth and defense, CNPs improve the absorption and transport of essential nutrients. Studies indicate that CNPs can facilitate the uptake of nutrients by modulating the permeability of cell membranes and improving nutrient transport pathways (Javed, et al., 2017). This mechanism is beneficial for plants grown in nutrient-poor soils, as it supports enhanced growth and vigor. Moreover, CNPs promote metabolic activities associated with the synthesis of secondary metabolites, including phenolic compounds, flavonoids, and alkaloids, which contribute to stress resistance and pathogen defense (Kamalipourazad et al., 2016).

4. IMPACT OF CHITOSAN NANOPARTICLES ON GENE EXPRESSION AND SECONDARY METABOLITE PRODUCTION

Studies have demonstrated that CNPs effectively stimulate the biosynthesis of alkaloids, particularly in medicinal plants like *Catharanthus roseus* (Pliankong et al., 2018). In *C. roseus*, CNP treatment led to an upregulation of genes involved in terpenoid indole alkaloid (TIA) biosynthesis, such as *strictosidine synthase* (STR), *deacetylvindoline-4-O-acetyltransferase* (DAT), *peroxidase 1* (PRX1), and *geissoschizine synthase* (GS). These genes are crucial in the TIA biosynthetic pathway, producing compounds known for their medicinal properties, including anti-cancer and anti-microbial activities. The activation of these genes and subsequent accumulation of TIAs are often associated with stress conditions, suggesting that CNPs may mimic stress responses to enhance secondary metabolite production in plants (Khataee et al., 2019).

CNPs also play a pivotal role in inducing systemic acquired resistance (SAR), a mechanism that allows plants to strengthen their defenses against potential pathogens after initial exposure to elicitors. SAR involves the upregulation of defense-related genes, leading to an accumulation of pathogenesis-related (PR) proteins, which improve plant resistance against subsequent attacks (Chandra et al., 2017). CNP treatment has been shown to potentiate the expression of specific PR proteins, including chitinases (PR2), β-1,3-glucanase (PR3), and PR8, which can directly break down fungal cell walls, providing a physical barrier against pathogens (Saharan

et al., 2015). This activation of PR proteins underscores the role of CNPs in priming plants for enhanced immune responses.

CNPs are known to stimulate the phenylpropanoid pathway, which is essential for the synthesis of phenolic compounds, flavonoids, and lignin. These compounds play critical roles in plant defense, structural integrity, and stress resilience. Phenylalanine ammonia-lyase (PAL), a key enzyme in the phenylpropanoid pathway, regulates the production of lignin and other phenolic compounds. CNPs have been shown to upregulate PAL activity, leading to increased lignin accumulation, which reinforces cell walls and improves resistance to pathogen invasion (Choudhary et al., 2017). Additionally, the production of phenolic compounds enhances the plant's antioxidative defense system, helping to mitigate oxidative stress and prevent cellular damage.

Advances in mRNA expression analysis have allowed researchers to observe the broad impact of CNPs on various defense-related genes under biotic and abiotic stresses. Global gene expression profiling in CNP-treated plants has revealed upregulation of multiple genes linked to secondary metabolite pathways, including flavonoid biosynthesis and terpenoid production, which are critical for both stress tolerance and medicinal properties of the plant. The modulation of these pathways suggests that CNPs not only improve plant health and defense but also enhance the quality and yield of valuable secondary metabolites (Javed et al., 2017).

5. CONCLUSION

In conclusion, chitosan nanoparticles (CNPs) represent a promising, eco-friendly tool for enhancing fruit quality and resilience by influencing gene expression and secondary metabolism. The unique properties of CNPs, such as high surface area and biocompatibility, allow them to interact effectively with plant cells, facilitating the activation of defense-related genes and promoting the synthesis of secondary metabolites. These metabolites, including phenolics, terpenoids, and flavonoids, are crucial for fruit quality, providing improved antioxidant capacity, flavor, and stress resistance. By harnessing CNPs, researchers and agricultural practitioners can potentially reduce the need for synthetic agrochemicals, paving the way for sustainable approaches in fruit cultivation. Future studies are essential to refine application methods, optimize dosages, and understand the long-term impacts of CNPs on fruit physiology and genetic pathways to fully leverage their benefits in agricultural systems.

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THE ROLE OF SECONDARY METABOLITES IN PLANT STRESS RESPONSES: BIOTECHNOLOGICAL APPROACHES FOR CROP IMPROVEMENT

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ABSTRACT

Secondary metabolites (SMs) are vital compounds in plants, playing critical roles in defense against biotic and abiotic stresses, such as pathogens, drought, salinity, and temperature fluctuations. Secondary metabolites include alkaloids, terpenoids, flavonoids, and polyphenols producing via complex biosynthetic pathways and provide functions including antioxidant defense, structural support, and modulation of signaling pathways. Recent advancements in biotechnology have revolutionized the ability to modulate the production of these secondary metabolites, offering a promising approach for crop improvement. CRISPR/Cas9 and RNA interference (RNAi) technologies have emerged as key biotechnological tools that enable precise and targeted manipulation of genes responsible for secondary metabolite biosynthesis. CRISPR/Cas9 allows for the specific modification of genes and regulatory elements in metabolic pathways, leading to enhanced production of high-value compounds such as carotenoids, terpenoids, and flavonoids. Targeting transcription factors and regulatory genes with this gene-editing technique has optimized metabolic activity in the direction of targeted metabolites. RNAi complements CRISPR by providing an effective strategy to silence specific genes, thus suppressing unwanted metabolic pathways while promoting the accumulation of beneficial compounds like anthocyanins and alkaloids. Small RNAs, including miRNAs and siRNAs, further regulate secondary metabolite biosynthesis by fine-tuning the expression of key genes. This post-transcriptional regulation allows for precise control of metabolic pathways, improving the production and quality of secondary metabolites in horticultural crops. Additionally, nanotechnology has enhanced the delivery of CRISPR and RNAi components, increasing the stability and efficiency of gene editing in plants. Biotechnological approaches, such as genetic engineering, marker-assisted selection, and metabolic engineering, are applied to enhance SM accumulation and optimize stress response mechanisms. Elicitors are also used to stimulate SM production, improving plant resilience under controlled conditions. The integration of omics technologies, such as metabolomics and transcriptomics, along with advanced gene editing and elicitor applications, provides sustainable and innovative strategies for crop improvement. These methods help meet the challenges posed by climate change, environmental stressors, and food security needs, ensuring the development of resilient, high-yielding crops with enhanced nutritional and medicinal properties. These innovations offer precise, efficient, and sustainable solutions for improving crop resilience, quality, and yield, contributing to the future of sustainable agriculture and food security.

Keywords: Secondary metabolites, Stress, RNAi, CRISPR/Cas9, Elicitors

1. INTRODUCTION

Climate change is one of the most challenging concerns of modern agriculture, forcing scientists to develop methods to cope with it. On the other hand, increased awareness among consumers has led to a demand for products with high-quality traits that meet both the needs for food supply for the growing population and the desire for improved products. Secondary metabolites in plants are key features, and understanding them can help scientists intervene in their production to address the needs mentioned above.

Continuous and unavoidable changes in ecosystems necessitate adaptations in biological and physiological processes to improve plants' resilience and ability to cope with various stresses. Plants employ different adaptation mechanisms in response to abiotic, biotic, and anthropogenic factors, primarily through the synthesis of numerous organic compounds. These organic compounds are categorized into three main groups. The first group, known as primary metabolites (e.g., carbohydrates, proteins, and fats), is crucial for normal plant growth, development, and reproduction. The second group, phytohormones, are chemical messengers that coordinate cellular activities and regulate physiological processes even at very low concentrations (Güney et al., 2021). Unlike primary metabolites, secondary metabolites, another category of plant phytochemicals, do not directly participate in growth or reproduction, and their absence does not immediately cause cell death. However, these compounds are essential for long-term plant survival and fertility. Secondary metabolites contribute to various physiological and ecological roles, such as regulating growth, attracting pollinators through color and scent, defending against pathogens, deterring herbivores, and responding to environmental stresses like temperature changes, drought, UV radiation, and other elicitors (Piasecka et al., 2015; Yang et al., 2018; Guerrieri et al., 2019; Isah, 2019; Bodoira & Maestri, 2020; Corso et al., 2020; Revutska et al., 2021; Pang et al., 2021). They are also significant in the pharmaceutical and food industries, contributing to human health through diet (Ergun & Zarifikhosroshahi, 2020; Ullrich et al., 2019; Fakhri et al., 2020).

Although plants produce secondary metabolites primarily for their defense mechanisms, these compounds are also highly valued in human consumption due to their significant impact on fruit quality. Secondary metabolites are considered some of the most desirable traits in fruits, contributing to factors such as flavor, aroma, color, and overall taste, which are critical for consumer preference and market value (Isah, 2019). For example, phenolic compounds and flavonoids, two common classes of secondary metabolites, are known for their ability to provide vibrant colors to fruits, which is essential for attracting pollinators in nature and appealing to consumers (Kosmacz et al., 2020). In addition, terpenoids and alkaloids contribute to the distinctive aromas and flavors in many fruits, making them more desirable for consumption (Piasecka et al., 2015).

Furthermore, secondary metabolites play a pivotal role in promoting human health due to their high antioxidant content. Antioxidants such as phenolic acids and flavonoids help neutralize harmful free radicals in the body, thus reducing oxidative stress and lowering the risk of chronic diseases such as cancer, cardiovascular diseases, and neurodegenerative disorders (Ergun & Zarifikhosroshahi, 2020). Fruits rich in secondary metabolites, such as berries, grapes, and

citrus fruits, are particularly prized for their health benefits, as their antioxidant properties contribute to the prevention of diseases and promotion of general well-being (Fakhri et al., 2020). These metabolites not only enhance the nutritional value of fruits but also contribute to their sensory appeal, ensuring a high-quality diet.

Moreover, secondary metabolites such as anthocyanins are responsible for the pigmentation in many fruits, adding not only aesthetic value but also functional benefits such as protection against UV radiation. This pigmentation also has implications for human health, as anthocyanins have been shown to exhibit anti-inflammatory, anticancer, and cardioprotective properties (Guerrieri et al., 2019). The ability of secondary metabolites to improve both the health benefits and sensory qualities of fruits highlights their importance in the food industry and dietary preferences.

In addition, the presence of secondary metabolites such as terpenes and alkaloids can significantly influence the taste profiles of fruits. For instance, certain alkaloids impart a bitter taste, which can either enhance or detract from the overall flavor depending on the type of fruit and consumer preference. These taste and aroma compounds are key elements that contribute to the unique and often region-specific flavors of fruits, making them essential for culinary diversity and innovation in the food industry (Yuan & Grotewold, 2020).

Therefore, both conventional and biotechnological tools have been applied to enhance the production of desired secondary metabolites, aimed at improving crops by bolstering defense against biotic and abiotic stresses, as well as enhancing fruit quality. These approaches help in fortifying the plant's natural defense mechanisms while simultaneously improving traits such as flavor, aroma, and nutritional content, which are essential for consumer preferences and overall marketability (Gosal et al., 2010; Guerriero et al., 2018; Chen et al., 2022).

2. CLASSIFICATION OF SECONDARY METABOLITES

Plant secondary metabolites (SPMs) are categorized into four major groups: phenolic compounds, terpenes, nitrogen-containing compounds and Sulfur-containing compounds.

2.1. Terpens

Terpenes are the largest group of secondary metabolites. Terpenoids, which include monoterpenes, sesquiterpenes, diterpenes, tritrpenes and olyterpenes are synthesized via the mevalonic acid pathway and serve as critical defense mechanisms against herbivores. They also have various roles in attracting pollinators and seed dispersers due to their volatile nature. Monoterpenes, for example, are neurotoxic to insects, making them effective insect repellents (Eisner & Meinwald, 1995). Sesquiterpene lactones, another subclass of terpenoids, are known to possess strong antifungal and antibacterial properties (Picman, 1986).

2.2. Phenolic Compounds

Phenolic compounds, which include lignins, flavonoids, tannins, and coumarins, are synthesized via the shikimic acid pathway. They serve multiple defense roles, including deterring herbivores and protecting plants from pathogens (Zarifikhosroshahi et al., 2021). They are also widely distributed in the plant kingdom and contribute to a plant's defense mechanisms against ultraviolet (UV) radiation, parasites, and pathogens.

Flavonoids: One major subclass of phenolic compounds, flavonoids, functions not only as pigments but also as UV filters and antioxidant molecules. They are crucial in protecting plant cells from UV-B radiation. For example, the protective role of flavonoids is highly enhanced in certain environmental conditions, such as elevated ozone levels (Savirnata et al., 2010).
Lignins: Lignins are important structural components of the plant cell wall and provide rigidity. They also play a role in the defense against pathogen invasion by reinforcing the plant's structural barriers (Higuchi, 2018).
Coumarins: Coumarins and their derivatives exhibit antifungal and antiherbivore properties, acting as defensive agents in plants (Brooker et al., 2008).

2.3. Nitrogen-Containing Compounds
This group includes alkaloids, cyanogenic glycosides, and glucosinolates, all of which have potent biological activities. These compounds are primarily involved in plant defense mechanisms against herbivores and pathogens. For example, alkaloids are a diverse group of nitrogen-containing secondary metabolites known for their potent toxic effects on herbivores. They are synthesized from amino acids such as lysine, tyrosine, and tryptophan (Ogbemudia & Thompson, 2014).

2.4. Sulfur-Containing Metabolites
These compounds include glutathione (GSH), glucosinolates (GSL), Phytoalksin alliin, thionins, and defensins, which are directly and indirectly involved in the plant's defense mechanisms against microbial pathogens.

3. PATHWAYS FOR SECONDARY METEBOLITES PRODUCTION

Secondary metabolites are derived from primary metabolic pathways through two main biosynthetic routes:
3.1. The Mevalonic Acid Pathway
This pathway involves the conversion of acetyl-CoA to mevalonic acid, which then leads to the formation of isoprenoid compounds, such as terpenoids. These compounds, especially terpenoids, are crucial for the plant's defense against herbivores and pathogens (Gershenzon & Croteau, 1991).
3.2. The Shikimic Acid Pathway
The shikimic acid pathway is essential for the synthesis of aromatic amino acids, such as phenylalanine, which serves as the precursor for phenolic compounds and other aromatic secondary metabolites. The enzymes involved in this pathway play a critical role in producing important defensive compounds such as lignins and flavonoids (Ramawat & Merillon, 1999).

4. FUNCTIONS OF SECONDARY METABOLITES IN PLANT DEFENSE SYSTEMS

Secondary metabolites (SMs) play an essential role in the defense mechanisms of plants against biotic and abiotic stresses. These compounds include terpenoids, alkaloids, phenolic compounds, and sulfur-containing molecules, each serving distinct purposes in plant protection. For example, terpenoids help in repelling herbivores and attracting beneficial organisms like pollinators, while phenolic compounds function as antioxidants and antimicrobials, shielding

plants from pathogens (Isah, 2019). Alkaloids, another significant class, deter herbivores by being toxic or unpalatable. Sulfur-containing metabolites like glucosinolates also serve as deterrents against insect attacks and have roles in pathogen defense (Marone et al., 2022).
Plants produce these compounds in response to stress, creating a complex network of signaling pathways that activates secondary metabolite biosynthesis under stress conditions such as drought, high salinity, and pathogen invasion (Jan et al., 2021). The biosynthesis of SMs is often linked to pathways like the shikimate pathway, which is involved in producing aromatic amino acids that serve as precursors for many secondary metabolites (Chen et al., 2022).

5. CONVENTIONAL SYSTEMS FOR SECONDARY METABOLITE PRODUCTION

Traditional methods for enhancing secondary metabolite production rely on optimizing growth conditions, such as temperature, light, and nutrient availability. Historically, plant breeders have utilized selective breeding and hybridization to enhance traits linked to secondary metabolite production. However, these methods are often slow and inefficient because they require several generations of plants before the desired traits are stably expressed (Gosal et al., 2010). Another conventional approach involves the use of in vitro culture systems, such as cell or organ cultures, where plants are grown under controlled laboratory conditions to stimulate the production of secondary metabolites. In vitro cultures are particularly useful for producing valuable metabolites from medicinal plants, especially when field cultivation is challenging (Guerriero et al., 2018).

6. ADVANCED BIOTECHNOLOGICAL APPROACHES FOR SECONDARY METABOLITE PRODUCTION

In addition to conventional breeding methods, advanced biotechnological approaches are increasingly employed to boost agricultural productivity. These include RNA interference (RNAi), microRNA (miRNA), artificial miRNA (amiRNA)-mediated gene silencing, and designer Transcription Activator-Like Effector (dTALE)-mediated regulation of gene expression.

6.1. Marker-Assisted Breeding

Marker-assisted breeding (MAB) uses molecular markers linked to specific genes responsible for secondary metabolite production. This approach allows breeders to track the inheritance of these traits and select plants with enhanced metabolite production more efficiently. MAB is particularly valuable for traits controlled by multiple genes, such as the production of terpenoids or flavonoids. By using genetic markers, breeders can expedite the development of crop varieties with improved resistance to biotic and abiotic stresses, alongside increased metabolite production (Gosal et al., 2010).
For instance, researchers have identified several quantitative trait loci (QTLs) associated with flavonoid production, and these markers are now used in breeding programs to improve the nutritional quality and stress tolerance of crops (Jan et al., 2021). This technology significantly reduces the time required to breed plants with high levels of desired secondary metabolites compared to conventional breeding methods.

6.2. Elicitor-Induced Production

Elicitation involves the application of biotic or abiotic factors to stimulate the production of secondary metabolites in plants. Biotic elicitors include microbial cells, fungal components, or plant-derived molecules, while abiotic elicitors can be environmental factors such as light, temperature, or chemicals like jasmonic acid. Elicitors activate the plant's defense mechanisms, which, in turn, trigger secondary metabolite biosynthesis pathways (Chen et al., 2022).

Polyamines, such as putrescine and spermidine, are examples of abiotic elicitors that have been shown to enhance secondary metabolite production, particularly in medicinal plants. These molecules activate stress-related pathways that increase the production of bioactive compounds like alkaloids and flavonoids, which are vital for plant defense (Nandy et al., 2022). Elicitor-induced production has been successfully applied in the large-scale cultivation of plants for pharmaceutical purposes, where secondary metabolites like artemisinin are harvested for their medicinal properties (Guerriero et al., 2018).

6.3. Metabolic Engineering

Metabolic engineering involves the modification of biosynthetic pathways within the plant to enhance the production of specific secondary metabolites. This can be achieved by introducing genes from other organisms or by overexpressing or silencing endogenous genes involved in metabolite production. Advances in genetic tools like CRISPR/Cas9 and RNA interference (RNAi) have allowed scientists to precisely edit genes responsible for metabolite biosynthesis, thus improving both the quantity and quality of secondary metabolites produced (Guerriero et al., 2018).

For example, metabolic engineering has been used to increase the production of alkaloids in *Artemisia annua*, the plant that produces artemisinin, a crucial anti-malarial drug. By introducing specific genes from other species and silencing regulatory pathways that limit metabolite production, scientists have significantly boosted artemisinin yields in genetically modified plants (Nandy et al., 2022).

6.4. CRISPR Technology in Secondary Metabolite Production

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a cutting-edge gene-editing technology that allows precise DNA alterations by utilizing Cas proteins, which function as molecular scissors. The CRISPR-Cas system enables the modification, deletion, or insertion of specific genes, making it a highly effective tool for introducing desirable traits in plants. Its application in agriculture is broad, from improving crop yield and boosting resistance to diseases to enhancing tolerance against environmental stressors. Recent research emphasizes CRISPR's ability to elevate secondary metabolite production, strengthen plants' defenses against biotic and abiotic challenges, and develop disease-resistant varieties (Al Aboud, 2024; Wang et al., 2023).

CRISPR functions by guiding Cas proteins to specific genome regions using a guide RNA (gRNA) that matches the target DNA sequence. Upon locating the target, Cas9 or another Cas protein induces a cut, leading to gene editing through processes like non-homologous end joining (NHEJ) or homology-directed repair (HDR). Its versatility and accuracy allow the simultaneous targeting of multiple genes, which is crucial for regulating complex traits such as

drought resistance and improved nutritional profiles (Rajput et al., 2021; Das et al., 2023). For instance, CRISPR-Cas technology has been successfully implemented in fungal genome engineering to boost secondary metabolite synthesis (Wang et al., 2023).

This tool allows researchers to directly manipulate genes that control the biosynthesis of essential secondary metabolites, such as alkaloids, terpenoids, and phenolic compounds, which are vital for plant defense against pests, pathogens, and environmental pressures (Rajput et al., 2021). By knocking out negative regulators, CRISPR/Cas9 has significantly enhanced metabolite production important for plant defense (Bhambhani et al., 2021).

One of CRISPR's key advantages is its ability to target multiple genes involved in complex metabolic pathways. This enables the manipulation of entire gene clusters, leading to increased yields and concentrations of secondary metabolites (Jeena et al., 2022). For example, CRISPR has been employed to boost lycopene production, a potent antioxidant in tomatoes, by targeting regulatory genes in its biosynthetic pathway (Moh Zahid et al., 2024). Additionally, CRISPR has been used to enhance the synthesis of taxol, an anticancer compound derived from plants, through the editing of genes in the terpenoid biosynthesis pathway (Bashir et al., 2023).

6.5. RNAi Technology and its Role in Enhancing Secondary Metabolite Biosynthesis

RNA interference (RNAi) is a natural mechanism that silences genes by regulating gene expression at the post-transcriptional level. RNAi technology involves the introduction of small RNA molecules, such as short interfering RNA (siRNA) or microRNA (miRNA), which bind to specific messenger RNA (mRNA) targets and block their translation, effectively silencing the gene. This approach is particularly valuable for downregulating undesirable traits, such as susceptibility to pathogens or pests (Bharathi et al., 2022; Rajput et al., 2021).

The application of RNAi in agriculture has been highly effective in creating crops that are resistant to viruses, pests, and various environmental stresses. By silencing genes linked to disease susceptibility, RNAi technology has enabled the development of more resilient crop varieties (Bharathi et al., 2022; Mujtaba et al., 2021). For instance, RNAi has been successfully used to engineer plants with enhanced resistance to biotic stressors like insect pests and fungal pathogens (Mujtaba et al., 2021). Additionally, RNAi is applied to improve crop quality traits, including enhanced nutrient content and extended shelf-life (Handa, 2019; Rajput et al., 2021). RNAi technology has also been utilized to boost the production of secondary metabolites by silencing genes that negatively regulate their biosynthesis (Sharma et al., 2023). This technique has proven effective in increasing the production of alkaloids, flavonoids, and terpenoids, which are important for plant defense against herbivores and pathogens (Talekar & Kaur, 2024). Furthermore, RNAi has been used to enhance flavonoid production, which not only provides antioxidant benefits but also helps plants cope with environmental stressors like UV radiation and drought (Moh Zahid et al., 2024). Additionally, RNAi can target transcription factors involved in regulating secondary metabolite pathways, leading to a coordinated increase in multiple defense-related compounds (Sharma et al., 2023).

6.5.1. Synergistic Use of CRISPR and RNAi in Secondary Metabolite Enhancement

In recent years, the combination of CRISPR and RNAi technologies with nanotechnology has revolutionized the delivery of genetic materials into plants. Nanocarriers have proven to be

highly efficient in delivering RNAi and CRISPR molecules into plant cells without causing damage, effectively addressing limitations associated with traditional methods like Agrobacterium-mediated transformation (Mujtaba et al., 2021). This innovative approach enhances the precision and efficiency of gene editing and gene silencing, offering significant advantages for sustainable agriculture.

Both CRISPR and RNAi present immense potential in tackling critical issues such as food security and climate change. CRISPR's precision in gene editing, coupled with RNAi's ability to silence undesirable traits, offers a powerful, complementary strategy for improving crop traits. As these technologies continue to evolve, they are expected to play a pivotal role in future crop breeding programs, offering novel solutions to pressing agricultural challenges (Hameed & Awais, 2021; Akanmu et al., 2024).

Moreover, these technologies have emerged as crucial tools for enhancing secondary metabolite production in plants, which is vital for defense against biotic and abiotic stresses. The combined application of CRISPR and RNAi allows for fine-tuning secondary metabolite pathways by knocking out genes that limit metabolite production and silencing negative regulators. This approach has been particularly successful in increasing the production of terpenoids and other key metabolites essential for plant defense (Bhambhani et al., 2021). For instance, in *Brassica napus*, the use of both technologies has led to higher levels of glucosinolates, important metabolites for deterring herbivores and pathogens (Moh Zahid et al., 2024). This precise control over secondary metabolite biosynthesis pathways enhances crop resilience and leads to higher yields (Sharma et al., 2023).

7. CONCLUSION

In conclusion, secondary metabolites are essential components in plants, contributing not only to their defense against biotic and abiotic stresses but also to their attractiveness and nutritional value for human consumption. The ongoing challenges posed by climate change and consumer demand for high-quality agricultural products have driven the development and application of both conventional and biotechnological tools to enhance the production of these metabolites. Techniques such as marker-assisted breeding, elicitor-induced production, and metabolic engineering, including the use of CRISPR and RNAi, offer advanced methods for improving crop resilience, fruit quality, and overall agricultural productivity. These innovations enable scientists to target specific genes involved in secondary metabolite biosynthesis, allowing for precise manipulation that enhances plant defense mechanisms and improves traits like flavor, aroma, and nutritional content. The continued integration of these technologies in agriculture promises not only to meet the challenges of food security but also to provide healthier and more desirable products to consumers.

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TARIM ALANINDA NANOPARTİKÜLLERİN KULLANIMI

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ÖZET

Dünya üzerinde artan nüfus odaklı olarak ortaya çıkmış hızlı ve plansız kentleşme, nüfus ihtiyaçlarını karşılamak amacıyla yapılan yoğun tarımsal uygulamalar ve sanayi faaliyetleri günden güne ekolojiyi olumsuz yönde etkilemekte ve birçok felaket senaryosunun başrolünü oynamaktadırlar. En önemli konulardan birisi nüfusun besin ihtiyaçlarını karşılamaktır. Bunu sağlamak amacıyla ise birim alandan elde edilen ürünün artırılmasına yönelik çalışmalar her geçen gün artmaktadır. Kimyasal gübrelerin önemli bir yer tuttuğu bu tarımsal faaliyetler dolayısıyla topraklarda ve yer altı sularında ciddi bulaşmalar olmakla birlikte bu materyallerin kullanımı tam anlamıyla eksiklikleri gideremmektedir. Birim alandaki ürün artışını sağlamaktaki zorunluluk, olumsuzluklarına rağmen kimyasal gübre kullanımında artışa sebebiyet verecektir.

Son yıllarda çevreci politikalardaki değişiklikler, bireyler ve toplumların kazandıkları bilinç sayesinde çevre dostu ürün kullanımı giderek yaygınlaşmaktadır. Özellikle tarımsal faaliyetlerde ortaya çıkan birçok doğa dostu materyalin kullanımı ve etkisi üzerine çok sayıda çalışma yapılmaktadır. Son dönemlerde popüler hale gelen çevreci ürünlerden birisi ise nanopartiküllerdir. Özellikle bitki özleri, bitki dokuları, mantarlar, bakteriler ve algler gibi doğal malzemeler kullanılarak yeşil sentez yöntemi ile üretilen nanopartiküller doğa dostu ürünlerdir. Ayrıca nanopartüküllerin boyutları ve yüzey alanlarının genişliği bitkiye nüfuzunu kolaylaştırmaktadır. Bu sebeplerle sentetik gübrelere kıyasla daha az miktarda ürünle daha fazla etki sağlayabilmektedirler.

Bu çalışmada, çevre dostu ürünler olan ve sentetik gübrelere alternatif olarak yüksek bir potansiyele sahip olan nanopartiküller hakkında detaylı bilgiler verilerek tarımsal amaçlı kullanım olanakları ve yapılmış çalışmalar irdelenmeye çalışılacaktır.

Anahtar Kelimeler: Tarım, nanopartiküller, çevre, kirlilik

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USE OF NANOPARTICLES IN AGRICULTURE

ABSTRACT

The rapid and unplanned urbanization driven by the growing global population, intensive agricultural practices aimed at meeting population demands, and industrial activities are increasingly negatively affecting the ecology and playing a central role in numerous disaster scenarios. One of the most crucial issues is meeting the food needs of the population. To achieve this, efforts to increase the yield per unit area are intensifying every day. While chemical fertilizers play a significant role in these agricultural activities, they cause serious contamination of soils and groundwater, and their use cannot fully address nutrient deficiencies. The necessity to increase the yield per unit area will lead to a rise in the use of chemical fertilizers, despite their negative impacts.

In recent years, thanks to changes in environmental policies and the awareness gained by individuals and societies, the use of environmentally friendly products is becoming increasingly widespread. Numerous studies are being conducted on the use and effects of many eco-friendly materials, particularly in agricultural activities. One of the eco-friendly products that have gained popularity in recent times is nanoparticles. Nanoparticles produced using the green synthesis method, especially with natural materials such as plant extracts, plant tissues, fungi, bacteria, and algae, are environmentally friendly products. Moreover, the small size and large surface area of nanoparticles facilitate their penetration into plants. For these reasons, they can provide more effect with a smaller amount of product compared to synthetic fertilizers.

In this study, detailed information about nanoparticles, which are environmentally friendly products with high potential as alternatives to synthetic fertilizers, will be presented, and their agricultural usage possibilities and existing studies will be reviewed.

Keywords: Agriculture, nanoparticles, environment, pollution

1. GİRİŞ

İnsan beslenmesi ve hayatının devamı açısından en önemli faaliyetlerden birisi tarımdır. Tarımsal faaliyetler insanlıkla beraber var olmaya başlamış ve gün geçtikçe daha modern ve teknolojik bir yapıya dönüşmüştür. Artan dünya nüfusunun beslenme ihtiyaçlarını karşılama kaygısı birçok tekniğin veya ürünün geliştirilmesine ve yoğun şekilde kullanılmasına yol açmıştır. Günümüz modern tarımının verim ve kalite gibi faktörler için sunduğu en önemli silah gübre ve ilaç kullanımı olmuştur. Bu kimyasalların kullanımı beklenen faydaları sağlamış olsa da, uzun vadede toprak, su ve hava gibi insanlığın yaşam kaynaklarını yoğun şekilde kirlettiği de ortaya çıkmıştır (Alp vd. 2016, İpek vd. 2017). Aşırı gübreleme, ilaçlama, sulama, iklim değişikliği ve küresel ısınma gibi faktörler birleştiğinde kaynaklarda meydana gelen bozulmalar bitki gelişim ve verimini olumsuz etkilemiş, meydana gelen olumsuzluklara çözüm bulmak amacıyla çiftçiler kimyasal ürünlere daha da çok sarılmışlardır. Ortaya çıkan kısır döngü özellikle tarım topraklarını kullanılamaz hale dönüştürmeye başlamıştır (Youssef ve Eissa, 2014).

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Bilimsel gelişmeler, toplumsal farkındalık, ulusal veya uluslararası anlaşmalar, çevre bilincinin artması ve çevreci örgütlerin çalışmaları gibi faktörlerle üretimde doğa dostu yaklaşımlara yönelim artmıştır. Eğitim ve gelir seviyesinin yüksek olduğu ülkeler başta olmak üzere birçok ülke çevreci politikaları benimsemiş ve gerekleri uygulamaya yönelik adımlar atmışlardır. Tüketicilerde artan bilinç ise biyolojik, ekolojik veya organik yöntemlerin öncelendiği üretim sistemlerinin ürünlerini tüketmeye özen göstermeye başlamışlardır (Özyazıcı vd., 2010; Kodaş, 2011; Dursun vd., 2019).

Özellikle tarımsal üretimde kimyasal girdilerinin azaltılmasına yönelik yoğun çalışmalar yapılmış ve yapılmaya da devam etmektedir. Bu çalışmaların içerisinde son yıllarda sıkça söz edilen konulardan birisi de nano-partiküllerin tarımda kullanılmasıdır.

2. NANOPARTÜKÜLLER ve TARIM

Nanoteknoloji biliminin bir ürünü olan partiküller, 1-100 nm boyut skalasında olan ve farklı alanlarda kullanım olanağı bulunan materyallerdir (Miller vd., 2004). Latincede cüce anlamına gelen “nano” kelimesinden isimlendirilmiş olan bu materyallerin boyutunu anlatmak için metrenin milyarda biri ifadesi kullanılmaktadır. Nano boyuttaki malzemelerin daha büyük ölçek gruplarında bulunan malzemelere göre en büyük üstünlüğü boyutları dolayısıyla yüzey alanlarının oldukça geniş olmasıdır (Şekil 1). Bu sayede etkinlik, iletkenlik ve reaktivite gibi konularda avantaj sağlamaktadır (Erdim vd., 2019).

Bu malzemeler doğada bazı süreçlerle birlikte kendiliğinden oluşabildiği gibi sentetik olarak da üretilebilmektedir. Ayrıca yeşil sentez denilen süreç içinde mikroorganizmalardan veya bitkilerin farklı kısımlarından da elde edilebilmektedirler (Lewis Oscar vd., 2016; Raghuvanshi vd., 2017). Bu üç sentez yaklaşımı fiziksel, kimyasal ve biyolojik olarak sınıflandırılmıştır. Bu sınıflandırmada yukarıdan aşağı veya aşağıdan yukarı şeklinde ifade edilen sentez yöntemi farklı sonuçları doğurur. Yukarıdan aşağı yaklaşımı malzemelerin mekanik olarak nanometre ölçeğine indirmeyi, tersi olan aşağıdan yukarıya yaklaşımı ise atomlar veya moleküllerin bir araya getirilerek nanometre boyutunda parçacıklar oluşturmasını ifade eder (Ghosh vd., 2021).

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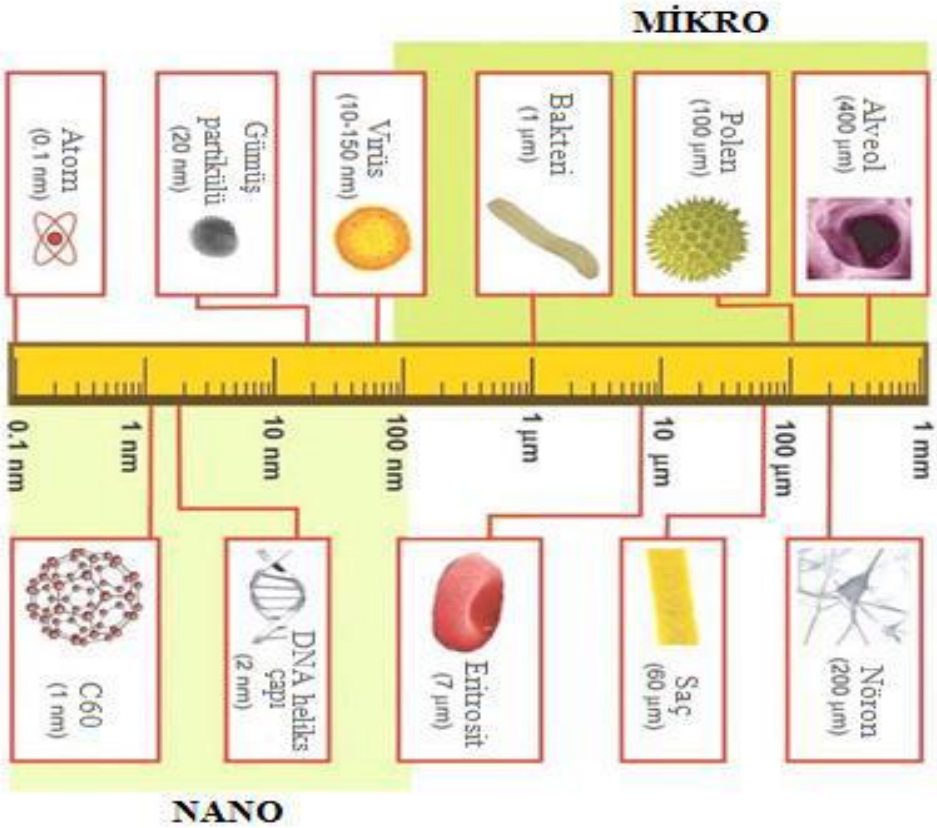

Şekil 1. Farklı bileşenlerin metrik karşılaştırması (Özkurt, 2020/649791 TEZ)

Nano malzemeler, nanokristaller, nanotüpler, nanoçubuklar, nanopartiküller, nanoteller olarak sıralanabilir. Bu malzemeler ilaç, kozmetik, gıda, biyomedikal, çevre, endüstri ve tarım gibi birçok farklı alanda kullanım alanına sahiptirler ve tarımsal amaçlı nano malzemelerin kullanımı giderek yaygınlaşmaktadır.

Küresel ısınma, iklim kaymaları, ekosistemdeki bozulmalar ve değişiklikler gibi faktörler bitkisel üretim anlamında bütün dünyada problemlere neden olmuştur (Akhtar vd., 2022). Çevresel problemlerle birlikte hızlı bir şekilde devam eden şehirleşme ve sanayileşme ise tarımsal alanların azalmasına sebep olmaktadır. Üretim süreci öncesi, sırası ve sonrasında ortaya çıkan problemler azalmadığı gibi dünya nüfusu devamlı artma eğilimindedir. Artan nüfusun besin ihtiyacının karşılanması ise öncelikli konu olarak karşımıza çıkmaktadır.

Gıda talebinin karşılanması, yoğun tarımsal üretim süreçleri ile meydana gelmektedir ve giderek artan bilinç bu süreçlerde doğa dostu, kimyasal kullanımına bağlılığı azaltan, güvenilir, sürdürülebilir, akıllı ve daha yeşil üretim tekniklerine önem verilmesini sağlamaktadır. Bu beklentilerle birçok araştırma ve geliştirme faaliyetleri yapılmaktadır. Nanoteknolojik malzemeler ise bu ürünlerin en önemlilerindendir ve son yıllarda özellikle gelişmekte olan ülkelerde oldukça rağbet görmeye başlamıştır (Qureshi, 2018; Chhipa, 2019;; Akhtar vd., 2022). Nanoteknolojinin tarımsal amaçlı kullanımı gelecek vadetmekle birlikte sağlıklı ve verimli bir tarımsal üretimi de vadetmektedir (Rajput vd., 2021; Singh vd., 2021).

Nanopartiküllerin diğer adı yeşil sentez olan biyosentez yöntemi ile elde edilmesi, basit yapılı materyallerden daha karmaşık yapıda materyaller elde etmeyi hedefleyen bir süreçtir. Kimyasal veya canlı organizmaları kullanarak gerçekleştirilen bu süreçte algler, bakteriler, bitkiler, mantarlar gibi organizmalar rol oynayabilmektedir (Bar vd., 2009; Philip vd., 2010; Dubey vd., 2010). Bu yöntemin toksik bir materyal içermemesi, ekonomik olması, basit bir uygulama olması gibi sebepler son zamanlarda sıkça tercih edilmesinin sebebidir. Doğa dostu bir çözüm olan yeşil sentez yoluyla nanopartikül (NP) üretimi, son dönemde birçok çalışmada kullanılmış ve farklı türlerde bitkilerde denenmiştir.

Tarımsal amaçlı kullanılan ilaçlar ve gübreler gerek bitkiler tarafından alımında yaşanan aksaklıklar, gerek dozlamalardaki problemler sebebiyle çevreyi kirletmesi bakımından bazı riskler barındırmaktadır. Nanopartiküllerin kullanımı bunlar gibi problemlere alternatif bir çözüm olarak sunulabilir (Verma vd., 2018). Nanopartiküllerin özellikle metal bazlı olanlarının yapılan çalışmalar genelinde yüksek dozlarda olumsuz etkilerinin olduğu birçok kez bildirilmiştir. Metalik nanopartiküllerin toksik etkileri, bitkilerin ve tohumların gelişimini engellemeleri ve beslenme yoluyla hayvan veya insan bünyesine toksik maddelerin nüfuzu konuları bazı çalışmalarda bildirilmiştir (Rico vd.,2011; Ghodake vd., 2011; Atha vd., 2012). Nanopartiküllerin düşük dozlarının olumlu etkilerinin bulunduğu da birçok çalışmada bildirilmiştir. ZnO, SiO2, CeO2, Fe2O3, Fe3O4 ve Fe(0) gibi birçok farklı nanomalzemenin çeşitli bitkilerde bitki büyümesine olumlu etkisinin olduğu gözlemlenmiştir (Pariona vd., 2017; Janmohammadi vd., 2017; Elanchezhian vd., 2017; Palchoudhury vd., 2018).

2.1. Yapılmış Çalışmalar

Demir oksit nanopartiküllerinin test edildiği bir çalıĢmada, farklı konsantrasyonlarda tarla şartlarında uygulanan demir oksit NP' lerinin soya fasülyesinin gelişimini pozitif şekilde etkilediği ve verimi artırdığı saptanmıştır. Bunun yanında bu NP'lerin fotosentez miktarını artırdığı, yapraklara demir transferinin daha etkili bir şekilde gerçekleştiği belirlenmiştir (Sheykhbaglou vd.,. 2010).

Gen aktarım çalışmalarında da bitkiler üzerinde kullanılan altın nanopartiküller ile yapılan çalışmada, plazmitin altın nanopartiküller ile transferinin yapılabildiği ortaya konulmuştur (Christou vd., 1998). Torney vd. (2007) yapmış oldukları çalışmada, silika nanopartiküllerinin yüzeye bağlanma ve enkapsülasyon açısından etkinliklerini gözlemlemişler ve gen aktarımında diğer yöntemlere nazaran çok daha etkili olduğunu açığa çıkarmışlardır.

Ayçiçeğinde TiO_2 nanopartikülleri ile yapılan çalışmalarda, kullanılan nanopartikülün gelişim ve yağ içeriğine önemli katkılarda bulunulduğu (Janmohammadi vd., 2017) ve aynı nanopartikülün arpa (Mattiello ve Marchiol, 2017); maydanoz (Dehkourdi ve Mosavi, 2013); buğday (Rafique vd., 2015; Du vd., 2011); domates (Qi vd., 2013); soya (Rezaei vd., 2015); salatalık (Servin vd., 2013) gibi çeşitli bitkilerde de gelişimi arttırdığı kaydedilmiştir. Yine bu nanopartiküllerin ıspanakta fotosentezi artırdığı (Gao vd., 2008; Yang vd., 2007), kabak, marul, keten ve mısır gibi bitkilerde ise tohum çimlenmesine ve kök-gövde uzunluğunun artmasına ayrıca fide büyümesine katkıda bulunduğu bildirilmiştir (Andersen vd., 2016; Aghdam vd., 2016; Lyu vd., 2017).

ZnO nanopartikülleri ile farklı bitkilerde çalışmalar yapılmıştır. ZnO nanopartiküllerinin farklı dozlarının kurak koşullarda soyanın farklı özelliklerine olumlu etkiler yaparak strese toleransı artırdığı (Sedghi vd., 2013), yer fıstığında in vivo çalışmalarında yine tohum çimlenmesi ve gelişim parametrelerini olumlu etkilediği (Prasad vd., 2012), hıyar tohumları ile yapılan bir çalışmada ise çimlenme özellikleri ve gelişim parametrelerini olumlu etkilediği bildirilmiştir (de la Rosa vd., 2013). Farklı bitkilerde benzer sonuçlarla alakalı çalışmaları çeşitlendirmek mümkündür. Muzda (Helaly vd., 2014), mısırda (Zhao vd., 2013), bezelyede (Mukherjee vd., 2014) ve turpta (Garcia-Gomez vd., 2015) bitki gelişim parametreleri ile ilgili olarak önemli faydalar sağlandığı çalışmalarda bildirilmiştir.

Yine demir nanopartikülleri ile yapılan çalışmalarda ayçiçeğinde (Shahrekizad vd., 2015; Mohammadi vd., 2020), soyada (Alidoust ve Isoda, 2013), buğdayda (Rizwan vd., 2019), mısırda (Li vd., 2016; Elanchezhian vd., 2017), domateste (Shankramma vd., 2016) tohum çimlenmesi, bitki gelişimi ve abiyotik stres koşullarının tolere edilmesi konusunda önemli faydalar sağlandığı bildirilmiştir.

3. SONUÇ

Sonuç olarak, nanopartiküllerin farklı türler üzerinde olumlu etkilerini artırmak oldukça mümkündür. Birçok çalışma bu nano büyüklükteki materyallerin bitki gelişimi ve verimi üzerinde olumlu etkilerinden sıkça bahsetmektedir. Bu etkilerin sebepleri yukarıdaki bölümlerde bahsettiğimiz gibi nanopartiküllerin yapısal özellikleridir. Bitkilere hızlı nüfuz etmeleri, etkinlik derecelerinin yüksek olması, az miktarda ürünle daha fazla katkı sağlanması gibi faktörler nanopartiküllerin tarımda kullanılabilirliğini işaret etmekle birlikte, kimyasal kullanımının azaltılmasına da katkıda bulabileceklerini göstermektedir. Farklı türlerle yapılmış çok sayıda çalışma olmakla birlikte, hala birçok türde yapılacak çalışmalara ihtiyaç duyulmaktadır. Bazı çalışmalar nanopartüküllerin toksik etkilerinden de bahsetmektedir. Ancak bu konu tam anlamıyla aydınlatılmış değildir. Bu sebeple bu konuda çalışmaların artırılması ve literatüre katkıda bulunulması konusu oldukça önem arz etmektedir.

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ÖZET

Tarımsal faaliyetlerin en önemlilerinden birisi bahçe bitkileri yetiştiriciliğidir. Bahçecilik faaliyetlerinde meyve yetiştiriciliği ve ıslahı önemli bir yer tutar. Çok eski tarihlere dayanan bir faaliyet alanı olan meyve yetiştiriciliği bazı teknik ve teknolojik gelişmeler ile birlikte daha yoğun bir tarımsal üretim alanı haline gelmiştir. Meyve anaçlarının ıslahı ve kullanımı bu gelişmelerin en önemlilerindendir. Meyvecilikte anaç kullanımı çok yönlü amaçlar için kullanılmakta ve yetiştiriciliği yapılacak tür ve çeşitleri birçok açıdan etkilemektedir. Anaç kullanımı sayesinde bitkilerin gelişim özellikleri amaca göre ayarlanabilmekte, yetiştiricilik kısıtları bulunan topraklarda üretim imkanı sunulabilmektedir. Elma, ayva, badem vb. türlere ait anaçlar Türkiye meyveciliğinde sıklıkla kullanılan ve yaygınlaşmış olan anaç türleridir. Sert kabuklu bir meyve olan ceviz, Türkiye' de olduğu gibi dünyanın birçok ülkesi için önemli ve değerli bir meyve türüdür. Yetiştiriciliği ve ıslahı ile ilgili birçok çalışma yapılmıştır ve yapılmaya devam etmektedir. Ceviz yetiştiriciliğinde anaç kullanımı bazı ülkelerde başlamış olsa da ülkemizde bu konuda var olan uygulama ve bilgi yok denecek kadar azdır.

Bu çalışmada ceviz türünde anaç kullanımı ile ilgili bilgiler ve çalışmalara yer verilerek özellikle Türkiye ceviz yetiştiriciliği bakımından ceviz anacı kullanımının potansiyeli tartışılmaya çalışılacaktır.

Anahtar Kelimeler: Ceviz, anaç, *Juglans regia*

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USE OF ROOTSTOCKS IN WALNUT CULTIVATION

ABSTRACT

One of the most important agricultural activities is the cultivation of horticultural plants. In horticulture, fruit cultivation and breeding hold a significant place. Fruit cultivation, a practice with ancient roots, has become a more intensive area of agricultural production through various technical and technological advancements. The breeding and use of fruit rootstocks are among the most important of these developments. In fruit growing, rootstocks are used for multiple purposes and significantly influence the species and varieties to be cultivated in various ways. The use of rootstocks allows for the adjustment of plant growth characteristics according to specific objectives, offering cultivation possibilities in soils with growing constraints. Rootstocks for species such as apple, quince, and almond are commonly used and widespread in Turkish fruit cultivation. Walnut, a hard-shelled fruit, is an important and valuable crop for many countries, including Turkey. Numerous studies have been conducted on its cultivation and breeding, and research continues. While the use of rootstocks in walnut cultivation has begun in some countries, the application and knowledge of this practice in Turkey are almost nonexistent.

In this study, information and research on the use of rootstocks in walnut species will be presented, with a focus on the potential for using walnut rootstocks in walnut cultivation in Turkey.

Keywords: Walnut, rootstock, *Juglans regia*

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1. GİRİŞ

Tarımsal üretimde meyvecilik, sebzecilik ve süs bitkilerinin vejetatif çoğaltımı amacıyla anaçlar yaygın olarak kullanılmaktadır (Gregory vd., 2013; Nawaz vd., 2016; Warschefsky vd., 2016). Kuvvetli ve sağlıklı kök siteminin oluşturulması, çevre ve iklim koşullarına uygun anacın seçilmesi ile mümkün olabilmektedir (Gundesli vd., 2018; Sharma vd., 2020). Seçilen anaç, bitkinin su ve besin alımına etki etmesi ve hormonal özellikler üzerinde değişiklikler yapması şeklinde kalemin büyümesi üzerinde etkili olabilmektedir (Martínez-Ballesta vd., 2010; Goldschmidt, 2014; Albacete vd., 2015; Warschefsky vd., 2016). Ticari anlamda sağladığı faydaların yanında, abiyotik veya biyotik stres koşullarına daha toleranslı anaçlar çeşidin de bu streslere karşı daha dirençli olmalarını sağlarlar (Schwarz vd., 2010; Wang vd., 2017; Kumar vd., 2017; Liu vd., 2020).

Ceviz (*Juglans regia* L), genel olarak tohumla çoğaltılan bir türdür. Heterozigot özellikte olan ceviz tohumlarının genetik olarak açılım göstermesi, tohumdan elde edilen bitkilerin standart bir özellik göstermemesine sebep olmaktadır. Bu gibi bitkiler düşük verime ayrıca uzun gençlik kısırlığı dönemlerine sahip olabilmektedirler (Vahdati, 2003). Ceviz türünde tohumdan üretim, ıslah amacı olan yetiştiricilik programları veya anaç üretimi sebebiyle olabilmektedir (Hassani vd., 2020). Fidan üretim sürecinde anaçlık kullanmak amacıyla tohumdan üretilmiş bitkilerin değişken özelikleri standart özellikte plantasyonların kurulmasını engellemektedir.

Cevizlerin aynı özellikler gösteren klon bitkiler olarak çoğaltılmasının yolları vejetatif çoğaltma yöntemlerinden geçmektedir. En yaygın yöntem aşılama olmakla birlikte bu üretim sürecindeki zorluklar ceviz aşılamasındaki başarıyı zaman zaman düşürmekte ve birim maliyetleri artırabilmektedir (Vahdati vd., 2021). Aşılama dışında çelik alma veya daldırma yöntemleri de ceviz türlerinin vejetatif çoğaltımı amacıyla denenmiş olsa da çoğaltma başarısının düşüklüğü bu yöntemlerin tercih edilmemesine neden olmuştur (Tajbakhsh vd., 2009; Liu vd., 2018).

1.1. Cevizde Mikroçoğaltım

Son yıllarda ceviz anaç ıslahı konusunda özellikle biyoteknolojik yöntemlerde önemli gelişmeler olmuş ve bu konuda önemli başarılar elde edilmiştir. Ceviz mikroçoğaltımı ile ilgili ilk başarılı çalışmalar 1980' li yıllara dayanmaktadır (Driver ve Kuniyuki, 1984; McGranahan vd., 1987; McGranahan vd., 1988; Revilla vd., 1989). Kullanılan türün genetik özellikleri, çevresel koşullar, eksplantların sağlık durumu ve besleme ortamı gibi faktörlerin başarıyı etkilediği ceviz mikroçoğaltımı sürecinde birçok çalışma yapılmış ve bu konulara odaklanılmıştır. Ceviz mikroçoğaltımında adventif kök oluşumun çoğaltım aşamasının en kritik süreci olduğu birçok çalışmada bildirilmiştir. Kök oluşumunu etkileyen faktörler ise içsel ve dışsal olarak sınıflandırılmıştır. Mikroçoğaltım aşamasında sıcaklık, nem, ortam ışığı, eksplantlar ve durumları, kullanılan hormon cinsleri ve besin ortamı çeşitleri vb. konular süreci etkileyen faktörler olarak karşımıza çıkmaktadır. Bu faktörler birçok araştırmaya konu olmuş ve doğru koşulların neler olduğu araştırmacılar tarafından rapor edilmiştir.

1.2. Ceviz Anaçları

Özellikle Amerika, Çin ve Fransa gibi ülkelerde ceviz klon anacı üzerine çalışmalar yoğun bir şekilde yürütülmüştür. Bu çalışmaların temelinde cevizin mikroçoğaltımı ile ilgili gelişmeler önemli bir yer tutmuştur. Amerika' da tohumdan üretilmiş anaç kullanımı giderek terkedilmiş anaç ıslahı çalışmaları sonucunda *J. regia* ve *J. hindsii* türlerinin melezinden ortaya çıkan klon Paradox anacı ceviz bahçelerinin %80' ine yayılmıştır. Paradox anaçları Armillaria ve Phytophtora gibi bazı hastalıklara tolerans sağlamıştır. Bu başarı, diğer ceviz hastalıklarına toleranslı ceviz anacı ıslahı çalışmalarını hızlandırmıştır. Daha sonraları Amerika' da Vlach, RX1, VX211, Ng209 ve Grizzly gibi farklı özelliklere sahip anaçlar geliştirilmiştir (Vahdati vd., 2021). Ceviz ıslahı konusunda diğer önemli bir ülke olan Fransa' da ilk anaç ıslahı çalışmalarında *J. nigra* ve *J. regia* türleri kullanılmıştır. Yapılan çalışmalarda *J. nigra* türünün zayıf toprak koşullarında *J. regia* daha iyi gelişim gösterdiği tespit edilmiştir (Ramos and Doyle,1984; Bernard et al., 2018). Önemli bir ıslah kurumu olan Fransa' nın INRAE kuruluşunda sonraları bazı ceviz anaçları ıslah edilmiştir. *J. nigra* ve *J. regia* melezleri olarak ortaya çıkarılan klon anaç tipleri Lozeronne, RA 611 ve Culplat isimleri ile tescil edilmiştir. Armillaria hastalığına *J. regia'*dan daha dayanıklı olduğu tespit edilen klonların, antraknoz hastalığına da Paradox anacından daha dayanıklı olduğu tespit edilmiştir (Kim et al., 2012; Manthos ve Rouskas, 2021). Çin'de ise farklı türlerin anaçlık özellikleri üzerine araştırmalar yapılmıştır. Liu vd., (2020), Çin' in farklı bölgelerine yayılmış J. regia, J. sigillata, J. cathayensis, J. hopeiensis ve J. mandshurica türlerini tohum çimlenmesi, fide gelişimi ve fidanların morfolojik ve fizyolojik performansları bakımından incelemişlerdir. Ceviz türleri bakımından zengin bir genetik zenginliğe sahip Çin' de farklı türlerin önemli yetiştiricilik kabiliyetlerine sahip olduğu belirtilmiştir.

Ceviz anaç ıslahı konularında önemli çalışmalar yapan bu ülkelerin dışında yine abiyotik veya biyotik stres koşullarına tolerans, kuvvetli gelişim performansı, kuraklığa dayanıklılık gibi konuları göz önünde bulundurarak ıslah programları yürüten bazı ülkeler bulunmaktadır ve İran, Macaristan, Romanya gibi ülkeler bunlardan birkaçıdır.

2. SONUÇ

Günümüzde anaçlar tarım, bahçecilik ve ormancılıkta meyvelerin, sebzelerin ve süs bitkilerinin vejetatif çoğaltımı amacıyla yaygın olarak kullanılmaktadır. Anaçlar üzerlerine aşılanmış çeşitlerin su, mineral, besin ve hormon durumunu etkiler ve çeşitlerin gelişim performanslarını düzenlerler. Anaçlar ayrıca aşılı bitkilerin biotik ve abiyotik streslere karşı dirençlerini artırmak için yaygın olarak kullanılmaktadırlar.

Juglans cinsi, dünya üzerinde kapsadığı geniş yayılma alanı, değerli meyveleri ve kerestesi, besleyici özellikleri ve stratejik yeri dolayısıyla önemli meyve türlerinin başını çekmektedir. Birçok ülkede tohumdan yetişmiş anaçlar üzerinde yetiştirilen ceviz çeşitlerinde anaç standardı bulunmamaktadır. Bu durum farklı ekolojik koşullara uygun anaç seçimi ile yetiştiriciliği imkansız kılmaktadır. Bu konuda çalışan sayılı ülkelerde ceviz mikroçoğaltımı ile ilgili başarılı sonuçlar elde edilmiş, anaç ıslahı çalışmaları sonucunda klon anaçlar geliştirilebilmiştir. Bunun

sonucunda farklı stres faktörlerine göre anaç seçimi yapılabilmiştir, verim ve gelişim parametrelerinde artışlar sağlanabilmiştir.

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EFFECTS OF ABIOTIC STRESS FACTORS ON FRUIT SPECIES BIODIVERSITY

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ABSTRACT

Abiotic stress factors such as temperature extremes, water availability, soil salinity, and pollution can have profound effects on the biodiversity of fruit species. Here are some key effects. Heat Stress: Elevated temperatures can reduce fruit set, size, and quality. Some species may not survive or reproduce effectively, leading to a decrease in biodiversity. Cold Stress: Frost and cold temperatures can damage fruit tissues, reducing yield and potentially killing plants not adapted to such conditions. Species with low cold tolerance may decline in number or disappear from certain areas. Water scarcity can lead to reduced fruit size, quality, and yield. Species that are not drought-tolerant may be outcompeted by more resilient species, leading to a reduction in biodiversity. Flooding: Excess water can cause root hypoxia, leading to poor plant health and reduced fruit production. Species that cannot tolerate waterlogged conditions may decline. High salt concentrations in the soil can impair plant water uptake and lead to physiological stress. Sensitive species may suffer reduced growth and reproductive success, potentially leading to decreased biodiversity as more salt-tolerant species dominate. Overall, abiotic stress factors can create challenging conditions for fruit species, leading to shifts in species composition, reductions in genetic diversity, and changes in ecosystem dynamics. Adaptation to these stressors varies among species, influencing which species thrive and which decline, thereby affecting overall biodiversity. In the present review, effects of common abiotic stress factors on fruit species biodiversity are discussed.
Anahtar Kelimeler: Abiotic Stress, Drought, Fruit, Salinity

ABİYOTİK STRES FAKTÖRLERİNİN MEYVE TÜRLERİNİN BİYOÇEŞİTLİLİĞİ ÜZERİNDEKİ ETKİLERİ

ÖZET

Aşırı sıcaklıklar, su mevcudiyeti, toprak tuzluluğu ve kirlilik gibi abiyotik stres faktörlerinin meyve türlerinin biyolojik çeşitliliği üzerinde derin etkileri olabilir. İşte bazı önemli etkiler. Isı Stresi: Yüksek sıcaklıklar meyve tutumunu, boyutunu ve kalitesini azaltabilir. Bazı türler hayatta kalamayabilir veya etkili bir şekilde çoğalamayabilir, bu da biyolojik çeşitliliğin azalmasına yol açabilir. Soğuk Stresi: Don ve soğuk sıcaklıklar meyve dokularına zarar verebilir, verimi azaltabilir ve potansiyel olarak bu koşullara uyum sağlayamayan bitkileri öldürebilir. Soğuğa toleransı düşük olan türlerin sayısı azalabilir veya bazı bölgelerde yok olabilir. Su kıtlığı meyve boyutunun, kalitesinin ve veriminin azalmasına neden olabilir. Kuraklığa dayanıklı olmayan türler, daha dirençli türler tarafından rekabette geride bırakılabilir

ve bu da biyolojik çeşitliliğin azalmasına yol açabilir. Su baskını: Aşırı su, kök hipoksisine neden olabilir, bu da bitki sağlığının bozulmasına ve meyve üretiminin azalmasına neden olabilir. Suyla dolu koşulları tolere edemeyen türlerin sayısı azalabilir. Topraktaki yüksek tuz konsantrasyonları bitkinin su alımını bozabilir ve fizyolojik strese yol açabilir. Hassas türlerin büyümesi ve üreme başarısı azalabilir, bu da tuza dayanıklı türlerin baskın olması nedeniyle potansiyel olarak biyolojik çeşitliliğin azalmasına yol açabilir. Genel olarak abiyotik stres faktörleri, meyve türleri için zorlayıcı koşullar yaratarak tür kompozisyonunda değişimlere, genetik çeşitlilikte azalmalara ve ekosistem dinamiklerinde değişikliklere yol açabilir. Bu stres etkenlerine uyum, türler arasında farklılık gösterir; hangi türün gelişip hangisinin azaldığını etkiler ve dolayısıyla genel biyolojik çeşitliliği etkiler. Bu derlemede yaygın abiyotik stres faktörlerinin meyve türlerinin biyolojik çeşitliliği üzerindeki etkileri tartışılmaktadır.
Anahtar Kelimeler: Abiyotik Stres, Kuraklık, Meyve, Tuzluluk

1. GİRİŞ

Biyoçeşitlilik, farklı bitki, hayvan ve mikroorganizma türlerini ve bunların oluşturdukları ekosistemleri kapsayan Dünya üzerindeki yaşam çeşitliliğini ifade eder. Ekosistemlerin sağlığını ve dengesini korumak, temiz hava, su, gıda ve iklim düzenlemesi gibi hayati hizmetleri sağlamak için gereklidir.

Bitkilerde biyoçeşitlilik bakımından büyük bir zenginlik bulunmaktadır. Bitki biyoçeşitliliği, belirli bir alan veya ekosistem içindeki bitki türlerinin çeşitliliği ve bolluğunun yanı sıra bu türler içindeki genetik farklılıkları ifade eder (Swingland, 2001). Ekosistemlerin istikrarına ve dayanıklılığına katkıda bulunan, genel biyolojik çeşitliliğin önemli bir parçasıdır. Bitki biyoçeşitliliği ekosistemlerin sağlığı ve insanın hayatta kalması için hayati öneme sahiptir. Ekosistem hizmetlerinin sürdürülmesine, gıda güvenliğinin desteklenmesine ve iklim değişikliğiyle mücadeleye yardımcı olur. Bitki biyoçeşitliliğinin korunması, doğanın dengesinin korunması ve kaynakların gelecekte kullanılabilirliğinin sağlanması açısından hayati öneme sahiptir (Dar vd., 2018).

Bitkilerin biyoçeşitliliği çevresel faktörlerden dolayı etkilenmektedir. Birçok çevresel stres faktörü bulunmakta olup bitkilerin bu streslere adaptasyonu süresince farklı uyum yetenekleri ile bitkiler hayatta kalabilmekte veya ölmektedir (Awodoyin vd., 2015). Böylece çevresel stres faktörleriyle bitkilerin biyoçeşitliliği etkilenebilmektedir (van Der Meer vd., 2020). Biyoçeşitlilik incelenirken hem kendiliğinden yabani olarak yetişen bitkiler hem de yetiştiriciliği yapılıp bölgede seneler boyunca uyum sağlamış bitkilerin değerlendirilmesi gerekmektedir.

Bitkilerde stres faktörleri genel olarak ikiye ayrılmaktadır. Canlı etmenlerin sebep olduğu stres; biyotik stres ve cansız etmenlerin sebep olduğu stres abiyotik stres. Bu derleme abiyotik stres faktörlerinin meyve ağaçlarının biyoçeşitliliğini nasıl etkilediği ve hayatta kalmaları için nasıl uyum sağladığı hakkında bilgi vermektedir.

2. ABİYOTİK STRES FAKTÖRLERİ VE BİTKİLERİN BİYOÇEŞİTLİLİĞİNE ETKİLERİ

Abiyotik stres faktörleri kuraklık, düşük sıcaklık, kireç gibi cansız etmenlerden kaynaklanan bir stres olup meyve ağaçlarının biyoçeşitliliğini etkilemektedir. Bazı meyve ağaçları bu

streslerden olumsuz etkilenerek hayatta kalamazken bazı dayanıklı türler farklı savunma mekanizmaları ile yaşayabilmektedir.

Kireç stresi hem ülkemizde hem de dünyada karşılaşılan önemli bir abiyotik stres etmenidir. Bu stres hem toprak hem de su kaynaklı olabilir. Toprak veya sulama suyundaki karbonat ve/veya kirecin fazla olması durumunda ortamın pH'sı yükselmektedir. Bu durumun sonucunda demir (Fe) elementinin yarayışlılığı azalmaktadır. Demir elementi hem Fe^{+3} hem de Fe^{+2} değerinde bulunmaktadır ve bitkiler için yarayışlı değeri Fe^{+2}'dir. Fe^{+3}'ün yarayışlı olması için Fe^{+2}'ye indirgenmesi gerekmekte olup bu indirgenmeden sorumlu enzim demir şelat redüktazdır. Bu enzimin aktivitesi yüksek pH koşullarındaki alkali ortamlarda düşmekte olup Fe indirgenmesi azalmaktadır (Pestana vd., 2001; Martínez-Cuenca vd., 2013). Bu sebeple kireçli topraklarda meyve yetiştiriciliği kısıtlanmaktadır. Demir eksikliğine ve/veya kireçli strese karşı meyve ağaçları bazı savunma yöntemleri ile adapte olmuşlardır. Bazı ağaçlar kendi bünyelerinde bazı organik asitlerin üretimini arttırarak hücreler arası boşluklarındaki ve ksilemdeki sıvının pH'sını düşürerek Fe yarayışlılığını artırabilmektedir (Pii vd., 2015; Aras vd., 2018). Bu savunma mekanizması ile bölgedeki biyoçeşitliliğini koruyan birçok meyve ağacı bulunmaktadır.

Kuraklık stresi özellikle son yıllarda büyük bir sorun teşkil etmektedir. Kuraklık stresine dayanıklılık kazanan meyve ağaçları bölgede biyoçeşitliliğini sürdürürken dayanıklılık kazanamayanlar yaşayamamaktadır (Clark vd., 2016). Bitkiler bünyelerinde su tutma yeteneğine sahip bazı biyokimyasal maddelerin (osmoprotektan) birikimini sağlayarak kuraklığa karşı dayanıklılık sağlayabilmektedir. Bu osmoprotektan adı verilen maddelerin birikimini arttırıp dayanıklılık sağlayan birçok meyve ağacı belirlenmiştir (Karimi vd., 2018; Devin vd., 2023). Ayrıca birçok meyve ağacı stoma açıklıklarını minimuma indirip kapatarak bünyelerindeki suyun kaybolmasını engellemekte ve kurak bölgedeki varlığını sürdürebilmektedir (Gomes vd., 2004).

Düşük sıcaklık stresi meyve ağaçlarının biyoçeşitliliğini sınırlandıran en önemli streslerin başında yer almaktadır. Meyve ağaçlarının gövdesi -40°C' ye dayanabilmekte, fakat tomurcuklar ve çiçekler -2, -3°C'lerde zarar görebilmektedir. Düşük sıcaklık stresi meyve ağaçlarının bölgedeki biyoçeşitliliğini oldukça kısıtlamaktadır (Tewari vd., 2018). Özellikle iklim değişikliğinden dolayı bölgelerdeki düşük sıcaklığın şiddeti artabilmekte ve daha dayanıklı meyve ağaçları bölgeye adapte olabilmektedir. Bu adaptasyonda hücre ve hücreler arası boşluklarındaki sıvıların yoğunluklarını şeker, protein gibi biyokimyasal maddelerle arttırarak donma noktalarını düşürebilmektedir (Ashworth ve Wisniewski, 1991). Düşük sıcaklığın yanında yüksek sıcaklık da önemli bir stres olup meyve ağaçlarının çeşitliliğini etkilemektedir.

Tuz stresi yanlış gübreleme, sulama ve sahil kesimlerinde yetiştiricilik yapılmasından kaynaklanabilmektedir. Tuz stresine dayanıklı meyve ağaçlarının o bölgelerde yetiştiricilik yapılması ile biyoçeşitlilik oluşmaktadır. Meyve ağaçları genel olarak tuz stresine karşı hassas veya orta hassas olup dayanıklı tür ve anaçların seçilmesiyle yetiştiricilik yapılabilmekte ve bölgedeki biyoçeşitlilik oluşmaktadır (Rahman vd., 2011).

İklim değişikliği hava sıcaklığını etkilemesinin yanında yağışları da etkilemektedir. Son zamanlarda aşırı yağışlar sel baskınına sebep olmakta ve bu sorun bölgedeki yabani ağaçların ve meyve ağaçlarının çeşitliliğini etkilemektedir (Zhang vd., 2022). Sel baskını bitkilerde

kökün su altında kalıp boğulması ve böylece kökün oksijensiz kalmasına sebep olmaktadır. Sel baskını olan bölgelerde dayanıklı anaçların kullanılması ile biyoçeşitlilik korunabilmektedir. Kayısı ağaçları sel baskınına karşı hassastır ve erik anacı kullanılması ile dayanıklılık sağlanabilmektedir (Domingo vd., 2002).
Bu streslerin dışında ağır metal stresi de bulunmaktadır. Bu stres özellikle maden yataklarının olduğu bölgelerde veya sanayi bölgelerinde yetişen ağaçların yetiştiriciliğini ve biyoçeşitliliğini sınırlandırmaktadır.

3. GENEL DEĞERLENDİRME VE SONUÇ

Meyve ağaçlarında biyoçeşitlilik incelenirken hem kendiliğinden yabani olarak yetişen ağaçlar hem de yetiştiriciliği yapılıp bölgede seneler boyunca uyum sağlamış meyve ağaçlarının değerlendirilmesi gerekmektedir. Çevresel stresler yetiştiriciliği olarak yetiştiriciliği yapılan türleri ve kendiliğinden yetişen meyve ağaçlarının çeşitliliğini etkilemektedir. Stres faktörleri hem meyve ağaçlarının yetiştiriciliğini kısıtlamakta hem de bölgede biyoçeşitliliğini sınırlandırmaktadır. Varolan biyoçeşitliliği korumak amacıyla stres faktörleriyle mücadele edilmesi gerekmektedir. Meyve ağaçlarının çeşitliliğinin korunması bakımından bölgedeki stres faktörüne dayanıklı anaçların kullanılması önerilebilir.

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ANATOMICAL ALTERATIONS AFFECT BIODIVERSITY OF FRUIT SPECIES

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ABSTRACT
Anatomical changes in fruit species can significantly impact biodiversity through various mechanisms. Here are some ways in which these changes might affect biodiversity. Genetic Diversity: Anatomical changes often arise from genetic mutations or selective breeding. These genetic changes can either increase or decrease genetic diversity within fruit species populations, depending on whether the alterations lead to new traits or a reduction in genetic variability. Pollination and Seed Dispersal: Changes in fruit anatomy can influence how fruits are pollinated and how seeds are dispersed. For instance, modifications that make fruits more attractive to certain pollinators or animals can affect the reproduction and spread of the species, potentially altering the ecological dynamics of the region. Adaptation to Environment: Anatomical alterations can enhance or diminish a fruit species' ability to adapt to environmental stresses, such as drought, pests, or diseases. These changes can influence the survival and reproductive success of the species, thereby affecting overall biodiversity. In the current review, anatomical adaptations such as stomatal behaviors, xylem functions, wax properties affecting biodiversity are discussed.
Anahtar Kelimeler: Anatomy, Fruit, Xylem, Wax

ANATOMİK DEĞİŞİKLİKLERİN MEYVE TÜRLERİNİN BİYOÇEŞİTLİLİĞİNİ ETKİLEMESİ

ÖZET
Meyve türlerindeki anatomik değişiklikler, çeşitli mekanizmalar yoluyla biyolojik çeşitliliği önemli ölçüde etkileyebilir. İşte bu değişikliklerin biyolojik çeşitliliği etkileyebileceği bazı yollar. Genetik Çeşitlilik: Anatomik değişiklikler sıklıkla genetik mutasyonlardan veya seçici üremeden kaynaklanır. Bu genetik değişiklikler, değişikliklerin yeni özelliklere mi yoksa genetik çeşitlilikte bir azalmaya mı yol açtığına bağlı olarak, meyve türü popülasyonlarındaki genetik çeşitliliği artırabilir veya azaltabilir. Tozlaşma ve Tohum Dağılımı: Meyve anatomisindeki değişiklikler meyvelerin nasıl tozlaştığını ve tohumların nasıl dağıldığını etkileyebilir. Örneğin, meyveleri belirli tozlayıcılar veya hayvanlar için daha çekici hale getiren değişiklikler, türlerin üremesini ve yayılmasını etkileyerek bölgenin ekolojik dinamiklerini potansiyel olarak değiştirebilir. Çevreye Uyum: Anatomik değişiklikler, bir meyve türünün kuraklık, zararlı böcekler veya hastalıklar gibi çevresel streslere uyum sağlama yeteneğini artırabilir veya azaltabilir. Bu değişiklikler türün hayatta kalmasını ve üreme başarısını etkileyebilir, dolayısıyla genel biyolojik çeşitliliği etkileyebilir. Bu derlemede stoma

davranışları, ksilem fonksiyonları, mum özellikleri gibi biyoçeşitliliği etkileyen anatomik adaptasyonlar tartışılmaktadır.
Anahtar Kelimeler: Anatomi, Meyve, Ksilem, Mum

1. GİRİŞ

Ormanlar, otlaklar, sulak alanlar ve mercan resifleri gibi farklı ekosistemlerin her biri farklı bitki yaşamını destekler. Ekosistem çeşitliliğinin korunması, genel biyolojik çeşitlilik için çok önemlidir. Çeşitli bitki türleri, besin zincirlerini ve besin döngülerini koruyarak ekosistemlerin dengelenmesine yardımcı olur.
Bitkilerin biyoçeşitliliğinin korunması oldukça önemlidir. Biyoçeşitliliğin korunmasını engelleyen en önemli sorunlar çevresel stres faktörleridir. Bazı bitkiler bünyelerinde farklı anatomik değişimler ile savunma mekanizması oluşturarak bu stres faktörlerine karşı dayanıklı hale gelip biyoçeşitliliğini koruyabilmektedir. Biyoçeşitlilik incelenirken hem kendiliğinden yabani olarak yetişen bitkiler hem de yetiştiriciliği yapılıp bölgede seneler boyunca uyum sağlamış bitkilerin değerlendirilmesi gerekmektedir. Biyoçeşitliliği sınırlandıran faktörler çevresel stres etmenler olup bu stres faktörleri genel olarak ikiye ayrılmaktadır. Canlı etmenlerin sebep olduğu stres; biyotik stres ve cansız etmenlerin sebep olduğu stres abiyotik stres. Bu derleme meyve ağaçlarının anatomik değişimler ile abiyotik stres faktörlerine karşı biyoçeşitliliğini nasıl koruyabildiği hakkında bilgi vermektedir.

2. MEYVE AĞAÇLARININ ANATOMİK ÖZELLİKLERİ

Meyve ağaçları kök, gövde, sürgün, yaprak, meyve gibi birçok organ veya dokudan oluşmaktadır ve bu dokularda özelleşmiş anatomik yapılar mevcuttur. Meyve ağaçlarında iki adet iletim demeti bulunmaktadır: Ksilem ve floem. Ksilem lignin maddesinden oluşur ve ölü bir doku olup yenilenme özelliği bulunmamaktadır (Meinzer vd., 2001; Liu vd., 2015). Ksilem özellikle su ve besin elementlerinin aşağıdan yukarı taşınmasından sorumludur (Aras vd., 2021). Floemde ise hem aşağıdan yukarı hem de yukarıdan aşağı taşınım gerçekleşmekte olup özellikle şeker, hormon gibi fitokimyasal maddeler taşınabilmektedir (Lee vd., 2020).
Meyve ağaçlarında her doku canlı hücrelerin bulunduğu korteks hücrelerinden oluşmaktadır. Bu korteks hücreleri dokunun ilk gelişim safhasında bölünme yeteneğine sahip olup bölünme evresi bittikten sonra büyüme özelliğine sahip olup dokunun büyümesi gerçekleşmektedir (Gonzalez vd., 2012). Korteks hücreleri içerisinde su, besin elementleri, proteinler gibi birçok maddeyi bulundurmaktadır (Singh vd., 2013).
Yapraklar genel olarak incelendiğinde en dışta kutikula tabakası ve epidermis hücreleri bulunmaktadır (Jetter vd., 2020). Bu kutikula tabakası mum (wax) ile kaplanmıştır. Yaprağın içinde ise palizat ve sünger parankiması bulunmaktadır (Gonçalves vd., 2008). Palisat parankiması klorofil gibi fotosentezde görev alan renk pigmentlerini içermekte olup fotosentez yapabilmektedir. Sünger parankiması ise hava boşluklarına sahiptir ve gaz depolanmasında büyük rol üstlenmektedir. Meyve ağaçlarının yaprağının alt kısmında stoma bulunmakta olup gaz alışverişi ve terleme (transpirasyon) işlemleri bu kısımdan gerçekleşmektedir (Bai vd., 2013).

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3. ABİYOTİK STRESLERE KARŞI MEYVE AĞAÇLARININ BİYOÇEŞİTLİLİĞİN KORUNMASINDA YER ALAN ANATOMİK DEĞİŞİKLİKLER

Abiyotik stres faktörleri meyve ağaçlarının biyoçeşitliliğini oldukça etkilemektedir. Birçok çevresel stres faktörü bulunmakta olup bazı ağaçlar varlığını sürdürmek amacıyla farklı anatomik değişiklikler gerçekleştirmektedir.

Kuraklık stresinde stomalar büyük rol oynamaktadır (Rieger vd., 2003). Stoma açık kaldığı müddetçe bitkiler kökleriyle su alır ve su ihtiyaç duyulan organlara taşınır. Stomaların açık kalması aynı zamanda terlemenin ve gaz alışverişinin de olduğunu göstermektedir. Meyve ağaçları kuraklık koşullarında stoma açıklıklarını kısarak bünyelerindeki suyun kaybını önleyebilmektedir. Bu anatomik değişimi absisisik asit hormonu ile kontrol etmektedir (Loewenstein ve Pallardy, 1998). Yapraklarda tüy miktarının ve yoğunluğunun artması da kuraklığa karşı verilen önemli bir savunmadır, bu sayede yapraklardan su kaybı önlenmektedir (Balsamo vd., 2003).

İklim değişikliği özellikle son yıllarda güneş ışığını şiddetini de etkileyerek yüksek ultraviyole ışınlarının gelmesine sebep olmuştur ve bu da biyoçeşitliliği etkilemektedir. Meyve ağaçları yapraklarını yüksek ultraviyole ışınlarına karşı koruyabilmek amacıyla yapraklardaki epikutikular mum takabasında mum birikimini arttırarak dayanıklı hale gelebilmektedir (Liakopoulos vd., 2001). Bu mum tabakası fazla güneş ışığının yapraklardan emilmesini engelleyerek yansıtabilmektedir (Diarte vd., 2021). Ayrıca yapraklarda kalın bir mum tabakasının olması yapraklardan su kaybını da önleyebilmektedir.

Sel baskını stresi meyve ağaçlarının çeşitliliğini etkileyen önemli bir unsurdur. Sel baskını sonucunda bitkilerin kökleri su altında kalıp oksijensiz kalmakta, boğulmaktadır (McGee vd., 2021). Bu stresin süresinin uzun sürmesi sonucunda ağaçların ölümü gerçekleşebilir. Erik ağacı gibi dayanıklı ağaç ve anaçlar bünyelerinde hava depolayan kısımlarını geliştirerek hayatta kalabilmektedir (Pistelli vd., 2012). Bitkilerde hava depolayan kısımlar köklerdeki aerenkima dokusu, hücreler arasındaki apoplastik boşluklar ve yapraklardaki sünger parankimasıdır (Klumb vd., 2020; Zhang vd., 2023). Bu hava depolayan kısımların genişletilerek gaz depolanması sonucu ağaçların hayatta kalması biyoçeşitlilik üzerine büyük bir önem arz etmektedir.

Toprakta bulunan besin maddeleri zamanla yetersiz bulunmakta olup özellikle yabani olarak kendiliğinden yetişen ve gübre uygulanmayan meyve ağaçlarında büyük bir sorun hale gelmektedir. Bitkiler topraktan kökleri ile su ve besin maddelerini alıp ksilem iletim demeti vasıtasıyla ihtiyaç duyulan organlara gönderir. Bazı meyve ağaçları besin yetersizliği altında ksilem çapını arttırabildiği ve besin yetersizliğinde bu sayede hayatta kalabildiği bildirilmiştir (Aras vd., 2021). Bu mekanizma ile ağaçların biyoçeşitliliğinin korunması büyük bir önem arz etmektedir.

3. GENEL DEĞERLENDİRME VE SONUÇ

Yetiştiriciliği yapılan veya yabani meyve ağaçlarının biyoçeşitliliğini birçok çevresel stres faktörü olumsuz olarak etkilemektedir. Biyoçeşitliliğin korunması bitkilerin bünyelerinde gerçekleştirdiği anatomik değişiklikler ile sağlanabilmektedir. Ksilem iletim demetinin çapının veya sayısının artması, hücrelerin sayısının ve büyüklüğünün artması gibi anatomik adaptasyonlar ile çevresel stres faktörlerine hem uyum sağlanmakta hem de biyoçeşitlilik sürdürülebilmektedir.

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SSR AND TRANSCRIPTOME ANALYSIS IN HORTICULTURAL FRUITS

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ABSTRACT
SSR markers and transcriptome analysis are essential tools in the genetic enhancement and conservation of horticultural fruit crops. SSR markers, known for their high polymorphism and codominance, are widely utilized in genetic mapping, marker-assisted selection (MAS), and germplasm conservation to assess genetic diversity, improve fruit quality, and increase resistance to diseases. Transcriptome analysis, particularly through RNA sequencing (RNA-Seq), has significantly advanced the development of SSR markers by providing a rich source of expressed gene sequences, especially for non-model species. This has enabled more efficient breeding programs and the conservation of genetic resources. Transcriptome-derived SSR markers are instrumental in identifying genetic variation and supporting the development of new, higher-yielding, and more resilient fruit varieties. This review explores the acquisition, application, and implications of SSR markers derived from transcriptome data, emphasizing their vital role in improving productivity and sustaining biodiversity in horticulture.
Keywords: SSR, Transcriptome, Horticulture, Fruits, Genetic Diversity, Breeding, Germplasm Conservation.

1. INTRODUCTION

Molecular analyses, particularly SSR markers and transcriptome analysis, are widely recognized as crucial tools in the genetic enhancement and conservation of horticultural fruit crops. SSR markers, noted for their high polymorphism and codominance, are extensively applied in genetic mapping, marker-assisted selection (MAS), and the conservation of genetic resources. These markers facilitate the assessment of genetic diversity, improvement of fruit quality, and enhancement of disease resistance (Guo et al., 2022). Transcriptome analysis, particularly using RNA sequencing (RNA-Seq), has significantly advanced the development of SSR markers by providing a rich source of expressed gene sequences, especially for non-model species. For instance, in Pennisetum species, SSR markers derived from transcriptome data were utilized to analyze genetic diversity, underscoring their importance in preserving ornamental plant resources (Guo et al., 2022). In citrus, the development and characterization of genomic and expressed SSRs have contributed significantly to molecular breeding efforts and diversity assessment,

demonstrating the versatility of SSR markers in different genomic regions (Liu et al., 2013). SSR markers also play a pivotal role in horticultural plant breeding by supporting cultivar identification, genetic mapping, and the conservation of germplasm resources. Moreover, transcriptome-derived SSR markers in Perilla have facilitated genetic diversity analysis and association mapping, further proving their utility in breeding programs (Kim et al., 2021).

Transcriptome analysis conducted through RNA sequencing (RNA-Seq) has significantly advanced the development of SSR markers by providing a rich source of expressed gene sequences. This method enables the implementation of more efficient breeding programs and the conservation of genetic resources, even in non-model species. For instance, in a study on Pogostemon cablin (Patchouli), a large set of EST-SSR markers was developed using RNA-Seq, demonstrating its usefulness in genetic diversity analysis (Ouyang et al., 2018).
Transcriptome-derived SSR markers play a crucial role in identifying genetic variations and developing new, higher-yielding, and more resilient fruit varieties. In a study on Prunus species, SSR markers located on genes associated with cold stress were found to have potential as functional markers for breeding programs in almond and other Prunus species (Alisoltani et al., 2016).
The first molecular marker technique used in determining genetic relationships in plants was the RFLP (Restriction Fragment Length Polymorphism) technique. Although this technique was applied for variety identification and genetic mapping, it had disadvantages such as being expensive, time-consuming, and requiring the use of radioactive materials (Botstein et al., 1980). Later, PCR (Polymerase Chain Reaction)-based techniques were developed. The first PCR-based molecular marker was the RAPD (Random Amplified Polymorphic DNA) technique (Williams et al., 1990). PCR-based DNA markers are divided into two groups: dominant (RAPD, ISSR, AFLP, SRAP, AP-PCR) and codominant (SSR, STS, SNP, CAPS, SCAR) (Powell et al., 1996). Morphological, physiological, and biochemical methods used to determine genetic diversity are influenced by environmental factors and are also very time-consuming. However, with the development of DNA marker techniques, genetic materials from different ecologies can be identified more easily (Güney et al., 2018).
Transcriptome analysis which involves examining the entire set of genes expressed by an organism under specific conditions, is a powerful tool for understanding genetic mechanisms. This analysis uses advanced techniques like RNA sequencing (RNA-Seq), which provides a rich source of expressed gene sequences, accelerating the development of SSR markers even in non-model species. For example, transcriptome analysis of Welsh onion using RNA-Seq technology allowed identifying a wide range of SSR loci, supporting genetic diversity studies and aiding breeding programs in this and related species (Yang et al., 2015).
In horticulture, transcriptome-derived SSR markers are crucial for identifying genetic variations and developing fruit varieties with higher yields and improved resistance. For instance, research on Chinese hawthorn employed RNA-Seq to develop EST-SSR markers, facilitating genetic diversity analysis and cultivar characterization (Ma et al., 2019).

The process of transcriptomic analysis, which involves examining the entire set of genes expressed by an organism under specific conditions, is essential in plant breeding to identify the

expression patterns of genes in response to various stimuli. This method utilizes advanced techniques such as RNA sequencing (RNA-Seq) to provide a comprehensive resource of expressed gene sequences, facilitating the development of SSR markers and accelerating breeding even in non-model species (Yang et al., 2015). Particularly in horticulture, transcriptomic analysis aids in selecting plants with desirable traits, such as higher yield, quality, and resilience, making it a valuable tool for understanding the genetic basis of plant quality and stress resistance (Ma et al., 2019).

2. SSR AND TRANSCRIPTOME ANALYSIS IN HORTICULTURAL FRUITS

To comprehensively analyze gene expression and uncover functional insights in horticultural fruits, RNA sequencing, and subsequent bioinformatics analyses are essential.

2.1. Applications of Transcriptomics in Horticulture

1- Breeding Studies: It enables the development of productive and resilient plant species by analyzing differences among expressed genes. For example, it is used to identify and select genetic variants that can improve fruit quality.
2- Genetic Diversity Analysis: It is utilized in genetic diversity analysis to conserve genetic resources and ensure the sustainable preservation of biodiversity.
3- Stress Responses and Resilience Studies: It play a critical role in identifying stress-related genes to understand plant responses to abiotic (such as drought, and salinity) and biotic (such as diseases) stresses.
4- Discovery of Metabolic Pathways: Examining metabolic pathways that determine quality traits such as taste, aroma, and color in plants, helps to understand the molecular basis of these characteristics.

2.2. RNA sequencing and bioinformatics analyses

The general steps of RNA sequencing and bioinformatics analyses are as follows:
1- Sample Preparation: The first step is to isolate RNA from the target tissues or cells. Obtaining high-quality RNA is critical for accurate results.
2- RNA Quality Control: The quality and purity of the isolated RNA are checked using spectrophotometers or biofluidic devices. High-quality RNA is essential for reliable data.
3- cDNA Synthesis and Library Preparation: RNA is converted into cDNA through reverse transcription. This cDNA is then processed to create a library for sequencing.
4- Sequencing: The prepared cDNA library is sequenced, usually using high-throughput sequencing platforms (e.g., Illumina). This process provides large amounts of data showing the expression levels of each gene.

5- Data Analysis: The raw data obtained are processed with bioinformatics tools. Expression levels are calculated, differentially expressed genes are identified, and these genes are classified into biological pathways based on their functions.
6- Validation of Results: In some cases, additional analyses such as qRT-PCR are used to verify the accuracy of the obtained data.

2.3. Studies on Transcriptome-Derived SSR Markers

Some recent studies in the literature on transcriptome-derived SSR markers in horticultural fruits are presented below:
Blanca et al., (2011) aimed to characterize the transcriptome of squash (*Cucurbita pepo*) and to discover high-throughput SSR (Simple Sequence Repeat) and SNP (Single Nucleotide Polymorphism) markers. The study generated 512,751 EST sequences from various tissue samples, identifying 49,610 unique gene sequences. From these sequences, 1,882 SSRs and 9,043 high-confidence SNPs were identified. The findings provide a foundation of molecular markers that can be used in gene discovery, genetic mapping, and quantitative trait locus (QTL) analysis in squash breeding, representing a significant advancement in squash genetic research.
One et al., (2011) investigated the transcriptome of pomegranate (Punica granatum) fruit peel to discover genes involved in the biosynthesis of natural products and to develop SSR markers. They used RNA sequencing on the Illumina platform, yielding over 100 million reads, which were assembled into 9,839 transcriptome sequences. This analysis identified candidate genes associated with the biosynthesis of bioactive compounds like hydrolyzable tannins and anthocyanins, as well as 115 SSR markers, with primers designed for 77 of them. These findings provide valuable resources for genetic studies and breeding in pomegranate, highlighting next-generation sequencing as an effective tool for gene discovery in non-model plant species.
Li et al., (2014), conducted a de novo transcriptome assembly to analyze the genetic and molecular basis of Chinese jujube (Ziziphus jujuba Mill.) fruit development. They sequenced cDNA libraries from early and late developmental stages of the ‘Dongzao’ fruit using 454 pyrosequencing, generating 97,479 unigenes. Among these, they identified 9,893 SSR markers, which exhibited high cross-species transferability and can be applied to genetic mapping and diversity studies. This transcriptome data offers a comprehensive foundation for gene discovery and breeding applications in Chinese jujube, highlighting pathways such as the Smirnoff-Wheeler pathway for ascorbic acid biosynthesis, key in determining nutritional quality.
Yue et al., (2014) developed genic SSR markers for pear (Pyrus) through transcriptome sequencing of pear buds. From a set of 116,282 unigenes, they identified 8,375 genic SSR loci, with dinucleotide and trinucleotide repeat motifs being the most common. They designed 4,100 primer pairs, synthesizing and testing 343 for amplification and polymorphism, and identified 104 polymorphic genic SSR markers. These markers, particularly effective in differentiating genetic relationships, were used to assess genetic diversity across 28 pear accessions, revealing a clear distinction between Oriental and Occidental pear groups. This study enriches SSR resources for Pyrus and provides valuable tools for molecular phylogeny and genetic diversity research in pear species.

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Another study conducted by Köse et al., (2018) aimed to enhance genetic resources for apricot (*Prunus armeniaca*) through transcriptome sequencing and the identification of SSR markers. In the study, transcriptome assembly was performed for seven different apricot varieties, resulting in over 85,000 transcripts. Among these sequences, 14,722 SSR motifs were identified, and primers were designed for 206 SSR loci based on these motifs. Testing of these primers led to the discovery of 72 polymorphic SSR markers, which can be used in genetic mapping and breeding programs, particularly for developing resistance to Plum Pox Virus (PPV). This research represents a significant step toward advancing molecular breeding tools and genetic diversity studies for apricots and related species.

Savadi et al., (2018) focused on the de novo assembly and characterization of the genome of the cashew plant (*Anacardium occidentale*). Using a hybrid assembly approach with Oxford Nanopore and Illumina sequencing platforms, they successfully completed the genome of this economically significant plant. The final genome size was 356.6 Mb with 91.8% completeness. During the study, approximately 31,263 genes and 3,104 candidate disease resistance genes (R genes) were identified. This research provides a strong foundation for genetic mapping and the development of molecular markers in cashew, particularly contributing to breeding efforts to enhance disease resistance and support genomics-assisted breeding initiatives.

A study conducted by Zhang et al., (2018) investigated transcriptome sequencing for almond (*Amygdalus communis* L.) to enhance genetic resources and support breeding programs. Using Illumina sequencing technology, they generated approximately 64 million clean reads from various almond tissues, resulting in 42,135 unigenes with significant functional annotations. The study also identified 8,641 SSR (Simple Sequence Repeat) markers with high cross-species transferability potential among almond species. This research provides molecular data supporting genetic diversity and breeding efforts for almonds, offering the first comprehensive transcriptome data to serve as a foundation for future studies on almond genetics and breeding programs.

Ding et al., (2019) performed a de novo transcriptome analysis to identify genic SSR markers in red-flowered strawberry, an intergeneric hybrid with significant ornamental and commercial value. Using RNA sequencing on the Illumina HiSeq 2500 platform, they assembled 91,835 unigenes and identified 14,264 SSR loci. Among these, di-, tri-, and tetra-nucleotide repeats were predominant, and PCR testing with 105 SSR primer pairs led to the identification of four markers associated with red flower color. These markers allow for the early selection of flower color traits, facilitating more efficient breeding and management of red-flowered strawberry varieties.

Kavas et al., (2020) aimed to discover simple sequence repeat (SSR) markers for hazelnut (Corylus avellana L.) through transcriptome sequencing and to characterize hazelnut varieties based on SSR markers. Using RNA sequencing data from three hazelnut varieties, they identified a total of 86,542 unigenes and 25,391 SSRs. Of the 40 primer pairs tested, 28 showed high polymorphism and were used to analyze genetic diversity. These markers effectively distinguished hazelnut varieties, particularly classifying them by traits such as bud break timing. These SSR markers enhance the utility of genetic fingerprinting and support breeding programs for hazelnut, providing molecular tools for developing new varieties.

Wu et al., (2021) conducted comparative transcriptome profiling to investigate endocarp lignification in walnut (*Juglans regia* L.). They focused on two walnut genotypes with different endocarp thicknesses, 'Liaoning 7' (L7) and 'Zanmei' (ZM), to understand the transcriptional mechanisms influencing lignin deposition in walnut shells. By using RNA sequencing at critical stages (20 and 45 days after full bloom), the researchers identified significant differentially expressed genes (DEGs) involved in lignin biosynthesis, plant hormone signaling, and phenylpropanoid pathways. Their findings showed that ZM, with its thicker shell, exhibited more upregulated genes related to lignin biosynthesis compared to L7, suggesting a stronger genetic basis for lignification in ZM. This research provides insights into the molecular mechanisms of lignification, offering potential targets for breeding walnuts with optimized shell characteristics.

2.4. Studies on Transcriptome

Some recent studies in the literature on transcriptomics in horticultural fruits are presented below:
In a study conducted by Guo et al., (2015) the aim was to identify the genetic differences in fruit development between cultivated and wild watermelon. Using RNA sequencing (RNA-Seq), the researchers analyzed gene expression profiles in cultivated watermelon (*Citrullus lanatus* subsp. *vulgaris*) and wild watermelon (*Citrullus lanatus* subsp. *lanatus*) to understand the molecular basis of traits such as sweetness, flesh color, and stress tolerance. The study identified differentially expressed genes associated with sugar metabolism, carotenoid biosynthesis (color formation), and ethylene signaling pathways that regulate ripening. Additionally, stress response-related genes, which are more pronounced in wild watermelon, were also identified, highlighting potential breeding targets to enhance fruit quality in cultivated varieties. The research provides valuable genetic data for future studies aimed at improving watermelon fruit quality and resilience. This study examines gene expression differences during the development of cultivated and wild watermelon fruits. The fruit quality of lycopene-rich watermelon is determined by factors such as sugar content, flesh color, and texture. In the study, gene expressions between the cultivated variety 97103 and the wild African species PI296341-FR were analyzed using RNA-Seq technology. A total of 2,452, 826, and 322 differentially expressed genes were identified, which play roles in biological processes, particularly in sugar and carotenoid metabolism. The study provides potential for breeding programs by identifying genes that affect fruit quality.
In a study conducted by Liu et al., (2019) the aim was to understand how metabolic processes are regulated in loquat fruit during postharvest cold storage. This study examines how lignin accumulation, which affects fruit quality and firmness, can be reduced through low-temperature conditioning (LTC) and heat treatment (HT). The researchers compared the transcriptome profiles of loquat fruits stored under different conditions (0°C, LTC, and HT) and identified key genes and transcription factors associated with lignin biosynthesis and stress responses. The findings indicate that LTC and HT treatments alter the expression of genes related to lignin metabolism, cell wall structure, stress responses, and hormone pathways, thereby potentially reducing lignification and improving the postharvest quality of loquat. This research provides valuable molecular insights for optimizing storage conditions to enhance the quality of loquat and similar fruits during cold storage. This study investigates methods to reduce lignin accumulation in loquat fruit during cold storage. Lignin levels increase during storage at 0°C, negatively affecting fruit firmness and quality. In the study, low-temperature conditions (LTC,

5°C) and heat treatment (HT, 40°C) were applied, and RNA sequencing was used to compare the expression levels of various genes under these conditions. Key genes in the lignin biosynthesis pathway were identified, and their connections with transcription factors were examined. This study sheds light on the molecular-level effects of these treatments on lignin accumulation in loquat, providing insights into strategies to reduce lignification during cold storage.

In a study conducted by Gao et al., (2020) the genetic basis of fruit texture differences in watermelon was investigated. This study examines key genes that determine fruit texture by comparing PI186490, a wild variety with hard and dense pulp, and 'sanbai,' a cultivated variety with a soft texture. Using RNA sequencing, the researchers identified important genes associated with cell wall components such as pectin, cellulose, and hemicellulose, which contribute to fruit firmness and texture. The study identified a total of 85 candidate genes related to cell wall metabolism and structural integrity, including pectinesterase, polygalacturonase, cellulose synthase, and beta-galactosidase. The findings indicate that these genes, along with transcription factors and hormone-related genes, play a crucial role in determining watermelon fruit texture, offering potential breeding targets to improve watermelon quality. This study examines the expression of various genes to understand the formation process of watermelon fruit texture. The study analyzed the pectin, cellulose, and hemicellulose contents in the watermelon cell wall at different stages of fruit development, observing that these components affect fruit texture. In particular, it was found that the textural differences between the PI186490 and 'sanbai' varieties are related to the content of cell wall materials. Through RNA-seq analysis, 85 candidate genes were identified, including pectinesterase, polysaccharide hydrolase, glycosyltransferase, cellulose synthase, and various transcription factors. The study provides a theoretical basis for improving the texture quality of watermelon fruit.

In a study conducted by Martinelli and colleagues, the genetic responses of citrus fruits to Huanglongbing (HLB) or citrus greening disease were investigated. Using next-generation sequencing (RNA-Seq) technology on healthy, asymptomatic, and symptomatic citrus fruits, they examined the effects of Candidatus Liberibacter asiaticus, the pathogen responsible for HLB. The study identified significant changes in gene expression across various metabolic pathways impacted by HLB. The findings revealed that HLB affects photosynthesis, ATP synthesis, hormone signaling, and stress responses, particularly increasing the expression of genes related to protein degradation and carbohydrate metabolism. This research provides valuable molecular targets for understanding the impact of HLB on citrus metabolism, contributing to the development of new strategies to mitigate the disease's adverse effects on fruit production and quality.

3. CONCLUSIONS AND FUTURE PERSPECTIVES

SSR and transcriptome analyses are revolutionizing horticultural science by providing deeper insights into biological and genetic processes, enabling the development of efficient breeding programs, enhancing productivity, and preserving genetic diversity in fruit crops. Transcriptomic data, though inherently large and complex, can be harnessed more effectively through integrated analysis platforms and data management strategies, offering researchers a more comprehensive

perspective. This review highlights the crucial roles of SSR markers derived from transcriptome data, which support faster, targeted selection in plant breeding, facilitate the development of plants with desirable traits, and advance genetic diversity studies. Together, these approaches are essential for improving productivity, conserving biodiversity, and contributing significantly to sustainable advancements in plant cultivation and agricultural efficiency.

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APPLE (*Malus domestica*) MİRNA EXPRESSION AND HORTICULTURAL IMPLICATIONS

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ABSTRACT
MicroRNAs (miRNAs) are critical regulators of gene expression in apple (*Malus domestica*), impacting essential processes such as stress tolerance, fruit development, pigmentation, and disease resistance. Recent studies have identified key miRNAs like miR156, miR482, and miR164, which regulate genes involved in drought and salinity tolerance, as well as pathogen defense mechanisms. Additionally, miRNAs play a significant role in enhancing fruit quality by controlling genes related to cell division and anthocyanin biosynthesis, influencing fruit size and color. Advances in miRNA research have opened up new avenues for genetic improvements in apple cultivation, with applications such as artificial miRNAs (amiRNAs) offering the potential to create apple varieties more resilient to environmental stresses, diseases, and market demands. This review provides a comprehensive overview of miRNA functions in apple and highlights their horticultural applications, offering insights into how miRNA-based genetic strategies can improve apple production and sustainability.
Keywords: *Malus domestica*, MicroRNA, gene regulation, stress response, fruit quality, biotechnology.

1. INTRODUCTION
Apple (*Malus domestica*) is one of the most economically significant fruit crops, cultivated globally for its high nutritional and commercial value (Verma et al., 2024). Belonging to the Rosaceae family, this fruit tree stands out for its nutritional value and variety. Apples are rich in fiber, vitamin C, potassium, and various antioxidants, contributing positively to health. Historically originating from Central Asia, the apple has now been cultivated worldwide with numerous varieties adapted to different climates. With high agricultural value, apples are used extensively both for fresh consumption and in the food industry. Apple production faces challenges from various biotic (diseases, pests) and abiotic (drought, salinity) stress factors. However, advancements in modern breeding techniques and biotechnological approaches are continually enhancing apple yield and quality. Given the importance of apples in agriculture and nutrition, recent research has focused on understanding molecular mechanisms, particularly

the role of microRNAs (miRNAs), to improve apple resilience, yield, and quality (Šečić et al., 2021).

Plants generate various types of endogenous small RNAs (sRNAs), among which 21-nucleotide small interfering RNAs (siRNAs) and 21-nucleotide microRNAs (miRNAs) are the most abundantly expressed (Borges et al., 2015). It is estimated that microRNAs comprise between 1% and 2% of a plant's total coding genes (Zhang et al., 2008). miRNAs have recently attracted attention for their role in regulating gene transcription across various biological processes, including growth, development, metabolism, and epigenetic modification, all of which influence agronomic traits in crops. Additionally, miRNAs enhance plant resilience to biotic stresses, such as pathogen infections, and abiotic stresses, including salinity, cold, heat, and drought (Kumar et al., 2024a).

qRT-PCR (Quantitative Real-Time PCR) is a highly sensitive method widely used in molecular biology research to measure RNA levels and analyze gene expression due to its accuracy, high-throughput capability, and real-time measurement. This technique amplifies cDNA derived from RNA, tracking the reaction with fluorescent dyes to provide precise and rapid quantification of gene expression levels (Bustin et al., 2005; Heid et al., 1996). RNA, or ribonucleic acid, is a single-stranded nucleic acid that transfers genetic information from DNA to the protein synthesis machinery within cells, mainly through messenger RNA (mRNA) (Alberts et al., 2002). In qRT-PCR, mRNA is converted to cDNA to assess gene expression, making it valuable in applications such as disease diagnostics, treatment monitoring, and comparative RNA expression studies across genetic research (Schmittgen & Livak, 2008). With these capabilities, qRT-PCR is instrumental in advancing genetic studies and plays a pivotal role in molecular diagnostics and research (Peng et al., 2024).

Recent research into miRNAs, small non-coding RNA molecules, has revealed their critical roles in regulating various biological processes such as growth, stress response, and fruit quality in apple (Gao et al., 2024; Shi et al., 2024). This review explores miRNA-mediated regulatory networks in apple, focusing on their implications for horticultural practices.

2. miRNAs IN STRESS RESPONSE

2.1. Drought and Salinity Stress

Apple (*Malus domestica*) is an important economic fruit crop in the temperate regions of the world. Apple productivity is known to be affected by various biotic and abiotic stress factors. Among these, water scarcity and soil salinity significantly impact the physiological and metabolic processes of apple, leading to economic losses. Apple plants develop complex physiological responses to combat drought and salt stress, which are regulated by diverse endogenous molecular regulatory mechanisms. Modern '-omics' analyses have revealed the roles of various transcription factors in re-establishing cellular homeostasis and alleviating the adverse effects of drought and salinity stress. Recently, the roles of various miRNAs in the post-transcriptional regulation of gene expression under these stresses have been investigated. Protein-mediated regulatory networks involved in adaptation to drought and salt stress in apple have been deciphered. These regulatory networks ultimately induce the biosynthesis and accumulation of protective compounds to mitigate the negative effects of drought and salinity stress on apple growth (Verma et al., 2024).

Drought and salinity are major abiotic stresses that limit apple productivity. miRNAs such as miR164 and miR398 play significant roles in regulating apple's response to these stresses. miR164 regulates NAC transcription factors, enhancing root structure and drought tolerance (Wang et al., 2024). Additionally, miR398 targets Cu/Zn superoxide dismutase, improving oxidative stress tolerance and salinity resistance in apple plants (Verma et al., 2024). These findings suggest that manipulating miRNA expression could improve apple crop resilience under changing climatic conditions.

Zhang et al. (2024a) investigated the MdZAT5 protein, which regulates root development in response to drought stress in apple plants. As a member of the Cys2/His2-type zinc finger (C2H2) protein family, MdZAT5 was found to positively influence the drought tolerance of apple roots by enhancing water conductivity and root growth under drought conditions. The study determined that MdZAT5 activates the transcription of the MdMYB88 gene, which supports root development and increases root resistance to drought stress. Experiments conducted under prolonged drought conditions demonstrated that, in the absence of MdZAT5, the plants' resilience to drought significantly decreased. These findings provide new genetic targets for breeding apple varieties with improved drought resistance.

2.2. Heat and Cold Stress

Apple (*Malus* × *domestica* Borkh.) holds an important place among temperate fruit crops worldwide, and flowering plays a critical role in both production and breeding efforts. This review examines the complex mechanisms governing apple flowering within the context of climate change, addressing the impact of external and internal factors on biennial bearing, flower bud quality, and ultimately, fruit quality. In major apple-producing regions, the main issue is not a lack of flowers but an excess, which negatively affects fruit quality and necessitates thinning practices (Hanke et al., 2007; Kumar et al., 2024b). Climate change exacerbates these challenges, making apple trees more susceptible to heat and cold stress. Reduced snowfall during winter, early spring frosts, and unusual weather events such as hail during flowering and fruit set lead to crop loss. Changing climatic conditions, like increased spring warming and frost events, negatively impact developing flower buds, reducing overall yield. Heat stress can increase cellular damage and metabolic imbalances during flowering, while cold stress disrupts cellular functions, hindering flower development and adversely affecting pollination. Additionally, altered winter conditions impact the required chilling accumulation, disrupting flower development and synchrony. Although the physiological perception of apple flowering has been studied in the past, the genetic, epigenetic, and multi-omics regulatory mechanisms governing floral induction and flowering have rarely been addressed (Amasino et al., 2010).

Apple cultivars are highly susceptible to extreme temperatures, which impact flowering, fruit development, and yield. miRNAs such as miR156 regulate key genes involved in cold tolerance by enhancing photosynthesis efficiency and reducing damage to the plant's cellular machinery under cold conditions (Verma et al., 2024). miR156 also plays a crucial role in modulating apple's response to high temperatures by controlling heat-shock proteins (Xu et al., 2024).

3. miRNA REGULATION OF FRUIT DEVELOPMENT AND PIGMENTATION

3.1. Fruit Size and Cell Proliferation

Fruit size in apples is largely determined by cell proliferation and cell expansion during development, particularly in the early stages where cell division sets the framework for potential fruit size (Malladi & Hirst, 2010). Key genetic factors, such as MdCYCD3 and MdANT1, regulate the cell cycle and influence the total cell number, directly affecting the size of the fruit (Dash & Malladi, 2012). Plant hormones, including auxins, gibberellins, and cytokinins, further enhance cell proliferation and expansion, and are commonly applied in apple orchards to stimulate fruit growth (Ozga & Reinecke, 2003). Additionally, environmental factors such as temperature, sunlight, and water availability play a significant role, with warmer conditions accelerating cell division and water stress potentially limiting it, leading to smaller fruits. Nutritional elements like nitrogen, calcium, and potassium are also essential, as adequate supply during early growth stages supports higher cell division rates and thus larger fruit sizes (Faust, 1989). Together, these genetic, hormonal, environmental, and nutritional factors shape the ultimate fruit size, providing valuable insights for optimized cultivation and breeding practices aimed at enhancing apple yield and quality.

Fruit size is a major determinant of apple quality and marketability. miRNAs such as miR396 regulate cell division in apple fruit mesocarp, directly influencing fruit size. Overexpression of miR396 has been shown to enhance cell proliferation, leading to larger fruit (Tian et al., 2024). miR156 also regulates SQUAMOSA PROMOTER BINDING PROTEIN-LIKE (SPL) genes, which play roles in cell expansion during fruit development (Xu et al., 2024).

In plants, microRNAs (miRNAs) are essential small RNAs that regulate growth, development, and tissue coloring. This paper reviews miRNA mechanisms in plant coloring, focusing on physiological and molecular aspects, miRNA biosynthesis and function, and specific studies on leaf, flower, and fruit coloration. Additionally, it categorizes miRNA regulatory mechanisms in pigment biosynthesis and color formation into four types: targeting transcription factors, structural genes, long noncoding RNAs (LncRNAs), and generating trans-acting small interfering RNAs (ta-siRNAs). These insights aim to support further research into plant coloring mechanisms and molecular breeding (Zhang et al., 2024a).

3.2. Anthocyanin Biosynthesis and Fruit Pigmentation

In apples (*Malus domestica*), anthocyanin biosynthesis is essential for fruit pigmentation, affecting both aesthetic and nutritional qualities. The pathway involves key structural genes, such as CHS (chalcone synthase), DFR (dihydroflavonol 4-reductase), and ANS (anthocyanidin synthase), which contribute to the production of red, purple, and blue pigments in the fruit skin (Honda et al., 2002). MicroRNAs (miRNAs), particularly miR156 and miR858, regulate this process by targeting transcription factors like MYB and bHLH, which are critical for anthocyanin production (González-Villagra et al., 2017). These miRNAs modulate gene expression post-transcriptionally, creating a dynamic regulatory system that adjusts pigment synthesis in response to developmental and environmental cues, including light and temperature. This miRNA-based regulatory network provides valuable insights for breeding strategies aimed at enhancing apple fruit color and nutritional value.

miRNAs are key regulators of anthocyanin biosynthesis, which determines the red pigmentation in apple skin. miR156, miR172, and vsiR693 (a viroid-derived small interfering RNA) target transcription factors such as MdMYB10 and MdPIF1, which regulate genes involved in anthocyanin production (Zhang et al., 2024b). These miRNAs modulate pigment biosynthesis, impacting the aesthetic and nutritional value of apple fruits. Manipulating these miRNAs offers the potential to improve apple fruit coloration and market appeal.

4. miRNAs IN DISEASE RESISTANCE

4.1. Pathogen Defense

Fungal diseases pose a significant threat to apple production (Hamada et al., 2019; Zhang et al., 2015). Apple Alternaria leaf spot, caused by the fungal pathogen *Alternaria alternata* f. sp. mali, results in early leaf drop, weakened trees, and a substantial decrease in apple yield (Gur et al., 2017). Symptoms associated with Alternaria infection in apples include defoliation and fruit spotting, which can lead to up to 85% leaf loss and up to 80% of fruits affected in an orchard, resulting in significant economic losses (Fontaine et al., 2021). Upon bacterial or fungal attack, the miRNA expression profile in apple trees shifts rapidly, leading to changes in downstream target gene expression, which in turn modulates the host plant's disease resistance mechanisms.

Kitamoto et al., (2024) the gene expressions of regular and alternate bearing apple varieties (*Malus* × *domestica* Borkh.) with different biologically active gibberellic acid (GA) levels were comparatively analyzed. In this context, the regular-bearing 'McIntosh' and the alternate-bearing 'Wijcik' varieties were examined over a period of three years. The study found that the annual flowering rate remained stable in 'McIntosh', while significant fluctuations were observed in 'Wijcik'. Transcriptome analysis revealed that many genes with annual variation in 'Wijcik' are involved in functions such as photosynthesis and high light response. The study highlights differing expression levels of flowering-suppressing genes, such as MdTFL1, between ON and OFF years in 'Wijcik', explaining the impact of these genes on the biennial bearing tendency. These findings provide valuable insights into genetic mechanisms for understanding alternate bearing tendencies and promoting regular fruit production.

Plants have evolved various defense mechanisms against pathogens, including resistance gene (R gene)-mediated immunity, primarily involving NBS-LRR genes. miRNAs such as miR482 and miR393 are involved in apple's immune response to pathogens. miR482 targets nucleotide-binding site leucine-rich repeat (NBS-LRR) genes, which are essential for pathogen recognition and defense activation (Liu et al., 2024). miR482 has been shown to enhance resistance against fungal pathogens like Alternaria by regulating key defense-related genes (Gao et al., 2024).

MdMYB46 increases lignin accumulation in apples and enhances tolerance to salt and osmotic stress. In their study, Liu et al., (2024) investigated the relationship between MdMYB46 and biological stress, finding that the overexpression of MdMYB46 enhances apple resistance to C. gloeosporioides. Additionally, through yeast library screening, they identified MdARF1, a transcription factor upstream of MdMYB46, and determined that MdARF1 is regulated by miR7125 according to psRNATarget prediction. This regulatory relationship was confirmed by LUC and qRT-PCR experiments, showing that miR7125 negatively regulates MdARF1.

Promoter analysis of miR7125 revealed that miR7125 responds to SA signals, and an increase in SA levels results in a decrease in miR7125 expression levels.

4.2. Viroid-Induced Disease Resistance

Viroid-induced disease resistance in apples involves interactions between viroids, host gene regulation, and microRNAs (miRNAs). Viroids, which are small infectious RNA molecules, can trigger defense responses that sometimes enhance resistance to other pathogens. In apples, viroid infection activates specific miRNAs like miR156 and miR482, which regulate genes involved in stress and defense pathways. For instance, miR482 targets NBS-LRR resistance genes, which are crucial for pathogen recognition, and helps initiate defense responses (Zhang et al., 2014). This miRNA-mediated regulation shows a dual role in suppressing viroid activity and bolstering general disease resistance, providing insight into genetic and biotechnological advancements for improving apple disease resilience (Mishra et al., 2018).

Recent studies have shown that viroid-derived small interfering RNAs (vd-sRNAs) can suppress host miRNAs involved in disease defense. For instance, vsiR693 from apple dimple fruit viroid (ADFVd) suppresses anthocyanin biosynthesis by targeting the bHLH transcription factor MdPIF1, leading to reduced fruit coloration and disease symptoms (Zhang et al., 2024 b). Understanding these miRNA-pathogen interactions can lead to novel strategies for developing disease-resistant apple cultivars.

5. HORTICULTURAL APPLICATIONS OF miRNA RESEARCH

5.1. Genetic Engineering and miRNA-Based Breeding

Genetic engineering and miRNA-based breeding have emerged as transformative approaches in horticulture, offering precision in trait enhancement and disease resistance. miRNAs play a central role in regulating gene expression, enabling targeted modifications for improved plant resilience, productivity, and quality. miRNA-based breeding involves manipulating specific miRNAs to silence or activate genes, allowing for control over stress responses, growth regulation, and flowering patterns, which are critical in horticultural crops like fruits and vegetables (Pagano et al., 2021). Genetic engineering using artificial miRNAs (amiRNAs) has been successful in conferring resistance to pathogens and environmental stresses by targeting genes linked to susceptibility. These methods not only enhance desirable traits but also reduce the need for chemical inputs, supporting sustainable agriculture practices. With ongoing advancements in miRNA research, the potential for precise, miRNA-mediated improvements continues to expand, paving the way for next-generation breeding techniques in horticulture.

Gene silencing using artificial microRNAs (amiRNAs) is one of the most important methods for developing horticultural plants with desirable traits. Approximately 21 nucleotides in length, amiRNAs specifically suppress gene expression post-transcriptionally. Studies have shown that amiRNA technology is an effective biotechnological tool for enhancing traits such as disease resistance, yield, and quality in fruits, vegetables, and ornamental plants. This review focuses on the background of amiRNA and highlights the technology's contributions to disease resistance and plant quality (Kumar et al., 2024a).

The development of artificial miRNAs (amiRNAs) offers new avenues for genetic improvement in apple. amiRNAs are designed to target specific genes, allowing for precise

regulation of traits such as fruit size, stress tolerance, and disease resistance (Kumar et al., 2024 a). For example, amiRNA technology has been successfully used to enhance resistance to fungal infections and improve fruit quality in apple (Shi et al., 2024).

5.2. Enhancing Fruit Yield and Quality

In apples, miRNAs are crucial regulators of gene expression that influence fruit yield and quality by modulating various growth, stress response, and developmental pathways. Key miRNAs like miR156, miR172, and miR396 have been identified as major players in enhancing fruit size, color, and texture, as well as promoting tolerance to environmental stresses such as drought and salinity (Šečić et al., 2021). By targeting transcription factors and structural genes, these miRNAs control processes including cell division, nutrient uptake, and metabolic adjustments that are essential for improved fruit characteristics. Recent studies have also shown that manipulating miRNA expression through genetic engineering or selective breeding can significantly increase apple yield and quality, making miRNA research a promising approach in modern horticultural practices. Understanding and harnessing the role of miRNAs in apples thus presents exciting opportunities for sustainable yield improvements and higher quality produce.

miRNA-based interventions hold promise for increasing apple yield and improving fruit quality. By targeting miRNAs that regulate cell division, nutrient uptake, and stress response, it is possible to develop apple varieties that produce higher yields while maintaining fruit quality under adverse environmental conditions (Verma et al., 2024; Gao et al., 2024).

6. FUTURE DIRECTIONS AND CONCLUSION

The growing body of research on miRNA expression in *Malus domestica* presents significant potential for advancing apple yield, quality, and resilience. Future studies should focus on integrating miRNA-based genetic modifications with traditional breeding techniques, particularly by investigating the regulatory roles of miRNAs such as miR156, miR482, and miR858 in stress tolerance, growth, and pigmentation. By combining these approaches, breeders could develop apple cultivars with enhanced tolerance to drought, salinity, and pathogens, while improving key quality traits like color and texture. Innovations in miRNA-based biotechnology, including artificial miRNAs (amiRNAs) and precision gene editing tools, offer promising pathways to fine-tune gene expression in apples without compromising essential traits, supporting sustainable agriculture. Additionally, integrating multi-omics approaches to map miRNA networks and their interactions with hormonal and environmental signals will allow for more accurate trait prediction. As miRNA research progresses, it is poised to play an essential role in shaping apple cultivars that meet both agricultural productivity and consumer demands, paving the way for resilient, high-quality apple varieties suited to a changing climate and diverse market needs.

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TOPRAKSIZ TARIMDA BİYOGÜBRE OLARAK *CHLORELLA VULGARIS*'İN POTANSİYEL KULLANIMI

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ÖZET

Dünya nüfusunun artışıyla birlikte bitkisel üretime olan talep de hızla artış göstermektedir. Bununla birlikte tarıma elverişli alanlar günden güne azalmakta olup, topraksız tarım üretimine yönelişte artışlar gözlenmiştir. Topraksız tarım üretiminde birim alandan daha fazla ürün alınmakta ve verim artmaktadır. Topraksız tarımda bitkilerin ihtiyaç duyduğu gübreler bitki kök bölgesine besin eriği yöntemiyle uygulanmakta bu yüzden gübreleme doğru ve dengeli bir şekilde yapılmalıdır. Çevresel zarara yol açan yoğun gübre kullanımının azaltılmasına olanak sağlayan mikroorganizmalar, besin elementlerinin döngüsünde görev aldıkları için sürdürülebilirlik açısından önemli bir rol oynamaktadır. Bu bağlamda, *Chlorella vulgaris* gibi mikroalgler, topraksız tarımda biyogübre olarak kullanılarak hem gübre kullanımını azaltmakta hem de bitki büyümesini desteklemektedir. Bu çalışmanın amacı, *Chlorella vulgaris*'in topraksız tarım kültüründe biyogübre olarak kullanım potansiyelini incelemektir. Özellikle bitki gelişimi, verim artışı ve besin tasarrufu üzerindeki potansiyel etkileri değerlendirilecektir. Bu derleme, sürdürülebilir tarım ve gübre tasarrufu stratejileri için önemli bilgiler sunabilir.

Anahtar Kelimeler: *Chlorella vulgaris*, Topraksız tarım, Biyogübre

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THE POTENTIAL USE OF *CHLORELLA VULGARIS* AS A BIOFERTILIZER IN SOILLESS CULTURE

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ABSTRACT

The increasing world population has led to a rapid rise in the demand for plant production. However, arable lands are decreasing day by day and there has been an increase in the tendency towards soilless agriculture production. In soilless culture production, more products are obtained from the unit area and the yield increases. In soilless culture, the fertilizers needed by the plants are applied to the plant root zone with the nutrient solution method, so fertilization should be done correctly and balanced. Microorganisms, which allow the reduction of intensive fertilizer use that causes environmental damage, play an important role in terms of sustainability since they take part in the nutrient cycle. In this context, microalgae such as *Chlorella vulgaris* are used as biofertilizers in soilless agriculture, both reducing fertilizer use and supporting plant growth. The aim of this study is to examine the potential use of *Chlorella vulgaris* as a biofertilizer in soilless agriculture culture. In particular, its potential effects on plant development, yield increase and nutrient saving will be evaluated. This review can provide important information for sustainable agriculture and fertilizer saving strategies.

Key words: *Chlorella vulgaris*, soilless farming, Biofertilizer

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1. GİRİŞ

Topraksız tarım, toprak kullanılmadan yapılan bir tarım tekniğidir. Bu sistemlerin birçok avantajı vardır, örneğin besin çözeltisinin kontrollü koşulları, su ve besinlerin etkili kullanımı, besinlerin kolay erişilebilir olması, enerji tasarrufu, yüksek kaliteli ürünler, hastalık ve patojenlerden arınmış üretim, tuzluluk problemlerinin aşılması ve tarım alanlarından tasarruf. Diğer taraftan, teknik gereksinimler hakkında yetersiz bilgi ve yüksek başlangıç ve işletme maliyetleri dezavantajlar olabilir (Žunić ve ark. 2022). Optimal yetiştirme koşulları ve CO_2 konsantrasyonundaki artış, fotosentezi artırarak, açık alanda bitki üretimine kıyasla daha kısa sürelerde yüksek verimli sebze üretimi sağlar (Anpo ve ark., 2019). Pazı, fesleğen ve roka mikro yeşillikleri (Bulgari ve ark., 2017), ıspanak (Kameoka ve Hashimoto, 2019) ve marul (Schwarz ve Gross, 2004) gibi yeşil yapraklı sebzeler sıklıkla topraksız tarım sistemlerinde üretilmektedir. Yapraklı sebzelerin yanı sıra, bu yetiştirme yöntemiyle meyve sebzeleri üretmek için büyük bir potansiyel bulunmaktadır. Topraksız olarak üretilen meyve ve sebzeler, daha iyi gıda kalitesi sağlayabilir (Kameoka ve Hashimoto, 2019). Topraksız bitki üretim sistemleri, verimsiz toprak alanlarında önemli bir rol oynamaktadır ve bitkilerle mikroalglerin birlikte yetiştirilmesi, birden fazla ekolojik ve ekonomik fayda sağlayan yenilikçi bir biyoteknoloji alternatifi sunabilir (Žunić ve ark. 2022).

Biyogübreler, sürdürülebilir tarım için kimyasal gübrelerin yerini almak ve onları tamamlamak amacıyla kullanılan çevre dostu, uygun maliyetli ve yenilenebilir bitki besin kaynaklarıdır (Raja, 2013). Biyogübreler; azot fiksasyonu, fosfat ve potasyum çözündürme veya mineralizasyonu, bitki büyümesini teşvik eden maddelerin salınımı, antibiyotik üretimi ve topraktaki organik maddelerin biyolojik bozunumu gibi yollarla çeşitli mikro ve makro elementler sağlar (Goel ve ark., 1999; Sinha ve ark., 2010). Biyogübreler uzun yıllar kullanıldığında, başlangıçtaki inokülantlar çoğalarak yeterli hale gelir (Youssef ve Eissa, 2014) ve besin döngüsüne katılarak ürün verimine katkıda bulunur (Singh ve ark., 2011). Biyogübrelerin başlıca yararları arasında; (1) ucuz bir besin kaynağı olmaları, (2) mikro element tedarikçileri olmaları, (3) organik madde sağlamaları, (4) kimyasal gübrelerin olumsuz etkilerini dengelemeleri, (5) büyüme hormonu salgılamaları (Gaur, 2010), (6) ekosisteme zarar vermemeleri ve (7) uzun raf ömrüne sahip olmaları yer almaktadır (Sahoo ve ark., 2014).

Biyogübrelerde kullanılan başlıca mikroorganizmalar; Azotobacter, Azospirillium, siyanobakteriler, Azolla, fosfat çözündürücü mikroorganizmalar, mikoriza, Sinorhizobium ve bitki büyümesini destekleyen rizobakterilerdir (Hegde ve ark., 1999; Youssef ve Eissa, 2014). Alg biyokütlesi; makro besinlerin yanı sıra mikro besinler, büyüme düzenleyiciler, poliaminler, doğal enzimler, karbonhidratlar, proteinler, amino asitler ve bitkilerin vejetatif büyümesini desteklemek için vitaminler içerir (Abd El Moniem ve Abd-Allah, 2008; El-Fouly ve ark., 1992; Mahmoud ve Amara, 2000; Shaaban ve Mobarak, 2000). Ayrıca, alg biyokütlesi, vitaminler, oksinler ve gibberellinlerin varlığı sayesinde ürün verimini artırır. Biyogübre olarak test edilen alg çeşitleri ağırlıklı olarak mavi-yeşil algler (Cyanophyta) ve yeşil algler (Chlorophyta) dalına aittir. Mikroalglerin genel kabul gören tanımı, prokaryot ve ökaryot tek hücreli fotosentetik organizmalardan oluşan bir grup olarak ifade edilmektedir. Geniş bir mikroorganizma sınıfını oluşturan mikroalgler (genellikle boyutlarına göre, 3–10 µm, gruplandırılır), çok çeşitli

ortamlarda yaşar ve birincil üreticiler olarak sucul ekosistemlerin trofik zincirinin temelini sağlarlar (Usher ve ark.,2014; Kholssi ve ark., 2023). Yeşil alg *Chlorella vulgaris,* yüksek protein, vitamin, esansiyel amino asitler ve yağ asitleri içeriğinden dolayı önemli biyo-gübre olarak kabul edilmekte ve ticari önemi nedeniyle geniş çapta incelenmektedir (Dineshkumar ve ark., 2020a). Yapılan birçok çalışma, yeşil alglerin (1) organik madde ekleyebildiğini, (2) amino asitler, vitaminler ve oksinler sentezleyip serbest bırakabildiğini, (3) toprağın oksitlenebilir madde içeriğini azaltabildiğini, (4) rizosfere oksijen sağlayabildiğini, (5) tuzluluğu iyileştirebildiğini ve pH'ı tamponlayabildiğini, (6) fosfatı çözündürdüğünü ve (7) kültür bitkilerinin gübre kullanım verimliliğini artırabildiğini göstermiştir (Faheed ve Abd-El Fattah, 2008; Abd El Moniem ve Abd-Allah, 2008; Bileva, 2013; Dubey ve Dubey, 2010; Grzesik ve Romanowska-Duda, 2015; Vig ve ark., 2012).

Chlorella vulgaris mikroalginin topraklı tarımda yetiştiriciliği yapılan türlerde uygulandığına dair yapılmış pek çok çalışma bulunmaktadır. Önceki çalışmalarda, yeşil mikroalg *Chlorella vulgaris* uygulamasının yeşil mercimek yetiştiriciliğinde büyüme ve verimi artırdığı belirtilmiştir (Dineshkumar ve ark., 2020b). *C. vulgaris* özlerinin fasulye yetiştiriciliğinde yapraktan sprey şeklinde uygulaması, kontrol grubuna kıyasla maksimum büyüme ve verim elde edilmesini sağlamaktadır (Refaay ve ark., 2021). *Chlorella vulgaris* (biyofertilizatör), Hibiscus esculentus'un toprak besinlerini ve verimliliğini artırmada etkilidir (Obioma K.A. et al., 2017). *C. vulgaris* uygulaması, pazı bitkisinde fotosentetik pigment ve büyüme artışına neden olmuştur (Hajnal-Jafari ve ark., 2020). Bumandalai ve Tserennadmid, (2019), C. vulgaris süspansiyonunun domates ve hıyar tohumlarının çimlenmesini artırabileceği sonucuna varmıştır. Özellikle, 0.17 g/L ve 0.25 g/L konsantrasyonlarındaki alg süspansiyonlarının, sırasıyla domates ve hıyar tohumlarının kök ve sürgün uzunluklarını iyileştirdiği bildirilmiştir. Suchithra ve ark. (2022), genel olarak, *Chlorella vulgaris,* domates bitkisinde biyostimülan olarak değil, biyogübre olarak daha fazla etki göstermiştir. mikroalg *Chlorella vulgaris*, organik domates yetiştiriciliğinde sentetik kimyasal gübre yerine biyogübre olarak kullanılabilir sonucuna varılmıştır.

Son yıllarda, bitki ve mikroalg üretiminin birleşik bir stratejisi önerilmiştir (Schwarz ve Gross, 2004; Zhang ve ark., 2017; Barone ve ark., 2019; Bharti ve ark., 2019; Huo ve ark., 2020; Supraja ve ark., 2020). Böyle bir sistemde, mikroalgler, üretim sırasında besin eklenmeden bitkilerle birlikte üretilir. Ancak, mikroalglerin besin salınımı ve bitkiler tarafından kullanımı araştırmak çok karmaşık bir süreçtir. Çok az yazar, hidroponik sistemlerde ko-inokülantlar arasındaki etkileşimleri araştırmıştır. Supraja ve ark. (2020), mikroalgal karışımı ve domates bitkilerinin birlikte yetiştirilmesinin büyüme hızı üzerindeki olumlu etkisini ve azot, fosfor ve potasyum gibi besinlerin giderilmesi ve birikmesi olasılığını değerlendirmiştir. Huo ve ark. (2020), *C. vulgaris*'in aynı anda azot ve fosforu giderme yeteneğini kanıtlamış ve marulun taze ağırlığını artırmıştır. Ayrıca, *C. vulgaris*'in topraksız olarak domates bitkileriyle birlikte yetiştirilmesi hem domates sürgün ağırlığı hem de domates kök uzunluğu üzerinde olumlu bir sinerji göstererek mikroalgal biyokütlesinin artmasına yol açmıştır (Barone ve ark., 2019). Turhan ve ark. (2022), roka (Eruca vesicaria subsp. sativa) bitkisinde mikroalgal uygulamanın farklı gübre dozlarıyla bitki büyümesine etkisini incelemek amacıyla kontrollü sera koşullarında bir çalışma yapmıştır. Mikroalga (Chlorella vulgaris) uygulaması, fide

büyüme ortamına iki kez, her biri 100 ml ve 150 ml olmak üzere, saksı başına yapılmıştır. Kimyasal gübre olarak, NPK'nın %0, %50 ve %100'ü (160 mg N kg^-1, 80 mg P2O5 kg^-1 ve 100 mg K2O kg^-1) uygulanmıştır. Çalışmada, sürgün boyu, taze ağırlık, kuru ağırlık, sap çapı, yaprak alanı ve besin elementleri gibi parametreler incelenmiştir. Sonuçlar, mikroalgal uygulamaların bitki büyümesini olumlu yönde etkilediğini ve en iyi sonuçların %50 gübre + mikroalga ile %100 gübre + mikroalga uygulamalarında elde edildiğini göstermektedir.

2. TOPRAKSIZ TARIMDA CLORELLA VULGARS YEŞİL ALGİNİN ROLÜ

Topraksız tarım sistemlerinde biyogübre kullanımı, çevresel sürdürülebilirlik ve verimlilik açısından önemli bir potansiyel sunmaktadır. Bu bağlamda, mikroalg Chlorella vulgaris'in biyogübre olarak kullanımı, besin tasarrufu sağlama ve ürün kalitesini artırma konularında umut verici sonuçlar vermektedir. Topraksız yetiştirilen sera domateslerinde mikroalg *Chlorella vulgaris*'in besin tasarrufu üzerine etkisini araştırmak amacıyla yapılan bir çalışmada, bitki gelişimi, verim ve meyve özellikleri üzerindeki etkileri incelenmiştir. *Chlorella vulgaris*'in meyve kalitesi üzerindeki en iyi etkisi, azaltılmış besin seviyelerinde C vitamini içeriğini artırmak olmuştur. Ayrıca, domates meyvesinde P, Na ve Mg mineralleri içeriğini artırma potansiyeline sahiptir. *Chlorella vulgaris*'in kök bölgesindeki pH üzerinde anlamlı bir etkisi bulunmamış, ancak EC üzerinde anlamlı bir düşürücü etkisi gözlemlenmiştir (Aydoner Coban ve ark., 2018). Mikroalg *Chlorella vulgaris*'in, topraksız yetiştirilen marul bitkilerinde mineral gübre kullanımını azaltma potansiyelini araştıran benzer bir çalışmada, algin bitki gelişimi ve bazı kalite özellikleri üzerindeki etkileri incelenmiştir. Sonuçlar, *Chlorella vulgaris*'in besin çözeltisinde kullanılmasıyla mineral gübrelerin %60'a kadar azaltılabileceğini göstermiştir. Ayrıca, toplam çözünür katı madde (brix) ve C vitamini içeriğinde artış sağlanarak marul kalitesini de iyileştirmiştir (Ergun ve ark., 2018). Vildanova ve ark. (2023), hidroponik sistemlerde Chlorella vulgaris'in potansiyel etkilerini inceleyen bir çalışmada, bu mikroalg süspansiyonunun hıyar bitkilerinde sürgün ve kök uzunluğu ile kuru biyokütle üzerindeki etkisini araştırmıştır. Çalışmada, Chlorella süspansiyonu eklenmiş besin ortamında, sürgün uzunluğunun 11.30 cm'den 8.15 cm'ye, kök uzunluğunun ise 16.41 cm'den 10.59 cm'ye düştüğü, ancak kök biyokütlesinin 0.04 g'den 0.05 g'ye arttığı belirtilmiştir. Bu bulgular, Chlorella vulgaris süspansiyonunun hidroponik koşullarda hıyar bitkilerinin kuru biyokütlesi üzerinde olumlu bir etkiye sahip olduğunu göstermekte ve bu mikroalgin hidroponik sistemlerde kullanımını önermektedir. Akdeniz ikliminde topraksız yetiştiricilikte biyogübrelerin kimyasal besin tasarrufu sağlama potansiyelini araştıran bir çalışmada, dört ticari biyogübre (Cocktail mikoriza, Bacillus subtilis, Azotobacter vinelandii ve Chlorella spp.) kullanılmıştır. Üç farklı besin çözeltisi uygulanarak (%100 tam besin, %20 ve %40 azaltılmış besinler) biyogübrelerin verim ve bitki gelişimi üzerindeki etkileri değerlendirilmiştir. %20 ve %40 azaltılmış besin seviyelerinde "Mikroalg" uygulamaları kontrol grubuna kıyasla verimi artırmış, bitki gelişimi ve meyve özellikleri (ağırlık, uzunluk, çap, toplam çözünür katı madde) ise olumsuz etkilenmemiştir (Dasgan ve ark., 2010). Yine Dasgan ve ark., (2023) yaptıkları bir çalışmada, topraksız kültürdeki bebek ıspanaklarının mineral gübre kullanımını azaltmak amacıyla, mineral gübrelerin %50'sinin *Chlorella vulgaris* mikroalgleri, faydalı bakteriler ve mikorizalarla takviye edilmesi hedeflenmiştir. Araştırma, bebek ıspanaklarının yaprak kalitesini ve nitrat birikimini iyileştirmeye odaklanmıştır. Mikroalgler, potasyum, kalsiyum,

magnezyum, çinko ve manganez seviyelerini artırmıştır. Sonuç olarak, bio-gübrelerin, mineral gübrelerin %50'sine kadar yerine kullanılabileceği ve bu yöntemle ıspanak kalitesinin artırılabileceği, çevresel sürdürülebilirlik sağlanabileceği sonucuna varılmıştır.

3. SONUÇ

Derlemenin genel bulgularına dayanarak, *Chlorella vulgaris* uygulamalarının bitki büyümesi ve kalite parametreleri üzerindeki olumlu etkileri açıkça ortaya çıkmaktadır. Yapılan araştırmalar, mikroalg kullanımının, bitkilerin büyüme süreçlerinde çeşitli faydalar sağladığını göstermektedir. *Chlorella vulgaris*'in, özellikle topraksız tarım yetiştiriciliğinde, bitki büyümesini desteklediği ve besin elementleri içeriğini iyileştirdiği belirlenmiştir. Bunun yanı sıra, *Chlorella vulgaris*'in, bitkilerin besin değeri üzerinde de olumlu etkileri olduğu bulunmuştur. Özellikle fenolik bileşenler, vitamin C, total çözünebilen katı maddeler gibi kalite parametrelerinde artışlar kaydedilmiştir. Ayrıca, *Chlorella vulgaris* uygulamalarının, bitkilerin bazı besin elementlerinin (örneğin potasyum, kalsiyum, magnezyum, çinko) içeriğini artırdığı ve bu sayede bitkilerin genel sağlık durumunu iyileştirdiği belirlenmiştir.

Sonuç olarak, *Chlorella vulgaris*'in biyogübre olarak kullanımı, tarımsal üretimde kimyasal gübre kullanımını azaltma potansiyeline sahip olup, çevreye olan etkileri minimize ederken bitki büyümesini ve besin değerini artırmada etkili bir strateji sunmaktadır. Bu çalışmalar, mikroalg uygulamalarının sürdürülebilir tarım uygulamalarında önemli bir rol oynayabileceğini ve daha geniş çapta kullanılabileceğini göstermektedir.

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SEBZELERDE STRES TOLERANSINI ARTIRMAK İÇİN KULLANILAN BAZI AMİNO ASİTLER VE ETKİLERİ

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ÖZET

Küresel iklim değişikliği, sebze üretiminde verim ve kaliteyi olumsuz etkileyen abiyotik stres faktörlerinin (kuraklık, tuzluluk, yüksek ve düşük sıcaklık, ağır metal toksisitesi gibi) varlığını daha çok hissettirmesine neden olmaktadır. Abiyotik stresler, bitkilerin fizyolojik ve biyokimyasal süreçlerinde tahribata yol açarak büyüme ve gelişme üzerinde ciddi baskılar oluştururlar. Bu streslere karşı bitkiler, savunma mekanizmalarını devreye sokarak hücre yapısının korunması ve metabolik süreçlerin düzenlenmesi için amino asitler gibi çeşitli metabolitler sentezlerler. Son yıllarda yapılan bilimsel araştırmalar, abiyotik streslerin bitkiler üzerindeki olumsuz etkilerini azaltma stratejilerine odaklanmış, bu bağlamda eksojen amino asit uygulamaları dikkat çekici sonuçlar vermiştir.

Amino asitler, hücresel osmotik dengeyi koruma, antioksidan savunmayı güçlendirme ve stres sinyalleme mekanizmalarında önemli roller oynamaktadır. Eksojen olarak uygulanan amino asitler ise, bitkilerin stres toleransını artırmada tamamlayıcı bir rol üstlenmektedir.

Bu çalışmada, apolar amino asitler (triptofan ve prolin) ve polar amino asitler (asparajin ve glutamin) incelenerek, sebzelerde abiyotik streslere karşı savunma mekanizmalarındaki işlevleri ele alınacaktır. Derleme, sebzelerin abiyotik streslere verdiği fizyolojik tepkileri ve bu amino asitlerin dışsal uygulamalarının stres toleransını artırmadaki potansiyelini değerlendirmeyi amaçlamaktadır. Elde edilen bulgular, amino asitlerin stres yönetimi açısından taşıdığı önemi ortaya koymayı hedeflemektedir.

Anahtar Kelimeler: Sebze, Abiotik stres, Amino Asitler

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SOME AMINO ACIDS USED TO ENHANCE STRESS TOLERANCE IN VEGETABLES AND THEIR EFFECTS

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ABSTRACT

The impact of global climate change has exacerbated the presence of abiotic stress factors (including drought, salinity, extreme temperatures, and heavy metal toxicity) that negatively influence the yield and quality of vegetable crops. Abiotic stresses impair the physiological and biochemical functions of plants, leading to substantial limitations on their growth and development. To counteract these stresses, plants trigger defense mechanisms, synthesizing various metabolites such as amino acids to preserve cellular structure and regulate metabolic processes.

Recent studies have increasingly focused on strategies to alleviate the detrimental effects of abiotic stress on plants, with exogenous amino acid applications showing promising outcomes. Amino acids play vital roles in maintaining cellular osmotic homeostasis, strengthening antioxidant defenses, and participating in stress signaling pathways. When applied externally, these amino acids can enhance the plant's innate defense systems, ultimately improving stress tolerance.

This review will investigate the roles of apolar amino acids (tryptophan and proline) and polar amino acids (asparagine and glutamine) in the defense mechanisms of vegetables against abiotic stress conditions. The study aims to assess the physiological responses of vegetable crops to these stresses and evaluate the potential of some exogenous amino acid applications in improving stress tolerance. The results are anticipated to underscore the critical role of amino acids in plant stress management.

Key words: Vegetable, Abiotic stress, Amino acids

1. GİRİŞ

İklim değişikliği, abiyotik streslerin bitkisel üretim üzerindeki baskısını daha da artırarak bu stres faktörlerinin etkisini güçlendirmektedir. Son yıllarda, abiyotik streslerin sebze türleri üzerindeki olumsuz etkilerini incelemeye ve bu etkileri hafifletmeye yönelik bilimsel çalışmalar önemli ölçüde artış göstermiştir. Sebze türlerinin pek çoğunda kuraklık (Moles ve ark., 2018; Sahin ve ark., 2018; Altunlu ve ark., 2022), tuzluluk (Kuşvuran ve ark., 2007; Dölek ve Eker, 2010; Erdinç ve Kıpçak, 2016; Güngör, 2023; Sarıbaş ve ark., 2023; Şavkan ve Çandar, 2024) yüksek sıcaklık (Alsamir ve ark., 2021; Zhao ve ark., 2022), düşük sıcaklık (Özmen ve Mavi, 2024) ve ağır metal stresleri (Şahin, 2023) üzerine çalışmalar bulunmaktadır. Strese karşı geliştirilen tolerans seviyeleri türden türe değişmekle birlikte türler arasındaki çeşitlerde bile farklılık gözlenmektedir. Stres toleransını arttırmak için bitkilere eksojen olarak verilen pek çok uygulama bulunmaktadır. Dışsal uygulanan aminoasitler (AA) bu uygulamalar içinde yer almakta olup, stres koşullarına karşı bitkilerin direnç oluşturmasında önemli rolleri bulunmaktadır (Szabados and Savouré, 2010). Amino asitler (AA), optimum koşullar altında bitki büyümesi ve gelişiminde yararlı bir rol oynayan iyi bilinen biyostimülanlardır (Kowalczyk et al., 2008). Biyostimülan gibi doğal ürünlerin uygulanmasıyla tarımsal üretim sürdürülebilirliğini ve dayanıklılığını iyileştirmek için yeni yaklaşımlar getirilmiştir; bu ürünler çevre dostu, maliyet etkin ve ekili ürünlerin verimliliğini ve kalitesini artırmaktadır (El-Nakhel ve ark., 2022). Biyostimülan, bitki metabolizmasını, çimlenme oranlarını, fotosentez sürecini, besin emilimini artırarak ve verimliliği iyileştirerek bitki büyümesini teşvik eder (Yakhin ve ark., 2017).

AA'ların farklı bitkiler üzerindeki etkileri kapsamlı bir şekilde araştırılmıştır. Çalışmalar AA'nın gübre asimilasyonunu, besin maddelerini, su alımını ve çeşitli sebze bitkilerinin fotosentezini iyileştirebileceğini (Sarojenee ve ark., 2009) ve bunun sonucunda çiçek üretimi, meyve tutumu ve meyve veriminin arttığını göstermiştir (Neeraja ve ark., 2005; Fernandez ve Eicherd, 2009). Örneğin, AA karışımlarının uygulanması, sırasıyla hidroponik ve toprak ortamında yetiştirilen marul (Gunes ve ark., 1994), turpun (Gonzales ve ark., 2010) bitki, büyüme parametrelerini artırmaktadır. Amino asitler, bitkilerde nitrat alımı ve indirgenmesinin nihai ürünü olduğundan, bitki dokularındaki amino asit konsantrasyonunun artması nitrat alımını ve bitki kök hücrelerinde birikimini engelleyebilir. Bununla birlikte, AA'lar toprakta yavaş hareket eder ve inorganik azotun (N) yerini alamaz. Bu nedenle, yapraktan ve hidroponik besin solüsyonlarında uygulama daha etkilidir (Owen ve Jones 2001; Yasmeen ve ark., 2013) Araştırmacılar, amino asitlerin yapraktan uygulanmasının nitrit redüktaz enzimlerinin aktivitesini artırdığını ve marulda nitrat birikimini azalttığını bildirmişlerdir (Jalali et al., 2020). Besin çözeltisindeki nitrat, temel amino asitlerden oluşan bir karışımla değiştirildiğinde soyanın nitrat alımı ve birikimi engellenmiştir (Shekari ve Javanmardi 2017). Ayrıca, dışarıdan uygulanan amino asitler, lahana (Shekari ve Javanmardi 2017), Pak-choi (*Brassica chinensis* L.) (Wang ve ark., 2007) ve turp (Basha ve El-Aila, 2015) bitkilerinde nitrat birikiminin azaltılmasında olumlu bir etkiye sahiptir. Birçok rapora göre, sebzelerde aşırı nitrat birikimi beslenmeyle ilgili önemli bir endişe kaynağıdır, bu nedenle değerli ve maliyet açısından uygun bir azot kaynağı uygulaması gerekmektedir (Shekari ve Javanmardi 2017). Haghighi ve ark., (2022), tarafından yapılan bir çalışmada, 16 AA bileşiğinin bir karışımından oluşan toz formu

(arginin, sistein, glisin, fenilalanin, valin, treonin, triptofan, metiyonin, lösin, glutamin, lizin ve histidin, alanin, aspartik asit, asparajin, glutamik asit) lahana fidelerine uygulanmıştır. AA'ları yapraktan püskürtmenin lahananın büyümesini, biyokimyasal ve antioksidan özelliklerini ve ayrıca besin değerini önemli ölçüde artırdığını bildirmişlerdir. 300 mg/L'lik en yüksek AA konsantrasyonu lahananın büyümesi, antioksidan kapasitesi ve besin değeri üzerinde en büyük etkiye sahip olduğu bulunmuştur.

Tuz stresi koşullarında, amino asitler ozmolit görevi görerek iyon taşınımını düzenler, stomaların açılmasını modüle eder, ağır metallerin detoksifikasyonunu sağlar, enzimleri aktive eder, gen ekspresyonunu ve redoks dengesini destekler (Rai, 2002; Cheng ve ark., 2016). Ekzojen amino asitler proteinojenik amino asitleri, iyon emilimini ve marul bitkilerinin fizyo-biyokimyasal özelliklerini olumlu yönde etkilemektedir (Abdelkader ve ark., 2023). Bununla birlikte soğuk stresi altında, AA uygulanan marul bitkilerinde stoma iletkenliği ve taze ağırlıkta iyileşme gözlenmiştir (Botta, 2012). Genel olarak AA uygulamasının lahanada kuraklık stresinin zararlı etkilerini azaltarak fizyolojik parametreleri artırmada etkili olduğu görülmüştür (Haghighi ve ark., 2020).

Bu çalışma sebzelerin abiyotik streslere verdiği fizyolojik tepkileri ve bu amino asitlerin dışsal uygulamalarının stres toleransını artırmadaki potansiyelini değerlendirmeyi amaçlamaktadır. Elde edilen bulgular, amino asitlerin stres yönetimi açısından taşıdığı önemi ortaya koymayı hedeflemektedir.

2. PROLİN

Çeşitli stres koşulları altında bitkilerin hayatta kalmasını etkileyen yanıtlar arasında, proteinojenik bir amino asit olan prolin birikimi öne çıkmaktadır; bu birikim özellikle tuzluluk, kuraklık, ağır metal veya sıcaklık stresi gibi durumlarda önemli rol oynar (Wang ve ark. 2007; Liang ve ark. 2013; Signorelli ve ark. 2013a; Bouthour ve ark. 2015; Rodríguez-Ruiz ve ark. 2019). Prolinin stres koşullarındaki işlevleri arasında hücre turgorunu koruma, karbon ve azot kaynağı olarak hizmet etme, metal şelasyonu ve sinyal molekülü olarak görev yapma yer almaktadır (Kavi Kishor & Sreenivasulu 2014; Bouthour ve ark. 2015; de Freitas ve ark. 2018; Aghdam ve ark. 2019). Ayrıca hidrojen bağlarına bağlanarak protein stabilitesini iyileştirebilir ve zar bütünlüğünü korur (Hossain ve ark., 2019). Bir ozmolit olarak hareket etmesine rağmen, prolin aynı zamanda güçlü bir antioksidan savunma molekülü, metal şelatlayıcı, protein stabilizatörü, ROS temizleyicisi ve programlanmış hücre ölümünün bir inhibitörü olarak kabul edilir (Dar ve ark., 2016; Adejumo ve ark., 2021). Çoğu durumda, prolin birikimi reaktif oksijen türlerine (ROS) karşı genel bir temizleyici rol üstlenir. Bazı veriler, prolinin hidroksil radikali ($^{\bullet}OH$) ile etkileşime girdiğini öne sürerken, diğer çalışmalar $O_2^{\bullet-}$, tekil oksijen ($^1O_2$), nitrik oksit ($^{\bullet}NO$), nitrojen dioksit ($^{\bullet}NO_2$) veya peroksinitrit ($ONOO^-$) gibi moleküllere karşı doğrudan koruma sağlamadığını belirtir (Signorelli ve ark. 2013b, 2016). Bu nedenle, prolinin genel bir antioksidan olarak değerlendirilmesi dikkatle ele alınmalıdır. Prolin, stres olmayan koşullarda da sentezlenir ve bu ortamda çiçeklenme sürecini, erkek gametofit ve tohum gelişimini düzenler (Mattioli ve ark. 2008, 2022). Araştırmalar, prolinin pentoz fosfat, trikarboksilik asit, üre döngüsü ve fenilpropanoid gibi temel yollarla ilişkili olduğunu göstermektedir (Hare & Cress 1997; Shetty 2004; Priya ve ark. 2019). Prolinin dışsal uygulanmasının, sıcaklık ve soğuk stresi

gibi bazı stresleri hafiflettiği gösterilmiştir (Liang ve ark. 2013; Shin ve ark. 2018; Priya ve ark. 2019; Mattioli ve ark. 2020). Prolin uygulaması, stres koşullarında oksidatif hasarı ve zar yaralanmalarını azaltabilir; antioksidan enzimleri, yaprak su içeriğini ve fotosentezi artırabilir (Priya ve ark. 2019; Shakeri ve ark. 2019; Ghosh ve ark. 2022). Ekzojen prolinin uygulanması için birkaç yöntem vardır, bunların en önemlileri yaprak püskürtme ve tohum priming uygulamalarıdır (Hosseinifard ve ark., 2022). Fasulye bitkisine ekzojen olarak uygulanan prolinin yüksek sıcaklık stresini hafifletmede etkili olduğu bildirilmiştir (Priya ve ark., 2019).

3. TRİPTOFAN

Triptofan, tüm canlı hücrelerde protein biyosentezi için gerekli bir aromatik amino asittir. Şikimat yolunun son ürünü olan korismattan türemiştir ve bitkilerin çok çeşitli biyoaktif moleküllerin öncüsü olmasında önemli bir rol oynamaktadır (Maeda ve Dudareva, 2012). Ayrıca bir ozmolit, iyon taşıma düzenleyicisi olarak görev yapabilir, stoma açılmasını düzenleyebilir ve ağır metallerin zararlı etkilerini detoksifiye edebilir (Rai, 2002). Jiang ve ark. (2022), foliar yolla uygulanan triptofanın Cd stresine maruz kalan *Brassica oleracea* üzerindeki etkilerini incelemiş ve Cd stresinin sürgün ve kök yaş ağırlığında azalmaya neden olduğunu, ancak triptofan uygulamasıyla bu değerlerin sırasıyla %25 ve %120 oranında arttığını belirlemiştir.

Önceki araştırmalar, triptofan uygulamasının bitki dokularında IAA seviyelerini artırabileceğini ve çeşitli bitkilerde büyümeyi destekleyebileceğini göstermiştir (Antony ve ark., 2017; Hancı ve ark., 2019). Bununla birlikte bitki büyümesi, gelişimi ve stres toleransı üzerinde l -triptofanın dışsal uygulamasının etkisini değerlendirmek için çalışmalar yürütülmüştür (Hussein ve ark. 2014; Bakry ve ark. 2016; El-Gamal ve ark. 2016).

Triptofanın ekzojen olarak uygulanması sonrasında bitki dokularında oksin seviyeleri artar (Ahemad ve Kibret, 2014). Bitkilere triptofan uygulamanın çeşitli yolları vardır, bunlar toprak uygulaması (Muneer ve ark., 2009), yapraktan püskürtme (El-Awadi ve ark., 2011) ve tohum işleme (Abbas ve ark., 2013) şeklindedir. L-triptofanın oksin sentezi üzerindeki etkileri hem yaprak hem de toprak uygulamasından sonra gözlemlenmiştir (Rosa ve ark., 2023). L-triptofanın toprak uygulamasının bitki büyümesi ve verimi üzerindeki olumlu etkisi, kökler tarafından doğrudan alınmasından ve daha sonra bitki dokularında veya rizosfer mikroorganizmaları tarafından oksinlere metabolize edilmesinden kaynaklanabildiği belirtilmiştir (Khalid ve ark., 2004; Zahir ve ark., 2010).

4. GLUTAMİN

Abiyotik streslere karşı bitkiler tarafından sentezlenen spesifik metabolitlerden biri olan glutamin, bitkilerde inorganik nitrojenin metabolize edildiği ana asimilasyon ürünüdür ve diğer amino asitlerin oluşumunda öncü bir moleküldür (Coruzzi 2003; Hildebrandt ve ark., 2015; Muthuramalingam ve ark., 2020). Glutamin, birçok tarımsal üründe verimliliği artıran bir amino asit olarak öne çıkmaktadır (Nasırcılar ve Ulukapı, 2023). Soğan yapraklarına uygulanan glutamin, bitki boyu, yaprak sayısı ve soğan uzunluğu gibi büyüme parametrelerini iyileştirirken, aynı zamanda verimi ve kaliteyi artırmıştır. Bu uygulama, bitkinin biyokimyasal

özelliklerinde de değişim sağlamış; toplam çözünür şeker, fenol, serbest amino asit miktarı, kükürt bileşikleri ve yapraktaki fotosentetik pigment oranında artışa neden olmuştur (Amin ve ark., 2011). Soğanda elde edilen bu bulgulara benzer şekilde, 200 mg/l glutamin uygulaması bakla bitkisinde büyüme ve verimi desteklemiştir (Rashad ve ark., 2003). Marul bitkisinde yapılan glutamin uygulaması, kök ve sürgün büyümesi ile yaprak pigmenti ve C vitamini içeriğini artırmıştır (Noroozlo ve ark., 2019). Eksojen glutamin uygulamalarının hıyarda bitki rejenerasyonunu desteklediği bildirilmiştir (Vasudevan ve ark., 2004). Yapılan bir çalışmada, 1500 mg/l seviyesindeki yüksek dozda amino asit karışımı, *Vicia faba* üzerinde tuz stresinin neden olduğu tüm morfolojik, biyokimyasal ve genetik zararları hafifletici bir etki göstermiştir (Sh Sadak ve ark., 2015). Soğan bitkileri üzerinde yapılan bir çalışmada, glutamin uygulamasının normal ve tuz stres koşullarında çimlenme ve fide büyümesini önemli ölçüde artırdığı gözlemlenmiştir. Tuz stresine maruz kalan bitkilerde, glutamin uygulaması kök uzunluğunu ve taze bitki ağırlığını artırmış, tuz stresinin neden olduğu kromozomal anormallikleri büyük ölçüde azaltmıştır (Çavuşoğlu ve ark., 2020).

5. ASPARAJİN

Proteinojenik bir amino asit olan asparajin, proteinlerin yapısal bir bileşenidir. Asparajin, birçok bitki türünde azot depolama ve taşınmasında önemli bir role sahiptir ve damar dokusunda indirgenmiş azotun başlıca taşıyıcı molekülü olarak işlev görür; muhtemelen bu, karbon oranına göre en yüksek azot oranına sahip amino asit olmasından kaynaklanmaktadır (Lea ve ark. 2007; Gaufichon ve ark. 2010). Asparagin, azot taşınması ve stres tepkilerindeki rolü nedeniyle bilimsel araştırmalarda uzun zamandır çalışılmaktadır (Lea ve ark., 2007). Asparajin, tohum çimlenmesi, yaprak yaşlanması gibi normal fizyolojik süreçler sırasında ya da bitkiler karanlık ortama konulduğunda (Lin ve srk., 2004) veya çeşitli abiyotik streslere maruz kaldıklarında (Lea ve ark., Sulieman ve Tran, 2013; Oddy ve ark., 2020) seçici olarak çeşitli bitki dokularında birikebilir. Stres sırasında asparajin, azotun yeniden mobilizasyon sürecinin bir parçası olarak veya azot depolamak amacıyla birikmektedir; bu durum, normal gelişimdeki işlevine benzer şekilde gerçekleşmektedir (Oddy ve ark., 2020).

Endojen asparajinin yukarıda belirtilen rollerine ek olarak, dışarıdan uygulanan asparajinin de birçok biyolojik süreçte yer aldığı bulunmuştur; bunlar arasında sürgün gelişimini teşvik etme ve solmayı azaltma (Akhtar ve ark., 2016), tuz stresini hafifletme (Kaya ve ark., 2013), kök büyümesini düzenleme (Ivanov ve ark., 2012), klorofil içeriğini, şeker metabolizmasını ve prolin birikimini artırma (Sarropoulou ve ark.,2016), somatik embriyo oluşumunu teşvik etme (Sarker ve ark., 2007), ve *Phaseolus vulgaris*'te hücre uzaması ve bölünmesini teşvik ederek büyümeyi iyileştirme (Haroun ve ark., 2010) gibi etkiler yer almaktadır. Ayrıca, dışarıdan verilen asparjinin büyümeyi teşvik eden bir düzenleyici olduğu, bahçe teresi bitkisinde vegetatif büyümeyi, besin alımını ve pigment üretimini olumlu yönde geliştirdiği rapor edilmiştir (Le Moigne ve ark., 2018).

6. SONUÇ

Sebzelerde abiyotik stres koşullarına dayanıklılığı artırmak amacıyla kullanılan amino asitler, bitkilerin stres yanıt mekanizmalarında önemli bir rol oynamaktadır. Prolin ve triptofan gibi amino asitler, hücresel su dengesi, zar stabilizasyonu ve antioksidan savunma gibi işlevleriyle sebzelerin kuraklık, tuzluluk ve sıcaklık gibi streslere karşı direncini artırmaktadır. Glutamin ve asparajin gibi amino asitler ise, sebzelerde azot metabolizmasını destekleyerek büyümeyi teşvik etmekte ve stresin etkilerini hafifletmektedir. Araştırmalar, bu amino asitlerin dışsal uygulanmasıyla sebzelerin fizyolojik ve biyokimyasal tepkilerinin iyileştiğini, bu sayede verim ve kalite açısından olumlu sonuçlar elde edildiğini göstermektedir. Bu bağlamda, amino asit uygulamaları, sebze yetiştiriciliğinde stres yönetimi için umut vadeden biyokimyasal araçlar olarak değerlendirilmektedir. Gelecekteki araştırmalar, farklı sebze türlerinde optimum amino asit dozajları ve uygulama yöntemleri üzerine odaklanarak, bu yaklaşımın tarımsal sürdürülebilirlik üzerindeki potansiyel katkılarını daha net bir şekilde ortaya koyabilir.

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THE EFFECT OF BLOCKCHAIN TECHNOLOGY ON ACCOUNTING

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ABSTRACT

The fact that Bitcoin, which was introduced by Satoshi Nakamoto in 2008 into a digital currency that can raise awareness all over the world, has raised the likelihood of every sector to be influenced by this process. Accounting is one of the most affected sectors. The financial transactions of the companies are recorded by the accounting profession on the basis of documents through commercial books. After the registration phase, records are classified by the accounting programs used in computer environments and financial statements are created for the benefit of information users. In the context of changing and developing accounting applications with technological developments, differences arise in the context of presentation in the form of transactions and financial statements. The most important innovation of blockchain technology to accounting applications is shown as converting the traditionally adopted double-sided registration system into a unique feature of the system into a three-sided registration system. The examination of the effects of electronic transformation and blockchain technology on accounting applications is important in terms of guiding information users, especially accountants. In this context, the aim of the study is to examine the effect of blockchain technology on accounting applications.

Keywords: Blockchain, Technological Development, Accounting Applications

1.INTRODUCTION

Blockchain technology is a decentralized and secure digital ledger system. Blockchain, defined by Satoshi Nakamoto (2008), is a system where transactions are recorded chronologically and stored securely. Tapscott and Tapscott (2016) stated that blockchain offers the basic components of transparency and trust and forms the infrastructure of a decentralized economy. Blockchain technology; Cryptocurrencies promise significant efficiency and productivity increases in stock transactions, derivative products, interbank transactions and many other financial services infrastructures (Manta & Pop, 2017). Accounting and auditing operations are also business activities within the potential impact area of blockchain technology (Alarcon,

2018). As a result of blockchain technology spreading to a wider range of usage areas, especially focused on financial markets, and becoming an important technological solution for all business functions, from production to supply chain, from stock management to sales, the use of infrastructure in accounting and auditing functions has come to the fore. Based on this, the aim of the study is to examine the effect of blockchain technology on accounting practices. In the study, first the concept of blockchain was included, and then the advantages of blockchain technology and its relationship with accounting were mentioned.

2.BLOCKCHAIN TECHNOLOGY

Blockchain creates the infrastructure of a decentralized economy by providing the key components of transparency and trust. The most basic feature of the blockchain is that there is no regulatory institution/organization or higher authority regulating the system. Today, when anything containing value is exchanged between individuals or institutions, an intermediary or regulatory institution is needed to carry out the relevant exchange process correctly. For example, intermediary institutions and regulatory authorities are needed to exchange shares, similarly, when buying a house, a notary, a land registry office is needed to exchange the title deed, and often a bank is needed to exchange money in this process. Blockchain technology is the infrastructure that enables parties who want to carry out the exchange to carry out their transactions quickly without the need for any intermediary or regulator (Kosba et al., 2016). Mougayar (2016) stated that blockchain is a distributed ledger technology that allows data and transactions to be recorded in an immutable way. Conceptually, distributed ledger technology is seen as a superstructure that also includes blockchain technology. However, blockchain and distributed ledger technology are often used synonymously (Özdoğan and Karğın, 2018).

Blockchain technology offers advantages to users at various points. The first of these advantages is that the system offers a distributed ledger structure. Blockchain records the transactions carried out by all participants on a single ledger and provides this service without centralized transaction processes. In addition, this technology allows keeping copies of all transactions in the chain. It also makes it easier to access copies of a user's transactions through a single ledger, even if they are offline. Since each blockchain stores copies of previous transactions in the chain, it is also possible to access each of them retrospectively. The distributed structure of the system, which allows all participants to enter, observe and monitor the transactions, also allows a real-time copy of all transactions. The absence of a central authority or administrative control in the system means that all changes are seen, approved and

recorded by all users. The transparency provided by the system becomes even more important as it does not allow the elimination/deletion or modification of completed transactions (O'Leary, 2017). The stated situation also affects the accountability level of the system, as the reduction in costs will naturally lead to an increase in efficiency in examining compliance with regulations and laws. Thus, thanks to the distributed ledger structure offered by blockchain technology, all assets subject to economic transactions can be monitored more securely and more easily and faster than before. Transactions are collected in local ledgers using blockchain technology, and copies are then delivered to many computers around the world. As each transaction occurs, the blockchain sends the copy for a specific asset and its use. At this point, anyone can have an undistributed copy of the asset's history. For example, if a company's stock has been issued, sold, purchased and resold, it can be easily tracked in a historical context from the first transaction in the blockchain. Blockchain updates itself automatically and allows the desired reporting activities to be easily obtained from the system (Kılıç, 2020). Another advantage offered by blockchain technology is smart contracts. Smart contracts are pieces of code that can be stored in the blockchain. In other words, it is a form of coding in which the contracts necessary for normal business processes are embedded in the blockchain. Smart contracts have been developed to replace operational or administrative functions in internal and external reporting, producing data that can be translated into performance targets and budgets and reflect real results. These opportunities will make it easier for businesses to obtain better results from performance measurement tools. In addition, it allows the timely presentation and integrity of data in other economic transactions, such as buying and selling, use of credit, and transfer of intellectual and industrial rights (Wunsche, 2016).

The basic advantages of blockchain technology reveal the unique characteristics of the technological system. These are summarized as follows (Uçma Uysal and Kurt, 2018):

• **Real-Time Applications:** Blockchain allows recording transactions in almost real time. However, it eliminates the risk of payment or collection made by a user.

• **Distributed Ledger Structure:** Peer-to-peer distributed network allows historical classification of commercial transactions. A blockchain is a distributed, highly accessible network that provides secure proof of the transaction.

• **Irreversible Nature:** A blockchain contains a verifiable record of every transaction made on the chain. This also prevents the element traceable by the blockchain from being recorded twice.

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In addition, the fact that transactions are irreversible, unchangeable or cannot be intervened after they are recorded increases the realistic presentation of the data produced by the system.

• **Resistant to Censorship:** The economic rules within the blockchain model are presented in the form of flows so that independent participants can verify new blocks. Controlling the system or censoring entry permissions causes additional costs as it requires changing the technological infrastructure of the system.

This technology can find wide use in many financial and non-financial fields. Even though there are opinions that job opportunities will decrease or disappear in many sectors as this technology becomes widespread, this situation can be prevented by adapting the features of the technology to the sectors where it will be applied. For example, rather than seeing blockchain technology as a threat to traditional business models, financial institutions and banks have focused on taking advantage of the opportunities by doing the necessary work in this new technological field. (Crosby et al., 2016). Some of the areas where blockchain technology can be used are shown in Figure 1 below. (Puthal et al., 2018).

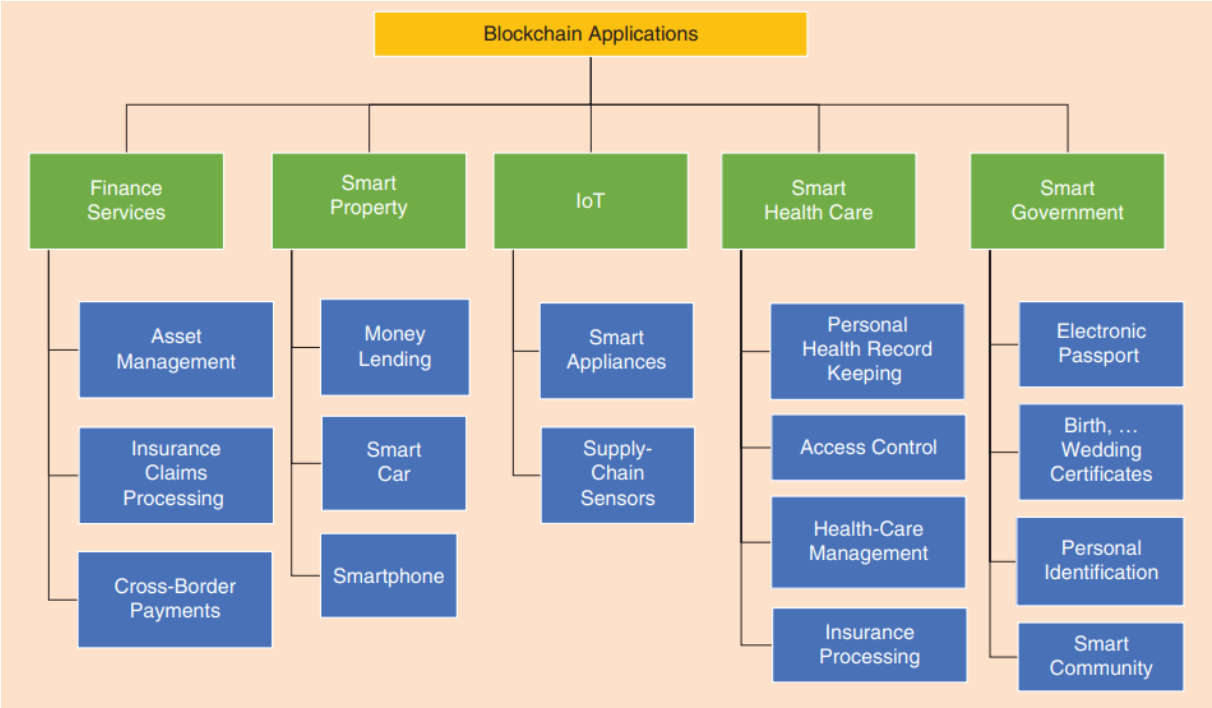

Figure 1: Blockchain Applications

Reference: (Puthal et al. 2018)

3. THE RELATIONSHIP BETWEEN BLOCKCHAIN AND ACCOUNTING

There are two aspects to using blockchain technology in accounting. Firstly, while accounting transactions are shared transparently through this technology, on the other hand, documents or details of the transactions realized can be viewed and the accounting policies and methods used by the business can be uploaded to the system. However, smart contracts will be needed to upload accounting policies to the system. By recording this information in smart contracts, transactions can be carried out automatically and audited. On the other hand, stakeholders of the business (especially institutional investors, auditors, lawyers, legal regulators and stock exchanges) will participate in the system in order to obtain the information they need in the most reliable and fastest way and will participate in the verification process of the transactions and ensure that the block in which the transaction takes place is included in the chain (Yu et al., 2018). Blockchain-based accounting system is an upper version of the double-entry accounting system and proposes a tripartite accounting system with an embedded third blockchain layer (Dai and Vasarhelyi, 2017). One of the main features of the double-entry accounting recording system is that all transactions are recorded in at least two accounts as debit and credit. Another feature is; It is balance sheet equality based on the principle that assets and liabilities are equal. The double-entry recording system, where both parties work simultaneously, consisting of asset and resource accounts, makes it possible to keep the records needed to analyze the financial situation and performance results of the business. The concept of three-party accounting system was first introduced by Grig (2005), but it found use with blockchain technology and came to the fore again. Grig (2005) proposes a system that would be built on top of the existing double-entry system, with a third blockchain layer embedded within it, and that would record transactions both within the organization and with external parties. The three-party accounting system defined by Grig is a system in which two parties make a transaction and the transaction is confirmed by the third party. To more accurately represent current assets and liabilities, the system will include a layer of symbols that can represent accounting entries.

Electronic invoice, electronic ledger and electronic archive applications, which are important parts of digital transformation in accounting, have enabled accounting transactions performed on paper to be transferred to the electronic environment. The e-ledger application, which has been used as of the 2014 calendar year, is a system that enables the journals and ledgers, which are legally required to be kept by businesses, to be kept on the digital platform and to be certified to the finance with the electronic signatures defined for them. In order to make audit processes more effective and faster, e-ledger submissions are made by the owner or consultant of the business. In the e-ledger system, a ledger certificate is created with a special code using a time

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stamp. Therefore, if the certificates during the audit process are the same as the certificates already received from the relevant unit, it means that no new record or correction record has been made. All transaction flows are also verified with an electronic signature or financial seal in order to determine the time when the data was produced, changed, sent, received or recorded with a time stamp. At the same time, a time-stamped certificate file is used to prove that the relevant books were delivered within the periods specified by law. The nature of accounting systems based on blockchain technology will create a complementary function, not as a replacement for ERP, but by moving it to the blockchain database with an integrated operation. Integrating blockchain technology into ERP systems will create a highly secure collaboration platform where the system of record can be freely shared with trusted parties. Thus, blockchain and ERP integration will offer a non-labour-intensive system with ease of access to decentralized and distributed data. This system will prevent unauthorized data changes. In this context, control mechanisms will be created through smart contracts, ensuring that company data is protected against cyber attacks (Ulucan Özkul and Alkan, 2020). With the blockchain infrastructure and smart contract system, the process will also be accelerated and shortened after stock buying and selling transactions on the stock exchange. In Turkey, clearing transactions take place on the second day following the transaction date. However, through smart contracts, exchange transactions will take place within seconds without the need for any intermediary or authority (Özdoğan and Karğın, 2018).

4.CONCLUSION

Blockchain technology, also referred to as distributed ledger technology, will offer many advantages in terms of accounting and financial controls. Well-designed blockchain platforms are fast and powerful databases. It is clear that data entry into the system will be done more efficiently compared to the interaction in existing accounting software applications. Smart contracts embedded within blockchain technology will automate many accounting functions, thus reducing errors and fraud significantly. Again, by using smart contracts, the intense workload faced by accounting units at the end of the period will be completed automatically and will reduce the workload. Following the initial cost of implementation, companies can expect to see rapid cost savings over traditional accounting systems. However, in the long run, the increase in efficiency and the reduction in errors in the operation of the system will reduce the cost. In order to change the records in the distributed ledger, the need to make changes to all copies at the same time will reduce the risk of fraud to zero.

Accounting applications based on blockchain technology will enable real-time reporting by instantly publishing accounting information to relevant parties such as managers, auditors, creditors and stakeholders, and will enable a faster, automatic and more secure accounting system as external participants will be able to access companies' real-time accounting information at a low cost. At the same time, this system will also be based on a private permissioned blockchain, as the company will be able to retain control over its information and therefore exclude unrelated parties. Since such a system requires fewer nodes to confirm a transaction, it will be faster and more efficient. Blockchain entries require verification, which can then be done, for example, by accountants, management and auditors. Addressing the security risk of permissioned blockchains and trusted parties, and since many entities within a business relationship have already established a certain level of trust, it is possible to state that this concern is minimized and permissioned blockchain models may be more appropriate. Additionally, blockchain technology will ensure that transactions and records are stored in a completely transparent and accountable manner, and there will be higher transparency and accountability in accounting processes.

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THE IMPACT OF DIGITAL TRANSFORMATION ON BUSINESS MANAGEMENT AND INNOVATIVE STRATEGIES

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ABSTRACT

In today's business world, digital transformation has become inevitable for companies to maintain their competitive edge and achieve sustainable growth. Digital transformation involves the restructuring of business processes, customer relations, employee engagement, and decision-making mechanisms through modern technologies. This transformation process has a multifaceted impact on business management, offering new strategic opportunities in areas such as efficiency, flexibility, speed, and innovation. Digital transformation accelerates decision-making processes in business management and shifts them towards a more data-driven structure. The use of big data and artificial intelligence supports managers in making strategic decisions, minimizing risks, and enabling faster responses to market conditions. Additionally, digital platforms, customer relationship management (CRM), and marketing analytics tools improve the customer experience and increase customer loyalty. Based on this, the primary objective of this study is to provide a general evaluation of the effects of digital transformation processes on business management. To achieve this goal, the study will focus on topics such as artificial intelligence, big data, agile management, automation, customer experience, and data security.

Keywords: Digital Transformation, Business Management, Innovative Strategies

INTRODUCTION

Digital transformation has emerged as one of the most critical business phenomena of the 21st century. The rapid advancement of technological developments requires companies to turn to innovative strategies to maintain their competitive advantage. Today, businesses are restructuring their business processes, customer relations and general business models by evaluating the opportunities offered by digital technologies. They have entered the process. This transformation involves not only the adoption of technology, but also cultural and structural changes. For example, equipping the workforce with digital skills, enabling managers

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to make decisions supported by data analytics, and adopting customer-centric approaches are integral parts of the digital transformation process.

In the digital transformation process, as the amount of data that businesses have increased, the analysis and use of this data has also become critical. Efficiency and the acceleration of decision-making processes offer a significant advantage for survival in a competitive market environment. In this context, technologies such as artificial intelligence (AI) and big data analytics allow managers to better understand market trends and develop proactive strategies. For example, big data analytics provides businesses with a significant competitive advantage by providing the ability to predict customer behavior and create customized marketing campaigns (Porter & Heppelmann, 2014, p. 100).

In addition, digital transformation paves the way for the adoption of agile management approaches in business management. Replacing traditional management methods, agile methods allow teams to move faster, adapt more easily to changing conditions, and respond more quickly to customer feedback. Such flexibility is critical in today's dynamic business environment (Kane et al., 2015, p. 67).

Another important aspect of digital transformation is customer experience. Businesses that adopt a customer-centric approach interact with their customers through digital platforms and can better understand their needs. Customer Relationship Management (CRM) systems and marketing analytics are the main tools used to increase customer satisfaction and improve loyalty (Chaffey, 2018, p. 70). Improving customer experience not only increases sales, but also strengthens the reputation of the brand.

Finally, the challenges encountered in the digital transformation process should also be taken into account. Data security is one of the issues that businesses are most concerned about in the digitalization process. The need to protect against cyber attacks necessitates the development of reliable data management systems (Anderson, 2020, p. 54). In addition, change management strategies need to be developed to ensure that employees adapt to digital transformation. Cultural resistance is an important factor affecting the success of the transformation process, and therefore training and support mechanisms should be created to facilitate employee adaptation to new technologies (Kotter, 2012, p. 95).

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1. THE ROLE OF TECHNOLOGY IN DIGITAL TRANSFORMATION

Digital transformation is a comprehensive change process that is not limited to the adoption of technological innovations, but also the integration of these technologies into business processes. In this process, various technological components help businesses increase their competitiveness and ensure their efficiency.

1.1. Artificial Intelligence (AI)

Artificial intelligence is one of the most decisive components of the digital transformation process. Businesses are using AI technologies to achieve efficiency in many areas such as data analysis, customer interaction and automated process management. AI systems analyze large data sets and identify trends and patterns, which allows managers to make more informed decisions. For example, AI-supported analysis tools can process sales data to determine which products are in higher demand and which markets make more sense to target (Porter & Heppelmann, 2014, p. 100).

AI also plays a significant role in customer service. Chatbots and virtual assistants increase customer satisfaction by providing 24/7 customer support and direct human resources to more strategic tasks. These technologies help employees focus on more complex customer requests by answering frequently asked questions and automating simple processes.

1.2. Big Data

Big data plays a critical role in the decision-making processes of businesses. The collection and analysis of millions of data points provides insights to managers and improves strategic planning processes. In this context, big data analytics is used to predict customer behavior, identify market trends and increase operational efficiency (Kane et al., 2015, p. 67).

For example, a company operating in the retail sector can develop product recommendation systems by analyzing customer purchasing habits. These systems provide customers with personalized recommendations based on their past purchases and preferred products. In this way, the customer experience is enriched and sales rates increase.

1.3. Automation

Automation in digital transformation is a critical tool for accelerating business processes and reducing human error. Automating routine tasks allows employees to focus on activities that

create higher added value. Technologies such as Robotic Process Automation (RPA) are frequently used in areas such as accounting, inventory management, and customer service. Such automation solutions minimize errors in processes and save businesses time and money (Westerman et al., 2014, p. 125).

In addition, automation systems accelerate data collection and analysis processes, allowing managers to make faster and more accurate decisions. For example, automated machines in production processes shorten production time and optimize resource use.

1.4. Cloud Computing

Cloud computing is another technology that plays an important role in digital transformation. Cloud services, which offer flexibility, scalability and cost-effectiveness to businesses, enable data to be stored in a central system and accessed from anywhere. Cloud-based applications allow for the digitalization of business processes and increased collaboration (Brynjolfsson & McAfee, 2014, p. 67).

Thanks to cloud computing, businesses can reduce infrastructure costs and use IT resources more efficiently. In addition, cloud services can work in integration with other technologies such as data analytics, AI and automation, which helps accelerate digital transformation processes.

1.5. IoT (Internet of Things)

The Internet of Things (IoT) is a technology that enables physical objects to exchange data over the Internet. This technology allows businesses to collect and analyze real-time data, thereby optimizing production processes and customer interactions (Rogers, 2016, p. 112).

For example, IoT devices used in a manufacturing facility can monitor the operating data of machines, predict failures, and determine maintenance requirements. This increases the continuity of production for businesses and reduces costs. In addition, IoT applications enable the development of smart products, which enriches the customer experience and creates new revenue models.

2. DEVELOPMENT OF BUSINESS MANAGEMENT PRACTICES

Digital transformation plays a decisive role in the evolution of business management practices. Traditional business management approaches are being replaced by more data-driven, flexible

and customer-focused methods, allowing businesses to achieve a more competitive and innovative structure.

2.1. Data-Driven Decision Making

Digital transformation is shifting business management towards data-driven decision making. In the traditional management approach, decisions were mostly made based on experience and intuition, but today, with the use of data analytics and big data technologies, this process has become more scientific and systematic. Managers can develop more conscious strategies by evaluating performance metrics, customer feedback and market trends using real-time data analytics (Sutherland, 2014, p. 45).

Data-driven decision making offers many advantages to businesses. First of all, managers can make strategic plans based on this data by better understanding market trends and customer behavior. For example, a business that analyzes customer behavior can determine which products are best-selling, during which periods sales increase, and which campaigns are effective. This information helps the business optimize its inventory management, marketing strategies, and product development processes.

Additionally, data analytics allow managers to better assess risk and respond quickly to market conditions. For example, a financial services company can analyze customer credit history to determine which customers are at risk and use this information to make loan approval processes more secure.

2.2. Agile Management

The adoption of digital tools allows businesses to adopt agile management practices. Agile management encourages a flexible and iterative approach in order to respond quickly to changing market conditions and develop solutions that meet customer demands. Agile methodologies create a more dynamic work environment by increasing collaboration and communication between teams (Kotter, 2012, p. 87).

Agile management practices allow projects to be developed in shorter cycles. By accelerating project stages, teams have the opportunity to continuously improve their products with the feedback they receive at each stage. For example, software development teams can review their products at the end of each sprint and take customer feedback into account. This process

increases the quality of service provided to customers and also increases the competitiveness of the business.

Agile management also creates an environment that increases employee motivation. When team members have more say in every phase of the project and actively participate in decision-making processes, their job satisfaction increases. This is reflected positively in the overall performance of the business.

2.3. Improving Customer Experience

Customer experience has become a major focus in the digital transformation process. Digital tools such as Customer Relationship Management (CRM) systems and marketing analytics allow businesses to improve customer interactions. These systems help businesses personalize the services they offer by analyzing customer data (Chaffey, 2018, p. 70).

Personalized services increase customer satisfaction and strengthen loyalty. For example, an e-commerce platform can make recommendations based on a customer's previous purchases and browsing habits. This type of approach enriches the shopping experience by offering solutions that are more tailored to the customer's needs.

Digital transformation also encourages omnichannel customer interactions. Customers can interact with businesses through various channels, such as social media, mobile apps, and websites. This allows businesses to collect customer feedback faster and continuously improve their services.

2.4. Human Resources Management

Digital transformation also significantly affects human resources management (HRM) practices. Traditional HRM processes are becoming more efficient and effective thanks to digital tools and platforms. Human resources software automates processes such as recruitment, training and performance evaluations, allowing managers to allocate their time to more strategic tasks. In addition, with digital tools, employee development processes can be better monitored (Brynjolfsson & McAfee, 2014, p. 67).

Digitalization increases employees' access to continuous education and development opportunities. E-learning platforms and virtual training tools help employees update their skills and advance their careers. This allows organizations to expand their talent pool and gain a

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competitive advantage. In addition, surveys and feedback mechanisms conducted through digital tools increase employee satisfaction and improve the internal culture of businesses.

2.5. Performance Monitoring and Evaluation

Digital transformation makes performance monitoring and evaluation processes more transparent and data-driven. Advanced analytical tools allow businesses to monitor and analyze performance indicators in real time. In this way, managers can better evaluate the performance of employees and teams, quickly identify deficiencies and make necessary improvements (Rogers, 2016, p. 112).

Performance evaluation processes, when supported by data-based feedback, increase employee motivation and job satisfaction. When employees have more information about their development and career goals, they have the chance to maximize their own potential. In addition, performance data provided through digital tools offers managers the opportunity to make more fair and objective evaluations.

3. INNOVATIVE STRATEGIES PROVIDED BY DIGITAL TRANSFORMATION

Digital transformation allows businesses to develop innovative strategies by radically changing the way they do business. This process allows both the improvement of existing business models and the creation of completely new business models. By using digital tools and technologies, businesses gain a sustainable competitive advantage and can better respond to customer expectations (Porter & Heppelmann, 2014, p. 24).

3.1. New Revenue Models

Digital transformation allows companies to explore new revenue models. Moving beyond traditional sales methods, businesses are turning to innovative business models that include subscription services, digital platforms, and the sharing economy (Osterwalder & Pigneur, 2010, p. 98).

For example, many media and entertainment companies have shifted from traditional broadcasting to digital subscription models. Platforms such as Netflix, Hulu, and Spotify have created a recurring revenue stream by allowing users to access unlimited content for a set fee (Deloitte, 2020, p. 15). In addition, the SaaS (Software as a Service) model allows businesses

to reduce costs and reach a wider customer base by offering software on the cloud (Choudhury, 2019, p. 50).

These new revenue models allow companies to increase customer loyalty, make more accurate revenue forecasts, and respond more quickly to changing market dynamics. The subscription model provides a regular revenue stream and facilitates the collection and analysis of customer data, helping to deliver personalized services (Kumar & Reinartz, 2016, p. 112).

3.2. Development of Product Offerings

Digital transformation is also revolutionizing the development of products. The integration of smart technologies into products creates opportunities to offer additional features and services, providing added value for the customer (Rogers, 2016, p. 112). Smart sensors, IoT (Internet of Things) technology and artificial intelligence contribute to making products more functional and user-friendly (Gartner, 2020, p. 35).

Smart home systems allow users to remotely control lighting, security, and energy management at home. Such products improve user experience and offer new service opportunities to businesses. In addition, smart products allow businesses to better understand customer needs and develop solutions accordingly, as they provide the opportunity to collect user data (Fitzgerald et al., 2014, p. 29).

This process also allows for faster collection of customer feedback and shorter product development cycles. By analyzing users' usage habits on a smartphone, manufacturers can make decisions about offering software updates and new features (Wirtz et al., 2016, p. 223).

3.3. Customer-Focused Innovation

Digital transformation also strengthens customer-focused innovation processes. By using customer feedback and data, businesses can continuously improve their products and services. This allows businesses to respond more quickly to market demands while also increasing customer satisfaction (Verhoef et al., 2015, p. 98).

Various tools such as digital platforms, social media and surveys are used to collect customer feedback. This data guides businesses in their product development processes and provides the opportunity to make necessary changes to meet customer expectations. For example, a clothing

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brand can determine which products are more popular and which styles are preferred by analyzing comments made on social media (McKinsey, 2017, p. 42).

This type of customer-focused approach helps businesses gain competitive advantage. Understanding customers' needs and offering appropriate solutions allows for the development of long-term customer relationships. In addition, innovation processes increase creativity within the business by creating an environment where employees can contribute (Brown, 2008, p. 57).

3.4. Automation of Business Processes

Digital transformation also encourages the automation of business processes. Automating routine tasks provides businesses with efficiency and offers the opportunity to direct human resources to more strategic tasks (Davenport, 2018, p. 15). For example, chatbots used in customer support services provide quick answers to users' questions, reducing the need for human intervention.

These automation processes reduce error rates in business processes while also reducing costs. Thanks to automation, businesses can achieve faster and more accurate results and use their resources more effectively. In addition, automation helps businesses make more data-driven decisions by accelerating data collection and analysis processes (Bessen, 2019, p. 122).

3.5. Competitive Analysis and Market Opportunities

Digital transformation offers businesses new tools to analyze competition and identify market opportunities. Big data analysis and artificial intelligence help businesses better understand market dynamics and analyze their competitors' strategies (McKinsey, 2018, p. 30). In this way, businesses can develop the necessary strategies to gain competitive advantage.

For example, a retail company can optimize its own pricing policies by analyzing the pricing strategies of its competitors. Such analysis provides opportunities to better respond to customer demands and strengthen its market position. In addition, digital tools help businesses monitor market trends and discover new business opportunities (Keeney, 2020, p. 80).

3.6. Transformation of the Supply Chain

Digital transformation also significantly impacts supply chain management. IoT devices, blockchain technology, and data analytics make supply chain processes more transparent and

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efficient. These technologies help prevent disruptions in the supply chain by allowing the movement and status of products to be monitored (Wang et al., 2016, p. 295).

For example, a food manufacturing company can use IoT devices to monitor every stage of its products in the supply chain. This allows for better management of production processes while ensuring food safety. In addition, analysis of data in the supply chain allows businesses to make more accurate demand forecasts and optimize their inventory management (Christopher, 2016, p. 37).

4. CHALLENGES AND CONSIDERATIONS

The digital transformation process offers businesses many opportunities, but it also causes them to face some challenges. Overcoming these challenges is critical to the successful implementation of digital transformation. Below are the main challenges encountered in the digital transformation process and the elements that need to be taken into consideration to overcome these challenges.

4.1. Data Security

With digital transformation, businesses' data is stored and processed more digitally. This increases the risk of vulnerability to cyber threats. Cyber attacks, data theft, ransomware and other malicious activities can pose serious dangers to businesses (Anderson, 2020, p. 54).

Ensuring data security is vital to maintaining customer trust. Therefore, businesses need to develop a strong cybersecurity strategy. Technologies such as firewalls, encryption methods, and multi-factor authentication should be used, and employees should be trained on cybersecurity (Ponemon Institute, 2019, p. 18). For example, an e-commerce company can increase security by encrypting data and performing regular security scans to protect customer information.

4.2. Cultural Resistance

The digital transformation process affects not only technological changes but also the organizational culture. Employees may resist adapting to new systems and processes. This resistance becomes more evident especially among employees who have difficulty giving up their usual ways of doing business (Kotter, 2012, p. 95).

To create an innovative culture, effective change management strategies need to be developed. It is important for leaders to include employees in this change process and clearly communicate the benefits of digital transformation. When employees see that processes are managed transparently, they become more open to change (Hiatt, 2006, p. 22).

In addition, training programs should be organized to ensure the active participation of employees in the transformation process. It is important to provide continuous training opportunities to increase employees' confidence in new technologies and to develop their digital skills (Bridges, 2009, p. 101).

4.3. Inadequate Infrastructure

Many businesses face inadequate technology infrastructure during the digital transformation process. Legacy systems can create obstacles to integration with new technologies and negatively affect the efficiency of the business. Updating the infrastructure is usually a process that requires high costs and time (Bharadwaj et al., 2013, p. 10).

Modernization of infrastructure is critical for businesses to succeed in their digital transformation process. Cloud-based solutions allow businesses to update their infrastructure and move to more flexible, scalable systems. However, careful planning and choosing the right technologies are required when implementing such solutions (McKinsey, 2019, p. 50).

For example, a manufacturing company can make its production processes more efficient by updating its automation systems. Such innovations both reduce costs and speed up processes.

4.4. Inadequate Budgeting

Digital transformation projects often require high costs. When businesses do not allocate sufficient budget for the transformation process, projects may be left unfinished or the expected results may not be achieved. In the budgeting process, the potential benefits and costs of digital transformation should be carefully evaluated (Bharadwaj et al., 2013, p. 11).

Inadequate budgeting can lead to project failure and make it difficult for businesses to remain competitive. It is recommended that businesses determine a long-term strategy for transformation projects and seek support from external sources when necessary (KPMG, 2019, p. 37).

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In addition, providing evidence that the economic benefits to be gained during the digital transformation process cover the costs plays an important role in influencing managers' budget allocation decisions. Businesses can convince senior management by clearly defining the value propositions that the transformation process will bring.

4.5. Competency Deficiencies

Digital transformation requires employees to adapt to new technologies. However, many businesses realize that their employees do not have sufficient digital competence. Training and development programs are critical to addressing these competency gaps (Deloitte, 2020, p. 55).

Employees need to receive continuous training to use new technologies effectively. Supporting training with practical applications will help employees acquire new skills more quickly and effectively (Collins & Halverson, 2018, p. 112).

It is also important for businesses to prioritize employees with digital competencies in their hiring processes. This can help quickly acquire the competencies needed during the transformation process. However, creating a culture of talent development among existing employees will also be beneficial in the long run.

4.6. Change Management Strategies

In the digital transformation process, it is of great importance to develop an effective change management strategy. Change management should include the necessary steps to facilitate the adaptation of employees to new systems and processes. This process should include communication, training and support elements (Kotter, 2012, p. 87).

The role of leaders in this process is also critical. It is important for change leaders to effectively direct the process and encourage employees to participate in the change. This contributes to employees' adoption of the change process and the successful execution of the process (Schein, 2010, p. 50).

An effective change management process requires continuous and open communication. Getting employee feedback and updating strategies based on this feedback can make the change process more effective.

4.7. Innovation and Continuous Development

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Digital transformation brings with it continuous innovation and development. However, it is difficult for businesses to maintain their innovation processes continuously. It is necessary to encourage innovative thinking, support the continuous development of employees and ensure the implementation of new ideas (Brown, 2008, p. 57).

Creating an innovation culture helps businesses increase their competitive advantage while also increasing employee motivation. To support their innovation processes, businesses can create platforms that encourage employees to share ideas. This type of approach encourages creative thinking and allows businesses to better adapt to changing market conditions.

CONCLUSION

Digital transformation has become an inevitable phenomenon in today's business world. The rapid development of technology and changing customer expectations force businesses to develop innovative strategies and restructure their business processes.

Digital transformation provides businesses with the ability to make data-driven decisions, allowing managers to develop more conscious strategies. The use of real-time data analytics allows managers to develop more effective strategies by evaluating performance metrics and customer feedback. In addition, artificial intelligence and big data applications accelerate managers' strategic decision-making processes and minimize risks. In this context, digital transformation enables businesses to transform into a more flexible, fast and customer-focused structure.

The digital transformation process also encourages agile management practices and allows significant steps to be taken towards improving the customer experience. Agile methodologies increase collaboration and flexibility between teams, improving the ability to respond quickly to market changes and customer demands. Digital tools such as Customer Relationship Management (CRM) systems and marketing analytics strengthen customer interactions, allowing businesses to personalize their services and increase customer satisfaction. This contributes to increased customer loyalty and, therefore, to the long-term success of businesses.

However, the digital transformation process is full of not only opportunities but also challenges. Problems such as data security, cultural resistance, inadequate infrastructure, budgeting deficiencies and lack of sufficient digital competencies complicate the transformation process

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of businesses. In order to cope with these challenges, it is of great importance to develop and implement effective change management strategies.

Data security is one of the most critical elements in digital transformation. As companies become more digital, they become more vulnerable to cyber threats. Therefore, developing a strong cybersecurity strategy is vital for businesses to maintain customer trust. Cultural resistance, on the other hand, includes employee reactions to change. In order to overcome this resistance, businesses should implement effective change management strategies to develop an innovation culture. Inadequate technology infrastructure is another challenge that many businesses face during the digital transformation process. The modernization process is often a process that requires high costs and time, so careful planning should be done. In addition, lack of digital competence makes it difficult for employees to adapt to new technologies, which reduces the effectiveness of the process.

The challenges that businesses face during the digital transformation process can also be considered as opportunities. Overcoming challenges increases the flexibility and resilience of businesses, while also providing an opportunity to encourage innovative thinking. For example, the challenges experienced during the digital transformation process allow businesses to review and improve their internal processes. This process can lead to the adoption of innovative approaches, reviewing ways of doing business, and increasing customer-focused services.

As a result, digital transformation plays a critical role in helping businesses achieve their sustainable growth goals. For success, this process must be carefully planned and managed, and the necessary steps must be taken to overcome the challenges encountered. By adopting digital transformation processes, businesses can gain competitive advantage and improve their ability to better adapt to changing market conditions. In the future, digital transformation will not only be a trend, but also a fundamental part of how they do business. Therefore, it is of great importance for businesses to see digital transformation as an opportunity and actively participate in this process.

It should not be forgotten that digital transformation is a constantly evolving process. Businesses should be open to learning and adaptation in this process. Continuous monitoring of innovative technologies and strategies will increase the competitiveness of businesses and strengthen their position in the market. As a result, digital transformation should be perceived

as an opportunity, not a necessity for businesses, and this opportunity should be evaluated in the best way possible.

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DIGITAL TRANSFORMATION IN ACCOUNTING AUDIT

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In the 21st century, technological developments and innovations all over the world have played a major role in achieving goals that seemed like "dreams" for people in the past. Although technological developments meet the needs of human beings, it is also known that with digitalization and the formation of big data, it is also known how accurate the data movements are and how difficult it has become to ensure their control. In this direction, in order to control big data traffic and strengthen the control points in these movements, the concept of "artificial intelligence" has been included in the system to facilitate digital transformation and is becoming increasingly widespread in the business world and enterprises. Digital transformation has been effective in all sectors and even started to be used intensively. This situation has also led to the emergence of new business models in enterprises. It is a fact that one of the areas most affected by this transformation process is accounting auditing. Accounting audit is defined as a branch of accounting developed to reach an opinion on the accuracy of financial information, documents and data. With the digital transformation, the use of artificial intelligence in the field of accounting audit provides significant benefits to businesses in terms of time, cost, human resources and efficiency. Based on these basic ideas, the aim of the study is to reveal the place and importance of digital transformation and artificial intelligence in the future of audit accounting, which is among the professions undergoing digital transformation, and to make some suggestions about its future status.

Keywords: Accounting Audit, Digital Transformation, Artificial Intelligence

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1. INTRODUCTION

Artificial intelligence, which is one of the highest levels of technological developments experienced today, will replace many professions and transform the business processes of many people in the future. Accounting and auditing professions, especially businesses, will be highly affected by this digital transformation brought by artificial intelligence. The idea of intelligentisation of machines, which was put forward in the 1950s, has now found a response today and the sectors and areas within the economic system have been filled with artificial intelligence technology products and digital transformation has started to be used in these areas. These technologies have the potential to transform traditional audit practices by simplifying routine tasks, enhancing data analysis capabilities and improving decision-making processes. With digital transformation, large amounts of financial data can be analysed, errors can be easily detected and real-time information can be provided to the relevant users. In this way, the audit processes in enterprises will become more efficient and the function of producing accurate information will be fully realised.

2. DIGITAL TRANSFORMATION

With the intensive use of information technologies in enterprises, the transfer of business processes and information to the digital (electronic) environment by saving money and time is called digital transformation. Transformation helps to carry the speed and convenience of the digitalised world to our business life in terms of both business and employee. With digital transformation, while the usual filing, documenting and storage methods such as documents, paper, paper are changing, it provides a competitive advantage to businesses with the cost advantage and time savings it provides. There are three basic elements of digital transformation. These are human, technology and process. If these three elements are included in the digital transformation process at the same time, the transformation will be efficient.

3. DEVELOPMENTS IN THE FIELD OF TECHNOLOGY

Although it is possible to trace the beginning of commercial life as far back as the history of mankind, it would be more accurate to explain the most important developments in technology that affect trade in economic terms under four main headings (Yılmaz Soğuksu, 2020, pp. 283-284);

- Towards the end of the 18th century, the 1st Industrial Revolution period, which started with the use of the first mechanical loom in 1784. This period is the period when water and steam powered mechanical production started.
- In the early 20th century, the 2nd Industrial Revolution period, which started with the use of the first production line in Cincinati slaughterhouses in 1870. This period is the period when mass production with electrical energy based on the division of labour started.
- The period of the 3rd Industrial Revolution, which started with the use of the first programmable logic controller in the early 1970s. This is the period when electronics and information technology began to advance the automation of manufacturing.
- The late 20th century saw the invention and use of the Internet, and the beginning of the 21st century saw the 4th Industrial Revolution, which began with the use of cyber-physical systems (CPS-Cyber-Physical Systems) in industry.

4. DIGITAL TRANSFORMATION IN ACCOUNTING AUDIT

With the Industry 4.0 era, the amount of data produced in the digital world has gradually increased and it has become possible to store and analyse data electronically. As in every field, the effects of Industry 4.0 have been seen in the field of accounting audit (Omoteso, 2012, p. 8490). Since audit processes are based on information, labour and data-oriented studies, they are very suitable for benefiting from the digital transformation process. In this respect, the developments in digital transformation enable the auditor to perform his/her existing duties in a faster and safer way. All these developments have an impact on the auditing of business activities and the reports prepared as a result of the audit, financial information users to act more rationally in their decisions and to develop consistent behaviour in line with their goals (Akdoğan & Akdoğan, 2018, pp. 4-5).

Digital transformation requires a radical transformation of business processes and models in the field of accounting auditing rather than development. Therefore, if a new corporate culture is formed and habits are changed, it will be possible for the auditing profession to transform and survive with digital transformation (Köse & Polat, 2021, pp. 18-19). Accounting audit is defined as ‘the process of collecting and evaluating evidence by an independent expert to investigate the degree of conformity of financial and non-financial information for a year or period with predetermined criteria and to prepare a report on this subject’ (Bozkurt, 2018, p. 29).

As a result of the rapid development of technology and the participation of information systems in business processes, the use of digitalisation in the audit process has become inevitable. With this transformation, it is easy to see who accessed which file and when. In addition, instead of keeping the documents to be examined during the audit process in physical file cabinets, transferring them to the digital environment and searching there saves time and cost for both businesses and auditors. A more digitalised audit increases the efficiency and accuracy of the audit and, more importantly, facilitates the audit of all financial data of an entity instead of a sample (Serçemeli, 2018, p. 381). In general, auditors can easily increase audit quality and effectiveness with computer-aided audit techniques (Biçer & Aydın, 2015, p. 213).

It is possible to list the advantages of digital transformation in accounting audit for enterprises as follows (Chukwudi et al., 2018, pp. 2-3; Özçetin, 2022, pp. 36-37);

- Auditors' use of expert systems to communicate internal assessment information to management enables managers to understand the internal control process, maintain the effectiveness of the internal control system and produce more reliable accounting outputs.
- In the field of auditing, manual processing and review of specific documents (e.g. contracts) will not be preferred and will be replaced by automated artificial intelligence analytics. This will lead to more accurate and more efficient results.
- Analysing large volumes of data in auditing is challenging. The use of technology and data analytics provides many opportunities for auditors, enhancing professional scepticism and professional judgement.
- The use of audit support systems by auditors, such as data analytics and machine learning in the audit process, can provide new opportunities for better information about the client, better documentation and reduced audit risk.
- Auditors can use machine learning for Quantitative Data Analytics and Qualitative Data Analytics (text mining).
- In the audit process, big data techniques and machine learning can best be used in the planning, evidence gathering and evaluation phase. The opinion formation and audit report stage is entirely dependent on the professional judgement of the human factor.

CONCLUSION

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Today, one of the main objectives of businesses is to maximise market value and reach the highest profit margin. In order to realise this goal, businesses need to produce the highest quality product or service at the least cost and establish competitive advantage over their competitors. In these conditions, the achievement of the stated objectives of the enterprises depends on the use of new technologies, that is, their adaptation to digital transformation. Digital transformation has led businesses to innovations in many areas, and accounting auditing has taken its share of these innovations. Storing the information obtained as a result of accounting in digital environment, reducing the labour power in accounting audit transactions and replacing it with computer-based intelligent systems are among the innovations that come with digital transformation. With computer-based software, systems where information is only stored and protected have been replaced by systems that process information, make decisions and interact. Audit software enables audits to be performed in a better quality, planned, efficient and short time. In the future, it is foreseen that auditors will transfer most of the work in the audit process to computer-aided intelligent software, but the final decisions and evaluations will still be made by auditors. Digital transformation is not a choice but a necessity for the audit profession. As a result, integrating new technological applications emerging with digital transformation into audit processes is vital for audits to maintain their existence and functionality. In order to provide more concrete results in this field, digital transformation practices need to be widespread and researches to be conducted on application examples or field studies are needed.

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USE OF FUZZY EXPERT SYSTEM IN DIAGNOSIS OF CORONAVIRUS (COVIT 19) DISEASE

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ABSTRACT

Coronaviruses emerged in the world in 1960. The first viruses were seen in chickens. These are infectious bronchitis virus and the subtypes HCoV-229E and HCoV-OC43 that cause colds. The SARS coronavirus emerged in 2003. HCoV NL63 was diagnosed in 2004, HKU1 was diagnosed in 2005, and MERS-CoV in 2012. Then the new coronavirus emerged. Viruses cause respiratory tract infections. The new coronavirus is a large type of virus that can cause disease in animals and humans. A virus is a microbe that causes infectious diseases. Microbes are invisible to the eye. The new coronavirus disease (COVID-19) emerged in an animal market in China in December 2019. It was named Covid-19 due to its emergence in 2019. The symptoms of the disease are fever, cough and shortness of breath. It then spread from person to person and spread throughout the world. It particularly affected the European and American continents. The effect of this disease has been seen in our country. Various variations have emerged over the years. Cases have been detected with the tests conducted by the Ministry of Health and many deaths have occurred.

Fuzzy expert systems have recently been used in every field. The first of these is the medical field. Fuzzy expert systems can be easily applied to every section of the medical field. The importance of the fuzzy expert system is increasing, especially due to the increase in diseases, the diversity of data, the evaluation time of the diagnosis and the errors of experts.

Thanks to this designed fuzzy expert system, the dependency on expert personnel will decrease. The treatment time of the disease will decrease. The success of the treatment process will increase. The quality of the training of experts receiving education in the field of medicine will increase. Patients who will access the system via the internet will easily detect their disease diagnoses if they enter the requested information. Since the designed system is web-based; patients will be informed and the communication disorder between the patient and the doctor will be reduced to the lowest level. It will provide many advantages in terms of saving time, space and labor due to remote access. Fuzzy expert systems method is used in the diagnosis of the new coronavirus disease.

Keywords: Coronavirus(Covid 19), Health, Fuzzy Logic.

1. INTRODUCTION

Artificial intelligence method reduces the cost of human expertise in the field of medicine, the time spent and medical errors. Due to the important features such as uncertainty, subjectivity and sensitivity that characterize medical diagnoses, decision support systems and expert systems have found a wide application area in the field of medicine thanks to intelligent programs for diagnosis. Although it is thought that these systems will replace doctors, this is not a correct idea [1].

These systems have been created to assist physicians in many areas. For example; finding hidden relationships between symptoms and diseases, revealing relationships between important factors in multifactorial diseases, providing up-to-date information to physicians, and helping physicians discover in advance the information they will gain through experience. In today's world where it is becoming increasingly difficult for physicians to make decisions due to the rapid obsolescence of information and the increasing amount of information, it is an undeniable fact that clinical decision support systems make the work of physicians easier and help them make decisions [2].

These systems have an important role in disease diagnosis when their benefits and advantages are taken into consideration.

It is also known that laboratory findings alone are not sufficient to diagnose diseases and therefore doctors sometimes have difficulty in diagnosing diseases. For this reason, artificial intelligence software is needed that can perform clinical diagnosis procedures that include the patient's medical history as well as laboratory tests to be taken from patients and make recommendations to doctors. Fuzzy expert system applications in the medical field have been largely successful and will be very helpful to doctors.

2.CORONAVIRUS

Coronaviruses were discovered in 1960. The first viruses were infectious bronchitis virus seen in chickens and the subtypes HCoV-229E and HCoV-OC43, which cause colds. SARS Coronavirus was discovered in 2003. HCoV NL63 in 2004, HKU1 diagnosed in 2005, and MERS-CoV in 2012. A new coronavirus emerged in 2019. Viruses cause respiratory tract infections.

2.1. New Coronavirus (Covid-19) Disease

Coronavirus disease 2019 (COVID-19) is an infectious disease that causes severe acute respiratory syndrome. The first case was encountered in China in 2019. It has continued to spread since then, causing a pandemic worldwide. As of April 12, 2024, there have been 704.753.890 confirmed cases in the world, 675.619.811 recoveries, and 7.010.681 patients have died due to the virus.

3.EXPERT SYSTEMS

We can define expert systems as computer programs that act as experts for a specific problem set and produce solutions to problems. Expert systems can be expressed as the transition from the data processing stage to the information processing stage [3]. Expert systems are knowledge-based systems and are an application area of artificial intelligence that examines and examines problems in a broader context and aims to imitate human intelligence in solving them. In expert systems, algorithms and inference mechanisms interact and operate. If we need to make a more specific definition for an expert system, it can be defined as a computer-aided decision-making tool that is created based on information obtained with the help of an expert and uses events and experiences in solving complex problems [4].

3.1 General Structure of Expert Systems

Figure 3.1 shows the general structure of an expert system. Expert systems basically consist of two basic components. These; knowledge base (database, rule base) and inference mechanism.

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knowledge base; It is where the knowledge is necessary to understand and solve problems is used. The interference mechanism is; it can be called as the method used to extract new information from the information we have [5].

Besides these basic components; There is also a user interface that allows users to communicate with computers, an annotation facility that uses facts 24 to produce a result, and an information retrieval facility used to hold and upload information.

Expert systems are systems that do not have algorithms and always do information-based operations. By calling information from the knowledge base, the operation is performed, the result is obtained and the explanation is made within the knowledge. The system can reach and use the information it needs, and if it is designed correctly, it can gain the ability to learn by improving itself [6].

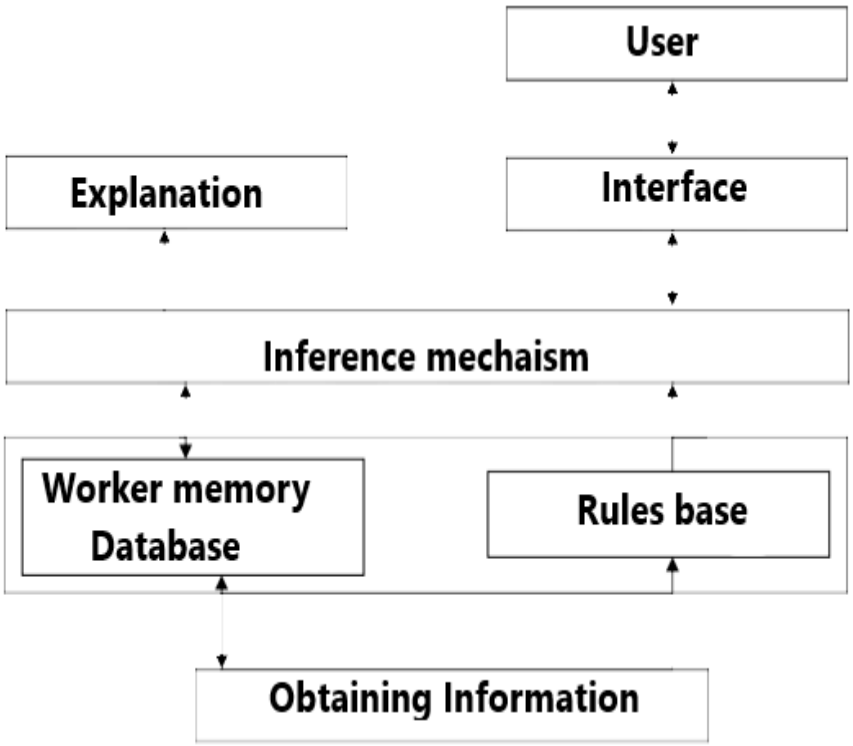

Figure 3.1. Structure of an expert system

An example of a medical decision-making system is given in Figure 3,2. In this system, the knowledge and experience obtained from a doctor is transferred to the knowledge base. An inference function about a disease is obtained by evaluating the information in the knowledge base. The information obtained from the user interface is transferred to the inference engine and a decision is obtained for the incoming query [7].

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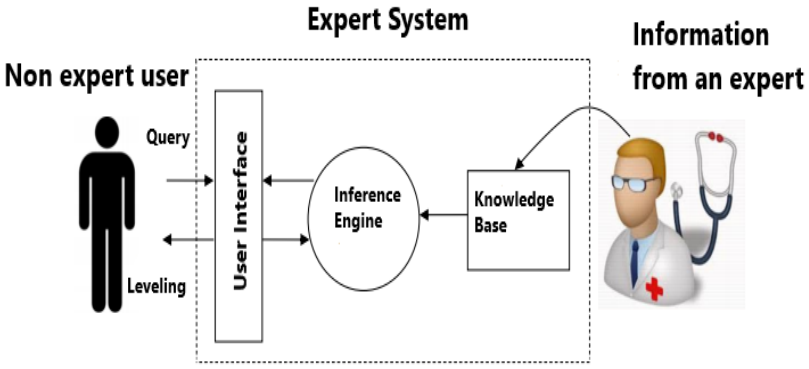

Figure 3.2. Demonstration of medical decision making system

4. FUZZY EXPERT DESİGN

The fuzzy expert system design for the diagnosis of the new Coronavirus disease has been examined in hospitals in Ankara. It has been investigated how much the Fuzzy Expert system makes a positive contribution compared to normal control systems. For this, a fuzzy control system, which is different from normal control systems, has been designed (Figure 4.1). In this design, the input parameters are Fever (ºC), cough, difficulty breathing, diarrhea and loss of taste and smell. The output parameters are designed as Coronavirus detection. All input and output parameters are seen in Figure 4.1.

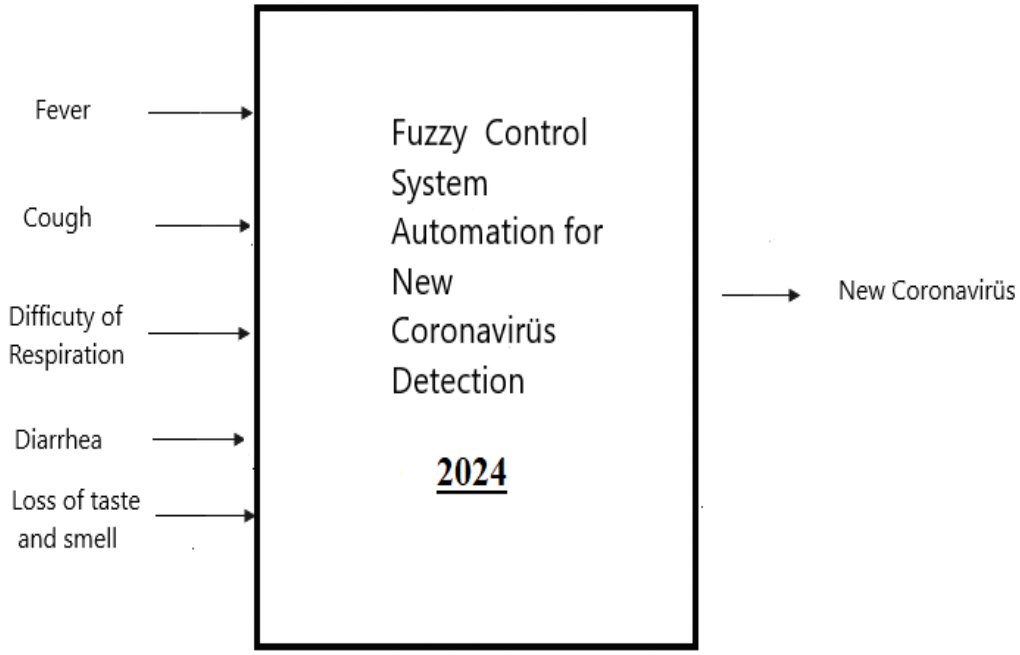

Figure 4.1 Fuzzy Expert Design 2024 Automation for Novel Coronavirus detection.

Fuzzy Control input and output values are defined with five linguistic expressions, as in the literature and according to expert opinion. These are; Very Low, Low, Medium, High, Very High.

Seven input parameters were selected as indicated below, and the determined linguistic expressions are given in Table 4.1.

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As input parameter:

1. The universal set for fever value is between [35…40] ºC values.
2. The universal set for cough value is between [0…100]%.
3. The universal set for respiratory distress value is between [0…100]%.
4. The universal set for diarrhea value is between [0…100]%.
5. The universal set for loss of taste and smell value is between [0…100]%.

As output parameter:

The universal set for the New Coronavirus is between % [0…100]. The use of the Mamdani fuzzy model was preferred for all fuzzy inferences made. The reason for this is that the Mamdani fuzzy model is both simple and suitable for the system structure. The fuzzy linguistic values of the system input/output variables and the properties of the variables are shown in detail in Table 4.1 and Table 4.2.

Table 4.1 Fuzzy Variables of System 2024 Input/Output Variables.

Variable Name	**Type**	**FUZZY VERBAL VARIABLES**
Fever	Input	Very Low, Low, Middle, High, Very High
Cough	Input	Very Low, Low, Middle, High, Very High
Difficuty of Respiration	Input	Very Low, Low, Middle, High, Very High
Diarrhea	Input	Very Low, Low, Middle, High, Very High
Loss of Taste and smell	Input	Very Low, Low, Middle, High, Very High
New Coronavirus	Output	Very Low, Low, Middle, High, Very High

Table 4.2 System 2024 Input/Output Variables Properties.

Variable	**Min**	**Max**	**Unit**
Fever	35	40	ºC
Cough	0	100	%
Difficuty of respiration	0	100	%
Diarrhea	0	100	%
Loss of Taste and Smell	0	100	%
New Coronavirus	0	100	%

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All input and output parameters are fuzzy for control. Triangular fuzzification is chosen here because it is seen from the literature that the most suitable and simple method is triangular fuzzification.

Since the membership functions of the fuzzy parameters are taken as triangles, their mathematical formulas are obtained appropriately. Here, the help of an expert is taken while determining the linguistic values.

In order not to have the new coronavirus disease, the fever should be below 36,5ºC. The fever can vary between 35ºC and 40ºC. The values of the right and left sides of the fuzziness degrees of the input linguistic values were determined with the help of an expert doctor. For example, "Medium" linguistic fever values will vary between 36 ºC and 37 ºC, and the largest value of the membership degree here will be 36,5 ºC, i.e. μ very low (36,5 ºC) = 1.

The mathematical expressions for the linguistic value of fire (X) are as follows (Figure 4,2).

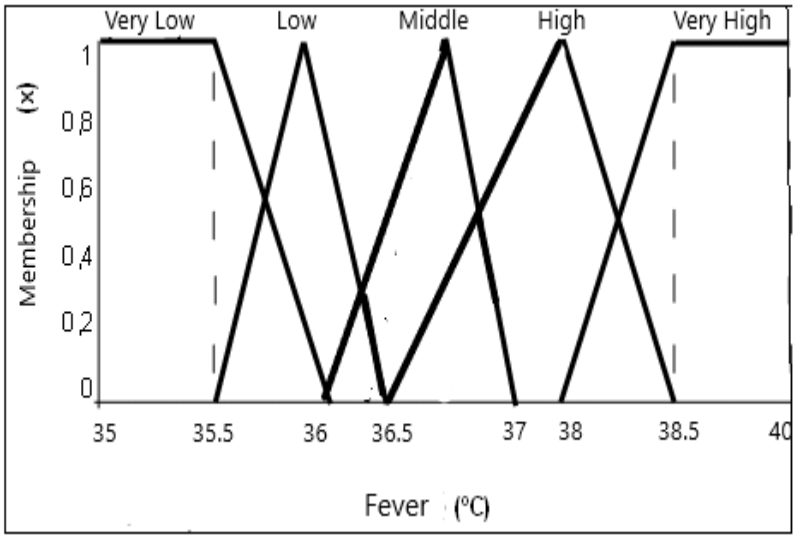

Figure 4,2 Membership Functions of Variables for the Fever Value of the Novel Coronavirus Disease

Below are the fever values for the new coronavirus disease.

Fuzzy expressions for fever (Fever=X, Fever value=x);

$$\mu_{\text{Very Low}}(x) = \begin{cases} 35 \le x \le 35.5 \; ; \; 1 \\ 35.5 \le x \le 36 \; ; \; (36 - x)/0.5 \\ x > 36 \; ; \; 0 \end{cases}$$

$$\mu_{\text{Low}}(x) = \begin{cases} x < 35 \text{ or } x > 35.5 \; ; \; 0 \\ 35.5 \le x \le 36 \; ; \; (x - 35.5)/0.5 \\ 36 \le x \le 36.5 \; ; \; (36.5 - x)/0.5 \end{cases}$$

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$$\mu_{Middle}(x) = \begin{cases} x < 36 \text{ or } x > 37 & ; 0 \\ 36 \le x \le 36.5 & ; (x - 36)/0.5 \\ 36.5 \le x \le 37 & ; (37 - x)/0.5 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} x < 36.5 \text{ or } x > 38.5 & ; 0 \\ 36.5 \le x \le 37.5 & ; (x - 36.5) \\ 37.5 \le x \le & ; (38.5 - x) \end{cases}$$

$$\mu_{Very\ High}(x) = \begin{cases} x < 38 \text{ or } x > 40 & ; 0 \\ 38 \le x \le 39 & ; (x - 38) \\ 39 \le x \le 40 & ; 1 \end{cases}$$

Fever fuzzy clusters found according to these values are given below.

$$\mu_{Very\ Low}(x) = \{ 1/35, 1/35.5, 0.2/35.9, 0/36 \}$$

$$\mu_{Low}(x) = \{ 0/35.5, 1/36, 0.4/36.3, 0/36.5 \}$$

$$\mu_{Middle}(x) = \{ 0/36, 1/36.5, 0.2/36.9, 0/37 \}$$

$$\mu_{High}(x) = \{ 0/36.5, 0.5/37, 0.2/38.3, 0/38.5 \}$$

$$\mu_{Very\ High}(x) = \{ 0/38, 0.5/38.5, 1/39, 1/40 \}$$

5. CONCLUSION

Coronaviruses emerged in 1960. 2019 met the new coronavirus. Especially in the early days, the medical world could not know the symptoms of the disease. It was diagnosed by gaining experience in the future.

In recent years, the disease has begun to be diagnosed early using expert fuzzy systems. With early diagnosis, the loss of life began to decrease. Early detection of the new Coronavirus disease will be provided with the help of Fuzzy Control.

During the study, expert doctors worked with university hospitals in Amkara province. Thanks to these expert doctors, the inputs and output values were determined.

In this study, basic information about Fuzzy Control was given, and the Fuzzy Expert System inputs and outputs required for the disease were determined. A suitable Fuzzy Expert System was designed. The widely used centroid method was used to calculate the Fuzzy Control output values.

In the study, the necessary data for the New Coronavirus disease were collected. Five linguistic values were used for the input parameters. The Delphi program was used for the designed expert fuzzy design.

The accuracy of the program was tested in the Matlap program. It was seen that the results obtained in the Fuzzy Expert System were correct.

The main purpose of the study is to detect the disease before testing and to ensure that precautions are taken. When Fuzzy Control is used, time and economic savings are achieved.

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PEEK CF30 TERMOPLASTİK MALZEMENİN DELİNMESİNDE DELME PARAMETRELERİNİN OPTİMİZASYONU

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ÖZET

Bu çalışmada, PEEK CF30 termoplastik malzemenin farklı delme parametrelerinde (kesme hızı, ilerleme ve matkap uç açısı) TiN HSS kaplamalı matkapla delinmesinde delme parametrelerinin itme kuvveti, yüzey pürüzlülüğü ve delaminasyona etkisi incelenmiştir. Delme işlemleri sırasında çok kanallı amplifikatöre bağlanan piezoelektrik dinamometre ile itme kuvvetleri ölçülmüş ve delik çıkışında oluşan delaminasyonun görüntüleri takım mikroskobu ile analiz edilmiştir. Deney tasarımı, Taguchi L27 ortogonal dizinine göre yapılarak Taguchi yöntemine ile delme işleminde kullanılan kesme parametreleri optimize edilmiştir. Ayrıca kesme parametrelerinin itme kuvveti, yüzey pürüzlülüğü ve delaminasyon üzerine etkilerinin belirlenmesi için varyans (ANOVA) analizi yapılmıştır. ANOVA sonuçlarına göre ilerleme ve matkap uç açısının itme kuvveti üzerinde, ilerleme hızının ise yüzey pürüzlülüğü üzerinde, matkap uç açısının delaminasyon üzerinde en önemli faktör olduğu görülmüştür. Optimum yüzey pürüzlülüğü 118° uç açısı, 120 m/dk kesme hızı ve 0,15 mm/dev ilerleme ile, optimum itme kuvveti 118° uç açısı, 40 m/dk kesme hızı ve 0,1 mm/dev ilerleme ile, optimum delaminasyon 118° uç açısı, 40 m/dk kesme hızı ve 0,15 mm/dev ilerleme ile elde edilmiş, böylece optimizasyonun geçerliliği Taguchi yöntemiyle doğrulanmıştır.

Anahtar Kelimeler: İtme kuvveti, yüzey pürüzlülüğü, delaminasyon, PEEK, termoplastik

1.GİRİŞ

Polimerler, düşük yoğunluk, korozyon direnci, düşük sürtünme katsayısı ve seri üretim olasılığı gibi mükemmel özellikleri nedeniyle havacılık endüstrisi, biyomedikal, optik endüstrisi gibi endüstrilerde yaygın olarak kullanılmaktadır. Çeşitli polimer türleri arasında, termoplastikler düşük elastisite modülü, düşük ısıl iletkenlik, yüksek ısıl genleşme katsayısı ve iç gerilim gibi karakteristik özelliklere sahiptirler [1]. Polieter Eter Keton (PEEK), yüksek sıcaklıklara, korozyona, aşınmaya ve radyasyona karşı direnç de dahil olmak üzere olağanüstü performansıyla bilinen son derece çok yönlü bir termoplastiktir. Bu özellikler, havacılık ve tıp gibi endüstrilerde yaygın olarak kullanılmasını sağlamıştır. Karbon Fiber Takviyeli Polieter Eter Keton (CF/PEEK), olağanüstü özelliklere sahip özel bir mühendislik malzemesi olan PEEK'in içine yaklaşık %30 oranında kısa karbon fiberlerin takviye malzemesi olarak eklenmesiyle oluşturulur. Karbon fiber takviyeli poli-eter-eter-keton kompozit (CF/PEEK), hafifliği, yüksek mukavemeti ve geleneksel kompozit malzemelerin entegre üretimi ile

karakterize edilir. Havacılık, uzay, otomotiv ve diğer alanlarda yaygın olarak kullanılır. Kompozit bileşeni oluşturduktan sonra, bileşenin montaj sürecini tamamlamak için perçinleme veya cıvata bağlantısı gerekir ve bu da fiber takviyeli kompozitlerin delinmesini önemli ölçüde kritik hale getirir PEEK parçalarının dikkate değer özellikleri ve sayısız uygulamaları nedeniyle, üretim yöntemleri ve işleme parametrelerinin işleme performansı üzerindeki etkisi üzerine araştırmalar büyük ilgi görmektedir [2-4]

Talaşlı imalat işlemi uygulanan bir parça için genellikle ilk işlem tornalama veya frezeleme işlemidir ve ardından son delik özelliklerini bitirmek için delme işlemi kullanılır. Delme, sektördeki tüm kesme işlemlerinin %30'undan fazlasını oluşturan en sık görülen işleme işlemlerinden biridir [5]. Mekanik delme işlemi için, kesme hızı, ilerleme hızı, delme derinliği ve uç açısı delme parametreleri çoğunlukla analiz edilir; tartışılan kesme özellikleri arasında itme kuvveti, tork, titreşim, kesme sıcaklığı, tahrik gücü ve takım aşınması bulunur ve ölçülen deliğin kalite özellikleri arasında delik merkezinin yer değiştirmesi, delinmiş duvarın yüzey pürüzlülüğü, yuvarlaklık, delik boyutu ve çapaklar bulunur. Genel olarak, kesme kuvveti, takım durumunu ve talaş oluşumunu gözlemlemek için işleme parametrelerinin optimizasyonuna ihtiyaç duyulabilmektedir [6-7]

Kompozit endüstrisi için delik açma performansını incelemek önemlidir. Delme işlemiyle oluşan hasarların araştırılması gereken bir sorun olarak tanımlanmıştır. Delik açma kalitesi, delme araştırmaları için önemli bir kriterdir. İtme kuvveti, sıcaklık, delme kaynaklı hasarlar ve delik yüzey kalitesi son yıllarda kapsamlı bir şekilde araştırılmaktadır. Chang ve diğerleri [8], PEEK plakalarının delinmesi sırasında kesme kuvveti, delme sıcaklığı, talaş morfolojisi ve titreşim gibi işleme özellikleri üzerindeki delme parametrelerinin etkilerini araştırdı. Deneysel sonuçlar, ilerleme hızının itme kuvveti üzerindeki etkisinin mil hızından daha büyük olduğunu gösterdi. Ge ve diğerleri. [9], karbon fiberle güçlendirilmiş poli-eter-eter-keton (CF/PEKK) kompozit delinmesinin çok amaçlı optimizasyon çalışmasını rapor etmiş ve farklı matris (epoksi ve PEKK) özelliklerinin optimizasyon sonuçları üzerindeki etkilerini araştırmak için hibrit optimizasyon algoritmasını kullanmıştır. Ge ve diğerleri [10], termoset kompozitlerin (CF/epoksi) ve termoplastik kompozitlerin (CF/PEKK) delme performansını incelemiştir. CF/PEKK, CF/epoksi ile karşılaştırıldığında daha yüksek itme kuvvetine ve sıcaklığa, daha düşük delaminasyon hasarına sahip olduğu görülmüştür. Xu ve diğerleri [11], farklı delme parametreleri altında termoplastik CF/poliimid (PI) ve termoset CF/epoksi kompozitlerin delik açma performansını karşılaştırmıştır. Sonuçlar, CF/PI'nin delinmesinde düşük itme kuvveti/işleme sıcaklığının iyi bir işlenebilirlik gösterdiğini ve deliğin geometrik doğruluğunu iyileştirdiği göstermiştir. CF/PI için, kesme hızının artırılması ile silindiriklik hatalarının azaldığı belirtilmiştir. Xu ve diğerleri [12] ayrıca, kesme hızı ve ilerleme hızının CF/PEEK ve CF/PI'deki delme delaminasyon hasarı üzerindeki etkisini araştırmak için tam faktöriyel bir deneysel çalışma yürütmüştür. Sonuçlar, her iki kompozitteki delaminasyon hasarının kesme hızını artırarak veya ilerleme hızını azaltarak azaltılabileceğini göstermiştir. Du ve ark. [13] farklı matkap uç geometrileri ile CF/PEEK kompozit malzemenin delinmesini araştırmışlardır. Matkap ucu geometrisinin delme sıcaklığı, itme kuvveti ve hasar üzerindeki etkileri analiz etmişlerdir. Sonuçlar, PEEK reçinesinin ısıyla yumuşadığını ve matrisin hem girişte hem de

çıkışta plastik deformasyon, çapak kaynaklı kümeleşme ve kıvrılma oluşturduğunu göstermektedir. Feito ve diğerleri [14], CF/epoksi delme işleminin çok amaçlı optimizasyonu için tam faktöriyel bir deney tasarlamışlardır. İlerleme miktarı, kesme hızı ve takım geometrisinin itme kuvveti, tork ve delik delaminasyonu üzerindeki etkisini ortaya çıkarmak için varyans analizi (ANOVA) kullanılmıştır. Giriş ve çıkış değişkenleri arasındaki ilişki, tepki yüzeyi metodolojisi (RSM) aracılığıyla kurulmuş ve çok amaçlı problem, her bir hedefin göreceli önemine göre ağırlık faktörleri atayarak tek amaçlı bir probleme dönüştürülmüştür. Sonuçlar, düşük ilerleme oranının (0,05 mm/dev) tüm koşullar altında tercih edildiğini göstermiştir. Ancak, optimum kesme hızı, her bir hedefe atanan ağırlık faktörlerinin değerinden büyük ölçüde etkilenmiştir. Bu çalışmada PEEK CF30 termoplastik malzemenin HSS TiN kaplamalı matkaplarla delinmesinde delme parametrelerinin itme kuvveti, yüzey pürüzlülüğü, delaminasyon üzerindeki etkileri deneysel olarak incelenmiş ve bu parametrelerin etkileri Taguchi analiz edilerek optimum kesme parametreleri belirlenmiştir.

2. MATERYAL VE YÖNTEM

2.1. Deney Şartları, Ekipmanlar ve Deney Düzeneği

Delme deneylerinde 75x100x10 mm ölçülerine %30 karbon fiber takviyeli PEEK-CF30 termoplastik plakalar deney numunesi olarak kullanılmıştır. Delik delme işlemlerinde 5 mm çapında 118°, 135° ve 140° uç açısına TiN kaplamalı HSS matkaplar kullanılmıştır. Delme deneylerinde oluşan kuvvetler VMC–550 Johnford CNC işleme merkezinde bağlanan Kistler 9272 tipi dinamometre ile ölçülmüş, veri aktarımı KISTLER 5070A tipi çok kanallı amplifier ile, veri analizleri KISTLER Dynoware yazılımı ile yapılmıştır. Deney düzeneği Görsel 1'de gösterilmiştir. Delme deneyleri kuru ortamda 40, 80, 120 m/dk kesme hızları, 0,1, 0,15, 0,2 mm/dev ilerleme hızlarında gerçekleştirilmiştir. Delme işlemlerinde maksimum 30.000 d/dk hıza çıkabilen hız kafası kullanılmıştır. Delinen deliklerin yüzey pürüzlülükleri delik çapına uygun prob kullanılarak MarSurf M300 yüzey pürüzlülük cihazı ile ölçülmüştür. Ölçümler delik çıkışına aynı mesafede ve delik eksenine paralel, her bir ölçüm için parça eşit açıda (yaklaşık 90°) döndürülerek en az dört ölçüm olacak şekilde ölçümler yapılmış ve bu değerlerin aritmetik ortalaması alınarak sonuçlar değerlendirilmiştir. Delik çıkışında oluşan hasarlar Nikon SMZ745T takım mikroskobu ile incelenip her delik fotoğraflanmıştır. Deliklerin fotoğrafları AutoCAD programında incelenerek deliklerde oluşan hasarların (delaminasyon faktörü, Fd) miktarları belirlenmiştir. Delaminasyon faktörü (Fd), maksimum çapın (Dmax), normal delik çapına (D) bölünmesi ile elde edilmiştir.

2.2. Deney ve Analiz Tasarımı

PEEK CF30 termoplastik malzemenin delinmesinde matkap uç açısı, ilerleme ve kesme hızının yüzey pürüzlülüğü ve itme kuvveti ve delik çıkışında oluşan hasarı belirlemek için üç seviyeli tam faktöriyel tasarım kullanılmıştır. Kontrol faktörü olarak üç farklı kesme hızı (Vc), ilerleme hızı (f) ve matkap uç seçilmiş ve seviyeleri Çizelge 1'de gösterildiği gibi belirlenmiştir. Taguchi yönteminin L27 ortogonal dizisi, optimum kesme koşullarını belirlemek ve işleme parametrelerinin etkilerini analiz etmek için kullanılmıştır.

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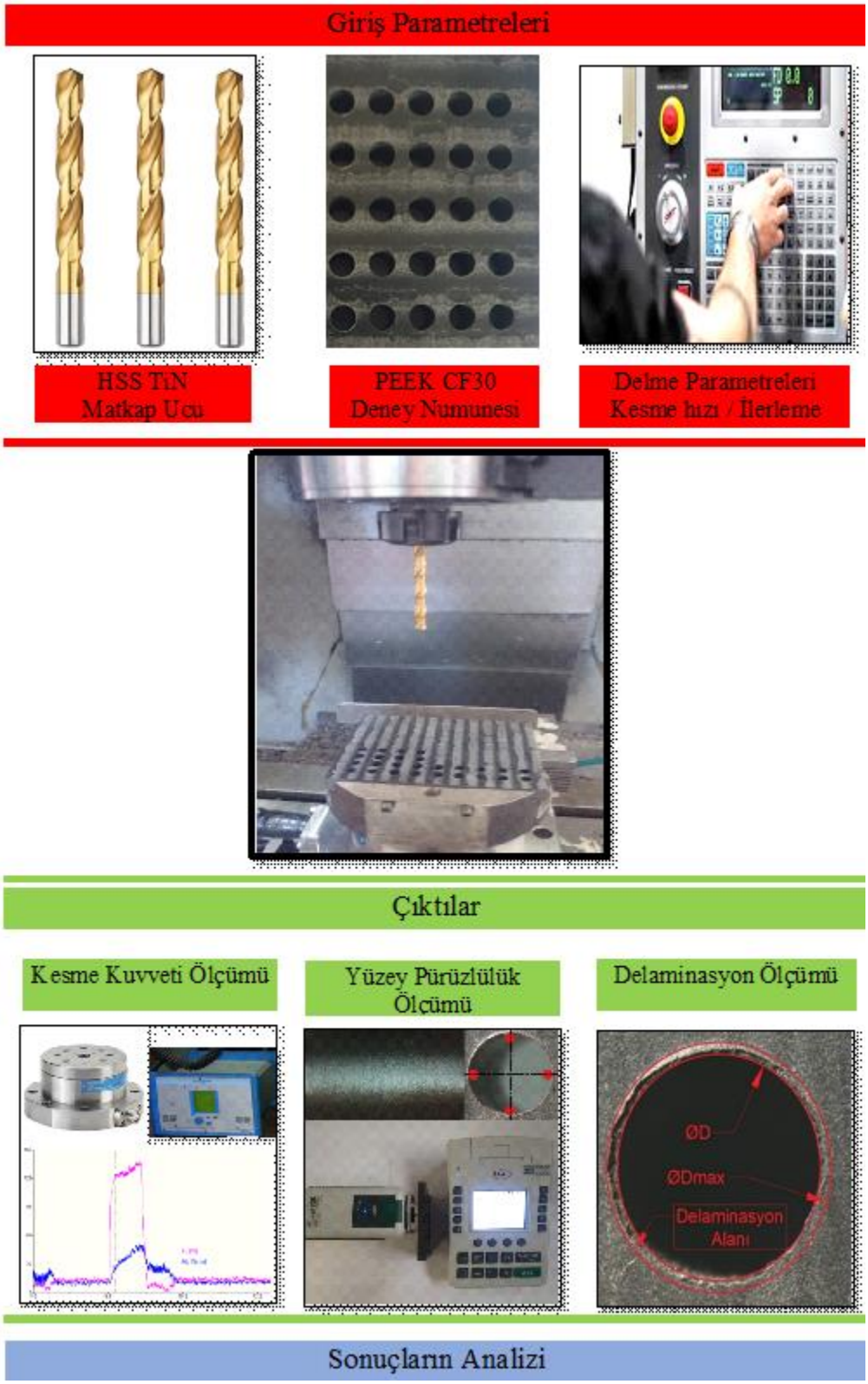

Görsel 1. Deney tasarımı

Değişkenlerin ortalama yüzey pürüzlülüğü (Ra), itme kuvveti (F) ve delaminasyon faktörü (Fd) üzerindeki önem düzeyini belirlemek için %95 güven düzeyinde ANOVA kullanılarak analiz edilmiştir. ANOVA'nın amacı, hangi kesme parametrelerinin bağımsız değişkenlerin

performans özelliklerini anlamlı bir şekilde etkilediğini tanımlamaktır. Deneysel testten elde edilen üç faktörün (kesme hızı, ilerleme hızı ve matkap uç açısı) üç yanıt değişkeni üzerindeki etkileri MINITAB yazılımı kullanılarak analiz edilmiştir. Kesme koşulları Fc, Ra ve Fd için ayrı ayrı optimize edilmiştir. S/N oranlarının hesaplanmasında; karakteristik tipine bağlı nominal en iyidir, en büyük en iyidir ve en küçük en iyidir metotları kullanılır. Bu çalışmanın amacı, yüzey pürüzlülüğünü, delaminasyon ve itme kuvvetini en aza indirmektir. Bu nedenle, optimum kesme koşullarını elde etmek için Ra, Fc ve Fd için en küçük-daha iyi performans karakteristiği gerçekleştirilmiştir. S/N oranı (η) şu şekilde tanımlanır [15].

$$\frac{S}{N(\eta)} = -10 \cdot \log\left[\frac{1}{n} \cdot \sum_{i=1}^{o} Y_i^2\right] \tag{2.1}$$

Burada Yi, deneyde gözlemlenen verilerdir ve n, deney sayısıdır. Ra ve Fc ve Fd'nin S/N oranları denklem (2.1) kullanılarak hesaplanmıştır.

Çizelge 1. Faktörler ve seviyeleri

Faktörler	Seviye 1	Seviye 2	Seviye 3
A: Kesme hızı, Vc (m/dk)	40	80	120
B: İlerleme miktarı, f (mm/dev)	0,1	0,15	0,2
C: Matkap uç açısı, (^{0})	118	135	140

3. DENEY SONUÇLARI VE TARTIŞMA

3.1 Deneysel Sonuçların Analizi

Görsel 2.a, 2.b ve 2.c'de itme kuvveti, ortalama yüzey pürüzlülüğü ve delaminasyon faktörünün kesme hızı, ilerleme miktarı ve matkap uç açısına göre değişim grafikleri sırasıyla verilmiştir. Delmede itme kuvveti, delme işlemini etkileyen en önemli parametrelerden biridir. PEEK CF 30 malzemenin delinmesinde eksenel yöndeki itme kuvveti matkabın iş parçasına uyguladığı yükü karakterize eder ve yüksek itme kuvveti yüksek delaminasyon hasarına yol açtığı için, itme kuvveti mümkün olduğunca azaltılmalıdır. Görsel 2.a'da görüldüğü gibi, itme kuvvetlerinin artan ilerleme hızıyla (f) arttığı görülmüştür. Bu olgu, Xu ve ark. [11] tarafından karbon/PEEK kompozitlerinin delinmesi sırasında ve Chang ve ark. [16] tarafından PEEK plakasının delinmesi sırasında elde sonuçlarla tutarlılık göstermiştir. İtme kuvvetinin ilerleme hızıyla birlikte büyük ölçüde artması, malzemeden çıkarılan talaş hacminin artmasıyla açıklanabilir. Kesme hızının artırılması daha yüksek delme sıcaklığına ve malzemenin termal yumuşama etkilerine yol açabileceğinden, kesme hızının artırılması itme kuvvetinde bir azalmaya yol açacaktır. Ancak, bu çalışmadaki bulgunun bununla çeliştiği görülmektedir. Bu durum, kesme hızının artmasıyla malzemede termal yumuşama sürtünme katsayısının artmasına neden olarak delme sırasında takım/iş parçası arayüzünde ek direnç oluşturmaktadır. Matkap uç açısının 118^0'den 135^0'ye çıkması ile itme kuvvetlerinde artış görülmektedir. Ancak matkap uç açısının 135^0'den 140^0'ye çıkmasıyla itme kuvvetlerinde azalma görülmüştür. Matkap uç açısının artmasıyla kesme kenar uzunluğu artmakta bu da sıcaklığın artmasına neden olmaktadır. Sıcaklığın artması termal bir yumuşamaya ve daha uzun takım talaş temas

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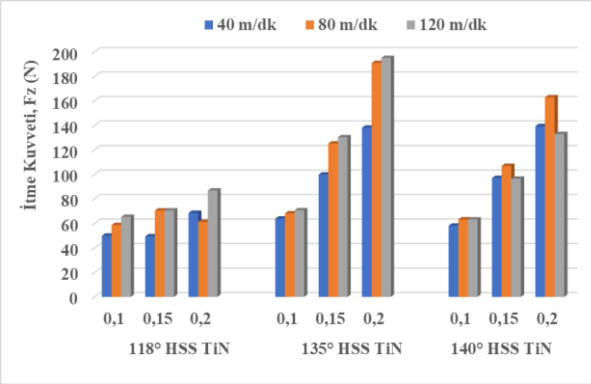
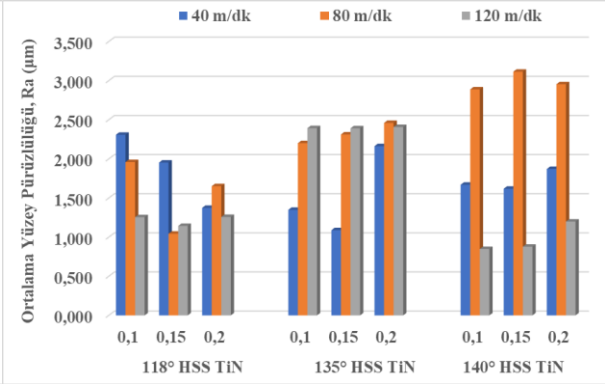
uzunluğuna neden olmaktadır. Bu, kesici takım ile kesilmemiş malzeme arasında ek sürtünme oluşturarak yüksek itme kuvvetine neden olmuştur.



a)



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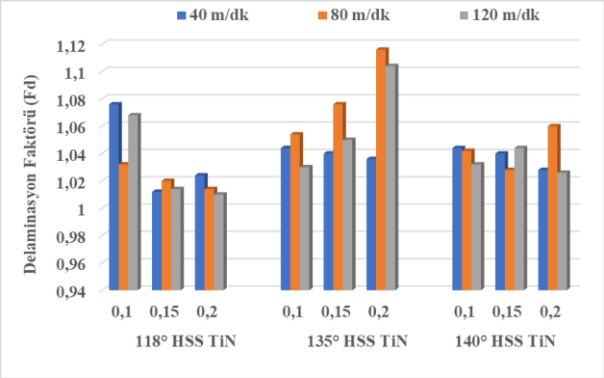

c)

Görsel 2. Kesme hızı ve ilerleme miktarına göre a) İtme kuvvetindeki b) Yüzey pürüzlüğündeki c) Delaminasyon faktöründeki değişim

PEEK-CF30 termoplastik malzemenin farklı seviyelerdeki kesme hızı ve ilerleme ve matkap uç açısı ile delinmesi ile elde edilen yüzey pürüzlülük değerleri Şekil 2b'te gösterilmiştir. En düşük yüzey pürüzlülüğü (0,848 µm) 130 m/dk kesme, 0.1 mm/dev ilerleme hızı ve 140^0 matkap uç açısıyla, en yüksek yüzey pürüzlülüğü (3,115 µm), 80 m/dk kesme hızı, 0.15 mm/dev ilerlemede (2.963 µm) olarak elde edilmiştir. Kesme hızının artması, sürtünme direncine göre ısı oluşumunu arttırırken, yüksek ilerleme hızları, takım-iş parçası arasında temas süresinin azalmasına sebep olur. Metalik malzemelerin işlenmesinde oluşan ısının çoğunluğu talaşla taşınırken, polimer malzemelerde ısının çoğunluğu takıma ve iş parçasına taşınmaktadır [11,17,18]. İş parçasındaki ısı artışı ergimeye neden olarak delik yüzeylerinde kötüleşmeye neden olmaktadır. Delik derinliğinin de bir etken olduğu delik sonuna doğru yüzey kalitesinin kötüleştiği görülmektedir. Ayrıca malzemenin yapısında bulunan %30 oranındaki karbon fiber parçacıkları matkabın kesme kenarında aşınmalara neden olarak yüzey kalitesinin kötüleşmesine neden olmaktadır (Görsel 2.b). Görsel 2.b incelendiğinde yüzey pürüzlülük değerlerinde değişiklikler olduğu bu düzensizliklerin delme sırasında oluşan ısı değişkenliğinden ve karbon fiber parçacıkların düzensiz takım aşınmasına etkisinden kaynaklandığı düşünülmektedir (Görsel 3).

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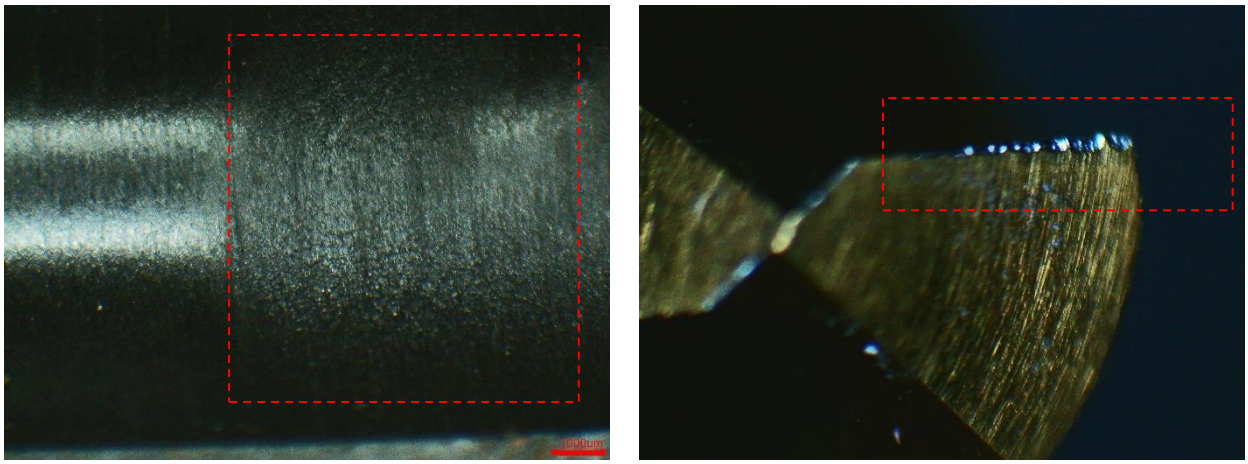
Delaminasyon, genellikle fiber esaslı kompozitlerin delinmesinde delik ve giriş çıkışında meydana gelen bir problemdir. Delaminasyon hasarını en aza indirgemek için işleme şartlarının belirlenmesi önemlidir. Özellikle delik çıkışında dışarı itme delaminasyonu meydana geldiğinden hasar delik girişine göre daha fazla olabilmektedir. Görsel 2.c'de TiN kaplamalı HSS matkaplarla delinen deliklerin delik çıkışında oluşan delaminasyon faktörünün kesme hızı ve ilerleme miktarına göre değişimleri gösterilmiştir. En yüksek delaminasyon miktarı 80 m/dk kesme hızı, 0,2 mm/dev ilerleme ve 135^0 matkap uç açısında meydana gelirken, en düşük delaminasyon 120 m/dk kesme hızı, 0,2 mm/dev ilerleme ve 118^0 matkap uç açısında oluşturmuştur. Delaminasyon miktarları genel olarak itme kuvvetlerine benzerlik göstermiştir.



a) b)

Görsel 3. a) Delik yüzeyinde oluşan erime b) kesici takımda oluşan aşınma

3.2. Sinyal-Gürültü (S/N) Oranının Analizi

PEEK CF30 malzemenin delinmesinde ortaya çıkan kesme kuvveti, ortalama yüzey pürüzlülüğü ve delaminasyon, L27 ortogonal dizisine göre yapılan deneyler sonrasında ölçülmüştür. Her bir değişkenin optimum seviyelerinin belirlenmesinde kullanılacak olan deney sonuçlarından elde edilen Ra, Fz ve Fd verilerinin S/N oranları denklem (2.1)'e göre hesaplanmış ve deney sonuçları ve hesaplanan S/N oranları Çizelge 2'de verilmiştir.

Her bir kontrol faktörünün itme kuvveti, yüzey pürüzlülüğü ve delaminasyon üzerindeki etkisi analizi edilmiş ve Fz, Ra ve Fd için S/N'nin yanıtları Çizelge 2'de gösterilmiştir. Taguchi yöntemi kullanılarak yapılan bu tablo, optimum itme kuvveti, yüzey pürüzlülüğü ve delaminasyon değerleri için optimum kontrol faktörlerinin seviyelerini göstermektedir. Çizelge 2'de verilen Fz, Ra ve Fd için kontrol faktörlerinin seviye değerleri, Görsel 4'deki grafiklerde gösterilmiştir. İtme kuvveti, yüzey pürüzlülüğü ve delaminasyonu en aza indirmek için kontrol faktörlerinin optimum işleme parametreleri bu grafiklerden kolayca belirlenebilir. Her bir kontrol faktörü için en iyi seviye, kontrol faktörünün seviyelerindeki en yüksek S/N oranına göre bulunmuştur. Buna göre en iyi Fz değerini veren faktörlere ait seviyeler ve S/N oranları faktör A1, B1 ve C1 olarak belirlenmiştir. Başka bir deyişle, 40 m/dk kesme hızı (A1), 0,1 mm/dev ilerleme hızında (B1) ve 118^0 uç açısı (C1) ile optimum bir Fz değeri elde edilmiştir

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(Şekil 2a). Bu nedenle Çizelge 3'teki S/N oranları dikkate alındığında ortaya çıkan yüzey pürüzlülüğü için optimum kesme koşulları A3 (120 m/dk), B2 (0,15 mm/dev) ve C1 (118^0) iken delaminasyon için optimum kesme şartları 40 m/dk), B2 (0,15 mm/dev) ve C1 (118^0) olarak belirlenmiştir.

Çizelge 2. L_{27} deney tasarımı ve S/N oranları

Deney No	Değişkenler			Deneysel Sonuçlar			Sinyal/Gürültü Oranı (S/N)		
	A	B	C	Fz (N)	R_a(µm)	Fd	Fz (N)	R_a(µm)	Fd
1	40	0,1	118	49,90	2,322	1,076	-33,962	-7,267	-0,636
2	40	0,1	135	63,85	1,348	1,044	-36,103	-2,598	-0,374
3	40	0,1	140	58,05	1,651	1,044	-35,276	-4,452	-0,374
4	40	0,15	118	49,40	1,944	1,012	-33,875	-5,815	-0,104
5	40	0,15	135	99,80	1,091	1,040	-39,983	-0,742	-0,341
6	40	0,15	140	96,95	1,590	1,040	-39,731	-4,186	-0,341
7	40	0,2	118	68,55	1,366	1,024	-36,720	-2,761	-0,206
8	40	0,2	135	138,05	2,158	1,036	-42,801	-6,701	-0,307
9	40	0,2	140	139,30	1,849	1,028	-42,879	-5,441	-0,240
10	80	0,1	118	58,55	1,950	1,032	-35,351	-5,845	-0,274
11	80	0,1	135	68,10	2,164	1,054	-36,663	-6,851	-0,457
12	80	0,1	140	63,15	2,864	1,042	-36,008	-9,213	-0,357
13	80	0,15	118	70,40	1,053	1,020	-36,952	-0,376	-0,172
14	80	0,15	135	125,10	2,303	1,076	-41,945	-7,282	-0,636
15	80	0,15	140	106,85	3,119	1,028	-40,576	-9,869	-0,240
16	80	0,2	118	61,20	1,624	1,014	-35,735	-4,356	-0,121
17	80	0,2	135	190,80	2,457	1,116	-45,612	-7,818	-0,953
18	80	0,2	140	162,80	2,932	1,060	-44,233	-9,409	-0,506
19	120	0,1	118	65,25	1,258	1,068	-36,292	-1,972	-0,571
20	120	0,1	135	70,60	2,378	1,030	-36,976	-7,578	-0,257
21	120	0,1	140	63,10	0,843	1,032	-36,001	1,431	-0,274
22	120	0,15	118	70,45	1,121	1,014	-36,958	-1,162	-0,121
23	120	0,15	135	130,20	2,391	1,050	-42,292	-7,572	-0,424
24	120	0,15	140	96,40	0,883	1,044	-39,682	1,128	-0,374
25	120	0,2	118	86,75	1,253	1,010	-38,765	-1,991	-0,086
26	120	0,2	135	194,95	2,393	1,104	-45,799	-7,630	-0,859
27	120	0,2	140	132,85	1,194	1,026	-42,467	-1,577	-0,223

Çizelge 3. Fz, Ra ve Fd'nin S/N oranlarına ilişkin yanıt tablosu

	İtme Kuvveti			Yüzey Pürüzlülüğü			Delaminasyon		
Seviye	A	B	C	A	B	C	A	B	C
1	-37,93	-35,85	-36,07	-4,395	-4,882	-3,467	-0,3247	-0,3971	-0,2545
2	-39,23	-39,11	-40,91	-6,732	-3,957	-6,052	-0,4129	-0,3057	-0,5120
3	-39,47	-41,67	-39,65	-2,954	-5,242	-4,562	-0,3543	-0,3891	-0,3254
Δ	1,54	5,82	4,84	3,778	1,285	2,585	0,0882	0,0914	0,2575
Rank	3	1	2	1	3	2	3	2	1

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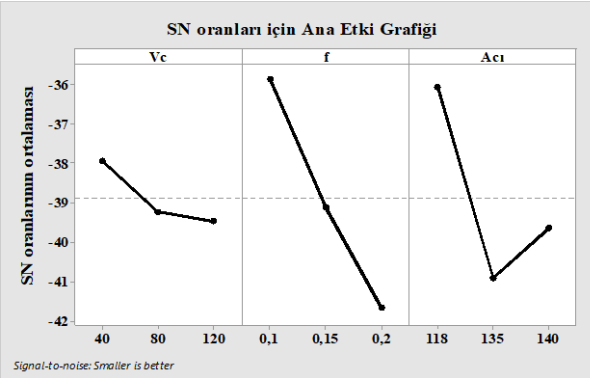

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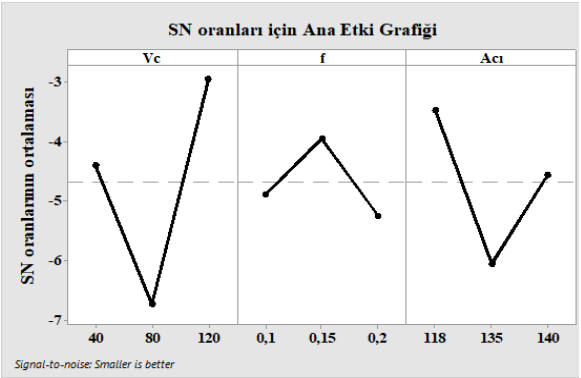

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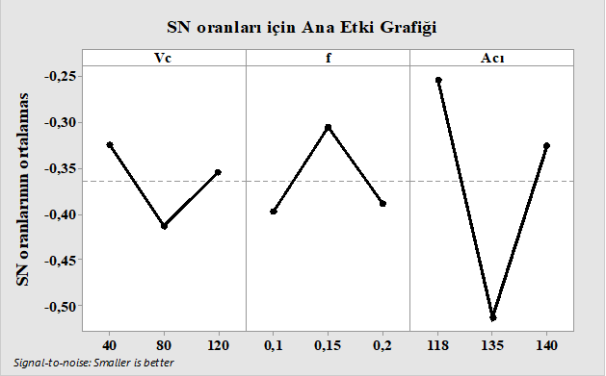

c)

Görsel 4. S/N oranları için etki grafiği a) İtme kuvveti, b) yüzey pürüzlülüğü c) delaminasyon

3.3. ANOVA yöntemi

Varyans analizi (ANOVA), hangi tasarım parametrelerinin itme kuvveti, yüzey pürüzlülüğü ve delaminasyonu hangi ölçüde etkilediğini araştırmak için kullanılmıştır. Bu analiz, P = 0.05'lik bir anlamlılık ve %95'lik bir güven düzeyinde gerçekleştirilmiştir. Çizelge 3, her bir varyasyon terimi için F-testleri ile ilişkili P değerlerini, yani gerçekleşen anlamlılık düzeylerini göstermektedir. P değeri 0.05'ten küçük olan terimlerin performans ölçütlerine istatistiksel olarak anlamlı bir katkısı olduğu ve elde edilen modellerin istatistiksel olarak anlamlı olduğu düşünülmektedir. Modelde seçilen koşulların yanıtlar üzerinde önemli etkileri olduğunu göstermektedir. İtme kuvveti, yüzey pürüzlülüğü ve delaminasyon için ANOVA sonuçları Çizelge 4'te, her bir varyasyon terimi için F-testleri ile ilişkili P değerlerini, yani gerçekleşen anlamlılık 'te gösterilmiştir. Bu tablo aynı zamanda her bir faktörün yüzde dağılım oranına (YD) ek olarak serbestlik derecelerini (SD), kareler ortalaması (KO), F değerlerini (F) ve olasılığı (P) gösterir. Değişkenlerin anlamlılık düzeyini sınıflandırmak için F oranları ve YD'leri dikkate alındı. Tabloda itme kuvveti (Fz) için ANOVA değerleri verilmiştir. ANOVA sonuçları, %46,6 değerleriyle ilerleme hızı ve %34,5 değerleriyle matkap uç açısının itme kuvveti üzerinde en etkili parametreler olduğu görülmüştür. %23,41 etki değeri ile kesme hızının yüzey pürüzlüğü için en etkili parametre olduğu, %26'lık oranla matkap uç açısının delaminasyon miktarı için önemli olduğu görülmüştür.

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Çizelge 4. ANOVA tablosu

İtme Kuvveti

Değişkenler	SD	**KT**	**KO**	F	P	**YD**
A	2	12,44	6,219	2,51	0,107	3,78
B	2	153,17	76,586	30,9	0,0	46,6
C	2	113,54	56,772	22,9	0,0	34,5
Hata	20	49,57	2,479			15.12
Toplam	26	328,73				100

Yüzey Pürüzlülüğü

Değişkenler	**SD**	**KT**	KO	F	P	YD
A	2	65,422	32,711	3,72	0,042	23,41
B	2	7,904	3,952	,45	0,644	2,821
C	2	30,304	15,152	1,72	0,204	10,84
Hata	20	175,837	8,792			62,92
Toplam	26	279,467				100

Delaminasyon Faktörü

Değişkenler	**SD**	**KD**	KO	F	P	YD
A	2	0,03626	0,01813	0,44	0,65	2,96
B	2	0,04608	0,02304	0,56	0,580	3,77
C	2	0,31844	0,15922	3,87	0,039	26
Hata	20	0,82376	0,04119			67,27
Toplam	26	1,22454				100

SD: Serbestlik Derecesi, KT: Kareler Toplamı, KO: Kareler Ortalaması, YD: Yüzde Dağılımı

4. SONUÇ

Bu çalışmada, PEEK CF30 termoplastik malzemenin delinmesinde optimum kesme koşullarını (ilerleme hızı, kesme hızı ve matkap uç açısı) elde etmek için Taguchi yöntemi kullanılmıştır. Deneysel sonuçlar ANOVA kullanılarak değerlendirilmiştir. Sonuçlar şu şekilde açıklanabilir.

- Taguchi analizi sonucuna göre optimum değerler incelendiğinde; itme kuvveti için 40 m/dk kesme hızı, 0,1 mm/dev ilerleme miktarı ve 118^0 uç açısının,
  Ortalama yüzey pürüzlülüğü için 120 m/dk kesme hızı, 0,15 mm/dev ilerleme ve 118^0 uç açısının,
  Delaminasyon miktarı için 40 m/dk kesme hızı, 0,15 mm/dev ilerleme ve 118^0 uç açısının miktarının en iyi sonucu verdiği görülmüştür.
- ANOVA sonuçlarına göre, itme kuvveti üzerindeki en etkili parametrenin ilerleme hızı ve matkap uç açısının (%46,6 ve %34,5) olduğu,

Yüzey pürüzlülüğü üzerindeki en etkili parametrenin kesme hızı (%23,41) olduğu, Delaminasyon miktarı üzerindeki en etkili parametrenin matkap uç açısı (%26) olduğu görülmüştür.

- Bu sonuçlara göre, PEEK CF 30 malzemenin delinmesinde optimum itme kuvvetinin yüzey pürüzlülüğünün ve delaminasyonun belirlenmesinde, Taguchi deneysel tasarım metodunu başarılı bir şekilde uygulanmıştır.
- Optimizasyon sonucu elde edilen değerlerin deneysel sonuçlara yakın bir değerde olduğu görülmüştür.

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BÖHLER K490 ÇELİĞİNİN SERMET KESİCİ TAKIMLA İŞLNEBİLİRLİĞİNİN ARAŞTIRILMASI

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ÖZET
Toz metalurji ile üretilen Böhler K490 Microclean çeliği yüksek aşınma ve tokluk direncine sahip bir soğuk iş takım çeliği olup birçok endüstriyel alanda kullanılmaktadır. Bu çalışmada farklı kesme hızı ve ilerleme miktarlarında PVD kaplamalı sermet kesici takım ile kuru ve buharlı soğuk hava ile işleme şartlarında Böhler K490 çeliğine tornalama yapılmıştır. Tornalama sonrası işleme parametrelerinin yüzey pürüzlülüğüne ve kesici takım performansına etkisi incelenmiştir. En düşük yüzey pürüzlülük değerleri her iki işleme şartında da 300 m/dk kesme hızında ve 0,08 mm/dev ilerleme miktarında elde edilmiştir. Sermet kesici takım incelendiğinde kesici takımlarda yığıntı talaş (BUE), çentik aşınması ve yan kenar aşınması gözlemlenmiştir. Yüksek kesme ve ilerleme hızlarında sermet kesici takımlarda kuru ve buharlı soğuk hava ile işlemede kırılmalar olmuştur. En düşük yan kenar aşınma ve yüzey pürüzlülük değerleri buharlı soğuk hava ile işlemede elde edilmiştir.

Anahtar Kelimeler: Toz metalurjik çelik, yüzey pürüzlülüğü, sermet, takım aşınması, soğuk takım iş çeliği

1. GİRİŞ
Genellikle takım çelikleri, ısıl işlemle yüksek sertlik değerlerine ulaşabilen yüksek karbonlu çeliklerdir. Böhler K490, toz metalurjisi kullanılarak üretilen dengeli bir özellik profiline sahip yüksek performanslı bir soğuk iş takım çeliğidir [1]. Takım çelikleri, daha yüksek C ve Cr içeriği nedeniyle, daha yüksek sertlik ve aşınma direncine sahiptirler. Genel olarak, takım çeliklerinin yapılarında farklı karbürlerin bulunması yüksek süneklik ve tokluk direncini etkiler, yüksek tokluk ve aynı anda aşınma direncine sahip takım çelikleri elde etmek sürekli bir zorluktur Karbürlerin boyutu, türü ve dağılımları, takım çeliklerinin ömrünü ve performansını önemli ölçüde etkiler [2]. Bu sorunları ortadan kaldırmak ve homojen karbür dağılımı ve boyutunu düzenleyerek yüksek tokluğa ve yüksek aşınma direncine sahip malzemeler üretmek amacıyla toz metalurjik malzemeler kullanılmaktadır. Soğuk iş takım çelikleri, aşırı sıcaklığın olmadığı, yüksek aşınma direnci ve tokluğun gerekli olduğu oda sıcaklığında çalıştırılan takımlarda ve kalıplarda da kullanılır. Toz metalurjisi kullanılarak üretilen soğuk iş takım çelikleri, işlenmesi en zor malzemeler arasındadır ve sinterlenmiş toz metalurjisi çelikleriyle çalışmak için kullanılan takımlar, standart karbon çelikleriyle çalışmak için kullanılan takımlardan daha kısa bir ömre sahiptir. Toz metallerin işlenebilirliği zayıftır çünkü gözeneklilikleri iletkenliklerini azaltır ve kesici takımda mikro kesintilere veya darbelere neden

olur. Sonuç olarak, kesici takımların aşınması, işleme süreçlerinin sürdürülebilirliğini de etkilemektedir [3].
İşleme sırasında yağlama veya sıvıların kullanımı yaklaşık 200 yıldır uygulanmaktadır [4]. Sıvı kullanımı, takım ve iş parçası arasındaki sürtünmeyi azaltarak işleme bölgesindeki sıcaklığı düşürür ve ayrıca işlenmiş yüzeyin yağlanmasını artırarak takım ömrünü ve iş parçasının tribolojik özelliğini artırır [5]. Kesme sıvıları soğutma ve yağlamada etkili olsa da genellikle önemli çevresel ve sağlık riskleri oluşturan tehlikeli kimyasal bileşenler içerirler [6]. Bu endişeleri gidermek için alternatif soğutma yöntemleri kullanılmakta ve bunlarla ilgili araştırmalar yapılmaktadır. Boy [1], Böhler K490 çeliğinin kaplamalı seramik uçlarla kuru, MQL ve nano-MQL ile tornalanması sırasında kaplamalı seramiklerin işleme performansını iyileştirmeyi amaçlamış ve sonuç olarak, takım aşınması, yüzey kalitesi ve güç tüketimi açısından en iyi değerler nano-MQL koşulları, özellikle çift jet nano-MQL tekniği kullanılarak elde etmiştir. Gupta ve Korkmaz [3], minimum miktarda yağlama (MQL) ve hBN ile zenginleştirilmiş nano-MQL soğutma/yağlama kullanarak Böhler K490 çeliğinin işlenmesinin işlem performansını artırmak için sürdürülebilirlik değerlendirme modeli geliştirilirken güç tüketimi ve takım aşınması, yüzey pürüzlülüğü ve talaş morfolojisi gibi işleme parametreleri dikkate alınmış ve sürdürülebilirlik performans göstergesi (SPI) belirlemişlerdir. Bu küresel SPI, nano-MQL kullanımının hem sürdürülebilirliği hem de işleme performansını iyileştirdiği iddiasını desteklemiştir. hBN ile zenginleştirilmiş nano sıvı uygulanmasının takım aşınma değerlerinde %26,9'a kadar azalttığını açıkça göstermiştir. Y. Su ve ark. [7], kuru kesme, MQL, hava soğutma, MQL ile hava soğutma [CAMQL] teknikleri altında PVD-TiAlN kaplamalı karbür uçlar kullanarak Inconel 718 alaşımı ve kalıp takım çeliği üzerinde deneysel bir çalışma yapmışlar. MQL ile soğutma hava ile takım aşınmasında diğer tekniklere göre daha az bir aşınma elde etmişlerdir. Mia ve diğerleri [8] takım aşınması ve yüzey kalitesini değerlendirmek için hava soğutma, azotlu hava soğutma, azot gazı ile MQL, Vortex hava soğutma ile NGMQL'yi karşılaştırdı. NGMQL ile Vortex hava soğutmada yan kenar aşınmasında diğerlerine kıyasla 50 mikronluk bir azalma tespit etmişlerdir. Yüksel ve Onat [9], alaşımlı çelik işlemede vorteks tüpü tarafından üretilen 3 farklı sıcaklıktaki soğuk havayı kullanarak işleme gerçekleştirmişler, sonuç olarak soğuk havanın kesme kuvvetlerinde önemli bir değişikliğe neden olmadığını belirtmişlerdir.

Lopes ve diğerleri [10], soğuk hava altında votreks tüpüyle MQL kullanarak AISI 4340 alaşımının taşlanmasını araştırmış ve 0 °C'de uygulanan kesme sıvısıyla umut verici sonuçlar gözlemlemişlerdir. Taha ve diğerleri tarafından yapılan çalışmada [11], A36 çelik iş parçasının frezelenmesi sırasında vorteks tüpünün kullanımı ortam havası soğutmasıyla karşılaştırıldı. vorteks tüpünün yalnızca soğutma etkisinden dolayı daha yüksek hızlarda etkili olduğu, ancak yağlama etkisinin olmaması nedeniyle daha düşük hızlarda iyi sonuçlar vermediği sonucuna varıldı. Valic ve ark. [12] sürdürülebilir işlemeye katkıda bulunmak amacıyla, martensitik paslanmaz çelik X20Cr13'ün alternatif soğutma ve yağlama teknikleri altında tornalanmasında, MQL ünitesinden gelen mikro damlacıkların ve vorteks tüpünden gelen soğutulmuş basınçlı havanın kesme bölgesine girmeden önce tek bir akışta bağlanmasına izin veren yeni bir nozul tasarlanmıştır, böylece eş zamanlı yağlama ve soğutma sağlanmışlardır. Özbek ve Saruhan [13], AISI D2 takım çeliğinin kuru ve MQL işlenmesinin sıcaklık, takım aşınması ve yüzey

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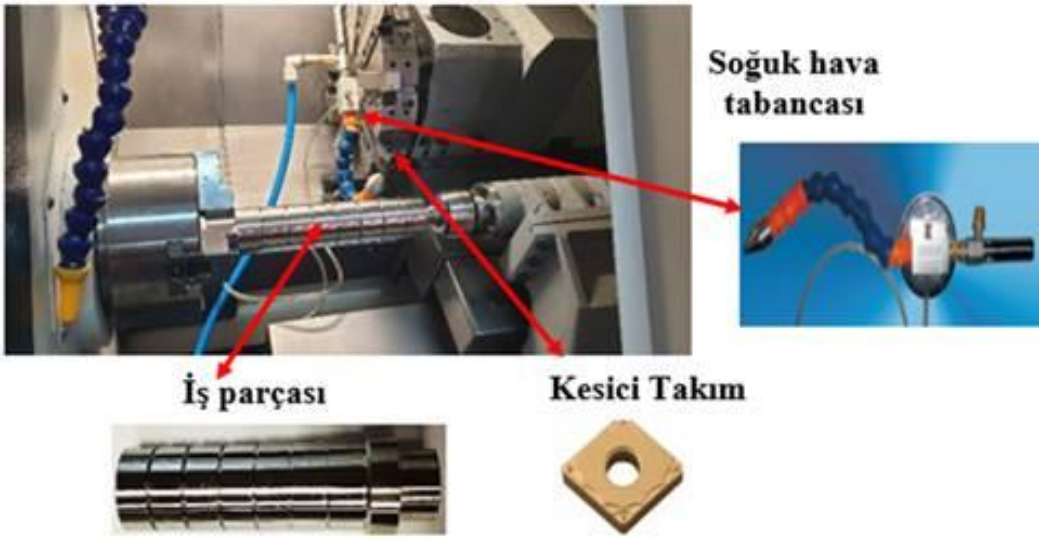
pürüzlülüğü üzerindeki etkilerini analiz etmişler ve MQL'nin kuru kesime kıyasla takım aşınmasını %23 oranında azalttığı sonucuna varmışlardır. Das ve diğerlerine göre [14], MQL, kaplanmamış sermet takımlarla sertleştirilmiş 4340 çeliği tornalarken hava soğutmanı kuru kesme koşullarından daha üstün olduğunu belirtmişlerdir. Yağmur [15], kuru işleme, MQL ve vorteks tüpü soğutma yöntemlerini kullanarak takım aşınması ve yüzey pürüzlülüğünün analizlerini farklı kesme hızları ve ilerlemeler kullanılarak gerçekleştirmiştir. Vorteks tüpü ile yapılan deneylerde ve MQL ile yapılan deneylerde sonuçların birbirine yakın olduğu görülmüştür. Bu çalışmada, vorteks tüpü ile işlemenin ıslak işlemeye alternatif bir seçenek olabileceği anlaşılmıştır. Cukor vd. [16], vorteks tüpü ile yaptıkları deneylerde, bazı işleme deneylerinde vorteks ile işlemede ıslak işlemeden daha iyi takım ömrü sağlamışlardır. Araştırmacılar ayrıca, bu çevre dostu yöntem kullanılarak genel üretim maliyetlerinin en aza indirilebileceğini keşfetmişlerdir. Pinar vd. [17], vorteks tüpü ve ıslak işleme süreçlerini karşılaştırdıkları deneylerinde, bu iki soğutma yöntemi ile benzer sonuçlar elde edilebileceğini vurgulamışlardır. Sonuç olarak, işleme kalitesini iyileştirmek ve toplam maliyet ve süreyi azaltmak için modern üretim tekniklerine ihtiyaç vardır. Bu çalışmada, üretkenliği en üst düzeye çıkarmak için sürdürülebilir işleme benimsenmiştir. Böhler çeliğinin sermet kesici takımla kuru ve buharlı soğuk hava ile tornalanmasında yüzey kalitesi ve takım aşınmaları deneysel olarak araştırılmıştır.

2. MATERYAL VE METOT

Deneylerde 60x250 mm ölçülerinde toz metalurji ile üretilen Böhler K490 çeliği kullanılmıştır. Deneyler Kyocera marka PVD (TiCN) kaplamalı CNMG 120404 GP PV7020 sermet kesici takım ile 225, 300, 375 m/dk kesme hızı ve 0,08,0,16, 0,24 mm/dev ilerleme miktarlarında ve 0,5 mm kesme derinliğinde yapılmıştır. Deneyler kuru ve daha sonra 6 bar hava basıncında Nex Flow marka Frigid-X Sub-Zero Vortex ile %5 oranında Mobilcut 100 soğutma sıvısı kullanılarak belirlenen kesme parametrelerinde işlenmiştir (Görsel 1).



Görsel 1. Deneysel tasarım

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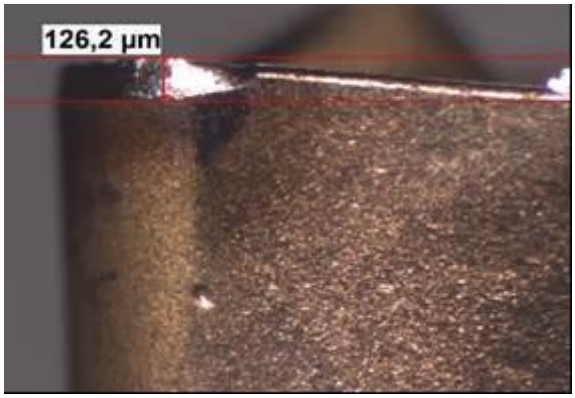
İşlenen yüzeylerin pürüzlükleri ölçümleri Marsurf M300 marka pürüzlülük cihazı ile yapılmıştır (Görsel 2). Sermet kesici takımla her bir işleme parametresinde iş parçasından 15 mm^3 talaş kaldırılmıştır. Kesici takımlardaki aşınmalar Nikon SMZ 745 takım mikroskobu elde edilen görüntüler incelenerek aşınma tipleri belirlenmiştir. Clemex Captiva yazılımında kesici takımlar görüntülenmiş ve görüntü üzerinden ölçümler yapılmıştır (Görsel 3).

Görsel 2. Pürüzlülük ölçümü



Görsel 3: Aşınma ölçümü

3.DENEYSEL SONUÇLAR VE TARTIŞMA

3.1 Yüzey Pürüzlülüğünün Değerlendirilmesi

Kuru işlemede, herhangi bir yağlayıcı kullanılmaz ve bu nedenle iş parçası ile takım arasındaki sürtünme veya direnç kuvveti en yüksektir. Çevresel açıdan bu yöntem önerilir ancak işleme açısından takım sıcaklığı hızla artar ve dolayısıyla takım aşınması da artar. Çünkü işlemede talaşlar takımın talaş yüzeyinden geçer ve enerjinin çoğu takım-iş parçası ve takım-talaş arasındaki sürtünme nedeniyle ısıya dönüşür. Kesme bölgesinde yüksek ısı oluşumu nedeniyle takım sertliğini kaybeder ve sonuçta kenarlar deforme olur, körelir ve takım bozulur. Bu nedenle, kuru işlemede takım aşınma direncinin artırılması için kesici takım malzemesi dikkatlice seçilmelidir. Takım malzemesi yüksek ısıya dayanıklı, sert ve yüksek sıcaklıkta kimyasal olarak kararlı olmalıdır. Kolay işlenebilirliğe sahip malzemeler kuru işleme olarak kullanılabilirken, titanyum, dubleks çelik vb. gibi işlenmesi zor malzemeler kuru işlemede ciddi sorunlara yol açabilir [18-19]. Sermet kesici takımla farklı işleme parametrelerinde kuru işleme ile elde edilen yüzey pürüzlülüklerinin ilerleme miktarındaki artışla arttığı Görsel 4'te görülmektedir. İlerleme miktarındaki artış, talaş kesitinin ve kaldırılan talaş hacminin artmasına neden olduğundan yüzey pürüzlülüğünde artışa neden olmaktadır [20-21]. Kesme hızının artırılması ve ilerleme hızının düşürülmesi ile düşük yüzey pürüzlüğü değerleri elde edilebilmektedir. Sermet ile kuru şartlarda 300 m/dk kesme hızı ve 0,08 mm/dev ilerleme ile işlemede 1,042 µm ile en düşük pürüzlülük değeri, 225 m/dk kesme hızında 0,24 mm/dev ilerlemede 3,970 µm ile en yüksek pürüzlülük değeri elde edilmiştir. 0,24 mm/dev ilerlemede kesme hızının 225 m/dk'dan 300 m/dk yükselmesiyle pürüzlülük değerinde %22'lik bir azalma olmuştur. Bu durum kesme hızındaki artış takım talaş ara yüzeyinde sıcaklığına artmasına ve dolayısıyla plastik deformasyon kolaylaşmasına atfedilebilir. Kesme hızının makul oranda artması pürüzlülük fazla bir değişime neden olmazken yüksek kesme hızları yüzey pürüzlüğünde kötüleşmeye neden olabilir. Kesme hızındaki artış yüksek sıcaklığa, takım

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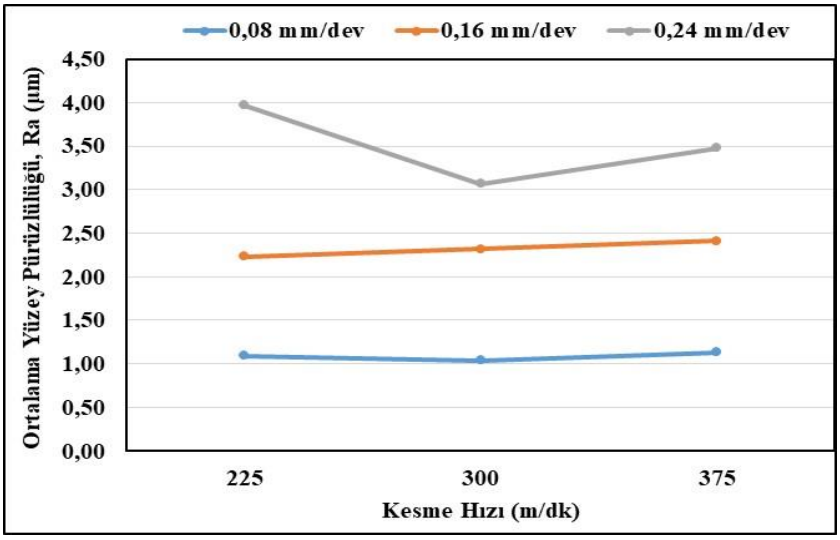
aşınmasına ve tezgâhtaki titreşimlerin artmasına neden olarak yüzey kalitesini kötüleştirmektedir [22-23]. 0,24 mm/dev ilerlemede kesme hızı 375 m/dk çıktığında pürüzlülükte bir artış olduğu görülmüştür.

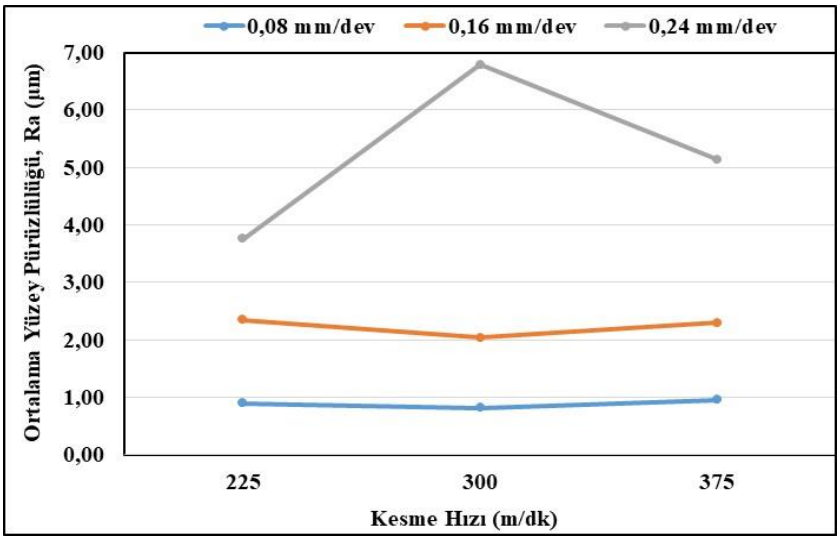


Görsel 4. Kuru işlemede yüzey pürüzlüğünün kesme hızı ve ilerme miktarına göre değişimi.

Bu yöntemde, Ranque-Hilsch girdap tüpünden çıkan sıkıştırılmış soğuk hava, işleme sırasında takım-iş parçası arayüzünü soğutmak için kullanılır. Cihaz, giriş havasının enerjisini iki parçaya ayırır ve hava akımı, sıcak bir akım ve soğuk bir akışkan akımı olarak ayrılır. Giriş bölümü, girdap dönüş odası, soğuk hava çıkışı ve sıcak hava çıkış bölümünden oluşur. Sıcak hava çıkış bölümü içi boş bir silindirle bağlantılıdır ve silindirin sonunda bir kontrol vanası vardır. Vana, iki akışkan arasındaki sıcaklık farkını düzenler. Hava önce bir kompresörden geçirilir, burada giriş atmosfer basıncı artırılır ve sıkıştırılmış hava teğetsel olarak girdap dönüş odasına beslenir. Sıkıştırılmış havanın yüksek basıncı nedeniyle hava yüksek rpm türbülans akışıyla döner ve içi boş silindir boyunca borunun sıcak ucuna doğru hareket eder. Borunun ucunda kısmen açık bir valf bulunur ve dış yüksek sıcaklıktaki sıvı kısmen açık valften çıkarken, iç sıvı içi boş silindirin iç bölümüne geri döner. Bu nedenle, dış türbülans akışı içinde bir iç türbülans akışı meydana gelir. İç soğuk sıvı, soğuk hava çıkış bölümüne geçmeden önce havayı bir delikten geçirerek kısma nedeniyle daha da soğutulur. Bu soğutma türünde, kesme sıvısı, su bazlı soğutucu olan buhar kullanılarak atomize edilmiş bir şekilde kesme bölgesi alanına üflenir. Bu soğutmanın avantajı, buharın geleneksel soğutucuların zorlandığı bölgelere kolayca ulaşmasıdır. Bu soğutmada, buharın basıncı ve akış yönü çok önemlidir. Normalde metal işleme sıvıları buhar soğutmasında kullanılır. Buhar soğutması çok daha az yağlayıcı gerektirir, bu nedenle çevre dostudur [24-26].

Böhler K490 çeliğinin buharlı soğuk hava ile tornalanmasında elde edilen yüzey pürüzlülük değerleri Görsel 5'te gösterilmiştir. Buharlı soğuk hava ile işlemede 300 m/dk kesme hızı ve 0,08 mm/dev ilerlemede en düşük yüzey pürüzlülüğü, aynı kesme hızı ve 0,24 mm/dev ilerleme miktarında ise en yüksek pürüzlülük değeri elde edilmiştir. İlerleme miktarındaki artış yüzey pürüzlülük değerlerinde artışa neden olmuş ve 0,24 mm/dev ilerleme miktarında yüksek

pürüzlülük değerleri ölçülmüştür. İlerleme miktarındaki artış, kaldıran talaş hacminde ve kesme kuvvetlerinde artışına neden olmakta dolasıyla yüzeylerde kötüleşme meydan gelmektedir. Yüksek ilerlemelerde kesme kuvvetlerindeki artış titreşime de neden olabilir. Ayrıca kesici takım büyük adımlarla ilerlediğinden parçada oluşan izlerin aralığı artar ve pürüzlülüğün artmasına neden olur. 0,08 mm/dev ve 0,16 mm/dev ilerlemede ölçülen pürüzlülük değerlerinin birbirlerine yakın olduğu, kesme hızının 225 m/dk'dan 300 m/dk'ya çıktığında pürüzlülük değerlerinde %10-12'lik bir azalma, kesme hızı 375 m/dk'ya çıktığında pürüzlülük değerlerinde %10-15 arasında bir artış görülmüştür.



Görsel 5. Buharlı soğuk havayla işlemede yüzey pürüzlüğünün kesme hızı ve ilerlemeye göre değişimi

Buharlı soğuk hava ve kuru işleme karşılaştırıldığında buharlı soğuk hava ile işlemede Ra değerlerinde bir azalma görülmüştür (Görsel 6). Ra değerlerindeki azalma takım-talaş arayüzeyindeki sürtünmenin azalmasına ve takım aşınmasının azalmasına atfedilebilir. Kesme hızı ve ilerleme miktarındaki artış artmasıyla Ra değerlerinin birbirine yakın olduğu ve hatta yüksek ilerleme miktarlarında Ra değerleri kötüleşmektedir. Bu durum soğutmanın ve yağlamanın yetersiz kalmasından kaynaklanabilir. Ayrıca yüksek işleme parametrelerinde çıkan talaşlar soğuk buhar nozulunun konumu değiştirerek kesme bölgesindeki sıcaklığın artmasına ve dolasıyla Ra değerlerinde kötüleşmeye neden olmaktadır.

3.2. Kesici Takım Performansının İncelenmesi

Böhler K490 çeliğinin kuru ve buharlı soğuk hava ile işlemesinden sonra kesici takımlar takım mikroskobu ile incelenmiş ve kesici takımlarda oluşan yan kenar aşınmaları ölçülmüş ve elde edilen değerlerin işleme parametrelerine göre değişimi Görsel 7'da gösterilmiştir.

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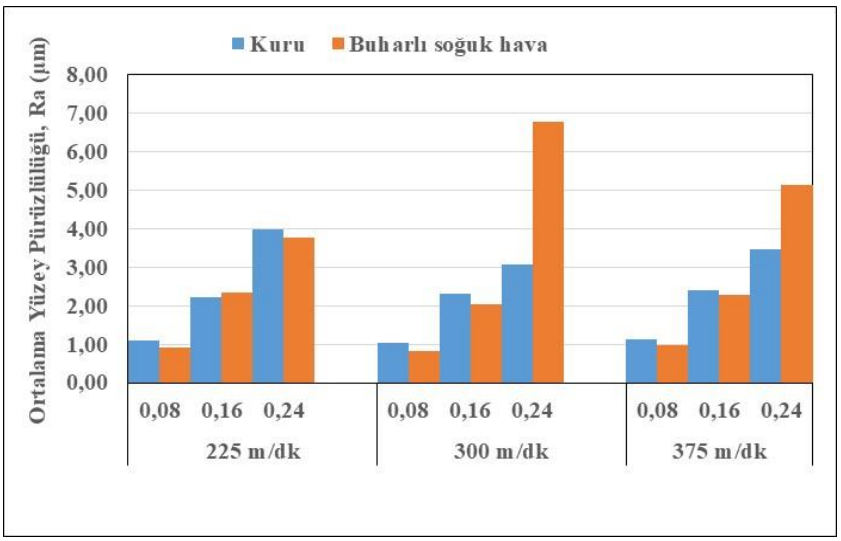
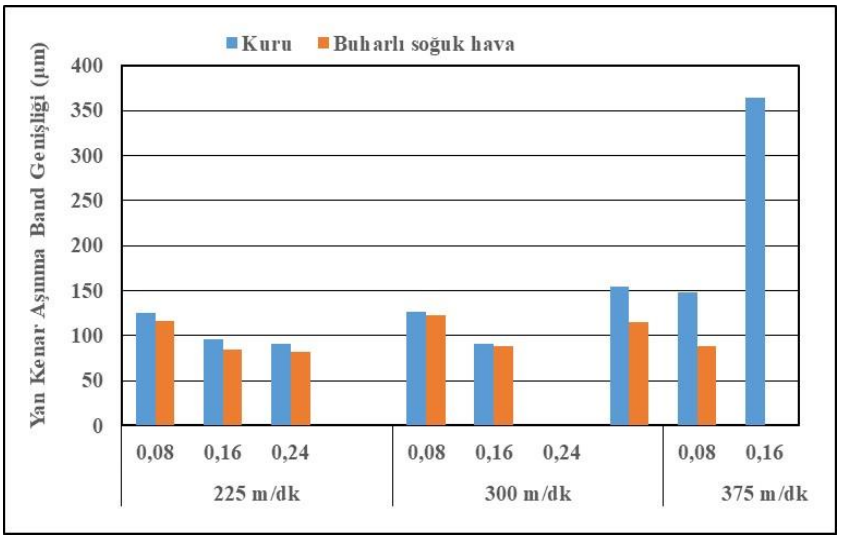


Görsel 6. Yüzey pürüzlülüğünün işleme şartlarına göre değişimi



Görsel 7. Kesici takımda oluşan yan kenar aşınma miktarının işleme şartlarına göre değişimi

225 m/dk kesme hızında basınçlı soğuk hava ile işlemede ilerlemenin artması ile aşınma miktarlarında azalma görülmüştür. İlerleme miktarındaki artış ile takım-iş parçası arasındaki temas süresinin azalması sıcaklık oluşumunu azaltmaktadır. Buharlı soğuk hava, kesme bölgesindeki sıcaklığı ve talaş sıvanmasını azalmakta bu da kuru işlemeye göre takım aşınmasında %7 ila %12 arasında bir azalmaya neden olmuştur. 300 m/dk kesme hızında takım aşınmalarında %12-%14 arasında bir azalma görülmüştür. Ancak her iki işleme şartında 0,24 mm/dev ilerleme miktarında kesici kırılmış ve takım ömrünü tamamlamıştır (Görsel 8). Benzer kırılma 0, 24 mm ilerleme miktarı ve 375 m/dk kesme hızında da görülmüştür. İlerleme miktarının artması ile kesme kuvvelerinde bir artış meydana gelir. Sermetlerin toklukları karbür takımlara göre daha düşük olduğundan yüksek ilerleme miktarlarında kesme kuvvetlerinin artmasıyla sermetlerde çatlak ve kırılmalar oluşabilir ve bu çatlaklar daha kolay ilerleyerek takım kırılmasına neden olur [27].

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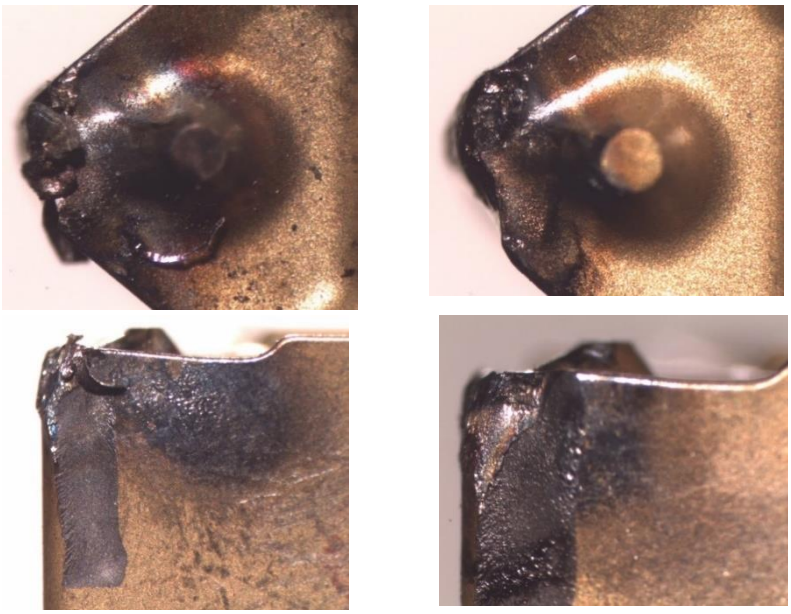
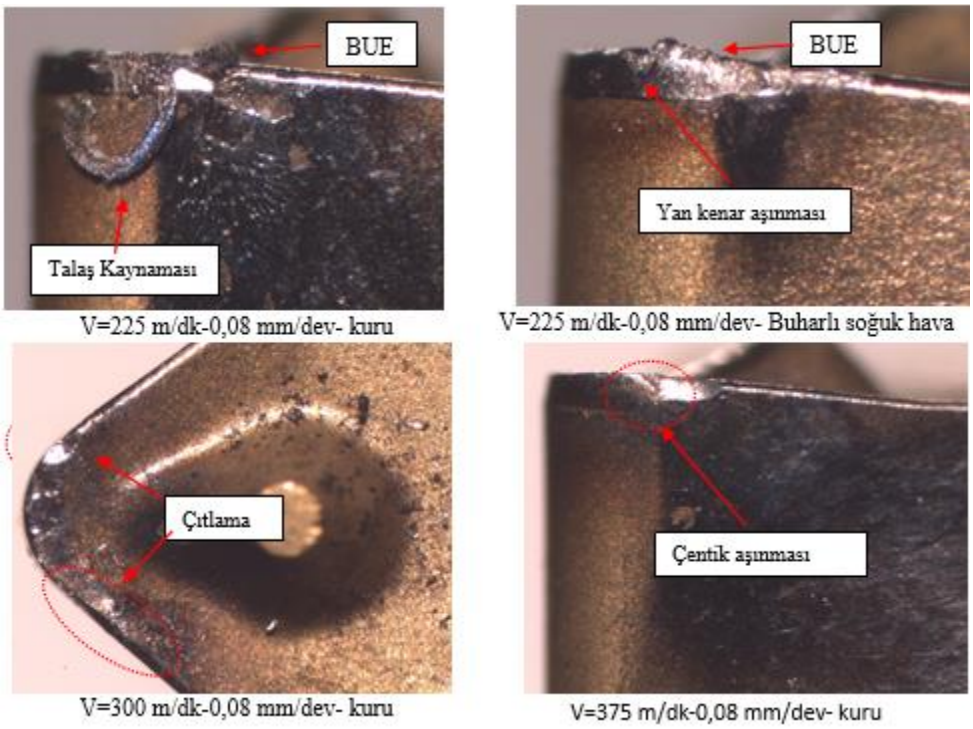


a) Kuru b) Buharlı soğuk hava

Görsel 8. 300 m/dk kesme hızı ve 0,24 mm ilerlemde takımda oluşan kırıklar.



Görsel 9. Sermet kesici takımda oluşan aşınma mekanizmaları ve tipleri

Sermet kesici takımlarda her iki işleme şartındaki performansları incelendiğinde takımlarda abresiv ve adhesiv aşınma mekanizmalarının oluştuğu görülmektedir. Düşük kesme hızı ve kuru işlemede yığıntı talaş oluşumu (BUE) görülürken buharlı soğuk hava ile BUE oluşumunda bir azalma görülmüştür. Kuru işleme şartlarında takımlarda makro kırılmalar daha fazla olduğu

görülmektedir. Yüksek işleme parametrelerinde her iki işleme şartında kesme kenarında çentik aşınması görülmüştür (Görsel 9).

4. SONUÇLAR

Böhler K490 çeliği farklı üç farklı kesme hızı ve ilerleme miktarlarında kuru ve buharlı soğuk hava şartlarında dış çap tornalama işleminde tabi tutulmuş ve tornalama işleminden sonra elde edilen yüzey pürüzlülük ve tornalamada kullanılan sermet kesici takımın performansı ve takımda oluşan aşınmalar incelenmiş ve elde edilen sonuçlar aşağıda belirtilmiştir.

- Her iki işleme şartında da ilerleme miktarının artmasıyla ortalama yüzey pürüzlülük değerlerinde genel olarak bir artış olduğu görülmüştür.
- En düşük yüzey pürüzlülüğü, kuru şartlarda 300 m/dk kesme hızı ve 0,08 mm/dev ilerleme ile işlemede ve buharlı soğuk hava ile işlemede 300 m/dk kesme hızı ve 0,08 mm/dev ilerlemede elde edilmiştir.
- En yüksek yüzey pürüzlülüğü değeri kuru işlemede 300 m/dk kesme hızı ve 0,24 mm/dev ilerleme miktarında 6,785 µm olarak ölçülmüştür.
- Genel olarak buharlı soğuk hava ile işlemede kuru işlemeye göre yüzey pürüzlülük değerlerinde bir azalma görülmüştür.
- Yüksek kesme hızı ve ilerleme miktarlarında kuru ve buharlı soğuk hava ile işlemede kesici takımlar kırılmıştır.
- Düşük kesme hızlarında kesici kenarda yığıntı talaş oluşumu, yüksek işleme şartlarında kesici takımlarda çentik aşınması görülmüştür.
- Buharlı soğuk hava yüzey pürüzlüğünü ve takım aşınmasını azalmasına katkı sağladığından alternatif bir soğutma yöntemi olarak uygulanabilir.

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16 EKİM 2024, KALE-MALATYA 5.9 (Mw) DEPREMİNİN YER HAREKETİ KAYITLARININ İNCELENMESİ

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ÖZET

Son yıllarda 2023 Kahramanmaraş, 2020 Elâzığ gibi yıkıcı depremlerden birçok şehrinin etkilendiği Doğu Anadolu bölgesinde 16 Ekim 2024 günü, Malatya'nın Kale ilçesi merkez üslü 5.9 Mw büyüklüğünde bir deprem meydana geldi. Bu deprem kısa süreli korku ve paniğe neden oldu. Meydana gelen deprem Malatya ve Elâzığ illerinin sınırında bir konumda meydana gelmesi nedeniyle Elazığ'da da şiddetli bir şekilde hissedilmiştir. Elâzığ ilinin yanı sıra Diyarbakır, Bingöl, Sivas gibi şehirler depremin hissedildiği illerin başında gelmektedir. İlk belirlemelere göre önemli can ve mal kaybına rastlanılmamıştır. Meydana gelen deprem nedeniyle Elâzığ ve Malatya'da bazı binalar kısmi olarak göçmüştür. Bazı yaralanmalar dışında resmi olarak bir can kaybı meydana gelmemiştir. Kahramanmaraş depremleri üzerinden çok uzun bir süre geçmemesi nedeniyle insanlar ciddi şekilde depremden etkilendiler. Büyüklük olarak orta büyüklükte bir deprem olarak nitelendirilebilecek depremin ivme değerleri ölçüm alan bazı istasyonlarda büyük değerler almıştır. Afet ve Acil Durum Başkanlığı'na (AFAD) ait istasyonlardan biri olan 4414 numaralı istasyonda ölçülen ivme değerlerinin 0.6 g mertebelerinde olduğu gözlemlenmiştir. Yapılan çalışmada 4414 numaralı istasyona ait davranış spektrumları ile Türkiye Bina Deprem Yönetmeliği 2018'de verilen tasarım ivme spektrumları DD1 ve DD2 yer hareketi seviyeleri için karşılaştırılmıştır. Elde edilen sonuçlara bakıldığında düşük periyot bölgelerinde DD2 yer hareket düzeyine ait spektrumların aşıldığı görülmektedir. Çalışma kapsamında meydana gelen deprem ile ilgili bilgiler verilmiş elde edilen sonuçlar gerekçeleri ile irdelenmiştir.

Anahtar Kelimeler: Kale Depremi, Yer Hareketi Kayıtları, Tasarım Spektrumu, Davranış Spektrumu, Deprem Gözlemi

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EXAMINATION OF GROUND MOTION RECORDS OF 16 OCTOBER 2024, KALE-MALATYA 5.9 (M_w) EARTHQUAKE

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ABSTRACT

On October 16, 2024, an earthquake with a magnitude of 5.9 Mw occurred with the epicenter of the Kale district of Malatya in the Eastern Anatolia region, where many cities have been affected by devastating earthquakes such as 2023 Kahramanmaraş and 2020 Elazig in recent years. This earthquake caused short-term fear and panic. The earthquake was also strongly felt in Elazig as it occurred on the border of Malatya and Elazig provinces. In addition to the province of Elazig, cities such as Diyarbakır, Bingöl and Sivas are among the provinces where the earthquake was felt. According to initial findings, there was no significant loss of life or property. Due to the earthquake, some buildings in Elazig and Malatya partially collapsed. Except for some injuries, there was no official loss of life. Due to the fact that it has not been a long time since the Kahramanmaraş earthquakes, people were seriously affected by the earthquake. The acceleration values of the earthquake, which can be described as a medium-sized earthquake in terms of magnitude, took large values at some stations that took measurements. It was observed that the acceleration values measured at station 4414, one of the stations belonging to the Disaster and Emergency Management Affairs(DEMA), were around 0.6 g. In the study, the behavior spectra of station 4414 and the design acceleration spectra given in the Turkish Seismic Code 2018 were compared for DD1 and DD2 ground motion levels. When the results are examined, it is seen that the spectra of DD2 ground motion level are exceeded in low period regions. Within the scope of the study, information about the earthquake was given and the results obtained were examined with their justifications.

Keywords: Kale Earthquake, Ground Motion Records, Design Spectrum, Response Spectrum, Earthquake Observation

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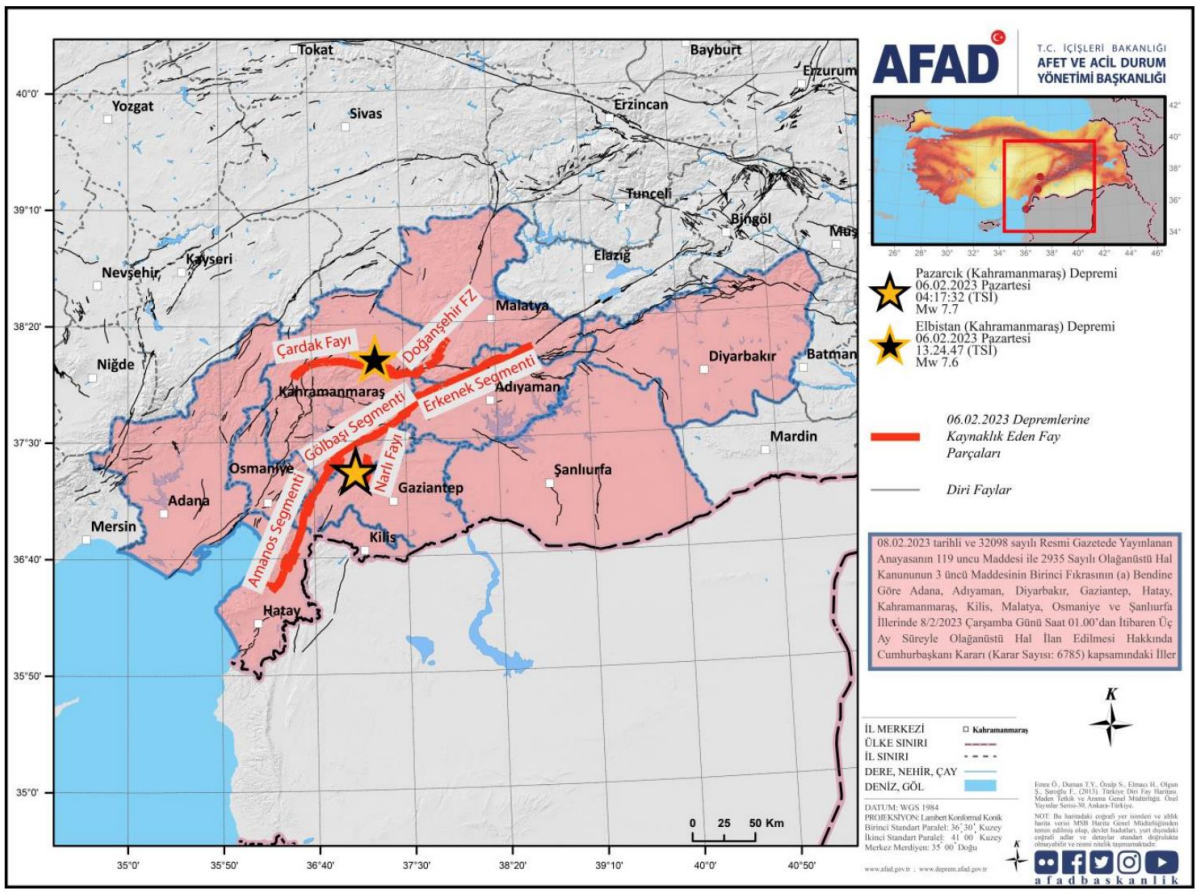
1. GİRİŞ

Son yıllarda meydana gelen en büyük depremlerden biri olan 6 Şubat Kahramanmaraş depremleri Türkiye'de önemli ölçüde can ve mal kayıplarına neden olmuştur[1–3]. Depremler sonrasında Türkiye'nin doğusu ve güneyinde yer alan 11 il depremden doğrudan etkilenmiştir. Yapısal hasar meydana gelen yapı sayısı 250.000 üzerindedir. Depremler kaynaklı can kayıpları resmi verilere göre 50.000 civarlarındadır[4]. 6 Şubat 2023 tarihinde meydana gelen Pazarcık ve Elbistan merkezli depremler Doğu Anadolu Fayı (DAF) ve kolları üzerinde meydana gelmiştir. Yerel saatle 04.17'de meydana gelen ilk deprem DAF ve Ölü Deniz Fay Zonu kesişiminde meydana gelmiştir[5]. Yine aynı gün içerisinde meydana gelen 13.24 yerel saatli Elbistan merkezli ikinci deprem DAF kollarından biri olan Çardak Fayında meydana gelmiştir (Görsel 1).



Görsel 1. 06 Şubat 2023 Kahramanmaraş depremler[5]

Bu iki depremin büyüklükleri sırasıyla 7.7 M_w ve 7.6 M_w olarak açıklanmıştır. Depremlerin büyüklüklerine bakıldığında ortaya çıkardığı etki tahmin edilebilmektedir. Bu derece büyük depremler önemli kayıplara ve önemli hasarlara neden olmakta ve büyük bir alanı etkilemesi beklenmektedir[6,7]. Bunun yanı sıra bu büyüklükteki iki depremin 9 saat gibi kısa bir süre içerisinde peş peşe meydana gelmesi deprem karakteristiklerini de önemli ölçüde etkilemektedir[8]. Özellikle depremler sonrasında meydana gelen artçı şok aktivitesinin yoğunluğunu ve zaman aralığını etkilemektedir. Kahramanmaraş depremleri sonrasında tek başına büyük deprem olarak ifade edilebilecek birçok artçı deprem meydana gelmiştir. Kahramanmaraş depremleri kaynaklı artçı şok aktivitelerinin yıllarca sürmesi beklenmektedir. Aşağıdaki Görsel 2'de verildiği gibi Kahramanmaraş depremlerinin artçı şok aktivitesi ve

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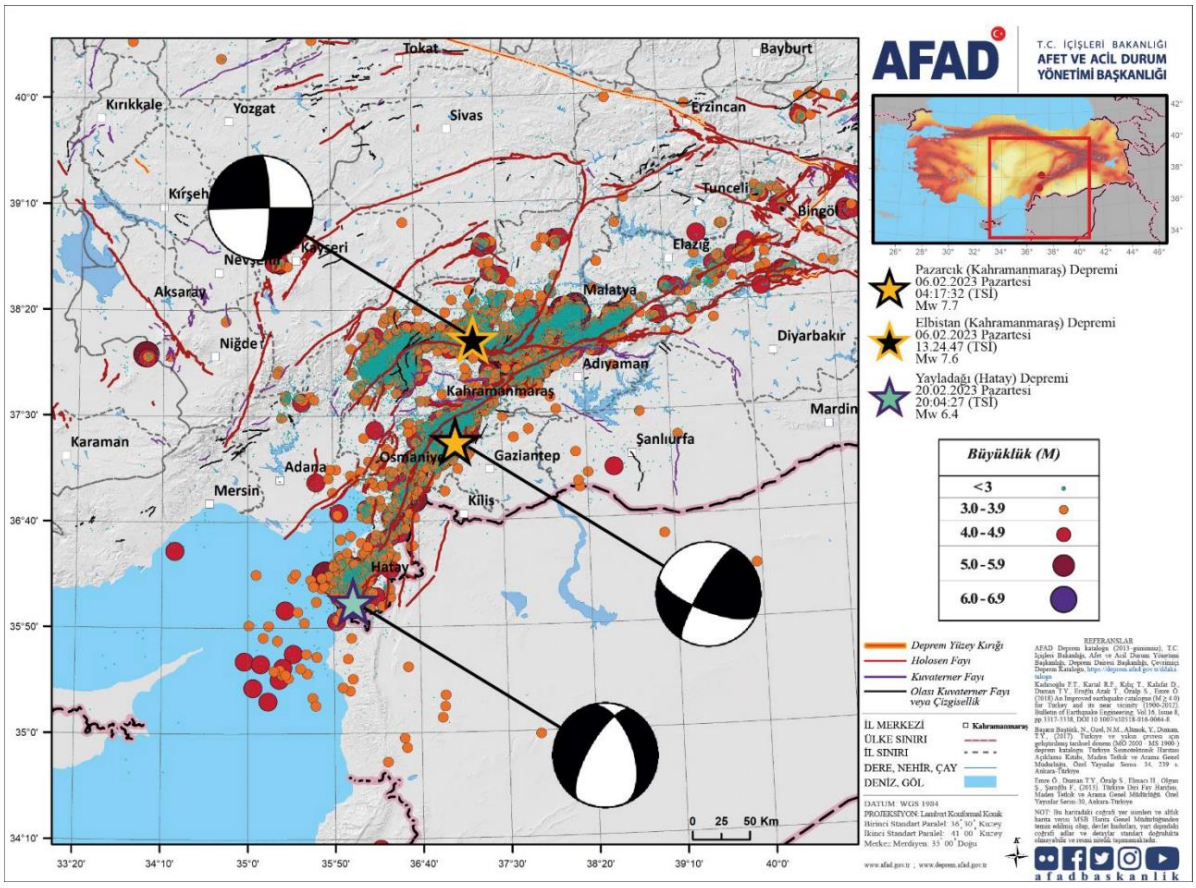
büyüklüklerin dağılımı görülmektedir. Görsel 3'te 6 Mayıs 2023 tarihine kadar meydana gelmiş artçı depremlerin haftalık dağılımı verilmiştir.



Görsel 2. Kahramanmaraş depremlerine ait artçı şok aktivitesi[5]

Görsel 3. Kahramanmaraş depremlerine ait artçı şok aktivitesinin haftalık dağılımı[5]

Yukarıda bahsedilen artçı şok aktivitelerine 16 Ekim 2024 tarihinde bir yenisi daha eklenmiştir. Bu çalışmada değerlendirilen artçı şok aktivitesi depremin meydana geldiği bölgede korku ve paniğe neden olmuştur. Yerel saatle 10.46'da meydana gelen depremin merkez üssü

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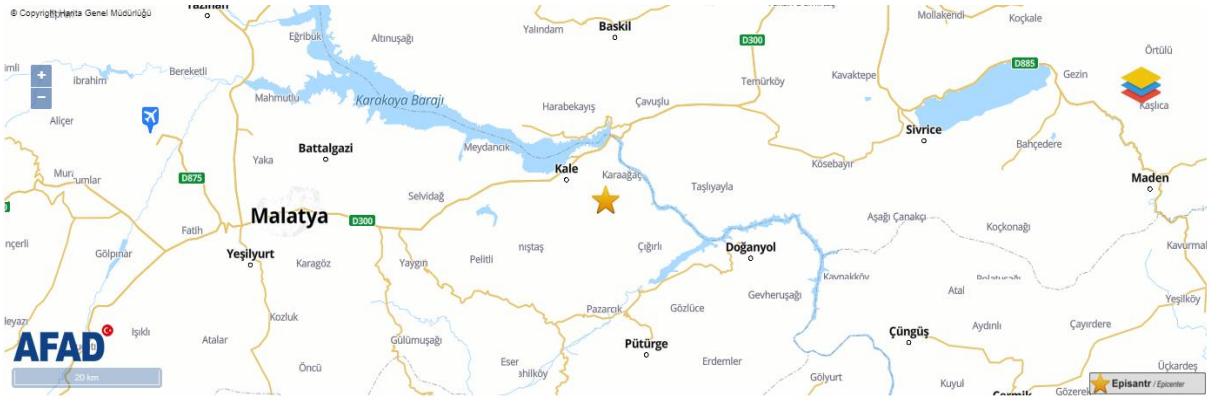
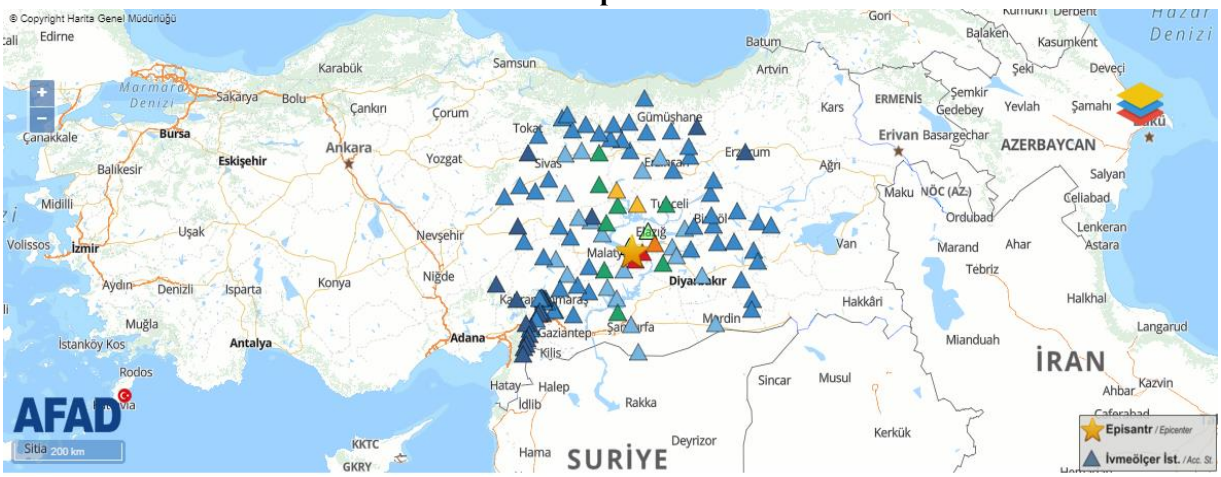
Malatya'nın Kale ilçesidir. Merkez üssü Karakaya baraj gölünün hemen güneydoğusunda yer almaktadır. Depremin büyüklüğü farklı istasyon ağlarına göre değişiklik göstermektedir. Kandilli rasathanesi 6.0 M_w, AFAD ise 5.9 M_w olarak açıklamıştır[9,10]. Gözlem istasyonlarının raporlarından elde edilen deprem ile ilgili bilgiler Çizelge 1 ve Çizelge 2'de verilmiştir. Meydana gelen deprem DAF üzerinde meydana gelmiştir. Yapılan ön incelemelerde meydana gelen depremin 6 Şubat 2023 Kahramanmaraş depremlerinin artçısı olduğu belirtilmektedir[10]. Artçı bir deprem olmasına rağmen deprem, meydana geldiği bölgede önemli ölçüde hissedilmiştir. Görsel 4 depremin meydana geldiği merkez üssüne ait haritayı göstermektedir. Görsel 5 ise depremin meydana gelmesi sonrasında kayıt alan AFAD istasyonlarını ve konumlarını göstermektedir.



Görsel 4. Kale Depremi merkez üssü



Görsel 5. Ölçüm alan AFAD istasyonları ve konumları[11]

Çizelge 1. Kandilli Rasathanesi'ne göre depreme ait bilgiler

Tarih	Saat (TSİ)	Enlem	Boylam	Derinlik	Büyüklük
16.10.2024	10:46:30	38.3410 K	38.8155 D	6.5 km	6.0 (M_w)

Çizelge 2. AFAD tarafından açıklanan depreme ait bilgiler[12]

Tarih	Saat (TSİ)	Enlem	Boylam	Derinlik	Büyüklük
16.10.2024	10:46:31	38.3658 K	38.8086 D	10.48 km	5.9 (M_w)

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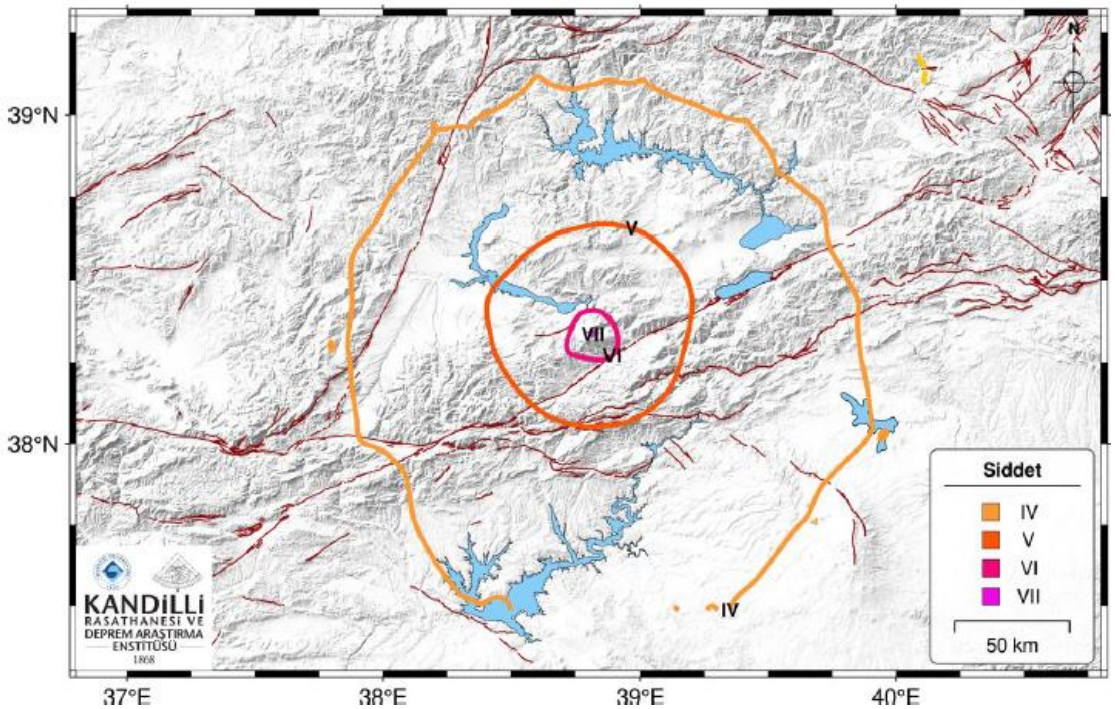
Verilen bilgiler ışığında Kahramanmaraş depremlerinin artçı şoklarından biri olan Kale Depremine ait bilgiler bu çalışma kapsamında değerlendirilecektir. Ölçüm alan istasyonlardan 4414 ve 2311 no'lu istasyonlardan elde edilen deprem verileri incelenerek depremin etkileri irdelenecektir. Elde edilen sonuçlar gerekçeleri ile açıklanacaktır.

2. KALE DEPREMİNİN YER HAREKETİ KAYITLARI ÜZERİNDEN DEĞERLENDİRİLMESİ

16 Ekim 2024'de meydana gelen Kale Depremi, depremin merkez üssüne yakın bölgelerde önemli ölçüde hissedilmiştir. Görsel 6'da verilen şiddet haritası incelendiğinde, şiddet seviyesi VI ve VII küçük bir alanda etki etsede V şiddet seviyesi Malatya ve Elazığ şehir merkezlerine yakın bölgeleri kapsamaktadır. IV şiddet seviyesi ise çevre illerde deprem düşükte olsa hissedildiğini açıklamaktadır.



Görsel 6. Kale depremine ait şiddet haritası[9]

Çalışma kapsamında merkez üssüne yakın iki adet istasyona ait veriler incelenmiştir. AFAD istasyonlarından olan 4414 ve 2311 numaralı istasyonlar çalışmada kullanılmıştır. İstasyon sonuçları incelendiğinde 4414 numaralı istasyon merkez üssüne en yakın olan istasyondur. 2311 numaralı istasyonun kullanılmasının nedeni Elâzığ ilindeki etkinin incelenmesidir. 4414 no'lu istasyon incelendiğinde Doğu-Batı doğrultusuna ait kayıtlarda en büyük yer ivmesi 0.61g olarak ölçülmüştür. Kuzey-Güney doğrultusunda ölçülen değerler 0.43g olduğu görülmektedir. Görsel 7 incelendiğinde ivmelere kıyasla deplasman geçmişleri düşük değerler almaktadır. 2 cm civarında ölçülen deplasmanlar yapısal hasar açısından düşük değerlerdir. Ayrıca, Görsel 7'de verilen Arias yoğunlukları depremin etkili süresi ile ilgili fikir vermektedir. Bakıldığında depremin etkili süresi iki doğrultu için 3-4 saniye dolaylarındadır. Bu depremin etkisinin kısa süreli olduğunu göstermektedir.

Deprem sonrasında yapılan saha çalışmalarında, kamu kurumları birkaç yapı dışında önemli yapısal hasara rastlanmadığını açıklamışlardır. Bu durumun depremin çok büyük etkisinin

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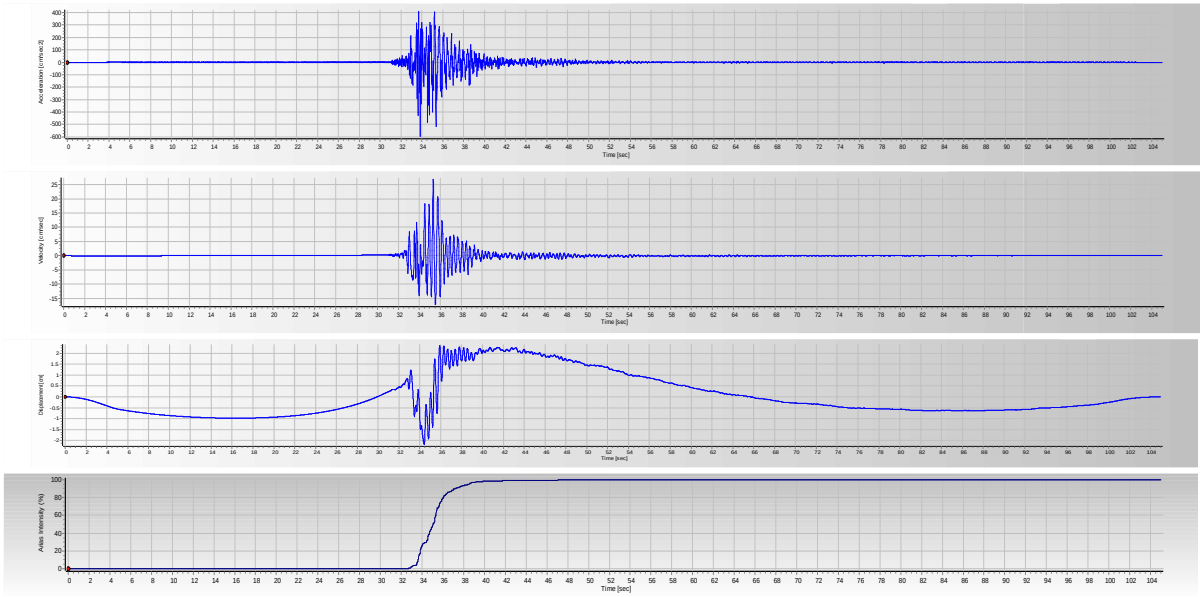
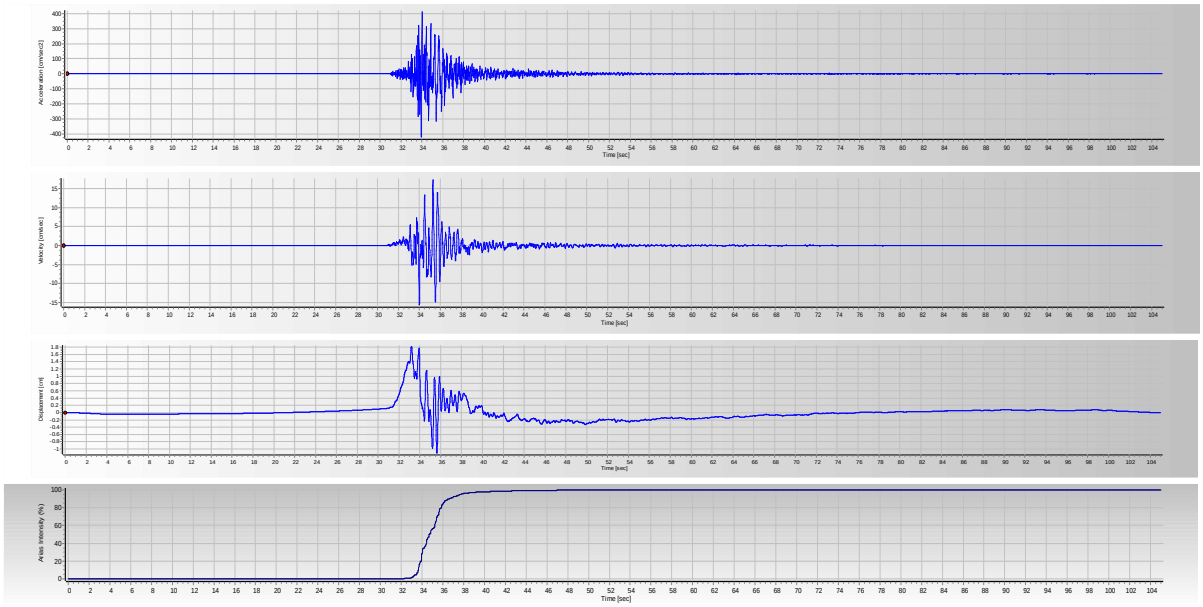
kentlileşmenin yüksek olduğu bölgelerde düşük etkiler göstermesinden kaynaklanmaktadır. Yanı sıra, bölgede 2020 Elâzığ ve 2023 Kahramanmaraş depremleri sonrasında, hasarlı yapılar yenilenmiş ya da yıktırılarak yapı stoklarının deprem direnci artırılmıştır[13]. Bu durum, bu derece büyük artçılarda yapılarının minimum etkilenmesine fayda sağlamaktadır.

Görsel 8, aynı şekilde 4414 no'lu istasyonun Kuzey-Güney doğrultusuna ait kayıtlar hakkında bilgiler vermektedir. İvme geçmişleri diğer doğrultuya göre düşük kalmaktadır. Bu grafiklere bakıldığında depremin etkili yönünün Doğu-Batı doğrultusunda olduğu söylenebilir. Yine deplasmanlar düşük değerlerde kalırken, etkili süreyi gösteren Arias yoğunlukları[14] 3 saniye civarlarındadır. Görsel 7,8 ve 9 Seismosignal yardımıyla elde edilmiştir[15].



Görsel 7. 4414 no'lu istasyona ait Doğu-Batı doğrultusundaki kayda ait ivme, hız, deplasman zaman geçmişleri ve Arias yoğunlukları



Görsel 8. 4414 no'lu istasyona ait Kuzey-Güney doğrultusundaki kayda ait ivme, hız, deplasman zaman geçmişleri ve Arias yoğunlukları

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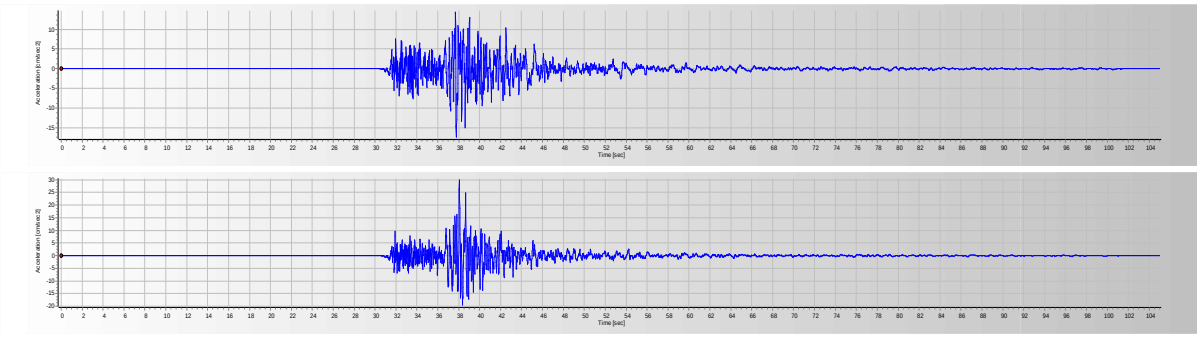
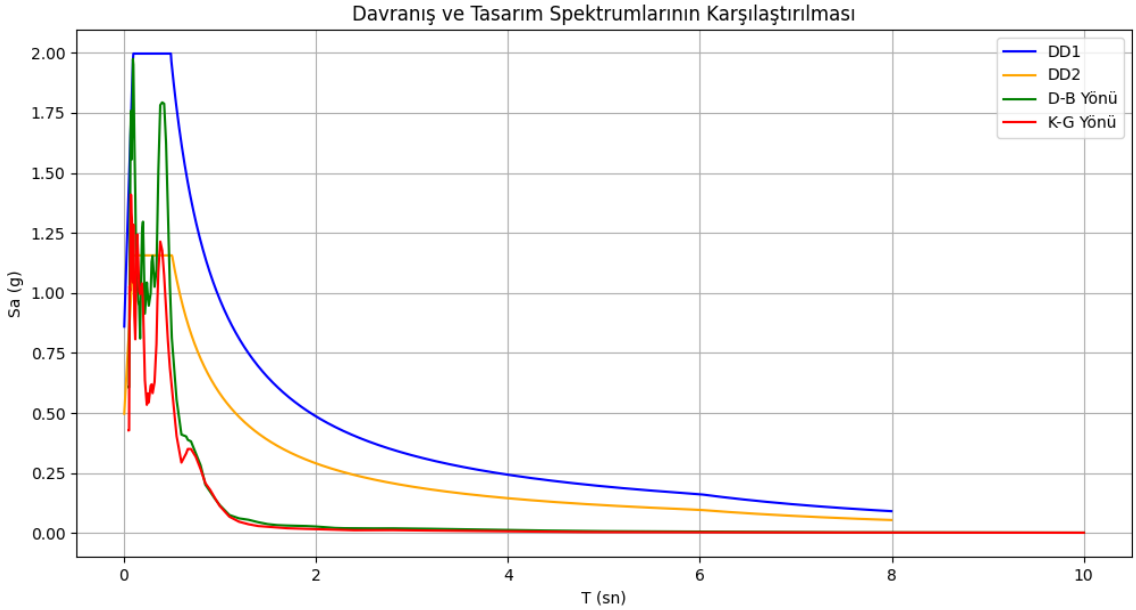
Görsel 9 ise çalışmada incelenen diğer istasyon olan 2311 no' lu istasyona ait iki doğrultudaki ivme-zaman geçmişlerini vermektedir. Görsel 9 incelendiğinde, 4414 no' lu istasyona kıyasla çok düşük ivme değerlerinin 2311 no' lu istasyonda ölçüldüğü görülmektedir. Bu durum Elâzığ şehir merkezindeki yapıların olumsuz etkilenmemesini açıklayan sonuçlardan biridir.



Görsel 9. 2311 no'lu istasyona ait Doğu-Batı ve Kuzey-Güney doğrultusundaki kayda ait ivme zaman geçmişleri

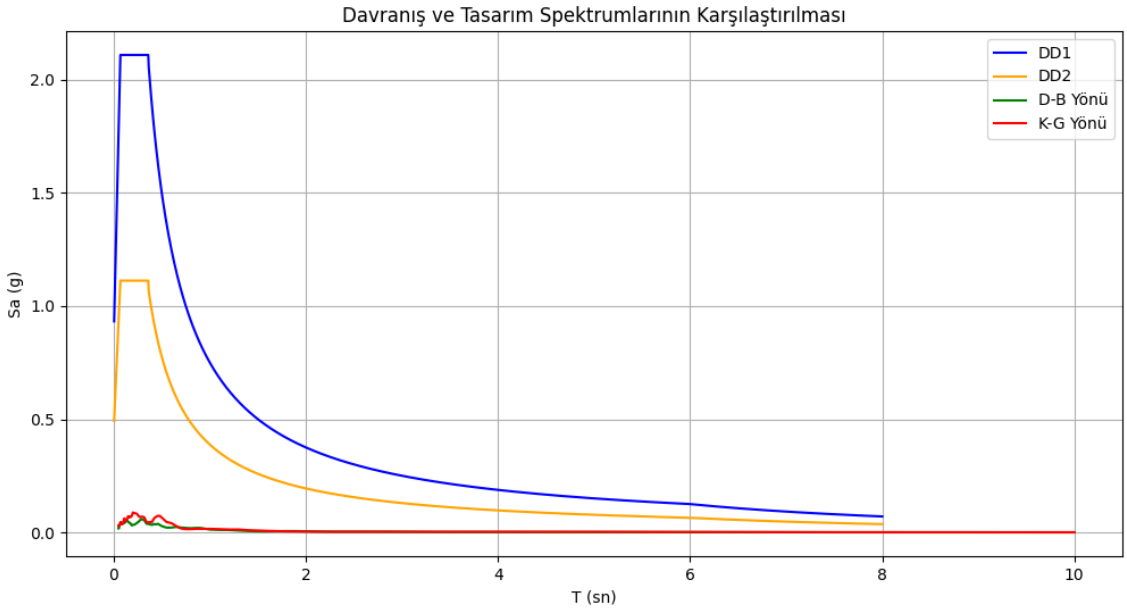
3. SONUÇLAR VE DEĞERLENDİRME

Çalışma kapsamında depremin yapılara etkisinin incelenmesi amacıyla deprem kayıtlarının alındığı istasyonlara ait iki doğrultudaki ivme kayıtlarından elde edilen tepki spektrumları hazırlanmıştır. Bunun yanı sıra tepki spektrumlarının değerlendirilebilmesi için Türkiye Bina Deprem Yönetmeliği 2018'de verilen tasarım spektrumları elde edilmiştir. 2 yer hareket düzeyi için elde edilen tasarım spektrumları ve deprem kayıtlarına ait tepki spektrumları 4414 istasyonu için Görsel 10'da verilmiştir. DD1, tekrarlanma periyodu 2475 yıl olan deprem yer hareket düzeyini ifade ederken, DD2 ise 475 yıl tekrarlanma periyoduna sahip standart deprem yer hareketini ifade etmektedir[16–18]. Görsel 11 ise 2311 istasyonuna ait deprem tepki ve tasarım spektrumlarını göstermektedir.



Görsel 10. 4414 no'lu istasyonu için davranış spektrumları ile tasarım spektrumlarının karşılaştırılması

Görsel 10 incelendiğinde, Doğu-Batı(D-B) ve Kuzey-Güney(K-G) doğrultularına ait tepki spektrumları kısa periyot bölgelerinde DD2 yer hareket düzeyine ait tasarım spektrumlarını aşmaktadır. D-B doğrultusundaki ivmelerin yüksek olması spektral ivme parametrelerini de etkilemektedir. Depremin artçı bir deprem olması, kısa periyot bölgelerinde aşılmaların meydana gelmesi ve depremin etkili süresinin kısa olması, deprem sonrası çevre şehirlerde yapısal hasarların ileri seviyede olmamasını açıklamaktadır. Ancak, kısa periyotta etkin olan depremin özellikle kırsal bölgelerde mühendislik hizmeti almamış olan 1-2 katlı köy tipi yapılarda hasarların meydana gelebileceği ihtimalini göstermektedir. Yapılan çalışmalar, depremden etkilenen yapıların kat sayılarının, depremin periyodu ile örtüşmesi durumunda hasarın derecesini etkilediğini göstermektedir[19].



Görsel 11. 2311 no'lu istasyonu için davranış spektrumları ile tasarım spektrumlarının karşılaştırılması

Görsel 11 ise, Elâzığ şehir merkezine yakın bir istasyon olan 2311 istasyonuna göre elde edilmiş spektrumların karşılaştırmasını göstermektedir. Spektrumlar incelendiğinde, davranış spektrumları her iki doğrultuda yönetmelik koşullarının altında kalmaktadır. Yönetmeliğe göre hazırlanan tasarım spektrumlarının aşılmaması, yapısal hasarların bölgede yayılmamasının göstergesidir[20]. Yönetmelik koşulları gözetilerek tasarlanan yapılarda bu deprem kaynaklı yapısal hasarın meydana gelmesi beklenen bir durum değildir. Ancak bazı yapılarda depremin oluşturduğu salınım kaynaklı yapısal olmayan sıva, duvar çatlağı gibi durumlara rastlanabilir.

4. GENEL DEĞERLENDİRME VE SONUÇLAR

Kahramanmaraş Depremleri ülkemizi maddi ve manevi olarak önemli ölçüde etkileyen depremlerden biridir. Meydana gelen kayıplar ve etkileri uzun yıllar devam edecektir. Bu etkilerden biri de artçı depremlerdir. Depremlerin büyüklüğü nedeniyle meydana gelecek artçıların meydana gelme süresi, sıklığı ve büyüklüğü fazla olmaktadır. Depremlerin üzerinden neredeyse 2 yıl geçmesine rağmen 16 Ekim 2024'te meydana gelen Kale Depremi bu depremlerin artçısı olarak nitelendirilebilir. DAF üzerinde meydana gelen bu deprem bölgede hissedilmiştir. İleri seviyede olmasa da bazı hasarlara neden olmuştur. Elde edilen sonuçlar

incelendiğinde merkez üssüne yakın olan 4414 istasyonu büyük ivme değerleri ölçmüştür. Ölçülen ivme değerleri, D-B doğrultusunda 0.61g'dir. Bu değer bölgede meydana gelmiş büyük olarak nitelendirilen depremlerle aynı etkide olduğunu göstermektedir. Tasarım ve davranış spektrumları incelendiğinde ise 4414 istasyonuna ait verilere göre DD2 yer hareket düzeyine ait spektrumlar aşılmaktadır. Ancak aşılma bölgesi kısa periyot bölgesine denk gelmektedir. Ayrıca incelenen diğer istasyon olan 2311 istasyonuna ait değerler depremin etkisinin Elazığ'da düşük kalmasını göstermektedir. Ancak, bu deprem sonrasında kırsal bölgelerde yaygın olarak yer alan düşük katlı yapıların incelenmesi gerektiğini göstermektedir. Depremler sonrasında alınan önlemlerin, riskli yapıların mevcut yapı stoku içerisinden temizlenmesi gibi durumların, Kale depremi gibi artçılarda hasar seviyesinin düşük kalmasını sağlamaktadır. Mevcut yapı stoklarımızın deprem direnci yüksek ve depreme hazır yapılardan oluşması deprem zararlarının en aza indirgenmesine fayda sağlamaktadır.

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EXAMİNATİON OF TRANSPORTATİON PROJECTS PLANNED TO BE CONDUCTED İN BURSA İN TERMS OF FEASİBİLİTY AND APPLİCABİLİTY

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ABSTRACT

With the development of cities, there is a constant increase in the number of people coming from rural areas to big cities. When irregular migration is added to this increase, the problems in the cities are both diversified and increasing day by day. Bursa is the 4th largest city in Turkey in terms of population and is also a bridge in terms of access to other provinces. Due to this important position of Bursa, there is constant migration to Bursa and these migrations bring many problems with them. One of the most important problems of Bursa is the transportation problem. There is no doubt that local and central administrators are looking for solutions to these problems. It is obvious that the projects planned to be carried out in order to find a solution to the traffic problem in Bursa will produce solutions to some problems. However, some of the projects considered as solutions will not contribute to producing the expected solution. In this study, the studies planned to be carried out in the province of Bursa in the coming years are examined and information is provided about them. The positive and negative aspects of these planned studies that will affect the transportation problem of the city if they are carried out are explained.

Key Words: Bursa, Traffic Problem, Traffic Solution, Transportation Projects

1. INTRODUCTION

The increase in migration from rural areas to metropolitan areas brings with it many problems. The most important of these problems is transportation problems. With the migration of people to metropolitan areas, new employment areas are created, and generally no effort is made to access these areas at first. In fact, the first thing to do should be to build roads to reach new industrial areas and then build industrial areas. However,

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when this situation is reversed, traffic-related problems occur. Undoubtedly, transportation-related problems do not only arise from the reasons stated above. When the increase in people's transportation demands is added to the increase in car ownership, the transportation problem in metropolitan areas turns into chaos.

In addition to the fact that these negativities experienced in traffic cause a decrease in the national wealth of the country, traffic also has a negative effect on people who lose hours of time. As the time spent in traffic increases, people have less time for their social lives, and it has a negative impact on people's emotional world. Meeting people's social and cultural needs and trying to provide people with a more livable life are among the duties of administrators.

Bursa province is also one of the cities that has received serious migration in recent years. Bursa's population has almost doubled in the last 20 years; this population increase has been followed by unplanned urbanization, and many problems have emerged throughout the province. The transportation problem is the most important of these problems. Traffic congestion is experienced on almost all main roads at the beginning of working hours throughout Bursa province, and people make serious efforts to reach their workplaces on time.

Despite these negativities, both central and local administrators are trying to find solutions to many problems of the city, as well as to the problems experienced in the field of transportation. Although they have presented many ideas and projects for this purpose, the feasibility of some projects or their usability after they are completed is debatable.

Within the scope of this study, transportation projects planned to be carried out in Bursa province were examined. The problems that may be experienced in the routes where these projects will be carried out, the positive and negative aspects of the routes were expressed. Alternative suggestions for these projects were presented and compared with the planned projects.

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2. RESEARCH FIELD

2.1. Bursa Province

Bursa province is like a bridge connecting three regions. In addition to being the door of Istanbul to the Aegean and Mediterranean regions, it also opens up to the Central Anatolia region with its proximity to Ankara (Figure 1).

Figure 1. The Location of Bursa [1]

In addition to this geopolitical position of Bursa, the fact that it also has international ports increases its importance. Furthermore, being an important cultural and tourism city causes tourists to visit.

There are also 3 important automotive factories in Bursa and a significant number of people work in this sector. Bursa is the leading city in Turkey not only in the automotive sector but also in the textile industry. There are approximately 4,100 textile and ready-made clothing companies operating in a total of 18 organized industrial zones and 1 free zone in Bursa [2].

3. PROJECTS PLANNED TO BE BUILT

3.1. Mimarsinan- Arabayağı Funicular Line

The planned funicular line project between Mimarsinan-Arabayatağı is meaningful. However, it has not been clearly shared with the public on how this project will be done. However, the feasibility of this project is not very realistic. Because it is clear that one of the destinations of the funicular line should be the university station of the light rail system. When we consider that the other destination should be Şevket Yılmaz State Hospital, it is seen that construction activities cannot be carried out in the place where the line will pass (Figure 2).

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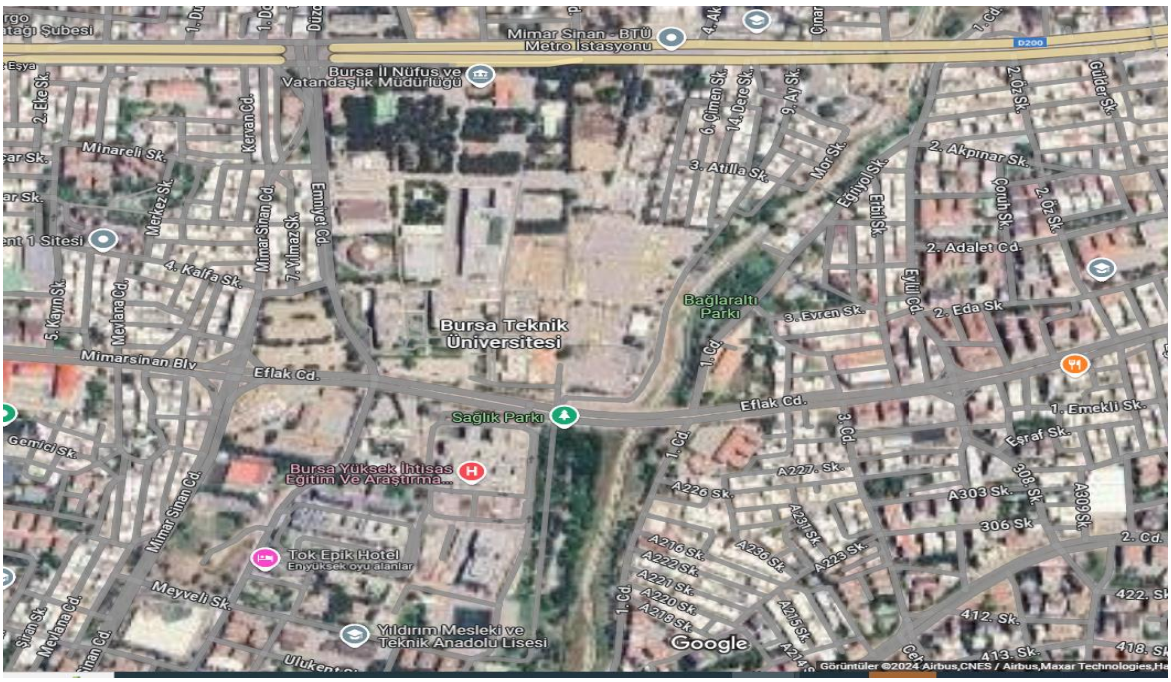

Figure 2. Mimar Sinan Tram Station [3]

3.2. Route Study Between Kestel and Teferrüç

With the new highway line work to be done in this region, an alternative will be created to the Ankara road, which carries a large burden of the city's traffic, and thus the traffic load will be reduced (Figure 3). However, the route of the road to be built in this region should be chosen carefully. Because the region is at the foot of the mountain, factors such as the road slipping and being subject to landslides should be taken into consideration, and since it will pass through a residential area, expropriation costs should be taken into account.

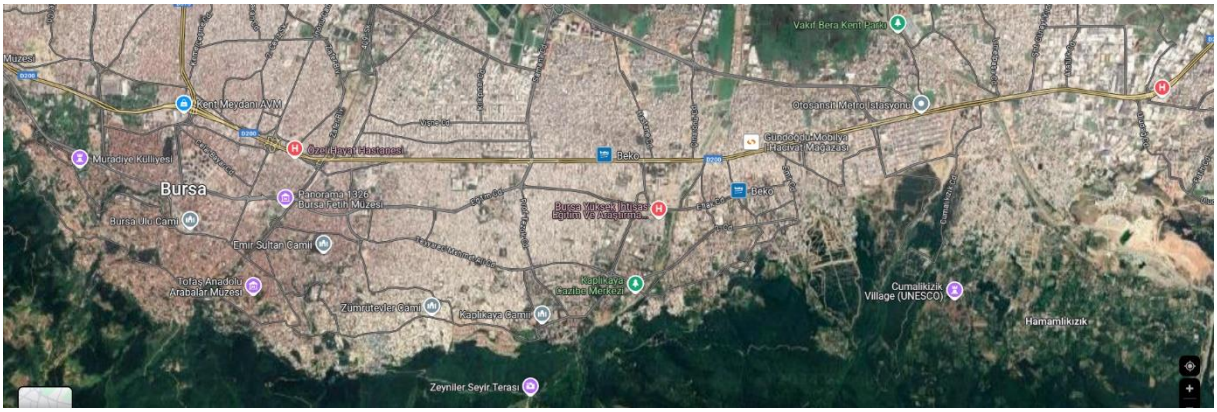

Figure 3. Kestel-Teferrüç Highway Route [3]

3.3. Acemler's Connection to the Ring Road Project

Acemler junction is almost like a bridge connecting the east and west of the city. People in the eastern part of the city, where the workforce is more, need transportation to the two large

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organized industrial zones (Organized Industrial Zone and Small Industrial Zone) located in the west of the city every morning. In this case, Acemler junction, where all the traffic of the city gathers and then splits into Mudanya and Izmir directions, creates a serious traffic load. For this, it is essential to distribute the traffic load created by people who will go to Mudanya and Izmir or come from these directions and go to the city center. For this reason, the viaduct solution planned as an alternative is a suggestion that will reduce the traffic load (Figure 4).

Figure 4. The Location of Acemler Intersection [3]

3.4. Görükle-Başköy Tram Line Project

The city has expanded significantly westwards, especially in the last 20 years, and new settlements have emerged in these areas. Settlements that were villages 20 years ago have been opened to construction and have virtually turned into concrete zones in the last 20 years. Görükle, which is a neighbor to Uludağ University, has undergone a major transformation in the last 20 years, with its population increasing almost 10-fold. The vast majority of students live in this area, and they demand transportation in the direction of the University in the morning and in the direction of Görükle in the evening. For this reason, the Görükle University line, which will be extended, is a project that should be in place for the region (Figure 5).

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Figure 5. Görükle-Başköy BursaRay Route [4]

4. RESULTS VE DISCUSSION

Bursa has shown excessive growth and development, especially in the last 20 years. Moreover, the population has increased. Unfortunately, this increase in population has not been followed by the number of projects in the city in a similar way. Consequently, problems have emerged in every area in the city; the traffic problem has been at the forefront of these problems. Local administrators have sought solutions to solve the traffic and transportation problem and have found solutions from time to time. This study touches on the projects planned for the coming years and emphasizes the shortcomings of these projects. In particular, the University-Görükle-Başköy light rail line project needs to be carried out and this project should be implemented as soon as possible. The other planned Acemler viaduct project is also a meaningful project since it will ease the traffic at the Acemler junction and will ease the traffic density of the city if it is carried out.

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DETERMINATION OF POINT BASED LIQUEFACTION POTENTIAL FOR KARŞIYAKA DISTRICT OF İZMIR PROVINCE

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ABSTRACT

Having sufficient knowledge, data and foresight about the behavior and mechanisms of soils according to soil types is of great importance in preventing irreversible damage. Although the basic mechanism of soil liquefaction is known, in many regions it causes negative consequences after a possible earthquake or dynamic movement as a result of inadequate behavior definitions and calculations. Within the scope of this study, regional-based geotechnical investigations were carried out in Karşıyaka district of İzmir province, sufficient data were collected and liquefaction analysis was performed and evaluated regionally. Data obtained from SPT tests and field experiments made by the ground company were used. Acceleration-time graphs used in the static project are given. The region has been evaluated in terms of its liquefaction risk. Within the available data and as a result of the analyses, it has been determined that this region is at risk of liquefaction. Envisaged improvement methods are stated. At the same time, information and analysis solutions regarding the structure to be built on it were shared.

Keywords: Acceleration, Regional Liquefaction, Risk Assessment, Soil Type.

1. INTRODUCTION

Liquefaction is an issue that causes collapse of the foundations of buildings, sliding problems on slopes or collapse of structures such as bridges, and has been studied by many researchers for many years, and its causes and solution methods have been investigated [1-4]. Seed and Idriss (1967) examined in detail the liquefaction that occurred in sand after the Niigata earthquake in Japan [5]. The liquefaction mechanism is based on the sudden increase of excessive pore water pressure in undrained conditions in the presence of a dynamic effect of water-saturated cohesionless soils, causing the effective stress to drop to a very small value or in some cases to zero, and as a result, the soil loses its bearing capacity. Liquefaction mechanisms may differ in terms of definition. Cyclic mobility, preliquefaction, microscopic liquefaction, sand boiling and steady state are among the definitions mentioned. Many

parameters such as the threshold intensity of the earthquake, the depth of the ground with liquefaction potential, the location of the groundwater level, the compactness of the ground, the fine grain ratio, overconsolidation ratio and the plasticity rate of the ground affect liquefaction (Table 1). Records show that liquefaction is not observed in earthquakes with magnitude 5 and intensity less than 6 [6]. It has been determined that the average depth in soils where liquefaction occurs is not more than 15m [7]. Studies have shown that as the fine grain ratio in the soil increases, the liquefaction potential decreases [8, 9].

Table 1. Basic Properties of Liquefiable Soils [6, 7]

Properties	Value
Fine grain (d<0.005 mm) content	Less than 10%
Uniformity coefficient	$(d_{60}/d_{10}) < 10$
Plasticity Index	Ip < 10
Average grain size	d50 = 0.02-1.00 mm

Day (2002) emphasized that in order for liquefaction to occur, the soils to be liquefied must be below the groundwater level and saturated. Additionally, it has been stated that the grain shape of the soil also affects the liquefaction potential, and that round grains have a higher liquefaction potential as they can be compressed more easily than square ones [10]. After liquefaction, damage to the structure supported by the ground usually occurs in the form of overturning or tilting on its side [11]. In triaxial pressure tests, under undrained conditions, the ratio of the change in the pore water pressure of the ground, which is in the direction of increase, to the change in the cell pressure is expressed by the B parameter (Eq.1).

$$\frac{\Delta u}{\Delta \sigma 3} = \frac{1}{1+\frac{nCv}{Csk}} \tag{1}$$

From Equation 1, where C_{sk} represents the porosity, C_{sk} represents the compression of the soil skeleton, and C_v represents the compression of the void present within the soil. In water-saturated soils, B coefficient is equal to 1 [12]. It is known that there are many expressions, situations and mechanisms that define liquefaction and that improvement is required for areas with liquefaction potential. In this study, a regional liquefaction risk assessment was conducted for Karşıyaka district of İzmir province. After the liquefaction risk assessment, the data and results of the structure to be built are also presented within the scope of this study. Maximum

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acceleration values obtained from seismic free field analysis were used in liquefaction analysis. An improvement method was proposed for depths with liquefaction potential, and after this stage, the results of the static analysis of the structure were shared using the data of the structure to be built on the ground.

2. MATERIAL AND METHODS

The soil parameters used in this study were determined as a result of experiments such as sieve analysis, Atterberg limits, water content, unit volume, weight, hydrometer, specific gravity and triaxial pressure test made by the soil company.

Figure 1: Survey Area Location Map

As for the soil type, CL, SC, CH, SM, ML soils were encountered along the drillings. The dominant soil type in the region was determined as clay. Drillings were continued to a depth of 30 m. The underground water level is at 8 m. Since the average SPT value of the land is determined as 16 and the number of SPT pulses (N60)30<15 according to TBDY 2018 Table 16.1, considering the shear wave speed Vs30=304 m/sec, ZD can be selected as the local soil class. Since there is a sand layer, the soil class is determined as ZF. The impact numbers from SPT tests samples taken from the field are given in Table 2.

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Table 2. SPT-N_{30} Data Obtained from Boreholes Made by The Soil Company

H	SK1	SK2	SK3
1.5	6	9	-
3.0	9	-	8
4.5	8	7	8
6.0	-	8	11
7.5	13	12	13
9.0	20	25	12
10.5	16	22	25
12.0	14	17	18
13.5	12	12	11
15.0	11	10	10
16.5	19	23	18
18.0	18	29	19
19.5	20	30	24
21.0	32	37	35

Graphs of the elastic design spectral acceleration (S_{ae}) and the reduced spectral acceleration (S_{aR}) obtained as a result of the ratio of this coefficient to the earthquake reduction coefficient are given in Figure 1.

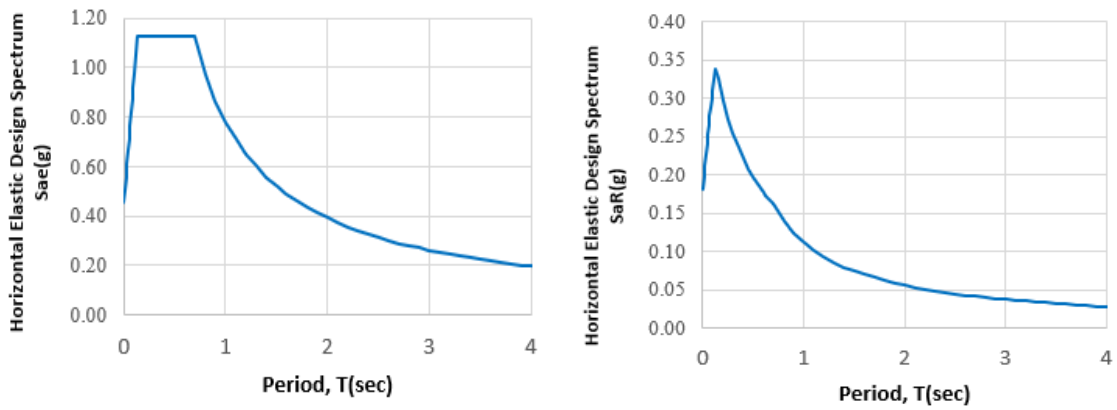

Figure 2. Horizontal Elastic Response Spectra for DD2

It is also site-specific earthquake spectra. New spectra were obtained by integrating 11 scaled earthquakes into the ground profile. For this building, the horizontal elastic spectrum starting from T=0 s with an interval of 0.05 up to T=4 s was calculated with the help of Excel. Table 3 gives the data that will be used in the static project of the building to be constructed after soil improvement with jet grout.

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Table 3. Parameters Used in The Static Project

Parameters	Symbol	Value
Shear Wave Velocity	Vs_{30}	304.10
Max.Ground Acceleration	PGA	0.450
Max.Ground Speed	PGV	27.182
Short Period Map S.Acceleration Coefficient	S_s	1.104
Period Map S.Acceleration Coefficient	S1	0.27
Design Spectral Acc. Coef. (Short Per.)	SDS	1.130
Design Spectral Acceleration Coefficients	SD1	0.780
Local Ground Class	YZS	ZF
Earthquake Design Class	DTS	DTS-1
Building Usage Class	BKS	BK3-1
Building Importance Coefficient	I	1.00
Earthquake Ground Motion Level	DD	DD2

3. RESULTS

Within the scope of this study, a small-scale regional liquefaction risk assessment was conducted for Karşıyaka district of İzmir province. For soil at risk of liquefaction, jet grout method, one of the improvement methods, and details of its calculations are given. Basic information about the project to be built on the improved ground is included. As a result of the liquefaction analysis performed according to TBDY-2018 (Seed and Idriss 1971 and Youd et al. 2001 Methods), the risk of liquefaction was determined between 6 and 12m and at the 15th m (Table 4).

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Table 4. Liquefaction Potential Calculation According To TBDY-2018 (Seed And Idriss 1971 And Youd *et al.* 2001 Methods)

No	Depth (m)	Liquefaction
1	6.00	State of liquefaction
2	7.50	State of liquefaction
3	9.00	State of liquefaction
4	10.50	State of liquefaction
5	12.00	State of liquefaction
6	13.50	N1(60)f>30 liquefaction is not expected
7	15.00	State of liquefaction
8	16.50	N1(60)f>30 liquefaction is not expected
9	18.00	N1(60)f>30 liquefaction is not expected
10	19.50	N1(60)f>30 liquefaction is not expected

Jet grout selection is determined as 60 cm depending on the column diameter to be applied. Considering that it meets the safety condition against liquefaction according to TBDY 2018, jet grout application with 3.0 x 3.0 m grid was found suitable to eliminate the liquefaction problem. The bearing capacity of the soil before improvement was found to be 20 tons/m^2. After the jet grouting process, the bearing capacity of the ground was determined as 28 tons/m^2. B+G+4-storey building project, in which a radia foundation system was created, was implemented on the improved ground (Figure 2).

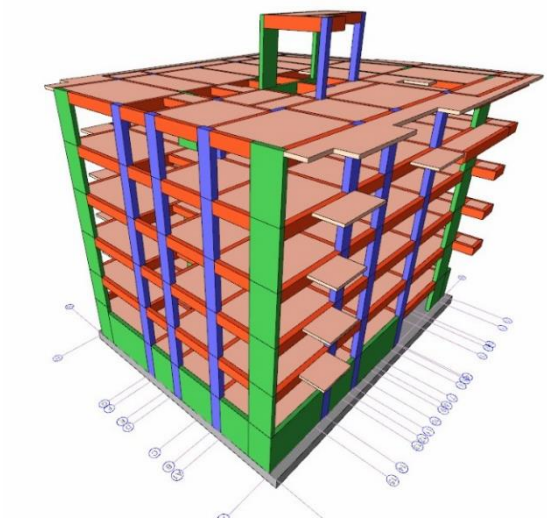

Figure 3. The Building To Be Constructed After The Soil Improvement

Figure 4 shows the deformations of the building in mode 1. In mode 1, the blue parts are less deformed, while the red parts represent the elements that are most deformed. Regional-based

deformations of the structure can be determined from the given color scale.Deformations in the structure vary between 0.004 and 5.3 cm.

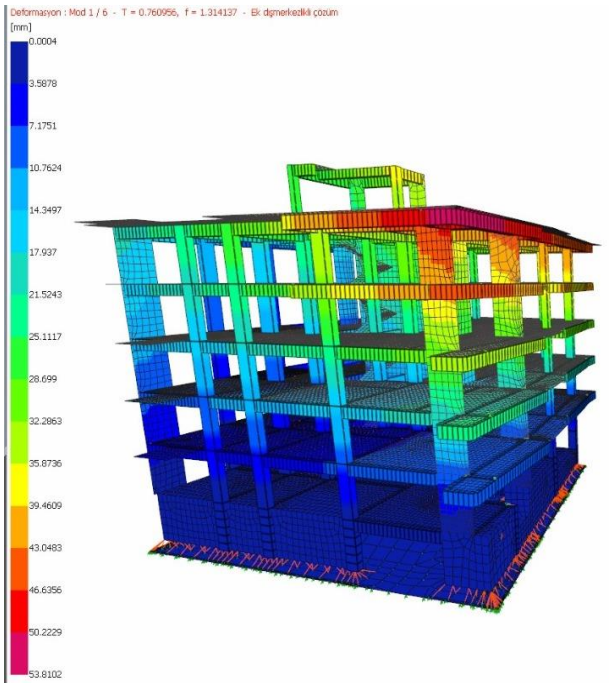

Figure 4. Display of the Deformations of The Structure with The Idecad Program

4. CONCLUSIONS

Within the scope of this study, liquefaction analysis was carried out using existing data for İzmir province, Karşıyaka district, Soğukkuyu neighborhood. In line with the analysis results, the risk of liquefaction was determined between 6-12 m and at the 15th m. Jet grout method was preferred to improve the ground. Information and images of the structure that will be built on the ground after the improvement have been shared.

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APPLICATION FIELDS OF GEOTECHNICAL ENGINEERING AND IMPORTANCE IN CIVIL ENGINEERING

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ABSTRACT

Civil engineering is a branch of engineering that includes many sub-branches of science, and geotechnical engineering, one of these branches, covers basic sciences such as soil mechanics, foundation construction and soil dynamics. Adequate knowledge of soil mechanics and foundation construction is necessary for the design and evaluation of problems in geotechnical engineering applications. Although the scope of the fields of study of geotechnical engineering is quite wide, the most basic ones can be listed as determining the soil bearing capacity, determining the settlements that they can make depending on time, determining the dimensions and slope angles of earth dams, designing the foundation soil against collapse under dynamic loads such as earthquake loads, determining the soil class to be used in foundation layers of structures such as roads, airports, etc., carrying out compression studies and calculating the lateral soil pressures acting on the retaining structures due to soil and surcharge loads in the design of retaining structures. Geotechnical engineering is a branch of engineering that is also very important in terms of soil-structure interaction and is essential for optimizing the without any problems and safe life of structures from a static perspective. In this study, the areas of use of geotechnical engineering and its importance in civil engineering are emphasized.

Keywords: Behavior, civil, engineering, geotechnics, soil.

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1. ENGINEERING AND ITS SUB-BRANCHES

Engineering is one of the indispensable professions for human life. The English word engineer comes from the Latin word ingenuity [1]. Engineering is the art of demonstrating problem-solving ability by combining the knowledge obtained as a result of experimentation and application with existing resources. Different engineering branches have emerged in order to create solutions to problems in different areas. The most basic of these are civil, mechanical, electrical, computer, aircraft, industrial, surveying, and chemical engineering. In addition to these, engineering branches such as space, petroleum, and automotive can also be counted (Figure 1). It is of great importance for an engineer to be technically equipped, to have the ability to put theoretical knowledge into practice and to have a mission that can keep up with technological changes that follow innovations. Engineers working in the field or in production should have up-to-date information on the use of tools and devices used. In studies carried out in the office or on software, which are called desk jobs, it is necessary to follow the literature up-to-date and be informed about innovations and changes.

Figure 1. Images of Different Engineering Fields [2]

2. CIVIL ENGINEERING

Civil engineering is one of the cornerstones of engineering branches and civil engineers are professionals who make the necessary plans, designs and applications to meet people's shelter needs and also provide control. This branch of engineering includes many main branches of science within itself (Figure 2), these main branches of science can be listed as follows:

- Construction
- Hydraulic
- Transportation
- Geotechnics
- Mechanics

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- Building Materials
- Construction Business

Figure 2. Images of Civil Engineering Fields [3]

Civil engineers have a wide range of work areas. Engineers who receive engineering education can choose between construction site or office options when they graduate and advance in these areas. Civil engineers working in the office are usually project authors, while engineers working on the construction site play an active role from the beginning of the construction site to the delivery of the structure. Civil engineers who perform static calculations must make projects by taking into account all necessary regulations and rules, and must follow current and local regulations. Site managers who will work on the site must ensure that the projects they receive from the project engineer are manufactured in accordance with the project.

3. GEOTECHNICAL ENGINEERING

Geotechnical engineering is considered one of the newest branches of civil engineering, and its founder is Karl Von Terzaghi (Figure 3). He was an Australian geological engineer and the first person to established the soil mechanics laboratory at what is now Istanbul Technical University [4]. The compulsory undergraduate courses in geotechnical engineering at universities are soil mechanics and foundation engineering courses. It is known that the geotechnical major was previously known as soil mechanics [4].

Figure 3. Karl Von Terzaghi [4]

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Especially in Türkiye and other countries with many earthquake zones around the world, it is of great importance to perform geotechnical analyses correctly and choose the right techniques. Geotechnical analyses aim to increase the resistance of structures against earthquakes and to minimize loss of life and property. In addition, thanks to the geotechnical science branch, structures are designed and constructed in accordance with their characteristics as a result of the correct determination of the soil profile, thus contributing to the extension of their service life and the reduction of maintenance costs (Figure 4).

Figure 4. Geotechnical Applications in The Field [5]

4. WORKING FIELDS OF GEOTECHNICAL ENGINEERING

There are many areas of work in geotechnical engineering, and it is essential to have the necessary experience and equipment to work in each of them. The areas where reality engineering is applied are listed below (Figure 5) [6]:

- To determine the safe bearing capacity of the soil,
- To determine the settlements in the soil,
- Determining and sizing the most appropriate foundation type according to bearing capacity and settlement conditions,
- Taking part in the calculations of water structures (dams, leakage problems, etc.),
- To make stability calculations of slopes,
- Conducting earthquake engineering studies,
- Planning tunnel routes and playing a role in their calculations,
- Deciding and implementing soil improvement methods.

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Figure 5. Working Fields of Geotechnical Engineering [7]

5. COURSES GIVEN WITHIN THE SCOPE OF GEOTECHNICAL ENGINEERING

Geotechnical engineering is a sub-branch of construction, but unlike other engineering branches, there is no compulsory project course in undergraduate courses. Compulsory courses given at the undergraduate level are limited to soil mechanics and foundation engineering courses, and this limits the mastery of technical information according to engineer news. When the undergraduate courses of geophysical and geological engineers who perform guillotine applications in application areas are taken into consideration, it is known that the soil mechanics course is not given at all in some universities, while its content is given weakly in others [6]. Unfortunately, this situation allows the training of low-quality engineers. Figure 6 shows some of the courses given in postgraduate education within the scope of the geotechnical department in our country and in the world.

Geotechnical earthquake engineering	*Engineering properties of soils*
Unsaturated soil mechanics	*Experimental soil mechanics*
Geosynthetics engineering	*Advanced foundation engineering*
Advanced soil mechanics	*Soil and site improvement*
Excavation and support systems	*Underground construction*
Soil structures	*Deep foundations*
Rock mechanics	*Environmental geotechnics*
Soil-structure interaction	*Soil dynamics*
Slope stability and retaining structures earth pressures and foundation structures	*Geotechnical measurements and exploration*
Numerical methods in geotechnical engineering	*Theoretical soil mechanics Analysis and constitutive modelling*
Shear strength of soils Stability of soil slopes	

Figure 6. Courses Given in Postgraduate Education [6]

Another important point that needs to be questioned is that there is an internship requirement in other major science branches, but there is no internship requirement in the geotechnical field. It is very possible that students will have difficulties in matching the theoretical knowledge they see in the courses with practice and in understanding the theoretical unity.

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6. APPLICATION AREAS OF GEOTECHNICAL ENGINEERING

6.1. Settlement Projects and Residences

It is an inevitable fact that every building we are in, be it a residence, shopping mall or business center, interacts with the soil underneath, and considering this awareness, it is essential to know the soil profile well before constructing the buildings. It should be recognized that soil investigation reports should be created using data obtained from laboratory tests and soil samples taken as a result of drilling operations. The soil class, the liquefaction risk, the depth of the groundwater level, the drilling depth, the improvement method to be applied if needed, and the control after the method should be provided. Considering the fact that our country is an earthquake country, it should never be forgotten that the margin of error in calculations and applications is almost non-existent.

Figure 7. A Representative Example of Residential Construction [8]

6.2. Transportation Systems

Another field of work and duty of geotechnical engineers is to design earthquake-resistant giant structures such as bridges and viaducts on highways and railways (Figure 8). There is a need for expert engineers and companies that can correct errors that occur as a result of insensitivity or oversight during project design. In cases where the earthquake performance of existing bridges and viaducts is low, the fastest and most economical method to increase it is to remove the existing supports and place earthquake isolators.

Figure 8. Transportation Structures [9]

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6.3. Tunnels and Underground Structures

Tunnels vary according to their intended use; design and calculation differences may be present depending on their use as a waterway, railway or road tunnel (Figure 9). Tunnel boring methods also vary. It is very important that the geotechnical engineers and civil engineers who will work in tunnel construction are experts in their fields. Geotechnical engineering is used in matters such as whether there is a fault line under the area where the tunnels will be built, whether the tunnel is rock or soil-based, earthquake loads and similar issues. The project depth should be associated with the distance to the settlement area and calculations should be made accordingly. Otherwise, the existing high cost will increase even more. While the proximity to the active fault line in ground tunnels up to 20 meters carries a danger potential, the earthquake risk is minimized in rock tunnels deeper than 30-40 meters [10].

Figure 9. Tunnel Visuals [10]

6.4. Ports and Coastal Structures

The design and static calculations of ports require expertise (Figure 10). When performing these studies, great care should be taken and errors should be largely avoided. The designs of the berthing areas are determined according to the purpose for which they will be used, as well as the depth of the dock and the condition of the soil. In addition to these, the dimensions and tonnage of the ships that will berth at the port are also very important. Moving loads, wind, waves, earthquake loads and possible ship collisions are also important issues to be considered when performing static calculations [11].

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Figure 10. Ports [11]

6.5. Waste Removal Structures and Facilities

Solid waste landfills store many wastes throughout their lifetime. Although the amount of these wastes varies over time, the stacking mainly consists of biomaterials such as food waste, synthetic textiles, wood, paper and plastic. The waste is decomposed and producing 50% CH_4, 50% CO_2 and temperature. The optimum temperature required for decomposing solid wastes by bacteria should be between 35-40 °C and between 50-60 °C depending on the type of bacteria [12]. The disposal of nuclear waste is critical because of any leakage can lead to irreversible catastrophes. Also, the temperature emitted by radioactive wastes occurs around nuclear waste storage areas and is limited by setting a limit value of 100 °C in countries such as Sweden and Finland. Canister elements in which radioactive waste is stored generate heat between 1000 and 2000 Watts during the decay of the waste [13-14]. The person who will make the necessary designs to ensure that the engineering parameters are not negatively affected by all these high temperature values must be an engineer who is an expert in the field of energy geotechnics.

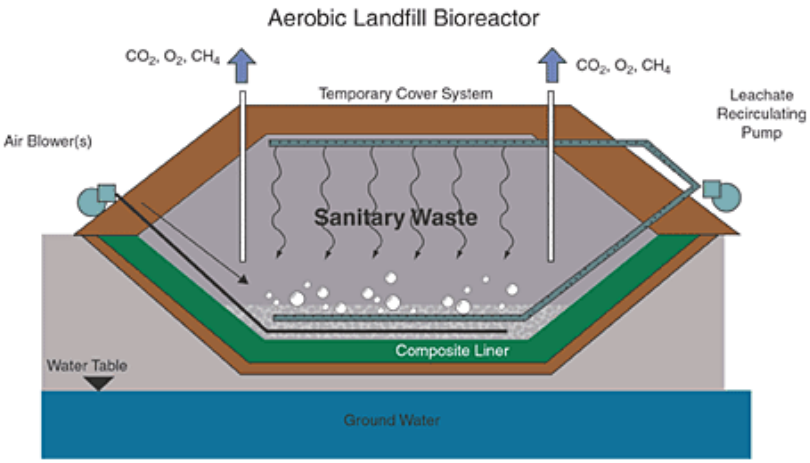

Figure 11. Landfill Design [15]

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INVESTIGATION OF THE EFFECT OF CRUSHED ZONE FORMATION WITH SHARP AND BLUNT TYPE BITS ON DRILLABILITY IN DRILLING

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ABSTRACT

Drilling methods are generally divided into two according to the rotation and impact process. Drillability in rocks is the ability of a drill to penetrate a rock in a given time. In other words, it is the ease of drilling a hole in the rock mass. Drilling speed is measured in m/min, cm/min or mm/min in rock. Parameters related to the machine, equipment and drilling process are controllable parameters, while parameters related to the ground and rock are uncontrollable parameters. In this study, the rock/drill bit interaction area under two types of drill bits (sharp and blunt tip type) and the formation of a crush zone were analysed with the FRANC2D program a finite element analysis method software. The results of the numerical analyses show that the stress distributions and crack propagation in the rock under a drill bit are highly dependent on the shape of the drill bit. According to the results, it is determined that the highest tensile and shear stress values occur in the rock in front of the conical type drill bit, but the crush zone is negligible. On the other hand, it was determined that the lowest tensile stress values developed in the rock under the blunt type drill bit and a very effective crush zone was formed.

Keywords : Crushed zone and drilling, sharp and blunt type drill bits, deep drilling and bit types

1. INTRODUCTION

Drill bits are cutting elements connected to the lowest end of the drill string and break the rock under the effect of rotation and weight. As the drill penetrates the formation, the drilling fluid (mud) or air passing through the drill string and the drill, removes the cuttings from the well. While the weight is given to the drill with the help of weight pipes in the drill string; rotational movement is transmitted by morset in core drilling, rotary table in rotary drilling, top drive system or motor.

In the last decade, the researches in mechanised excavation cutting and drilling have changed direction with the developments in chisels and machines. It has been seen that it is not sufficient to consider the investigations on the chisels and the machines using these chisels independently from the rock to be cut. For this reason, rock mechanics and rock fracture mechanics have gained importance in recent years [1], [3], [4], [10], [13]. In particular, detailed complex

analyses such as numerical modelling using the developing computer technology have been successfully used in rock mechanics. Rock fracture mechanics gained importance at the end of the 80s [12]. Rock fracture mechanics and rock mechanics are two different branches of mechanics. While rock fracture mechanics deals with small-scale fractures and fractures of the rock mass, i.e. fractures and cracks in a smaller rock region close to the free surface, rock mechanics deals with the mechanical behaviour of the rock mass on a larger scale.

In rock fragmentation studies with drill bits, great importance has been attached to the investigation of the interaction zone, which is the drill bit and rock contact zone. Because, it is understood that this interaction is primarily responsible for the zones formed under the drill bit [6], [8], [9]. Investigation of this drill bit/rock interaction zone will make great contributions to both the mechanical rock cutting field and rock fracture mechanics.

2. ROCK FRACTURING BY DRILL BITS

Rock indentation is the basic process in drilling and excavation by mechanical means. In general, the removal of material from a rock face is described as a contact loading or an indentation process. The name of indentation tool is indenter. A zone of highly fractured and inelastically deformed rock is created beneath the tip of the bits. Outside this zone different crack, systems will develop and eventually cause large rock fragments to erupt from the surface. So, the penetration into rock can be supplied with this fracturing.

Numerous researchers have identified two different zones under a drill bit: (i) the crushed zone, and (ii) the cracked zone (e.g. Kou et al., 1998; Chiaia, 2001). Within the cracked zone five crack types have been identified: (i) cone (Hertzian) cracks, (ii) radial cracks, (iii) median cracks, (iv) half penny cracks, and (v) lateral cracks, defined by their shape and lo-cation within the indenter/rock interaction region (Figure 1) [2], [5], [10]

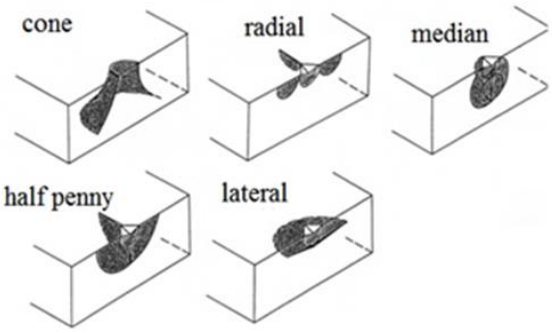

Figure 1. Crushed and crack zones under drill bits

A critical aspect of rock cutting in the brittle regime is the mechanism of initiation of a sub-horizontal tensile crack in a compressive stress field. According to several studies, the initiation of a tensile crack is actually closely related to the formation of a crushed zone ahead of the cutting tool. This zone acts as a wedge to induce a tensile crack. Moreover, the size of the crushed zone determines whether tensile fracture or shear/compression failure dominates the

mechanism of rock failure in the brittle regime. Factors that affect the size of the crushed zone include the pressure at the cutter/rock contact surface, the relationship between the depth of cut and the cutter width, the cutter geometry, the friction between the crushed rock and the cutter face, and the rock properties [2], [5], [7], [10], [11].

The objective of this study is to propose the mechanisms of cracks formation and propagation, and the characters of the crushed zone based on numerical modelling observation and theoretical considerations.

3. NUMERICAL MODELLING TO ANALYSE THE CRUSHED AND CRACK ZONES UNDER VARIOUS BIT PROFILES

The finite discrete element program, FRANC2D (FRacture ANalysis Code), was used to analyze the stress distribution and the fracture progress in the rock and cutter interaction analysis. The discrete analysis procedure in FRANC2D is based on the implementation of In numerical modelling, before starting the analyses with FRANC2D, the tip shape and rock sample to be modelled were mesh modelled with a mesh generator called CASCA, which is used with the program. Since the FRANC programme was developed using fracture mechanics, it is believed that it will give very good results in this project. Since it is not possible to determine what is happening in the rock under the insert at the micro scale in the experiments with the FRANC2D programme, numerical modelling programmes are very useful at this point. Both stress distribution analyses and cracking analyses can be performed with high accuracy and the reliability of the results of the program has been verified in the literature by comparing with experimental studies. Therefore, it was decided to use this numerical programme in this research programmethe principles of fracture mechanics together with the discrete fracture mechanics principles.

3.1 Numerical analysis of the sharp and blunt type cutters during loading and unloading cycles

Stress distributions of the maximum principal stress in a rock loaded under a sharp (conical) prototype bit are shown in Figure 2. As can be seen from the figures, there is a compression zone in front of the bit chisel, which means that a crush zone will be formed and there is a high tensile stress concentration immediately around this zone. These are the areas where lateral, i.e. radial, cracking will occur. This shows that the purpose of using assisted cutting, i.e. the use of neighbouring chisels side by side, is to ensure that each chisel communicates with the chisel next to it and the cracks they will create are combined to perform rock rupture/shattering. In this case, the radial cracks that will form on the sides of the bit are expected to intersect in the area formed in the centre.

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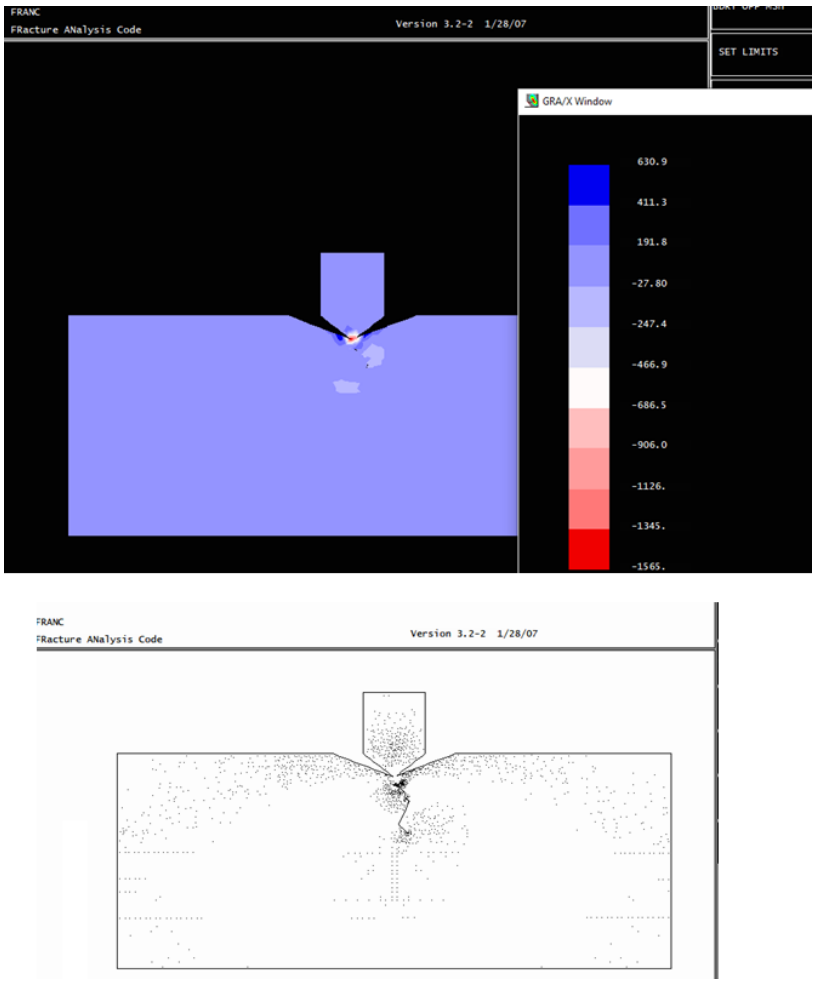

Figure 2. Maxiumum principal stress distribution results under a sharp (conic) type bit cutters during loading (negative values are compressive and pozitif values are tensile stresses)

Figure 3 shows the sharp type bit and rock interaction zone modelling and stress distributions. During unloading, tensile stress concentrations are observed immediately next to the bit, so that radial cracks can form.

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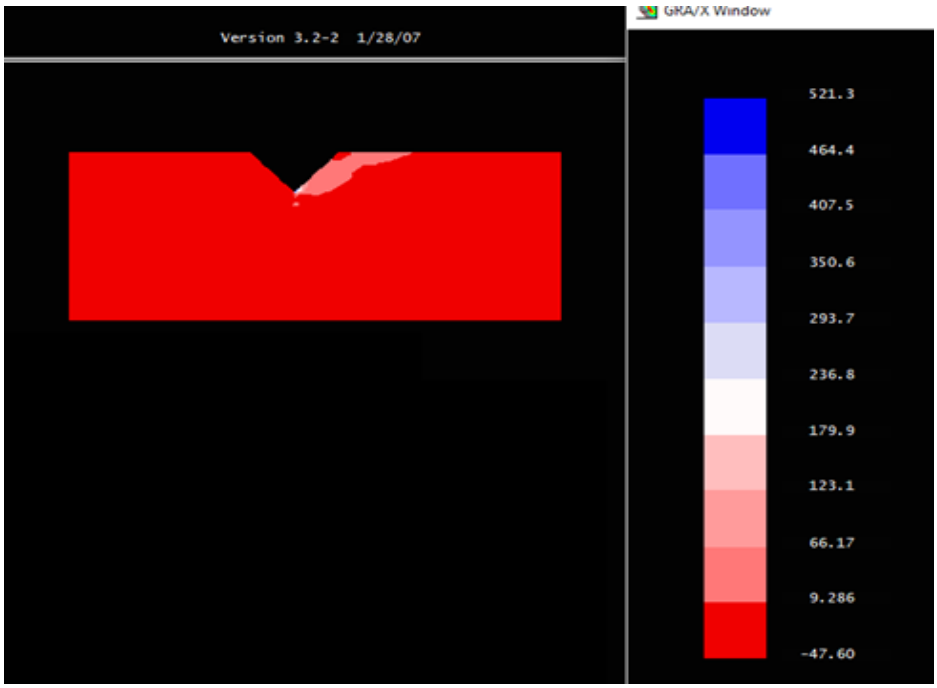

Figure 3. Maxiumum principal stress distribution results under a sharp (conic) type bit cutters during unloading (negative values are compressive and pozitif values are tensile stresses)

Figure 4 shows the numerical analysis of the blunt type cutters during loading. Is is seen that the applied load is distributed all over the contact area when a spherical indenter is indented to the surface. The compressive load creates a crushed zone (plastic deformation) both at around the contact area. Then, this plastic deformation gives rise to tensile stresses confined to a shallow skin outside this region immediately below the specimen surface. When the tensile stresses reach a sufficient level, a ring crack in the rock surface around the indenter is formed. With increasing of load, this ring crack grows in a direction normal to the principal tensile stress at crack tip. Finally, increasing of ring crack with unstable manner resulted to well developed Hertzian crack to the surface (Figure 5).

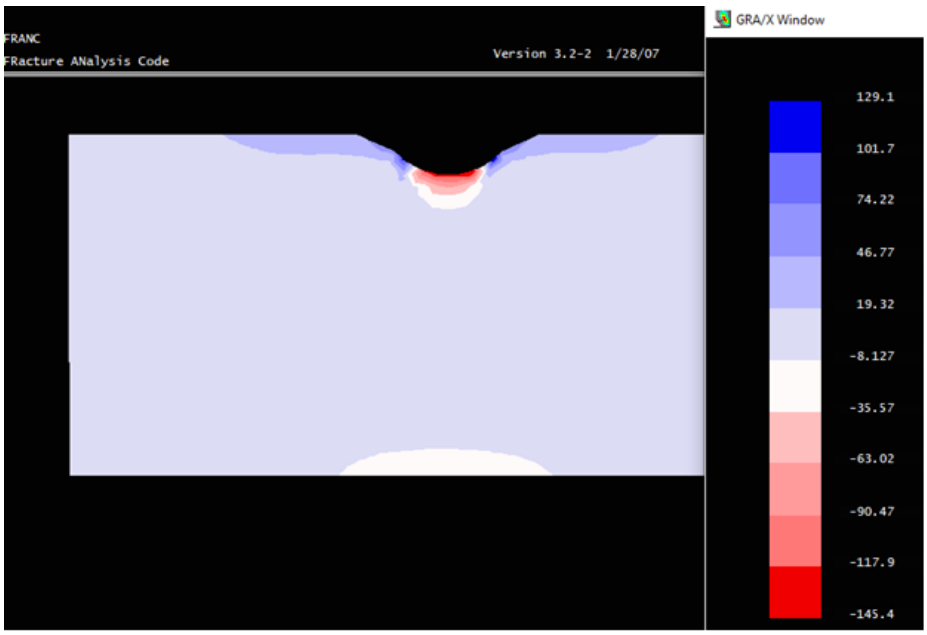

Figure 4. Maxiumum principal stress distribution results under a blunt type bit cutters during loading (negative values are compressive and pozitif values are tensile stresses)

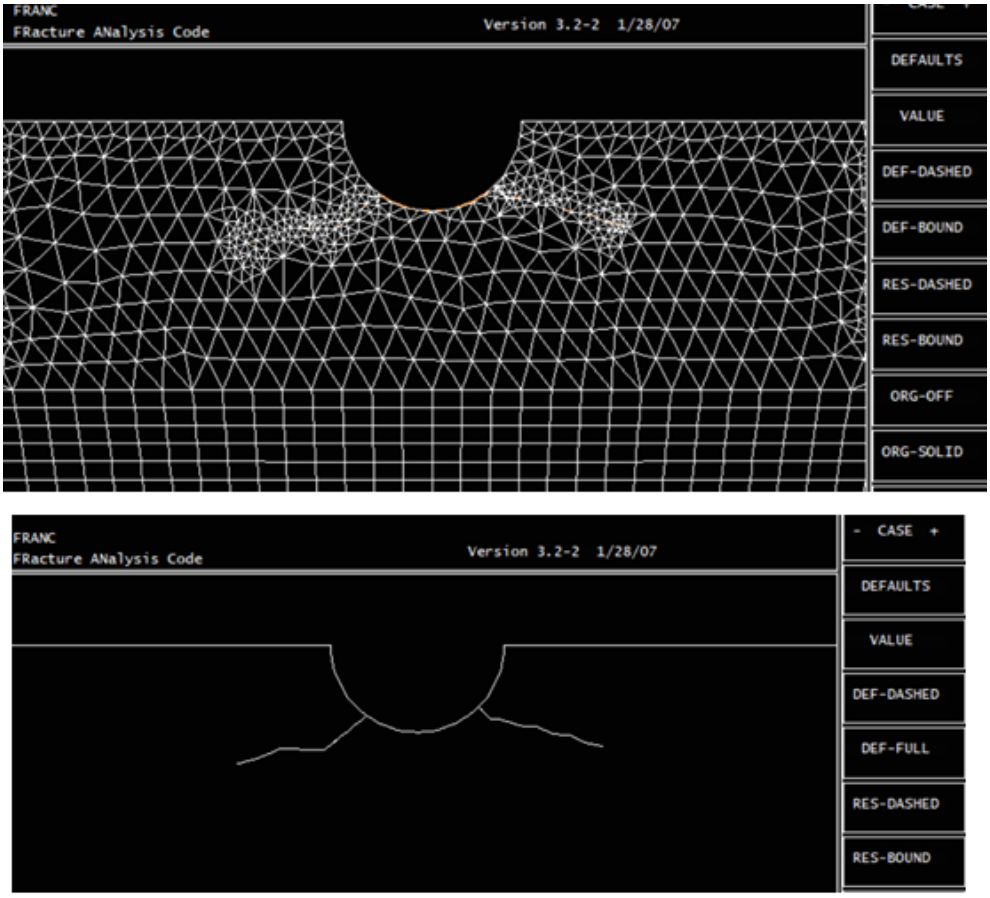

Figure 5. Fracturing under a blunt type bits during loading

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Figure 6 shows the formation of radial cracks and median cracks under the bit during unloading.

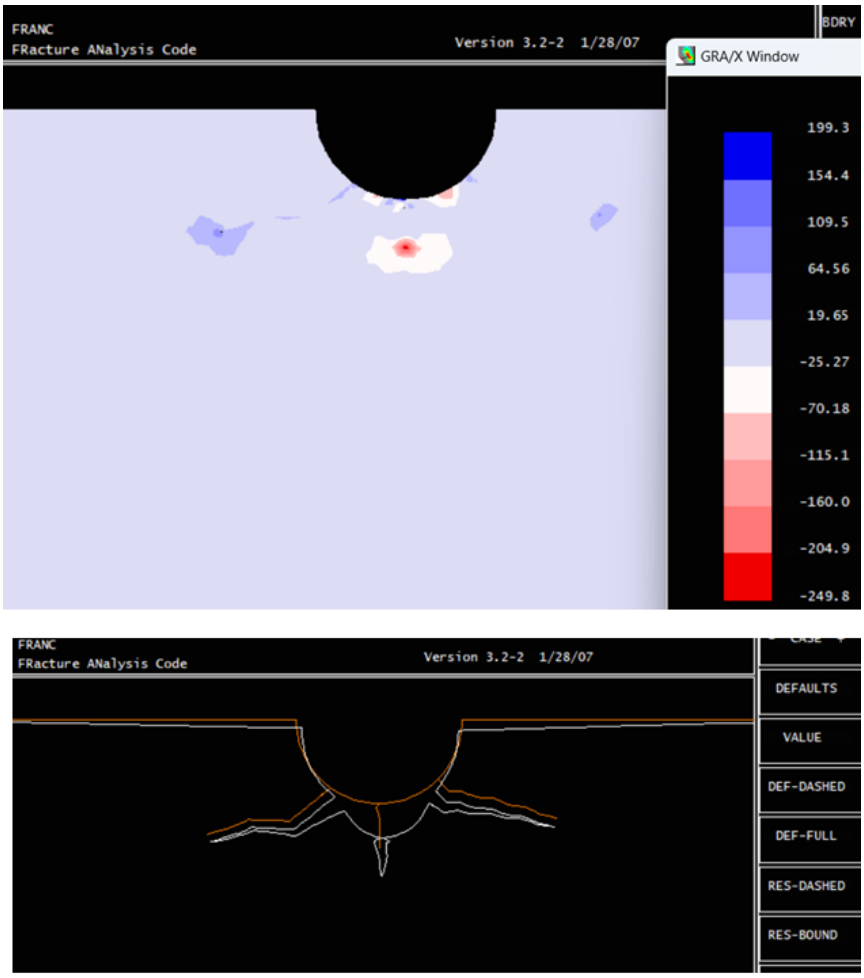

Figure 6. Fracturing under a blunt type bits during unloading

4. CONCLUSIONS

This study has shown that the numerical analysis method with FRANC2D are consistent with the results of the experimental analyses performed in the past. At this point, it is worth mentioning that the results of this research do not indicate which type of drill bit is the most economical. Because, there are many factors affecting the efficiency of a drill bit. Therefore, the results found in this study can be used as a guide for researches such as cutting head designs, blunt or sharp type insert researches.

It is shown in both cutter types that the dominance of tensile over shear fracture is intimately related to the existence of a crushed zone, which acts as a wedge to initiate a tensile macrocrack in a compressive stress field. However, the size of the crushed zone developed under blunt type cutters is much more bigger than the the zone under a shart type cutter.

Median type centrel macro cracks initiated and propagated just tip of a sharp type cutters during loading cycle while radial type cracks initiated at the side of the cutter and propagated through the surface of the rock. On the other hand, the lateral median cracks developed in rocks just at

both sides of a blunt type cutters during loading whereas median crack initiated and propagated just under the blunt type cutter during unloading cycle.

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ROCK FRAGMENTATION IN TUNNELLING WITH LOADING AND UNLOADING CYCLES IN DYNAMIC DISC TECHNOLOGY

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ABSTRACT

In hard rock\ore cutting, usually more than one disc is mounted on the cutter head according to a certain design, allowing the individual cracks formed under each disc cutter to generate rock particles and cutting rock. Two types of cutters are generally used in mechanical rock cutting; drag picks and disc cutters. With disc chisels, highly efficient cutting results are obtained in hard rocks up to 300 MPa. With the development of new technologies, dynamic disc cutting technologies aiming to cut the rock with fatigue have been developed. Rock fragmentation with dynamic cutting disc (DCD) is a dynamic cutting technology that cuts rock as a result of fatigue failures caused by high loading amplitudes and low number of load cycles. The formation of chips in mechanical rock cutting, both in classical and new technologies, is the main subject of all rock cutting theories. While explaining the damage mechanism effective in such a dynamic loading, dynamic/cyclic indentation and rock fatigue mechanisms, which are the closest studies to this mechanism, were analysed. As a result of the numerical analyses, it was found that during loading, a compressive stress zone was formed under the disc and damage zones caused by indirect (induced) tensile stresses were formed around it, while the compressive damage zone became smaller during unloading, whereas the indirect (induced) tensile stress damage zone became considerably larger and extended.

Keywords: Dynamic mechanical rock cutting, tunnelig and dynamic disc cutters, rock damage and dynamic cutting technology

1. INTRODUCTION

The biggest factor in the rapid development of mechanised excavation compared to the drilling and blasting technique is the ever-increasing population of the world and the increasing need and problems of people for both underground and surface structures. Mechanised excavation is an excavation method based on mechanically cutting and breaking the rock with the help of excavation machines and various chisels. In addition, mechanised excavation is the only way to ensure high production capacity at low costs by performing excavation operations quickly.

Excavation mechanics is the study of the relationship between the rock or soil and the chisel during excavation and its aim is to investigate the suitability of the rock or soil for mechanised excavation. Excavation mechanics also covers issues such as machine selection, performance prediction and feasibility (Bilgin et al., 2014). During machine excavation, forces act on the chisels in three dimensions. These are shear force (FC), normal force (FN) and lateral force (FS). The chisels used in excavation machines are given in Figure 1. Excavation mechanics is a branch of science that studies the relationships between the rock or soil and the chisel during

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excavation and its aim is to investigate the suitability of the rock or soil for mechanised excavation. Excavation mechanics also covers issues such as machine selection, performance prediction and feasibility.

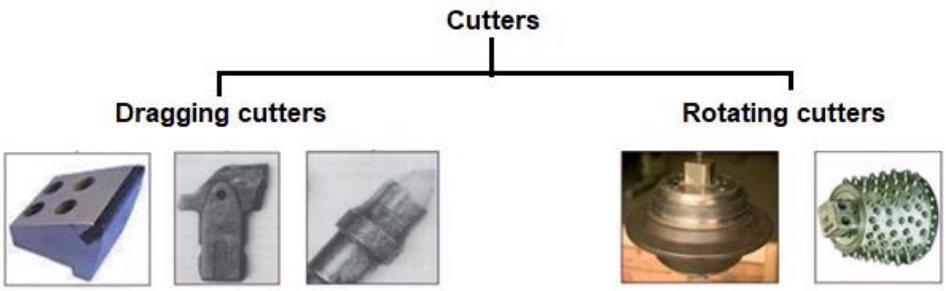

Figure 1. Rock cutters used in mechanical rock excavations

A tunnel boring machine (TBM) is a machine that can excavate tunnels in a single operation, called full-face drilling. It has a rotating head with cutting parts and runs on hydraulic or electric motors to excavate tunnels in which excavated through hard rock, wet or dry soil, or sand, each of which requires specialized technology. In general, TBM performance prediction efforts have been made to correlate TBM performance with rock mass, intact rock and machine parameters, either through empirical approach or physical based theories. However, specific energy (SE) is the most important empirical factor for TBM performance prediction [2], [3], [5].

Figure 2 Tunnel bring machine (TBM) machine

2. ROCK DAMAGE MECHANISM UNDER MECHANICAL CUTTERS

The formation of chips in mechanical rock cutting is the main subject of all rock cutting theories. According to fracture mechanics principles, a crack can propagate in any direction that provides the least surface energy and will continue to propagate as long as the stress intensity value at the crack tip is above the critical intensity factor (fracture toughness KIC). This propagation stops when the stress intensity falls below the critical value or when the crack encounters a free surface (this may be another surface). This means that in rock cutting with a conventional disc chisel without vibration, rock fragments can be formed at any angle towards the surface. When the distance between the chisels is large, cracks develop on the ridges (ridge zone: the bulging/swollen area between the two chisels) towards the cutting surface, and when they reach a free surface, small triangular pieces of broken rock are formed [2], [8], [10]. This causes a reduction in the pressure of the crushed zone and prevents further propagation of the cracks into other cuts, leaving the material between the chisels virtually untouched (Figure 3 (a)). The

process can continue until, in subsequent passes with higher cutter loads, two of the cracks interact and form a part. If the applied load is too high, the longer cracks may develop inwards and meet at an angle, resulting in an over-fracture/fragmentation (Fig. 3 b)). This results in thicker parts being produced below the cutting level. For the optimum spacing of two chisels, cracks propagate towards neighbouring cuts along a straight line with the shortest distance for ideal crack propagation and equal to half the spacing (Fig. 3 c). For an efficient cutting process, the ideal part removal process should be as shown in Figure 3 c.

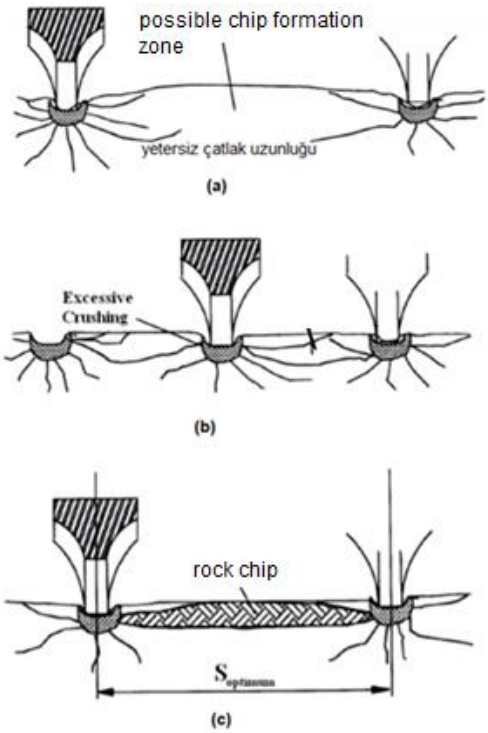

Figure 3. Chip formation in rock under disc chisels a) when the distance between two chisels is too large b) when the distance between two chisels is too small and c) when the distance between two chisels is ideal (optimum)

2.1 Rock fragmentation with the dynamic cutting mechanism

The mechanical behaviour of rock under static loading has been thoroughly investigated. However, rock reaction to cyclic, repetitive stresses resulting from dynamic loads has generally been neglected with the exception of a few rather limited studies. It is known that cyclic loading often causes brittle materials, such as ceramics and rocks, to fail at a stress level lower than their strength under monotonic conditions. This phenomenon is commonly termed as ‘fatigue’. Within the scope of this research, dynamic mechanical cutting technology (DMCT) was investigated for the first time in our country. Rock fragmentation and particle formation by DMCT can be explained by some cyclic indentation studies in the literature [1], [6], [7], [9]. For example, the penetration cycle of the disc cutter was explained by Lawn and Swain (1975) by comparing the penetration of a chisel into a brittle material. In the penetration cycle, the chisel, which sinks with the initial loading, creates an irreversible deformation zone around the contact point at the first contact with the rock. The size of this zone increases with the load

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(Figure 4. a). Then the critical zone is formed and a crack (median fracture) starts below the contact point and parallel to the loading direction (Figure 4 b and c). Stable crack growth is caused in front of this zone (Figure 5.14 d). Removal of the load (unloading) causes the median fracture to close (Fig. 4 e). Immediately afterwards, the relaxation of the deformed material in the contact zone superimposes intense residual stresses, resulting in cracks extending laterally and towards the surface, so-called lateral fractures (Fig. 4 f).

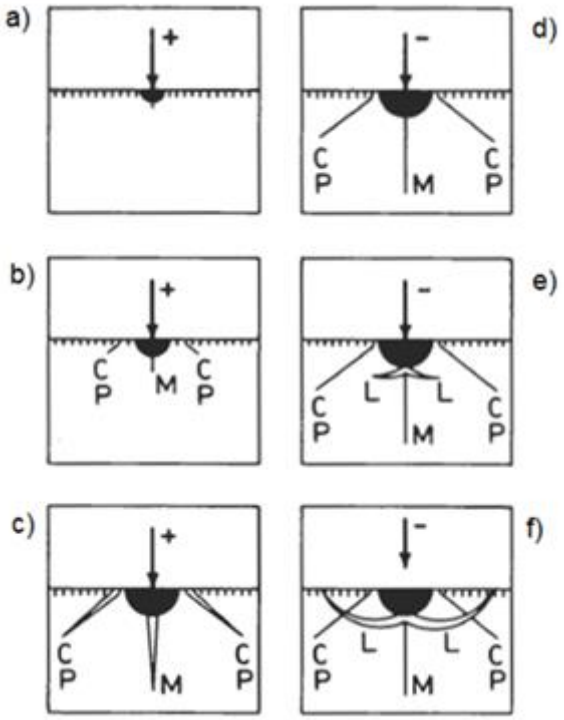

Figure 4. Zones and cracks formed during loading and unloading cycles provided by sinking movement under a cutter

3. RESULTS AND DISCUSSION

Since a technology such as DMCT is performed for the first time in our country and in the world, the mechanisms that are effective will also be the mechanisms encountered for the first time. Of course, DMCT technology is a dynamic cutting process that has and will have many unknowns. With the first findings obtained and with the support of the limited number of previous studies in the literature, the effective dynamic damage mechanism was tried to be explained in this research.

In general, more small pieces, namely 'chips', were obtained with the dynamic cutting tests compared to the conventional cutting tests with zero oscillation (Figure 5). With this research, the damage mechanism of the rock under a vibrating disc in the DCMT system can be explained by three basic mechanisms: 1) Formation of crushed and cracked zones under the non-dynamic disc chisel 2) The formation of a large fracture zone (Fracture Process Zone-FPZ) due to the rock fatigue mechanism and extra cracking starting in and around this zone, and 3) extra cracking during the application and unloading of the load due to the cyclic indentation mechanism.

Figure 5. Rock cutting grooves after one cutting (upper), excavated rock material (lower)

The damage mechanism of rock fatigue has been confirmed by this result since it is believed that the fractured crush zone called FPZ (Fracture Process Zone) is an effective parameter in obtaining more chips due to rock fatigue with the dynamic rock cutting [1], [6], [7], [8], [9].

4. CONCLUSIONS

In DMCT technology, a zone of irreversible deformation occurs during initial loading of the rock to develop the crushed zone around the cutting edge of the disc. Further loading causes to initiate the tensile cracks around this crushed zone, known as the median crack, for propagating deeper into the rock. The median tensile cracks close with the unloading of the oscillating disc cutter. Then the crushed zone (deformed contact zone) around the disc results in high compressive stress which produce tensile lateral cracks. Lateral cracks tend to be concave in shape and travel upwards to intersect the rock surface to form rock chips. Such rock failure theories related with indenters and drilling bits, which break rock by repeating load -unload dynamic loading cycles

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EAR INFLAMMATION IN CATS AND TREATMENT OPTIONS

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ABSTRACT

External ear inflammation is common in cats. Middle and inner ear inflammation may occur due to chronic and severe external ear inflammation. Factors predisposing to ear inflammation in cats are narrowness of the ear canal, auricle disorders, wetting of the ear canal as a result of humid environments or frequent bathing of the cat, the use of cotton wool for the removal of ear discharges, and damage during cleaning of the ear. Allergies are common causes of ear inflammation and infection in cats. Infections caused by bacteria and yeasts are usually secondary and opportunistic infections. *Staphylococcus* spp., *Pseudomonas aeruginosa*, *Pasteurella multocida*, *Corynebacterium* spp., *Mycoplasma* spp., *Corynebacterium provencense*, *Klebsiella* spp., *Streptococcus* spp. have been isolated in external ear infections of cats. The presence of rod-shaped bacteria and inflammatory cells in the ears of cats indicates a disease state. Causes of ear inflammation are foreign bodies, polyps, cancer, skin diseases, hormone diseases, immune-related diseases, sebaceous gland diseases, intensive ear cleaning and inappropriate drug applications (e.g. hydrogen peroxide and alcohol application). Scientific sources of recent years have been extensively evaluated and information on the most commonly used drugs and drug combinations and treatment options have been given.

Keywords: Cat, ear, inflammation, treatment.

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KEDİLERDE KULAK YANGISI VE SAĞALTIM SEÇENEKLERİ

ÖZET

Kedilerde dış kulak yangısı yaygın şekilde görülmektedir. Kronik ve şiddetli dış kulak yangısına bağlı olarak orta ve iç kulak yangısı şekillenebilir. Kedilerde kulak yangısına yatkınlık oluşturan faktörler kulak kanalının darlığı, kulak kepçesi bozuklukları, nemli ortamlar ya da kedinin sık şekilde yıkanılması sonucu kulak yolunun ıslanması, kulak akıntılarının uzaklaştırılmasında pamuklu çöplerin kullanılması, kulağın temizlenmesi sırasında oluşan hasarlardır. Alerjiler kedilerde kulak yangısı ve enfeksiyonun yaygın nedenidir. Bakteri ve mayalar tarafından oluşturulan enfeksiyonlar genellikle sekonder ve fırsatçı enfeksiyonlardır. Kedilerin dış kulak yangısında *Staphylococcus* spp., *Pseudomonas aeruginosa*, *Pasteurella multocida*, *Corynebacterium* spp., *Mycoplasma* spp., *Corynebacterium provencense*, *Klebsiella* spp., *Streptococcus* spp. izole edilmiştir. Kedilerin kulaklarında çubuk biçiminde bakteriler ve yangısal hücrelerin bulunması hastalık durumunu gösterir. Kulak yangısının nedenleri yabancı cisimler, polipler, kanser, deri hastalıkları, hormon hastalıkları, immün nedenli hastalıklar, yağ bezi hastalıkları, yoğun kulak temizleme ve uygun olmayan ilaç uygulamaları (örneğin hidrojen peroksit ve alkol uygulaması)'dır. Bu makale kapsamında son yıllara ait bilimsel kaynaklar geniş şekilde irdelenerek sağaltımda en çok kullanılan ilaçlar ve ilaç kombinasyonlarına yönelik olarak sağaltım seçenekleri hakkında geniş şekilde bilgiler verildi.

Anahtar Kelimeler: Kedi, kulak, yangı, sağaltım.

Giriş

Kedilerde dış kulak yangısı yaygın şekilde görülmektedir. Kronik ve şiddetli dış kulak yangısına bağlı olarak orta ve iç kulak yangısı şekillenebilir (Jones, 2022).

Etiyoloji

Kedilerde kulak yangısına yatkınlık oluşturan faktörler kulak kanalının darlığı, kulak kepçesi bozuklukları, nemli ortamlar ya da kedinin sık şekilde yıkanılması sonucu kulak yolunun ıslanması, kulak akıntılarının uzaklaştırılmasında pamuklu çöplerin kullanılması, kulağın temizlenmesi sırasında oluşan hasarlardır (Brame ve Cain, 2021).

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Alerjiler kedilerde kulak yangısı ve enfeksiyonun yaygın nedenidir. Bakteri ve mayalar tarafından oluşturulan enfeksiyonlar genellikle sekonder ve fırsatçı enfeksiyonlardır. Kulak yangısının nedenleri yabancı cisimler, polipler, kanser, deri hastalıkları, hormon hastalıkları, immün nedenli hastalıklar, yağ bezi hastalıkları, yoğun kulak temizleme ve uygun olmayan ilaç uygulamaları (örneğin hidrojen peroksit ve alkol uygulaması)'dır (Jones, 2022).

Kedilerde kulak yangısını ilerleten faktörler maya ya da bakterilerden kaynaklanır. *Malassezia* türleri dış kulak yangısı olan kedilerin kulaklarından yaygın şekilde izole edilmiştir (Nardoni ve ark., 2014; Shokri ve ark., 2010).

Kedilerin dış kulak yangısında *Staphylococcus* spp. (Kroemer ve ark., 2014), *Pseudomonas aeruginosa*, *Pasteurella multocida*, *Corynebacterium* spp., *Mycoplasma* spp. (Hoppers ve ark., 2020), *Corynebacterium provencense* (Kittl ve ark., 2018), *Klebsiella* spp., *Streptococcus* spp. (Ackermann ve ark., 2017; Brame ve Cain, 2021) izole edilmiştir. Kedilerin kulaklarında çubuk biçiminde bakteriler ve yangısal hücrelerin bulunması hastalık durumunu gösterir (Brame ve Cain, 2021).

Kedilerde kulak maytlarından *Demodex cati* ve *Demodex gatoi* kulak yangısına neden olur (Brame ve Cain, 2021). *Otodectes cynotis*'in kedilerin dış kulak kanalı yangılarının %50'den fazlasından sorumlu olduğu ve oldukça bulaşıcı olduğu bildirilmektedir (Griffin, 1993).

Klinik Bulgular

Kulak enfeksiyonu gelişen kedilerde genel olarak görülen klinik bulgular başını sallama, kulakların tırmalanması, başını eğme, kulak akıntısı ve koku, kulak kepçesinde şişlik, kırmızılık, ülser ve kulak ağrısı şeklindedir. Kulak enfeksiyonları bir ya da iki kulakta gelişebilir. Enfeksiyon ve yangı iç ve orta kulağa ilerlerken denge bozukluğu gelişir. Dış kulak yangısının nedenleri predispozisyon oluşturan faktörler örneğin anormal kulak biçimi (İskoç kıvrık kulaklı kediler), çok fazla kulak kiri üretimi, kulak kıllarının çok olması ve kulak kanalının anormal yapıda olmasıdır (Jones, 2022).

Orta kulak yangısı gelişen kedilerde başını sallama, kulak kaşıntısı, nörolojik bulgular gelişebilir. Nörolojik klinik bulgular başını eğme, kas koordinasyon bozukluğu, Horner sendromu (üst göz kapağı göz küresinin üzerini kısmi kapatır, pupilla tek taraflı daralır) ve yüz sinirinde paraliz şeklindedir (Brame ve Chain, 2021). Orta kulak yangısının tanısı kültür ve sitoloji ile gerçekleştirilir (Brame ve Chain, 2021).

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Tanı

Tanıda hastanın hikayesi, otoskopla kulak muayene, *Otodectes cynotis*'in varlığı ve sitolojik muayene değerlendirilir. Gerekli olduğunda ileri görüntüleme tekniklerinden yararlanılır. Kulakta polip ya da kitlenin varlığı araştırılır (Brame ve Chain, 2021).

Sağaltım

Kulak yangısının sağaltımında kullanılacak ilaçların etkinliğini en üst düzeye ulaştırmak için ilaç uygulamalarından önce kedinin kulakları temizlenir. Kedinin kulaklarında şiddetli ağrı varsa birkaç gün ilaç sağaltımı uygulandıktan sonra kedi kulaklarının temizlenmesini tolere edebilir (Kearley, 2020).

Kedilerde yerel olarak kulağa uygulanan ilaçlar iç kulağa temas ederse toksik etki oluşturur. Kulak zarı hasarlı kediye klorheksidin ve setrimit kombinasyonu akut orta kulak hastalığı ile ilgili bulgulara neden olur (Galle ve Venker-van Haagen, 1986). Yerel glukokortikoit ilaçlar kedilerin kulak kartilaj yapısını etkileyerek kulak kepçesinde düşük görünüme neden olur (Torres, 2013).

Kedilerin kulak yangısında bakteri ya da *Malassezia* mayası varsa orta kulak etkilenmemiş olsa dahi sistemik sağaltımlar tercih edilir. Kedide klindamisin, sefpodoksim ya da amoksisilin-klavulanat normal sağaltım dozlarında öncelikli olarak tercih edilen ilaçlardır (Kennis, 2013).

Kedilerin dış kulak yangısında izolatların %90'ının gentamisine duyarlı olduğu, *Pseudomonas aeruginosa*'nın gentamisine duyarlılığının %85 ve polimiksin B'ye duyarlılığının %100 olduğu ve *Pseudomonas* türlerine göre diğer izolatların amoksisilin/klavulanik asite duyarlılığının en fazla olduğu bildirilmiştir (Hariharan ve ark., 2006).

Kulak maytlarında piretrin esaslı ilaçlar kulağa uygulanır. Ense bölgesine damlatma biçiminde kullanılan selamektin kulak maytlarının sağaltımında iyi bir tercihtir. Bu ürün 14 günde 1 kez toplam 3 kez uygulanabilir. İvermektinin %0.01'lik kulağa damlatma formülasyonu 4 haftalık yaşa kadar olan yavru kedilerde de kullanılabilen lisanslı bir üründür (Kennis, 2013).

Kedilerde *Otodectes cynotis*'e bağlı ve sekonder bakteri ve mantar enfeksiyonlarıyla komplike dış kulak kanalı yangısının sağaltımında Oridermyl® kulak merheminin günde 1 kez 10 gün süreyle uygulanmasının önemli düzeyde iyileşme sağladığı ve canlı kulak maytlarının saptanmadığı bildirilmiştir.

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KOYUN VE KEÇİLERDE BAKTERİYEL AŞILAR

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ÖZET

Koyun ve keçilerin hayatlarını sağlıklı sürdürebilmeleri için koruyucu hekimlikte aşılar çok önemli rol oynar. Bakteriyel hastalıkların kontrol edilmesi, hayvanların yaşamını tehlikeye atabilecek bazı hastalıkları ortaya çıkmadan önlemek ancak aşılarla sağlanır. Bakteriyel hastalıklara karşı geliştirilen aşılar çok uzun yıllardır koruyucu hekimlikte kullanılmaktadır. Aşılar, hastalıklara karşı koruyucu hekimliğin en önemli uygulamalarından biridir. Sonuç olarak bu derlemede koyun ve keçilerde kullanılan bakteriyel aşılar ve önemi vurgulandı.

Anahtar Kelimler: koyun, keçi, bakteri, aşı

BACTERIAL VACCINES IN SHEEP AND GOATS

ABSTRACT

Vaccines play a very important role in preventive medicine in order for sheep and goats to lead a healthy life. Controlling bacterial diseases and preventing some diseases that may endanger the lives of animals before they occur can only be achieved with vaccines. Vaccines developed against bacterial diseases have been used in preventive medicine for many years. Vaccines are one of the most important applications of preventive medicine against diseases. As a result, bacterial vaccines used in sheep and goats and their importance were emphasised in this review.

Key Words: sheep, goats, bacteria, vaccine

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GİRİŞ

Küçük hayvan yetiştiriciliği, ülkemiz hayvancılığı ve yetiştiriciler açısından çok önemlidir. Yetiştiriciliğin açık olarak yapılması ve farklı sürülerin ortak mera kullanımı, koyun ve keçileri hastalıklara daha duyarlı hale getirir. Özellikle mera yetiştiriciliğin yoğun olduğu, meranın farklı sürüler tarafından otlatıldığı koyun yetiştiriciliğinde, koruyucu hekimlik ve aşılama çok önemlidir. Aşılama sonrası bağışıklığın %90 oranında sağlandığı bir sürüde, hastalığın görülmesi durumunda hastalığın bulaşma ve ölüm oranı çok az olur. Aşılama sayesinde hastalığın kontrolü çok daha kolay sağlanır. Ülkemizde, küçük hayvan işletmelerinde aşılamada istenen düzeye ulaşılamamıştır (3,4). Küçük hayvan yetiştiriciliğinde aşılamanın az yapılmasına bağlı olarak hayvan ölümleri çok görülür bu durum ülkemiz hayvancılığına büyük zararlar verir. Hayvancılıkta karlı bir işletme için, bu hayvanların aşı programlarının doğru şekilde hazırlanması, aksatılmadan uygulanması ve sürü sahiplerinin aşılama hakkında bilinçlendirilmesi gerekir (3,4). Hayvancılıkta hastalıklara karşı risk almadan önlemenin tek yolu koruyucu hekimlik aşılamadır. Hayvancılıktan para kazanmak ve iyi hayvancılık için koruyucu aşılama yapmak çok önemlidir. Koruyucu hekimliğin temel prensiplerinden birisi doğru ve düzenli aşı programlarının hayvanlarda yapılmasıdır. Sürü aşılamalarında sürünün tamamında istenen bağışıklık her zaman yüzde yüz başarılı oluşmayabilir. Böyle durumlarda aşıya kabahat bulmak doğru değildir. Önemli olan sürü aşılamasında çok fazla hayvanın istenilen hastalığa karşı bağışıklık kazanabilmesidir (2,3,4). Bir hastalığın aşısı varsa hastalığı önceden önlemek kolaydır ve başarılıdır. Sürü sağlığı hastalıklarında ancak bu şekilde başarılı olabiliriz. Aşı ile korumak her zaman başarılıdır. Aşıyla korumak ucuz ve garantilidir (2,3,4).

E. Koli Aşısı

Kuzu ve oğlaklarda ilk bir aylık dönemde bu hastalıklar ile çok karşılaşırız. Hastalıkta ölümlerin en aza indirilebilmesi için gebe koyunlara doğumlarına 8 hafta kala özellikle K99 ve *E. coli*'e yönelik aşılama yapılmalıdır. *E. Coli'*ye karşı hazırlanmış aşının içersinde rota ve korona virüs aşıları ile birlikte bulunur. Bazı *E. coli* aşıları klostridial aşılarla birlikte bulunur. Piyasada aşılardan bazıları ilk uygulamada bir kez uygulanırken, bazı aşılar ilk uygulamadan 2 hafta sonra bir kez daha yapılır. Koli ishallerinden korunmak amacıyla gebe koyun ve keçilere doğuma 60 gün kala 15 gün ara ile 2 kez aşı yapılmalıdır. Birinci aşı doğuma 60 gün kala, ikincisi doğuma 45 gün kala uygulanmalıdır. Bu aşı her yıl, yılda bir kere tekrar edilmelidir. Doğduktan sonra kuzulara septiserum uygulanmalıdır (1,2,3,4,5).

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Brusella Aşısı

Hayvanları aşılayarak koruyabiliriz. Kuzular 3-8 aylık olduklarında aşılanmalıdır. Hazırlanan aşı kendi özel damlalığı ile aşıyla temas etmeden uygulayan kişi koruyucu önlemlerini alarak dişi ve erkek kuzulara, erginlere göze bir damla damlatılarak uygulanır. *Brusella melitensis* Rev-1 genç aşısı, dişi, erkek kuzu ve oğlaklara 3-8 aylıkken yapılır. Bir kez yapılan aşılama ile ömür boyu koruma sağlanır. Aşı erginlere uygulanmaz. *Brusella melitensis* Rev-1 ergin aşısı, sağlıklı dişi koyun ve keçilere 8 aylıktan büyük olanlara bir yıl ara ile iki kez yapılır. Aşı besi kuzularına, kesilecek hayvanlara, damızlık olmayanlara yapılmamalıdır. Damızlık erkekler ile dişi annelere önceden aşı yapılmamış ise çiftleşmeden en az bir ay önce aşılama yapılmalıdır. Hazırlanan aşı kendi özel damlalığı ile dişi erkek kuzular ve erginlere göze bir damla damlatılarak yapılır (1,2,3,4,5).

Pasterollosis Aşısı

Aşılama solunum yolu hastalığına yönelik yapılır. Pastörelloza karşı kullanılacak aşının seçiminde içeriğindeki serotiplere dikkat edilmelidir. Koyunlarda en sık izole edilen serotiplerin A1, A2, A6, A7, A8, A9, A11, A12, en riskli serotiplerin A1, A2, A7, A9 olduğu göz önünde bulundurulmalıdır (10-16). Aşı, aşısız annelerden doğan kuzulara 15 günlükten itibaren, aşılı annelerden doğanlarda ise 6-8 haftalık yaşta uygulanır. İlk uygulamadan 4 hafta sonra aşı tekrar yapılır. Aşı hayvanlarda her yıl tekrar edilir. Gebe hayvanların, gebeliğin üç ile dördüncü ayında aşılanması ağız sütünde bağışıklık miktarını arttırdığından dolayı kuzuları bu hastalığa karşı bir iki ay korur (1,2,3,4,5).

Keçi Ciğer Ağrısı Aşısı

Aşı 6 ay ve üzeri keçilere gebeliğin son 6 haftasına kadar kulağa deri altı yolla 0,2 ml yapılır. Aşı bir yıl ara ile tekrar edilir(1,2,3,4,5).

Agalaksi Aşısı

Kış sonu, ilkbahar başı, sağım dönemi, yaz başı, mera dönemlerinden önce koyun ve keçilere aşı yapılmalıdır. Koruyucu aşılamada ölü ve canlı aşılardan birisi yapılabilir. Ölü aşı üç hafta ara ile iki kez uygulanmalıdır. Bağışıklık süresi altı ay sürer. Canlı agalaksia aşısı koyunlarda gebeliğin son iki ayında ve sağımın ilk iki ayı içerisinde uygulanmamalıdır diğer dönemlerde yapılmalıdır. Bağışıklık süresi ölü aşılara göre daha uzundur (1,2,3,4,5).

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Leptospirozis Aşısı

Leptospirozis aşısı, koruyucu olarak üç hafta ara ile iki kez uygulanır ve yılda bir kez tekrar edilir. Salgın durumlarında, hastalık belirtisi göstermeyen kuzu ve toklulara bir kez uygulanır (1,2,3,4,5).

Piyeten Aşısı (Ayak Çürüğü)

Hastalık özellikle ilkbahar ve son bahardaki bol yağışlar, nemli ortamlar hastalığın oluşumunu hızlandırır, ilkbahar ve sonbahar aylarında bulaşır ve yayılır. Piyeten hastalığının gözlendiği işletmelerde hem tedavi yapmak hem de korumak amacıyla kullanılabilir. Aşı hastalığın görülme ihtimalinin çok olduğu aylarda bir aylıktan büyük tüm hayvanlara yapılabilir. Hayvanlara ilk aşılama yapılır ve altı ayda bir tekrar edilmelidir. Hastalığın şiddetli seyrettiği sürülerde ilk aşılamadan bir ay sonra ikincisi uygulanır ve 6 ayda bir aşı tekrarı yapılır (1,2,3,4,5).

KLOSTRİDİAL KARMA AŞILAR

Koyunlarda klostridial hastalıklar enterotoksemi, kuzu dizanterisi, yanıkara, tetanoz, botulismus, basiller ikterohemoglobinüri, malignant ödem, enfeksiyöz nekrotik hepatitis, bradzot hastalıkları çok önemlidir. Bu hastalıklardan korumaya yönelik piyasada çok aşı vardır. Kullanılacak klostridial karma aşı seçiminde aşının içeriğine dikkat edilmeli ve riskli görülebilecek hastalıklara yönelik aşılar yapılmalıdır. Hayvanlarda klostridial enfeksiyonların tedavisi mümkün olmadığından dolayı korumak için mutlaka aşı yapılmalıdır. Aşılarda mutlaka Cl perfiringes A, B, C ve D tipleri olmalıdır. Aşı gebe koyun ve keçilere doğuma iki ay kala on beş gün ara ile iki kez aşı uygulanmalıdır. Birinci aşı doğuma atmış gün kala, ikinci aşı doğuma kırkbeş gün kala yapılmalıdır. Annelere aşı yapılmamış ise on günlükten itibaren kuzu ve oğlaklara Cl perfiringes A, B, C, D tiplerini bulunduran aşıların yapılması faydalıdır (2,3,4,7,8,9,10,16).

Enterotoksemi Aşısı

Clostridium perfringens tip A, B, C, D'nin toksinleriyle hazırlanan koruyucu amaçlı aşılardır. Koltuk altı kılsız bölgeye deri altı yapılır. Doğuma sekiz hafta kala gebe hayvanlara on beş gün arayla iki kez, hayvanlar daha önce aşılanmış ise bir kez aşı uygulanır, aşı altı ayda bir tekrar yapılmalıdır. Kuzuların anaları aşılı olanlar 4-8 haftalık yaşta, anaları aşılı olmayanlar 1-3 haftalık yaşta on beş gün ara ile iki kez, altı ayda bir tekrarı yapılarak aşılanır (2,3,4,7,8,9,10,16).

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Basiller İkterohemoglubinuri Aşısı

Hastalığın görülme olasılığının en çok olduğu zamandan dört hafta önce on beş gün ara ile iki kez aşı yapılmalıdır. Hayvanlara yılda bir kez aşı tekrar yapılması gerekir. Hastalığın çıkma ihtimalinin yüksek olduğu bölgelerde altı ayda bir aşı yapılmalıdır. Hastalığa yılın her dönemi rastlanabilmesine rağmen, genellikle yaz sonu ile sonbahar aylarında görülür (2,3,4,9).

Enfeksiyöz Nekrotik Hepatitis Aşısı

Hayvanlara ilk aşılamadan on beş gün sonra ikinci aşılama, daha sonra her yıl tekrar edilmelidir. Genellikle ilkbahar ve kış başlangıcında ya da ılık yağışlı aylarda görülür. Hastalığın meydana geldiği çiftliklerde, ilk aşılamanın ardından on beş gün sonra aşı tekrar yapılır. Korunmak için aşılamanın yaz aylarının başlangıcında yapılması daha iyidir (2,3,4,9).

Tetanoz Aşısı

Hayvanlara sekiz haftalık yaşta, erişkinlere her zaman yapılabilir. Aşı hayvanlara 2 ml kas içi veya deri altı yolla iki hafta arayla iki kez yapılır, bir yıl sonra 1 ml daha yapılır, bu sayede hayvanlar hastalığa karşı dört yıl bağışıklık kazanır (2,3,4,9).

Botulismus Aşısı

Clostridium botulinum tip C ve D'nin toksinleriyle hazırlanmış aşılardır. Botulismus aşısı karma klostridial aşıların içinde bulunmaz. Botulismus riski bulunan sürülerde aşı iki üç hafta ara ile iki kez uygulanır. Hastalığın riskine göre altı ayda bir veya yıllık tekrar edilir (2,3,4,9).

Gazlı Gangren

Hastalığın riskli olduğu yerlerde kuzular iki aylıktan itibaren aşılanmalıdır. Üç hafta arayla iki kez aşı yapılmalıdır. Hastalık riskinin olduğu bölgelerde yıllık aşı tekrarı yapılır (2,3,4,9).

Paratüberküloz

Ülkemizde ruhsatlı aşı bulunmamasına rağmen daha önceleri Etlik Veteriner Kontrol ve Araştırma Enstitüsü tarafından hazırlanan aşı buzağılara doğumdan sonra 10 ila 30. günler arasında gerdanın yan tarafından 1,5 ml tek doz olarak uygulanıyordu. Küçük hayvanlarda doz azaltılarak yapılabilir. Aşılanan hayvanlar ömür boyu tüberküloz testine pozitif cevap verebilir (2,3,4,9).

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Koyun ve Keçilerde Bakteriyel Hastalıklar İçin Aşılama Programı				
Aşı	**Hayvan**	**1.Doz**	**2.Doz**	**Aşının Tekrarı**
Enterotoksemi ve Klostridial Hastalıklar	Anneleri aşısız kuzu ve oğlaklar	2.hafta	21 gün sonra tekrar	6 ay – 1 yıl sonra
	Anneleri aşılı kuzu ve oğlaklar	8.hafta	21 gün sonra tekrar	6 ay – 1 yıl sonra
	Gebeler	Gebeliğin 3. ayı	21 gün sonra tekrar	Bir sonraki gebeliğin son 4. Haftasında
	Gebe olmayanlar ve erkekler	Her zaman	21 gün sonra tekrar	6 ay – 1 yıl sonra
Brusellosis	Genç 3- 8 aylık kuzu ve oğlaklara			
	Ergin 8 aylıktan büyük dişi koyun ve keçilere yapılır			1 yıl sonra
Kolibasillosis	Gebeler	Gebeliğin son ikinci ayı	İlk uygulamada n 21 gün sonra tekrar	Yılda bir kez gebeliğin son 4. haftasında tekrar edilir
Pasterollosis	Kuzu ve gebe koyunlar	Hastalık çıkış öncesi veya 2. haftadan sonra	4 hafta sonra	Bir yıl sonra, gebelerde ise kuzulamadan 4-8 hafta önce aşılanır
Agalaksi	Ölü aşılar tüm koyunlara	Hastalık çıkış öncesi	15 gün sonra	6-12 ay
	Canlı aşılar gebeliğin son 2 ayı ve sağımın 2 ayı hariç	Hastalık çıkış öncesi		1 yıl sonra

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Pseodotüberküloz	Anneleri aşısız kuzu ve oğlaklar	3. haftada	4 hafta sonra	1 yıl sonra
	Anneleri aşılı kuzu ve oğlaklar	8. haftada	4 hafta sonra	1 yıl sonra
	Gebeler	Doğum öncesi tek uygulama		
	İlk kez aşı uygulanacak tüm hayvanlar	Koç katım öncesi	4 hafta sonra, gebeliğin son ayına kadar	1 yıl sonra
Piyeten	Kuzular	4 hafta ve üzeri	4 hafta sonra	Riske göre 4-6 ay veya 1 yıl sonra
	Koyunlar doğum öncesi ve sonrası bir ay hariç	Hastalık çıkış öncesi	4 hafta sonra	Riske göre 4-6 ay veya 1 yıl sonra
Leptospirosis	Tüm hayvanlar gebelerde dahil	2 ay ve üzeri	3 hafta sonra	6 ay veya bir yıl sonra
	Erkekler	2 ay ve üzeri	3 hafta sonra	2 yıl sonra
Salmonellosis	Tüm hayvanlar	5 ay ve üzeri	3 hafta sonra	6 ayda bir veya yılda bir
Keçi Ciğer Ağrısı	Kuzu ve oğlaklara	6. aydan itibaren yapılır		1 yıl sonra

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KOYUN VE KEÇİLERDE VİRAL AŞILAR

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ÖZET

Koyun ve keçilerin yaşamlarını sağlıklı yürütebilmeleri için koruyucu hekimlikte aşılar çok önemlidir. Viral hastalıklara karşı geliştirilen aşılar uzun yıllardır koruyucu hekimlikte kullanılmaktadır. Aşılar, viral hastalıklara karşı koruyucu hekimliğin en önemli sahada yapılan uygulamalarındandır. Sonuç olarak bu derlemede hayvanlarda kullanılan viral aşılar ve önemi vurgulandı.

Anahtar Kelimler: koyun, keçi, virus, aşı

VIRAL VACCINES IN SHEEP AND GOATS

ABSTRACT

Vaccines are very important in preventive medicine for sheep and goats to lead a healthy life. Vaccines developed against viral diseases have been used in preventive medicine for many years. Vaccines are one of the most important field applications of preventive medicine against viral diseases. As a result, viral vaccines used in animals and their importance were emphasised in this review.

Key Words: sheep, goats, virus, vaccine

GİRİŞ

Küçük hayvan yetiştiriciliği, ülkemiz hayvancılığı ve yetiştiriciler açısından çok önemlidir. Yetiştiriciliğin açık olarak yapılması ve farklı sürülerin ortak mera kullanımı, koyun ve keçileri hastalıklara daha duyarlı hale getirir (3,4). Özellikle mera yetiştiriciliğin yoğun olduğu, meranın farklı sürüler tarafından otlatıldığı koyun yetiştiriciliğinde, koruyucu hekimlik ve aşılama çok önemlidir. Aşılama sonrası bağışıklığın %90 oranında sağlandığı bir sürüde, hastalığın görülmesi durumunda hastalığın bulaşma ve ölüm oranı çok az olur. Aşılama sayesinde hastalığın kontrolü çok daha kolay sağlanır. Ülkemizde, küçük hayvan işletmelerinde

aşılamada istenen düzeye ulaşılamamıştır (1-6). Küçük hayvan yetiştiriciliğinde aşılamanın az yapılmasına bağlı olarak hayvan ölümleri çok görülür bu durum ülkemiz hayvancılığına büyük zararlar verir. Hayvancılıkta karlı bir işletme için, bu hayvanların aşı programlarının doğru şekilde hazırlanması, aksatılmadan uygulanması ve sürü sahiplerinin aşılama hakkında bilinçlendirilmesi gerekir (1-6).

Rota ve Korona Aşısı

Rota ve korona virüs ishallerinden hayvanları korumak amacıyla gebe koyun ve keçilere doğuma iki ay kala on beş gün ara ile iki kez aşı yapılmalıdır. Birinci aşı doğuma 60 gün kala, ikinci aşı doğuma 45 gün kala yapılır. Doğduktan sonra septiserum uygulanmalıdır (1-9).

Şap Aşısı

Aşılı annelerden doğan yavrularda ilk aşılama iki aylık yaşta yapılır. İlk aşılamadan bir ay sonra aşı tekrar edilir ve bölgedeki hastalık durumuna göre her 4 ile 6 ayda bir aşılamaya devam edilir. Aşısız annelerden doğan yavrulara iki haftalık yaştan itibaren aşı uygulanabilir (1-11).

Koyun Keçi Veba Aşısı

Ülkemizde hastalığın kontrolü için canlı aşı kullanılır. Aşının bağışıklık süresi bir yıldır. Veba aşısı yapılmış anneden doğan hayvanlarda aşılamaya dördüncü ayda, aşısız annelerden doğan hayvanlarda iki aylık dönemde başlanır. Kuzular ilk aşılamadan, dört ay sonra tekrar aşılanırlar ve aşı yılda bir kez tekrar edilir. Aşı gebe hayvanlarda güvenle kullanılabilir (1-11).

Koyun Keçi Çiçek Aşısı

Koyun keçi çiçek aşısı canlı bir aşıdır. Aşı koruyucu olarak sağlıklı sürülerde altı ile on iki haftalık kuzulara 0,2 ml, on iki haftalıktan büyüklere 0,5 ml deri altı yapılır. Altı haftalıktan küçüklere uygulanmaz. Koyunlara doğumdan sonra ilk ayda ve gebeliğin son altı haftasında aşı uygulanmamalıdır. Yapılan aşının bağışıklığı yirmi bir günde olur ve on ay bağışıklık sürebilir. Hastalığın çıktığı bölgelerde aşılama beş yıl boyunca yılda bir defa yapılır. Son beş yılda hastalığın çıktığı yerlerdeki hayvanlar, yıl içinde çıkacak bölgelerdeki hayvanlar aşılanır (1-11).

Mavi Dil Aşısı

Sineklerin aktif olduğu yaz ve sonbahar mevsiminde çok görülür. Aşı sinekler aktif olmadan yapılmalıdır. Mavi dil aşısı canlı bir aşıdır üç aylıktan itibaren yapılır. Her yaştaki koyuna deri altı uygulanır. Gebe hayvanlarda aborta ve anomalilere neden olabileceği için aşılama doğum sonrası yapılır. Koçlara koç katımından sonra uygulanmalıdır (1-11).

Ektima Aşısı

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Hastalık yaygın olup ilkbahar sonları ve yaz ayları başlarında daha çok görülür. Aşı mart nisan aylarında yapılmalıdır. Ektima hastalığında canlı aşılar kullanılır. Aşılama yeni doğan kuzulara kasık bölgesine, derinin üst katmanına kanama olmayacak şekilde çizilerek 2-3 damla aşı damlatılarak uygulanır. Aşı bölgesi, aşılamadan bir hafta sonra mutlaka kontrol edilmelidir. Kabuklanmanın olmaması aşının etkili olmadığını gösterir. Hastalığın çok küçük kuzularda gözlendiği işletmelerde, annelerin koç katımından önce aşılanmaları iyi olur (1-11).

Kuduz Aşısı

Kuduz hastalığının belirlendiği bölgelerde tüm hayvanlar üç aylıktan itibaren aşılanmalı, üç hafta sonra ikinci uygulamayı takiben aşı yılda bir kez tekrar edilmelidir (1-11).

Parainfluenza

Hastalığın korunmasında karma aşılar kullanılabilir (IBR, PI3, BVD, BRS). İki haftalıktan büyük kuzu ve oğlaklara 4 hafta ara ile iki kez deri altı yapılabilir (1-11).

Respiratorik Sinsitisyal Virus Enfeksiyonu

Solunum sistemi hastalıklarından korunmak için en yaygın solunum patojenleri olan BRSV, PI3 yönelik aşı iki haftalıktan büyük hayvanlara 4 hafta ara ile iki kez deri altı yapılabilir (1-11).

Koyun ve Keçilerde Viral Hastalıklar İçin Aşılama Programı

Aşı	Hayvan	1.Doz	2.Doz	Aşının Tekrarı
Koyun Keçi Vebası	Anneleri aşılı kuzu ve oğlaklar	4 ay	1 yıl sonra	1 yıl sonra
	Anneleri aşısız kuzu ve oğlaklar	3 ay	1 yıl sonra	1 yıl sonra
Koyun Keçi Çiçek	Kuzu ve Oğlaklar	6 hafta üzeri		1 yıl sonra
	Erginler	Gebeliğin son 6 haftası hariç ve doğum sonrası ilk ay hariç		1 yıl sonra
Şap	Anneleri aşısız kuzu ve oğlaklar	2 hafta ve üzeri	1 ay sonra	4-6 ay sonra
	Anneleri aşılı kuzu ve oğlaklar	2 ay ve üzeri	1 ay sonra	4-6 ay sonra
	Tüm hayvanlar	Salgınlardan hemen önce	1 ay sonra	4-6 ay sonra
Mavi Dil	Kuzular	3 ay ve üzeri		1 yıl sonra
	Erişkinler	İlkbahar veya hastalık çıkış öncesi		
Ektima	Anneleri aşısız kuzu ve oğlaklar	1- 4 gün	1 ay sonra	Uygulanmaz

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	Anneleri aşılı kuzu ve oğlaklar	1 ay ve üzeri		Uygulanmaz
	Gebeliğin son 6 haftasına kadar	Hastalık çıkan bölgelerde tek uygulama		
Rota Korona Virus	Gebelere	Doğuma 8 hafta kala	3 hafta sonra	Yılda bir kere gebeliğin son 2 ayında tekrarlanır
Kuduz	Tüm hayvanlar	3 ay ve üzeri		1-2 yıl sonra
Parainfluenza Respiratorik Sinsitisyal Virus	Kuzu ve oğlaklar, Anneler	2 haftalıktan büyük	4 hafta sonra	1 yıl sonra

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ÇİFTLİK HAYVANLARI İÇİN SELENYUM KATKILARININ DEĞERLENDİRİLMESİ

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Özet

Selenyum (Se), hem insanlar hem de hayvanlar için gerekli olan bir eser elementtir ve antioksidan savunma sistemleri, bağışıklık fonksiyonu, üreme sağlığı ve genel verimlilik üzerinde önemli roller oynar. Se'nin biyolojik etkileri, selenoproteinler adı verilen özel proteinler aracılığıyla gerçekleştirilir. Selenoproteinler, özellikle glutatyon peroksidazlar (GSH-Px), tiyoredoksin redüktazlar (TRX'ler) ve iyodotironin deiyodinazlar (DIO'lar) gibi antioksidan enzimlerde önemli roller üstlenir. Hayvan beslenmesinde Se, genellikle inorganik (sodyum selenit [SS]) ve selometiyonin (SeMet) formunda organik (Se-maya [SY], OH-SeMet) formlarda yemlere eklenir. Hayvanları SeMet ile beslemenin, vücutta depo oluşturabilen ve ihtiyaç halinde kullanılabilen bir Se rezervi sağlama açısından inorganik Se'ye göre üstün bulunmuştur. Ancak SY'de SeMet oranının yüksek değişkenlik (%20-75) gösterdiği bildirilmiştir. Buna karşın Se'nin saf kimyasal olarak sentezlenen organik formu olan OH-SeMet'in yalnızca toplam organik Se içeriğini değil aynı zamanda SeMet formundaki Se'nin sabit konsantrasyonunu da garanti edebilmekte (>%98) ve böylece Se'nin sunulmasını garanti altına alabilmektedir. Buna ilaveten bu formun, hayvanların vücut dokularında zamanla biriken ve ihtiyaç anında serbest bırakılabilen bir Se rezervi oluşturduğu, böylece Se'nin uzun süreli etkilerini desteklediği bulunmuştur. Ayrıca OH-SeMet, yüksek stabiliteye sahip olup hem yem katkısı olarak hem de depolama sırasında diğer Se formlarına göre daha üstün bir performans sergilemektedir. Se kaynaklarının karşılaştırıldığı çalışmalar, OH-SeMet'in hemen organik SY ve inorganik Se'ye göre kas dokusunda daha fazla Se birikimi sağladığını göstermiştir. Sonuç olarak, OH-SeMet gibi üçüncü nesil Se formları, hayvanlarda dokusal Se birikimini artırarak büyüme, performans ve sağlık üzerinde olumlu etkiler sağlayan etkili bir Se kaynağı olarak değerlendirilmektedir. Bu durum, özellikle yem alımının azaldığı stres koşullarında hayvanların üretkenliğini sürdürmelerine yardımcı olur.

Anahtar Kelimeler: Çiftlik hayvanı, selenyum, OH-SeMet

Giriş

Selenyum (Se), insan ve hayvan beslenmesi için gerekli bir eser elementtir ve antioksidan sistemlerdeki, üreme, bağışıklık fonksiyonu, sağlık ve verimlilik üzerindek önemli etkileri vardır (Surai ve Kochish, 2019). Se'nin biyolojik etkileri aktif bölgelerinde selenosistein (Se-Cys) formunda Se bulunan selenoproteinler tarafından gerçekleştirilir. Selenoproteinler 21. amino asit olarak bilinir ve hayvanların selenoproteomunda 25'den fazla selenoprotein olduğu bilinmektedir (Papp ve ark., 2007). Selenoproteinler üç ana fonksiyonel grupta sınıflandırılabilir: glutatyon peroksidazlar (GSH-Px), tiyoredoksin redüktazlar (TRX) ve iyodotironin deiyodinazlar (DIO). Bu selenoproteinler arasındaki ortak nokta, hepsinin işlev görmek için bir Se-Cys içermesidir. Selenoproteinlerin hepsi antioksidan sistemin bir parçası değildir (Gladyshev, 2006). GSH-Px'ler memelilerde en bol bulunan ve hücre içi antioksidan savunma sisteminde reaktif oksijen türlerine (ROS) karşı anahtar enzimlerdir. Ayrıca Se selenometiyonin (Se-Met) şeklinde proteine de bağlanabilir. Burada Se bir mineral olarak işlev görmez ancak metiyonin normal metiyonin gibi kullanılabilir (Suzuki ve Orga, 2002). SeMet, proteinlerin yapısal veya işlevsel modifikasyonlarını indüklemeyen güvenli bir Se depolama formu olarak kabul edilir (Roman ve ark. 2014).

Yemlerin düşük düzeyde Se içerdiği göz önüne alındığında, bu mineral 1970 yılından bu yana hayvan beslemede yem katkı maddesi olarak kullanılmaktadır. Çiftlik hayvanlarının Se gereksinimlerini karşılamak için yemlere her zaman inorganik (sodyum selenit [SS]; SS ve soya proteini hidrolizatlarının karışımları), Se-maya (SY, SeMet ile zenginleştirilmiş maya) gibi organik formda veya L-SeMet veya hidroksi-selenometiyonin (OH-SeMet, 2-hidroksi-4-metilselenobütanoik asit olarak da bilinir- HMSeBA) gibi saf kimyasal olarak sentezlenmiş SeMet formda Se katılmaktadır. Se kaynağı/katkısı ne olursa olsun, hayvan rasyonlarına eklenebilecek maksimum ek Se miktarı Amerika Birleşik Devletleri'nde 0,3 mg/kg rasyon ile sınırlıyken (Food and Drug Administration, 1997), Avrupa Birliği'nde izin verilen maksimum ek Se miktarı 0,2 mg/kg rasyon organik Se ve 0,3 mg/kg rasyon inorganik Se'dir (EC, 2000, 2013).

Se kaynaklarının karşılaştırılması, hayvanların optimal sağlık ve performansı için uygun Se formunun belirlenmesi açısından önem arz etmektedir. Bu çalışma, hem inorganik (SS) hem de organik Se kaynakları (SY ve OH-SeMet) ile yapılan takviyelerin etkinliğini inceleyerek, hayvan beslemesinde Se'nin ideal formunun belirlenmesine katkı sağlamayı amaçlamaktadır.

Selenyum Kaynaklarının Karşılaştırılması

Se biyokimyasındaki son gelişmeler, çeşitli Se formları arasındaki emilim ve metabolizmadaki temel farklılıkların daha iyi anlaşılmasını sağlamıştır. Bu bağlamda farklı Se katkı maddelerinin biyo-etkinliğinin, farklı hayvan dokularındaki Se birikimi göz önünde bulundurularak değerlendirilebileceği ifade edilmiştir (Surai ve ark., 2018). SS, vücutta Se deposu oluşturamaz ve herhangi bir Se fazlası toksisite oluşmasını önlemek için derhal atılır (De Marco ve ark., 2021). Çiftlik hayvanı rasyonlarına SeMet ilave etmenin inorganik kaynaklara veya diğer organik Se bileşiklerine (örneğin SeCys'in diyet formları) göre avantajı, metionin ve SeMet arasındaki kimyasal benzerlik nedeniyle ikincisinin emilimi ve bir metionin

molekülü olarak metabolize edilmesidir. Bu özellik, hayvanların vücut dokularında daha sonra serbest bırakılabilen bir Se deposu oluşturulmasına yol açar (Schrauzer, 2000; Juniper ve ark., 2011). Birçok çalışmada, kaslardaki Se birikiminin organik Se formları kullanılarak önemli ölçüde artırılabileceği gösterilmiştir (Juniper ve ark., 2011; Briens ve ark., 2013; Simon ve ark., 2013; Couloigner ve ark., 2015; Van Beirendonck ve ark., 2016; Silva ve ark., 2019). Organik Se formları içinde SY'nin 60'tan fazla benzersiz Se türü içerdiği bildirilmiştir (Bierla ve ark., 2012; Arnaudguilhem ve ark., 2012; Ward ve ark., 2019). Se takviyesi olarak onaylanan SY, ortalama olarak >%63 SeMet, %2-25 SeCys ve <%1 selenit veya selenattan oluşur (EFSA, 2008, 2018, 2019). Bununla birlikte, sadece SeMet derinlemesine araştırılmış ve SY'nin aktif bileşiği olduğu kanıtlanmıştır. Ayrıca, SY'de SeMet oranının yüksek değişkenlik gösterdiği bildirilmiştir (%20-75) ve bu endüstri için büyük bir endişe kaynağıdır (Simon et al., 2013; Liu et al., 2017; Surai et al., 2018; EFSA, 2019). SY ile karşılaştırıldığında, üçüncü nesil Se kaynağı olan OH-SeMet yalnızca toplam organik Se içeriğini değil aynı zamanda SeMet formundaki Se'nin sabit konsantrasyonunu da garanti edebilmekte ve böylece Se'nin sunulmasını garanti altına alabilmektedir. Bu formlar saf kimyasal sentez yoluyla üretilir ve sırasıyla L-SeMet veya OH-SeMet olarak toplam Se'nin >%97 veya >%98'ini sağlayan Se bileşiklerinden oluşur (EFSA, 2013a; 2013b). L-SeMet doğal olarak oluşmasına rağmen, OH-SeMet SeMet'in bir öncüsüdür. Bununla birlikte, diyetle tüketildikten sonra OH-SeMet'in hızla SeMet'e dönüştüğü ve aynı şekilde metabolize edildiği gösterilmiştir (EFSA, 2013a).

Son yıllarda yürütülen çalışmalar, OH-SeMet ‘in biyolojik değeri en yüksek olduğu bilinen SeMet molekülünü etkin bir şekilde sağladığı ve hem inorganik SS ve hem de SY’e kıyasla en iyi Se kaynağı olduğunu ortaya koymuştur. Bu bağlamda OH-SeMet, broyler (Briens ve ark., 2013, 2014; De Marco ve ark., 2021), yumurtacılar (Jlali ve ark., 2013; Tufarelli ve ark., 2016), domuzlar (Jlali ve ark., 2014), süt sığırı (Li ve ark., 2020) ve besi sığırlarında (Grossi ve ark., 2021) SY’ye kıyasla daha yüksek emilim ve kullanım etkinliği gösterilmiştir Ayrıca sağlık ve performans üzerinde zararlı etkiler olmaksızın daha yüksek organik Se takviyesi ile kan Se seviyelerinde doğrusal artışlar da bildirilmiştir (Sun ve ark., 2017; Barbé ve ark., 2020; Sun ve ark., 2021).

Üçüncü nesil Se kaynaklarının etkilerini doğrulamak amacıyla 432 tavuk (Ross 308) etlik piliç üzerinde De Marco ve ark.(2021) tarafından yürütülen bir çalışmada, piliçler 14 gün boyunca negatif kontrol rasyonu (NC, Se takviyesiz) veya 0,3 mg/kg SS katkılı aynı NC rasyonyu veya %56 (SY56) ve %72 (SY72) SeMet içeren iki SY kaynağı (0,3 mg/kg) beslenmiştir. Diğer gruplarda ise NC rasyonuna 0,15; 0,3; 0,45 ve 0,6 mg Se/kg L-SeMet veya OH-SeMet ilave edildi. Denemenin sonunda göğüs kasındaki Se içeriğini belirlemek için her gruptan 9 piliçten örnek alınmıştır. Çalışma sonunda Se kaynaklarının kastaki Se birikimini önemli ölçüde etkilediği görülmüştür (Şekil 2). İstatistiksel değerlendirme, organik formların (SY56, SY72, L-SeMet ve OH-SeMet) sodyum selenit (SS) ile karşılaştırıldığında ve daha yüksek SeMet konsantrasyonu sayesinde daha etkili olduğunu göstermiştir. Sonuçlar ayrıca selenyum mayaları (SY56 ve SY72) ile karşılaştırıldığında L-SeMet ve OH-SeMet'in göğüs kasındaki Se birikiminde daha etkili olduğunu ortaya koymuştur. Biriktirme sonuçları ayrıca, L-SeMet veya OH-SeMet'in diyet takviyesindeki Se birikiminin doza bağlı olduğunu ve bu

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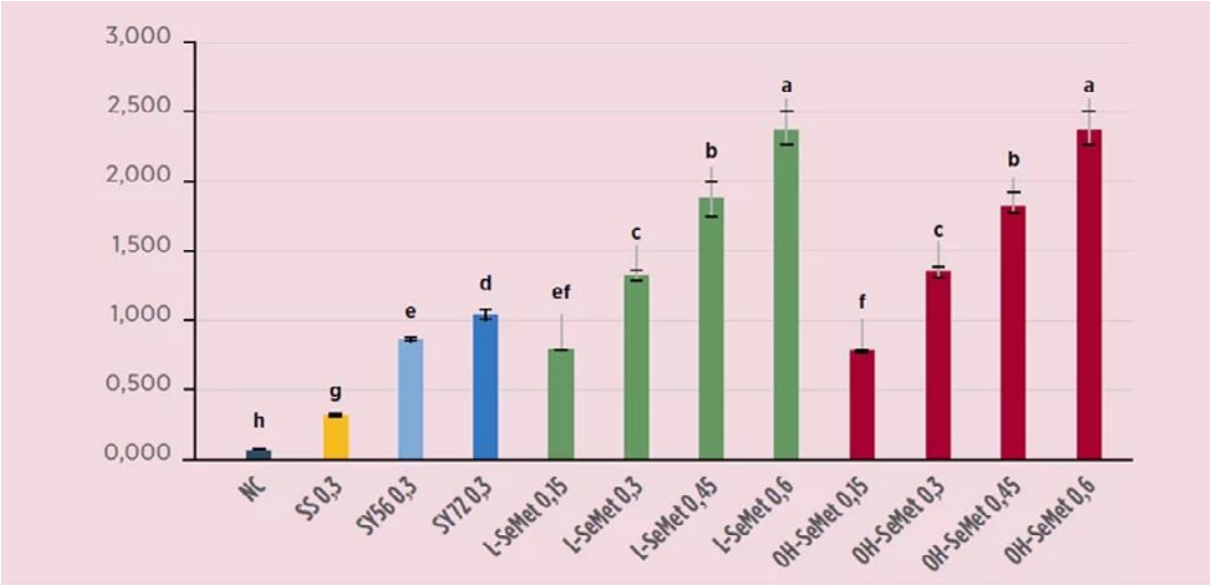
üçüncü nesil Se kaynaklarının, test edilen dört doz için eşdeğer biyolojik verimlilik (P> 0.05) gösterdiğini gösterdi (Şekil 1).

Son olarak, üçüncü nesil SeMet'i ayırt edebilen bir nokta, moleküllerin normal koşullar veya hızlandırılmış değerlendirme koşulları olarak adlandırılan koşullar altında depolamaya karşı stabilitesidir. EFSA, normal koşullar altında ve hızlandırılmış koşullar altında 3, 12 veya 18 ay boyunca saklanan OH-SeMet'in stabilitesini değerlendirdiğinde; 3 ay sonra normal koşullarda %98, hızlandırılmış koşullarda ise %97 oranında iyileşme tespit edildi ; 12 aylık depolama için geri kazanımlar %91 ve %80 iken, 18 aylık sonuçlar sırasıyla %89 ve %78 idi. Bu katkı maddesinin son değerlendirmesinde EFSA, stabil olduğu bilinen bir hidroksi-metiyonin molekülündeki selenyum olduğundan OH-SeMet'in stabilitesi konusunda olumlu bir görüş verdi.



Şekil 1. 14. günde farklı selenyum kaynakları ve seviyeleriyle beslenen etlik piliçlerin kaslarındaki ortalama selenyum değerleri. (a-h) Farklı harflere sahip ortalama değerler istatistiksel olarak farklıdır (p<.05). Hata çubuğu ortalamanın standart hatasını temsil etmektedir. NC: Se ile desteklenmemiş negatif kontrol; SS: sodyum selenit; SY56: seleno-maya %56 SeMet; SY72: seleno-maya %72 SeMet; L-SeMet: L-selenometiyonin; OH-SeMet: hidroksi-selenometiyonin; ardından kilogram yem başına mg Se cinsinden Se takviyesi seviyesi (De Marco 2021'den alınmışır).

Sonuç

Hayvanlara OH-SeMet gibi saf bir organik Se formu vermek, dokularda Se doku rezervleri oluşturur. Bu Se rezervi, biyotik veya abiyotik stres koşullarına nedeniyle yem tüketimi azaldığında yeterli miktarda antioksidan enzim üretilmesi sağlar ve böylece hayvan sağlığı ve performansının yanı sıra ölüm oranını azaltmasının etkili bir yolu olarak değerlendirilir.

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RUMİNANT ETİNİN FONKSİYONEL YAĞ ASİTLERİ İÇERİĞİNİ İYİLEŞTİREN BESLEME YAKLAŞIMLARI

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Özet

Diyet yağları insan sağlığını olumlu ve olumsuz yönde etkileyebilir; bu yüzden doymamış yağ asitleri (PUFA) açısından zengin gıdalar tercih edilir. Ruminant eti, insan sağlığı için faydalı PUFA'ların önemli bir kaynağıdır. Özellikle, α-linolenik asit (ALA, C18:3 n-3) ve linoleik asit (LA, C18:2 n-6) gibi esansiyel yağ asitleri ve bunların türevleri olan eikosapentaenoik asit (EPA, C20:5 n-3), dokosapentaenoik asit (DPA, C22:5 n-3) ve dokosaheksaenoik asit (DHA, C22:6 n-3) ruminant etinde bulunur. Ayrıca, konjüge linoleik asit (CLA) izomerleri ruminant etinde önemli bir yer tutar. Ancak, rumendeki biyohidrojenasyon süreci n-3 ve n-6 yağ asitlerinin büyük bir kısmını doymuş yağlara dönüştürdüğünden, etin bu yağ asitleriyle zenginleştirilmesi zorlaşmaktadır. Buna rağmen, n-6:n-3 oranını iyileştirmek ve CLA izomerlerini artırmak için çeşitli besleme stratejileri geliştirilmiştir. Çayır-mera veya silaja dayalı besleme, etin n-3 PUFA ve CLA içeriğini artırma konusunda etkili bir yöntemdir. Konsantre ve tahıla dayalı rasyonlar ise ruminant etinde n-6 yağ asitlerinin artmasına ve n-6 oranının yükselmesine yol açabilir. Tahıl ağırlıklı beslenen hayvanlarda LA ve diğer n-6 PUFA'lar artarken, n-3 PUFA'lar azalır. Keten tohumu, kanola yağı gibi n-3 yağ asitleri açısından zengin yağ kaynakları, ruminantların etlerindeki ALA, EPA, DHA gibi uzun zincirli PUFA'yı artırma potansiyeline sahiptir. Sonuç olarak, ruminant etinin fonksiyonel yağ asitleri açısından zenginleştirilmesi, hayvanların besleme stratejilerinde yapılacak düzenlemelerle mümkündür. Meraya dayalı beslenme ve uygun yağ kaynakları kullanımı ruminant etinin insan sağlığı için daha faydalı hale getirilmesine yardımcı olabilir.

Anahtar kelimeler: Kırmızı et, yağ asitleri, besleme stratejisi

Giriş

Diyet yağları insan sağlığını hem olumlu hem de olumsuz yönde etkiler. Genel olarak, düşük yağ içeriğine veya yüksek oranda doymamış yağ asitleri (PUFA) içeren gıdalar hedeflenir. Uzun süredir diyet kılavuzları kardiyovasküler hastalıkları önlemek için yüksek oranda doymuş yağ asitleri (SFA) alımından kaçınılmasını önermektedir (Krauss ve ark., 2000). Aksine, ruminant eti fonksiyonel yağ asitlerinin iyi bir kaynağıdır. Fonksiyonel yağ asitlerinin ana maddelerini [α-linolenik asit (ALA, C18:3 n-3)) ve linoleik asit (LA, C18:2 n-6)], ürünlerini

[eikosapentaenoik asit (EPA, C20:5 n-3), dokosapentaenoik asit (DPA, C22:5 n-3) ve dokosaheksaenoik asit (DHA, C22:6 n-3)] ve biyohidrojenasyon ara maddelerini [rumenik asit (cis(c)9, trans(t)11-18:2) ve trans vaksenik asit (TVA, cis(c)9, trans(t)11-18:1)] içerir (Ponnampalam ve ark., 2024). Ayrıca etin daha düşük n-6 PUFA/n -3 PUFA oranının insan sağlığına yararlı olduğu gösterilmiştir (Liu ve Ma, 2014).

LA ve ALA, hayvan ve insan vücudu tarafından sentezlenemeyen ve diyetten alınması gereken ana yağ asitleridir (Papandreou, 2014). Bu iki yağ asidi, daha uzun zincirli PUFA türevlerinin ve rumende biyoaktif ara maddelerinin sentezi için önemlidir (Ponnampalam ve ark., 2021). Bu nedenle, dünya nüfusunun çoğunluğu tarafından tüketilen ruminant etinin fonksiyonel yağ asitlerince zenginleştirilmesi insan sağlığına fayda sağlayabilir. Bu inceleme, ruminant etindeki fonksiyonel yağ asitlerinin zenginleştirilmesine katkıda bulunan çeşitli rasyonların ve beslenme stratejilerinin yönleri hakkında bir güncelleme sağlamayı amaçlamaktadır.

Etin Yağ Asidi Bileşimi

Et lipitleri temel olarak doymuş yağ asitleri (SFA), tekli doymamış yağ asitleri (MUFA) ve PUFA'lar içeren trigliseritler ve fosfolipitlerden oluşur. Sığır eti ve kuzu eti sırasıyla %4'ten ve %5,7'den daha az PUFA içerir (Wood ve ark., 2004). Trigliseridler depo lipidleridir ve SFA bakımından daha zengindir. Fosfolipidler ise genellikle hücre zarlarında yaygın olan fonksiyonel lipidlerdir ve bu nedenle trigliseridlerden daha fazla PUFA içerirler (Mapiye ve ark., 2012; Dugan ve ark., 2018). Membran lipidlerinin önemli bir kısmını oluşturan aynı zamanda depo lipidlerinin de bir parçasını oluşturan LA ve ALA PUFA'lar vücutta sentezlenemez ve bu nedenle esansiyeldir ve hayvana rasyonla sağlanmalıdır (Kearns ve ark., 2023). Bir MUFA olan oleik asit (C18:1 n-9) de faydalı olarak kabul edilir ancak esansiyel değildir. Ayrıca ruminant eti EPA, DPA ve DHA gibi çok uzun zincirli n-3 PUFA içerirler. Bu yağ asitleri sadece ALA'dan düşük miktarlarda sentezlenir ve çoğunlukla rasyonla dışardan alınırlar (Papandreou, 2014). Ruminant etinde bir diğer önemli PUFA ise araşidonik asittir (AA, C20:4 n-6) ve rasyonla alınır veya LA'dan endojen olarak sentezlenebilir (Papandreou, 2014).

Ruminant etleri nispeten yüksek düzeyde konjuke linoleik asit (CLA) izomerleri içerir (toplam yağ asitlerinin %0,5 ila 1,5'i). Ruminant etinde, PUFA biyohidrojenasyon ara ürünleri olan CLA izomerlerinin oranı bazı üretim sistemlerinde toplam lipitlerin %10-15'ine kadar ulaşabilir (Aldai ve ark., 2010). CLA'nın insan diyetine dahil edilmesinin, anti-enflamatuar ve anti-kanser özellikleri de dahil olmak üzere sağlık yararları iyi belgelenmiştir (Davis ve ark., 2022). Bu etkilerin çoğu rumenik asit ve CLA trans-10, cis-12 izomeri olmak üzere iki CLA izomerine atfedilmektedir (Badawy ve ark., 2023). Rumenik asit sığır yağında bulunan CLA izomerlerinin %75'ini temsil eder (Chin ve ark., 1992).

Ruminant etindeki n -3 yağ asitlerinin konsantrasyonları, hayvan rasyonunda bulunan n-6 yağ asidi miktarından etkilenebilir; bunun nedeni (1) enterositte emilim için n -3 ve n -6 yağ asitleri arasındaki rekabettir. Aynı enzimler LA ve ALA'nın desatürasyon süreçlerine aracılık eder. Hem yağ asidi desatüraz 1 hem de yağ asidi desatüraz 2, *n* -6 yağ asitlerine kıyasla *n -3'ü tercih eder,* ancak yüksek LA tüketimi (örneğin tahılla besleme*) ALA'nın EPA, DPA ve DHA'ya* desatürasyon sürecini etkileyebilir. (2) n-6 yağ asitlerinin periferik doku

düzeyinde desatürasyon enzimleriyle etkileşimidir (Ponnampalam ve ark., 2018). Bu nedenle insanlar gıdalarda <4'lük bir n-6: n-3 oranı hedeflenmektedir (Howes ve ark., 2015).

Rumende Lipitlerin Modifikasyonu

Rasyon PUFA'ları, rumende gerçekleşen yoğun biyohidrojenasyon nedeniyle yemden ete geçiş sırasında büyük değişime uğrarlar. Rumen mikrobiyal popülasyonu tarafından lipitlerin modifikasyonu hem lipoliz hem de biyohidrojenasyondan oluşur. Rasyon lipitleri rumen içindeki mikrobiyal lipazlar tarafından hidrolize edilerek gliserol ve serbest yağ asitleri açığa çıkar (Buccioni ve ark., 2012). PUFA'lar rumen mikroorganizmaları için toksiktir. Bununla başa çıkmak için rumen mikroorganizmaları izomerizasyonu/biyohidrojenasyon ile PUFA'yı daha az toksik SFA'ya, özellikle stearik aside (18:0) biyohidrojene eder. Son ürün olan stearik aside giden yolda doğrudan CLA veya CLA'nın önemli ara öncülleri üretilir (Toral ve ark., 2018). Örneğin, LA izomerizasyon yoluyla rumenik asit (c9, t11-18:2) ve ara ürün olarak daha fazla hidrojenasyon yoluyla trans-vasenik asit (TVA, t11-18:1) üretilir. ALA'nın ana süreci TVA ve ardından stearik aside dönüşür (Popova ve ark., 2022) (Şekil 1). Genel olarak, LA ve ALA'nın sırasıyla yaklaşık %80'i ve %92'si rumende biyohidrojene edilir (Doreau ve Chilliard, 1997). Rumende biyohidrojenasyondan kurtulan PUFA'lar ve biyohidrojenasyon ürünleri daha sonra ince bağırsaktan emilebilir ve ruminant etine katılabilir (Vahmani ve ark., 2015).

Ruminal biyohidrojenasyona ek olarak yağ dokusu ve meme bezinde öncül yağ asidi olan TVA'dan da endojen sentezlenebilir. Bu süreç emilen TVA'nın delta Δ9-desaturaz enzimi tarafından c 9, t 11-18:2 CLA'ya dönüştürülmesini içerir (Popova ve ark., 2022). Ruminant yağındaki toplam CLA'nın yaklaşık %80-90'ını oluşturan rumenik asittir (Nuernberg ve ark., 2002). Özetle ruminant ürünleri CLA'nın başlıca kaynağıdır ve rumen, hem CLA üretiminin birincil kaynağı hem de kas dokuda CLA sentezi için substratın kaynağıdır (Daley ve ark., 2010). Bu nedenle ruminant etleri nispeten yüksek CLA konsantrasyonlarına sahiptir (toplam yağ asitlerinin %0,5-1,5'i). Sığır eti lipitleri için Schmid ve ark. (2006) tarafından %0,1-1,0 arasında bir CLA aralığı bildirilmiştir.

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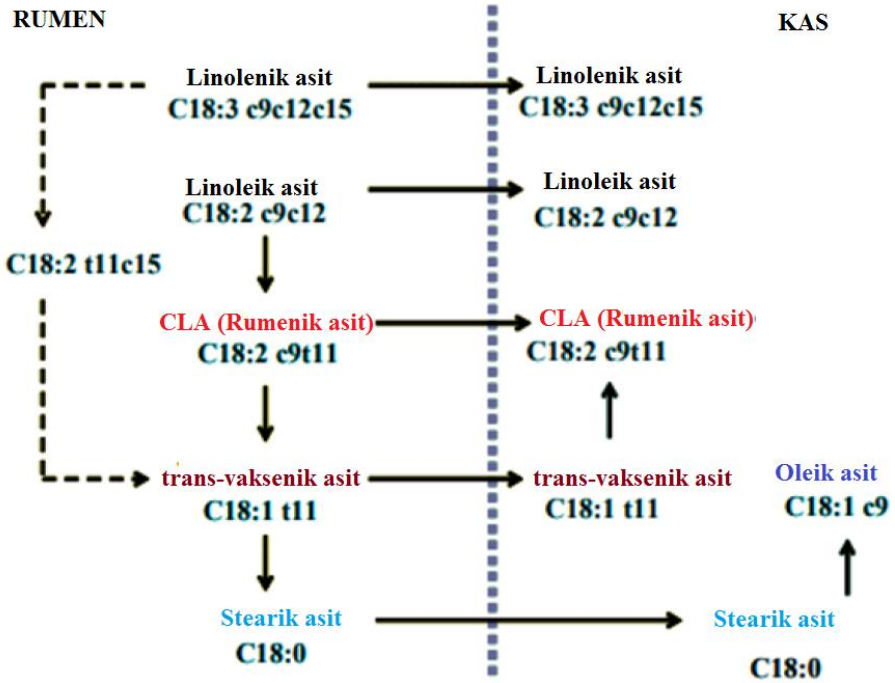

Şekil 1. Linoleik ve linolenik asitlerin rumen biyohidrojenasyonu (Bauman ve Griinari 2003'ten uyarlanmıştır)

Et Lipitlerini İyileştiren Beslenme Yaklaşımları

rumendeki biyohidrojenasyon süreci n-3 ve n-6 yağ asitlerinin büyük bir kısmını SFA'ya dönüştürdüğünden etin bu yağ asitleriyle zenginleştirilmesi zorlaşmaktadır. Buna rağmen, n-6:n-3 oranını iyileştirmek ve CLA izomerlerini artırmak için çeşitli besleme stratejileri geliştirilmiştir.

Bitkisel yağlar ve içerdikleri bitkiler veya tohumlar, PUFA açısından zengin yemlerin en önemli kaynaklarıdır (Boufaïed ve ark., 2003). Birçok bitkisel yağda, LA bol miktarda bulunur (örneğin ayçiçeği yağı ve soya fasulyesi yağında) ve bunların ette bulunan konsantrasyonun yaklaşık 20 katıdır. N - 3 yağ asidi ALA, özellikle yapraklı bitki dokularının lipitlerinde bol miktarda bulunur (Dierking ve ark., 2010), bu da lipit içeriği düşük olmasına rağmen kaba yemi iyi bir kaynak haline getirir. Keten tohumu yağı, aspir yağı ve kolza tohumu yağı gibi belirli bitkisel yağlar da ALA açısından zengindir. Karasal bitkiler çok uzun zincirli n-3 PUFA içermez. Bu yağ asitleri esas olarak alglerde ve dolayısı ile bu algleri tüketen deniz balıklarında bulunur (Ponnampalam ve ark., 2021).

Çayır-mera veya silaj dayalı beslemede, çoğunlukla fosfolipitler olarak biriktirilen yüksek seviyelerde ALA içeren et üretilir. ALA, kas dokularında doygunluk EPA, DPA ve DHA yağ asitlerinin sentezi daha da artırır (Nuernberg ve ark., 2005; Ponnampalam ve ark., 2021). Genel olarak, taze kaba yemler ve meralar, korunmuş kaba yemlere (yani silaj ve saman) kıyasla daha yüksek toplam lipit ve toplam PUFA içeriğine sahiptir. Bunun başlıca nedeni, kurutma ve silolama işlemleri sırasında PUFA'nın oksidatif bozunmasıdır. Türler açısından baklagiller, çoğu ot türüne kıyasla genellikle daha yüksek toplam yağ asidi, toplam PUFA ve n-3 PUFA, özellikle de ALA içeriğine sahiptir. Genel olarak, taze mera otlayan ruminantlar, silaj/kuru ot (Ciftçi ve ark., 2010) veya toplam karma rasyon (TMR) rasyonlarıyla beslenen

ruminantlara kıyasla daha yüksek miktarda n-3 PUFA tüketmektedir (Berthelot ve Gruffat, 2018; Gruffat ve ark., 2020). Mera türü etin faydalı yağ asidi bileşimini etkileyebilir. Farklı çayır otları, baklagiller ve çalımsı bitkilerden oluşan çok türlü meralarda otlayan kuzular (Lourenço ve ark., 2007) ve sığırlar (Kearns ve ark., 2023), reygras otlayan kuzu ve sığırlardan elde edilen ete kıyasla daha yüksek LA, ALA seviyelerine ve daha düşük n-6: n-3 oranına sahip kuzu ve sığır eti ile sonuçlanmıştır. Fenol bakımından zengin bitkilerin bulunduğu botanik çeşitliliğe sahip meralarda otlayan kuzular, yoğun şekilde yönetilen meralarda otlayan kuzulara kıyasla PUFA, ALA ve LA bakımından daha zengin et üretmektedir ve etteki bu FA konsantrasyonu meranın fenolik konsantrasyonuyla doğrusal olarak ilişkilidir (Willems ve ark., 2014). Baklagil ve yabani ot türlerindeki bitki sekonder metabolitleri (polifenol oksidaz, flavonoidler, tanenler, uçucu yağlar ve saponinler) rumendeki mikrobiyal biyohidrojenasyonu etkileyerek faydalı n-3 PUFA ve CLA çıkışını olumlu yönde etkileyebilir (Chikwanha ve ark., 2018; Frutos ve ark., 2020).

Literatürde, tahıl taneleri (yulaf, arpa ve buğday), mısır veya pamuk tohumu içeren konsantre veya tahıl bazlı diyetlerle beslenen hayvanların kaslarında LA artışı bildirilmiştir (Kashani ve ark., 2015; Baldi ve ark., 2019). Besi sığırlarında yürütülen çalışmalarda, tahıl ağırlıklı rasyonla beslemenin başta LA olmak üzere n-6 PUFA içeriğinin artmasına ve daha yüksek n-6:n-3 oranlarına yol açtığı belirlenmiştir (Vahmani ve ark., 2015; Berthelot ve Gruffat, 2018; Klopatek ve ark., 2022). LA'nın bir kısmı fosfolipitler olarak biriktirilir ve doygunluk giderme ve uzatma süreçleri yoluyla daha uzun zincirli C20:3n-6, C20:4n-6 ve AA üretimini daha da artırır. Merada beslenen hayvanların etleri, tahılla beslenen hayvanlara kıyasla daha yüksek n-3 PUFA içeriği içerir (Berthelot ve Gruffat, 2018; Gruffat ve ark., 2020); bunun nedeni, EPA, DPA ve DHA ve CLA'nın endojen üretimi için bir öncül olan taze meradaki doğal olarak yüksek ALA seviyeleridir (Siphambili ve ark., 2020; Ponnampalam ve ark., 2021). Buna ek olarak merada beslenen ruminantların, esas olarak daha elverişli rumen pH'ı ve mikrobiyal popülasyon nedeniyle 2-3 kat daha fazla CLA ürettiği ve yağ dokusunda CLA üretiminin ve birikiminin artmasına izin verdiği gösterilmiştir (Lourenço ve ark., 2007). Phillips ve ark. (2020). ALA bakımından yüksek bir rasyona sahip sığırların, dokularda CLA üretimini ve birikimini artıran spesifik mikroflora geliştirdiğini belirtmiştir. Ayrıca, mera ve kaba yemde bulunan sekonder metabolitler, PUFA'nın mikrobiyal biyohidrojenasyonuna karşı koruma sağlayarak, bunların daha fazla emilmesini ve birikmesini kolaylaştırır (Lourençove ark., 2008). Merada beslenen kuzulara ilave verilen tahıl düzeyi arttıkça bu avantajları azaltır (Berthelot ve Gruffat, 2018). Bu durum tahıla dayalı rasyonlarda baskın yağ asidinin LA olmasından kaynaklanmaktadır. Otlatma sonrası tahılla beslenme süresinin uzaması, ette biriken n-3 PUFA'yı azaltmakta ve kuzu etinde daha düşük ALA, EPA ve DHA ile CLA'lar (örn. RA) ve TVA seviyeleri gözlenmektedir (Scerra ve ark., 2011).

Kaba yemle besleme stratejilerine ek olarak, rasyonların n-6 bakımından zengin yağlı tahumlar ya da bitkisel yağlar ile desteklenmesinin n-3 PUFA bakımından zengin yağ kaynaklarına kıyasla kuzu (Chikwanha ve ark., 2018) ve sığır etindeki (Vahmani ve ark., 2020; Alves ve ark., 2021) LA, RA ve TVA'nın yanı sıra diğer CLA izomerlerinin oranlarını artırdığı gösterilmiştir. Keten ve kanola gibi yağlı, etin ALA ve daha uzun zincirli ω-3 yağ asidi konsantrasyonlarını artırabilir (Ponnampalam ve ark., 2021, 2022). Ayrıca, kuzu rasyonlarında deniz yosunu, alg, balık unu ve balık yağı gibi deniz bazlı ürünler, esas olarak kas dokularındaki

daha uzun zincirli ω-3 yağ asitleri olan C20:5n-3, C22:5n-3 ve C22:6n-3 konsantrasyonlarını artırır (Ponnampalam ve ark., 2002; Vahedi ve ark., 2015; Malau-Aduli ve ark., 2015). Antioksidanlar (polifenoller, flavonoidler, antosiyanidinler ve tanenler) bakımından zengin olan üzüm/ nar posası ve soya fasulyesi kabuğu gibi yan ürünlerin kuzulara yedirilmesi, ette ALA ve toplam n-3 PUFA seviyelerinin zenginleşmesine yol açmıştır (Gómez-Cortés ve ark., 2019; Natalello ve ark., 2019; Bennato ve ark., 2023).

Sonuç olarak, n-3 PUFA bakımından zengin mera veya yüksek kaba yem diyetleriyle besleme, ruminant etinde sağlığa faydalı n-3 PUFA (ALA, EPA ve DHA) ve bunların biyohidrojenasyon ara ürünlerinin (RA ve VA) daha yüksek olmasına yol açmaktadır.

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DISASTER RISK ASSESSMENT OF URBAN TRANSFORMATION PROJECT AREAS: THE CASE OF KAHRAMANMARAŞ

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ABSTRACT

The earthquakes centered in Kahramanmaraş on February 6, 2023 resulted in thousands of casualties and major structural destruction. In the process of reconstruction of cities and structures, urban transformation project areas were declared with the work carried out by the Ministry of Environment, Urbanization and Climate Change. There are 18 urban transformation project areas in Kahramanmaraş center with the declaration. In this study, the status of 18 urban transformation project areas within the borders of Kahramanmaraş center Onikişubat district and Dulkadiroğlu district, affected by the existing fault lines and the liquefaction potential of these areas in the ground were examined. The risk factors of these urban transformation project areas, which were examined in terms of disaster risk scenarios, were revealed and the situations to be considered in the reconstruction process were analyzed.

Keywords: Urban transformation, project areas, disaster risks, fault line effects, ground liquefaction.

1. INTRODUCTION

Turkey has experienced many disasters caused by natural events (floods, landslides, avalanches, etc.), especially earthquakes [1]. The main reason for this situation is the high number of buildings that have not received engineering and architectural services, have been constructed without any inspection and without a permit (illegally). In addition, the improper use of construction technology, deficiencies or errors in relevant regulations, and irregular construction site manufacturing (workmanship) have also caused the number of earthquake-

resistant building stock to increase [2]. The most obvious result of these situations emerged in the 7.7 magnitude earthquake centered in Kahramanmaraş on February 6, 2023. As a result of the earthquakes experienced on this date, thousands of lives were lost, thousands of buildings were destroyed or damaged to the point of collapse, and serious material and moral losses were experienced [3]. After February 6, 2023, risky area determinations and urban transformation project areas were determined within the scope of reconstruction in accordance with the relevant legislation (Anonymous, 2012). In this study, disaster risk status assessments of urban transformation project areas declared and initiated within the framework of Law No. 6306 after February 6, 2023 were made.

2. URBAN TRANSFORMATION PROJECT AREAS

A total of 18 urban transformation project areas have been declared within the borders of (Anonymous, 2024) Kahramanmaraş central Onikişubat and Dulkadiroğlu districts. The total size of these project areas is 454,69 hectares . These declared project areas, seen in Figure 1, are located in the areas where the greatest destruction occurred in Kahramanmaraş central in the earthquakes on February 6, 2023 and are the most problematic in terms of disaster risks [6].

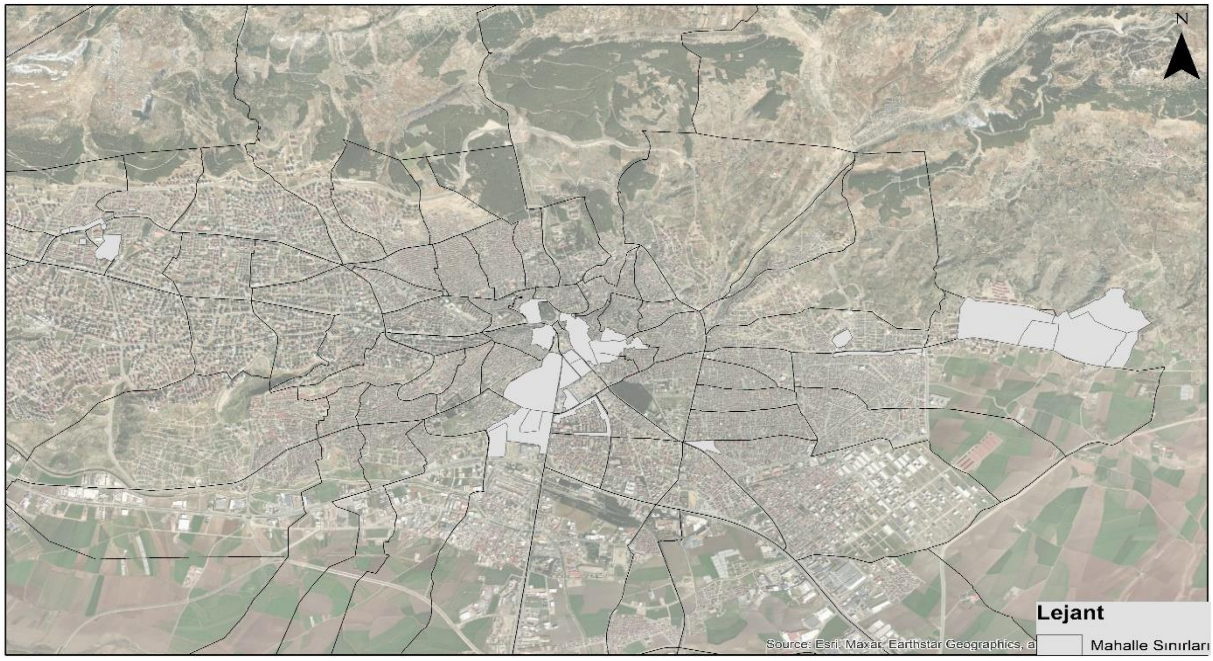

Figure 1. Kahramanmaraş city center urban transformation project areas (Anonymous, 2024)

2.1. Liquefaction Risk of Kahramanmaraş Urban Transformation Project Areas

Onikişubat and Dulkadiroğlu districts in the center of Kahramanmaraş are located in a risky area with a high liquefaction potential and problematic soil structure . This problematic situation is also indicated [6], [7]in the 1/5000 scale Zoning Plan prepared by the Kahramanmaraş Metropolitan Municipality with the classification of Precautionary Area (PA). According to the Precautionary Area classification, it is also emphasized that precautions should be taken against the liquefaction potential in the ground and that remedial planning and applications should be carried out regarding the ground in the structures to be constructed (Figure 2).

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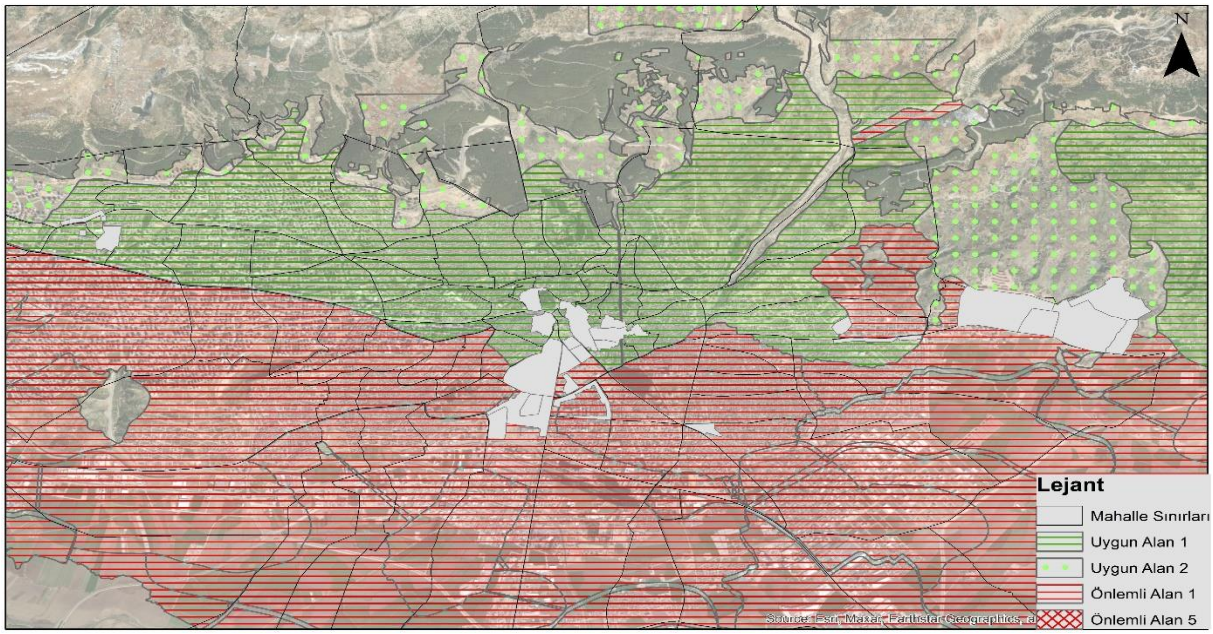

Figure 2. Kahramanmaraş city center urban transformation project areas, liquefaction precaution areas
(Kahramanmaraş revision zoning plan was produced in Arcmap with field study data)

2.2. Kahramanmaraş Urban Transformation Project Areas Fault Lines Relationship

located in the center of Kahramanmaraş, within the borders of Onikişubat district and Dulkadiroğlu district are located on fault lines or within the boundaries of the impact area . This problematic situation (Anonymous, 2024) is seen in the visual below, produced in the Arcmap program with the data of the General Directorate of Mineral Research and Exploration (MTA) (Figure 3).

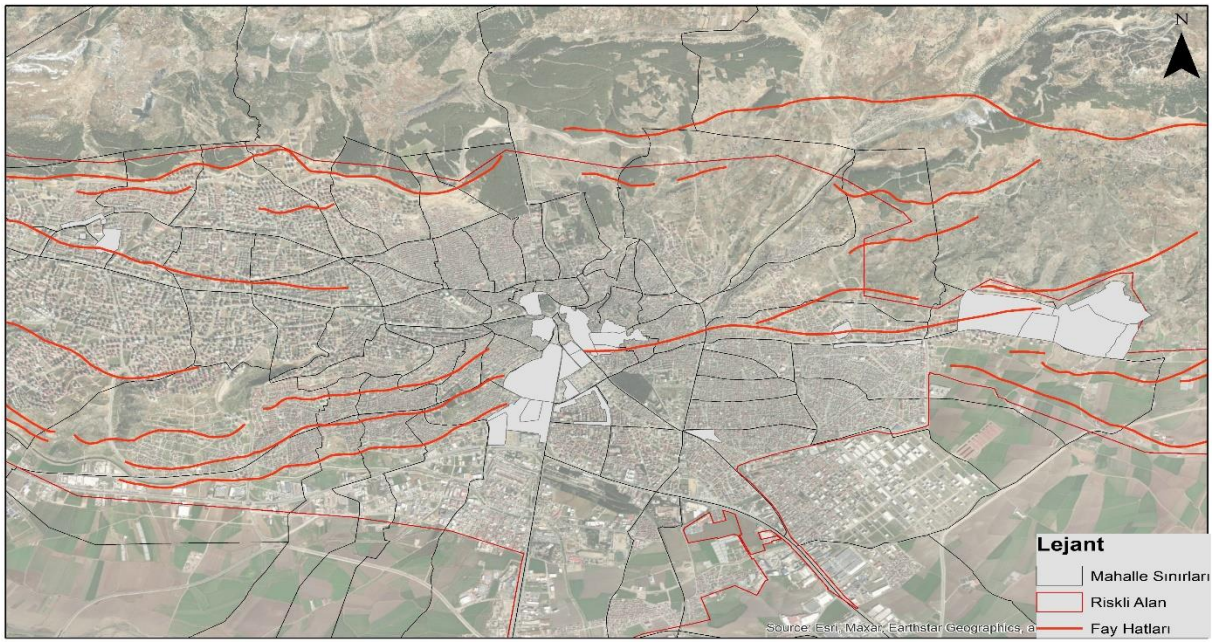

Figure 3. Kahramanmaraş city center urban transformation project areas, fault lines effect
(In Arcmap with MTA data)

3. RESULTS AND EVALUATION

Due to the earthquakes centered in Kahramanmaraş on February 6, 2023, most of the buildings in the center of Kahramanmaraş were destroyed, in urgent need of demolition or severely damaged. The process continued with the determination of urban transformation project areas to be reconstructed after the completion of the necessary demolition processes. With the work of the Ministry of Environment, Urbanization and Climate Change , 18 urban transformation project areas in the center of Kahramanmaraş, totaling 454.69 hectares, were declared as project areas.

The 18 urban transformation project areas declared in Kahramanmaraş city center are located on the impact area of earthquake-producing fault lines and also pose a risk of excessive liquefaction in terms of soil structure. This situation is clearly seen both in the ground surveys conducted with field work and in the 1/5000 scale Zoning Plan with the title of microzonation survey and the Precautionary Area classification.

4. GENERAL EVALUATION AND CONCLUSIONS

Cities built on fault lines and cities built in areas where the liquefaction effect on the ground is high are the regions where the damage is greatest in the event of an earthquake and the loss of life and property is most experienced. This situation is most strikingly seen in the earthquakes that occurred on February 6, 2023, with the destruction of structures located in the center of Kahramanmaraş, within the borders of Onikişubat district and Dulkadiroğlu district.

In the process of reconstruction of cities, the impact status of the fault lines mentioned above and the liquefaction potential in the ground should be carefully considered in determining urban transformation project areas. If possible, areas that do not have these problems should be preferred as project areas [8].

If, during the reconstruction process, construction activities must be carried out in regions that contain problematic situations referred to as project areas, construction techniques and building materials that will reduce fault lines and earthquake effects should be preferred [3]. On the other hand, ground improvement projects should be implemented in the construction activities of structures to be built on soils with high liquefaction risk and low bearing capacity. For this reason, especially plot-based ground survey reports should be prepared meticulously, correct ground improvement projects should be produced according to the soil characteristics and correct results should be obtained in their applications.

As seen in this study, 18 urban transformation project areas located within the borders of Onikişubat and Dulkadiroğlu districts in the center of Kahramanmaraş are located in the current demolition areas. The reconstruction of the city center in the same areas with risk factors has been planned and the construction process has also started. Therefore, the mentioned fault line effects and soil liquefaction potential should be taken into consideration with importance and should be reflected in the implementation projects with the necessary calculations. The prepared correct implementation projects should be meticulously applied in the field and the necessary inspections should be carried out meticulously.

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USE OF INNOVATIVE TECHNOLOGIES IN CONSTRUCTION OCCUPATIONAL HEALTH AND SAFETY

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ABSTRACT
Construction works are classified as works that involve high risk in terms of Occupational Health and Safety. Stakeholders in the sector should prioritize ensuring workplace safety and giving workers a safe environment. Thus, the use of technological breakthroughs is explored as a solution to this issue. Artificial intelligence, wearable technology, virtual and augmented reality, and sensors are some examples of these innovative technologies. In this study, research on the use of innovative technologies within the scope of OHS was examined. The technologies that can be used for OHS in the construction industry, their advantages and challenges are discussed in general terms.
Keywords: Occupational Health, Safety, Technology

1. INTRODUCTION
Construction works are classified as works that involve high risk in terms of Occupational Health and Safety. In addition to the damage they cause to workers' lives, construction accidents also cause serious losses to construction companies and the economy through hospital expenses, loss of workforce, and legal burdens [1]. For this reason, it is

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important to prevent or minimize construction work accidents and occupational diseases. Ensuring safety in the work environment and providing this safe environment to employees should be the priority of sector stakeholders. Due to the dynamic structure of the construction industry, it is difficult to take precautions and control occupational health and safety. Therefore, a solution to this problem is sought by utilizing technological innovations [2]. There is an increasing tendency to study the use of innovative technologies on OHS. These innovative technologies are shown in Figure 1.: artificial intelligence, virtual reality, augmented reality, sensors, wearable technologies. In this study, research on the use of innovative technologies within the scope of OHS was examined. Their advantages and challenges are discussed in general terms.

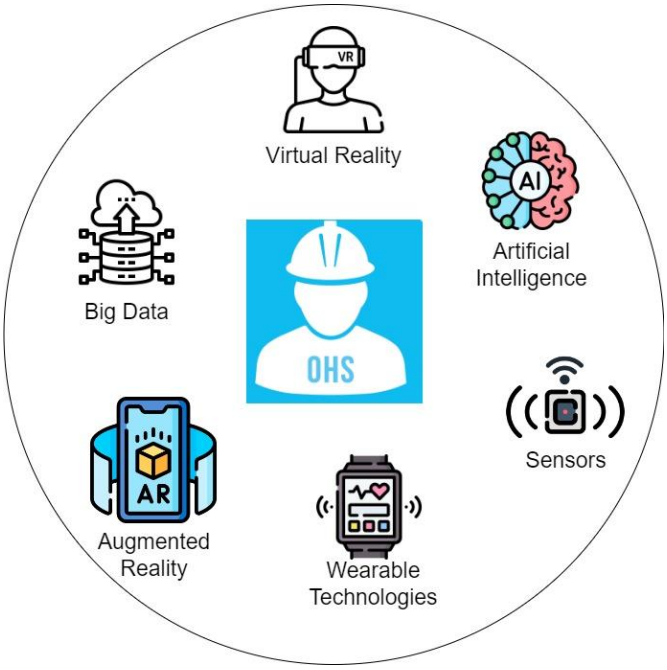

Figure 1. Technologies to be used for occupational health and safety

The integration of technology into the construction industry aims not only to prevent work accidents but also to increase work efficiency and reduce costs by creating safe working environments in construction sites. Providing a safe working environment will reduce the legal and financial burdens that may arise from work accidents.

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2. INNOVATIVE TECHNOLOGIES FOR OCCUPATIONAL HEALTH AND SAFETY

2.1. Wearable Technologies and Sensors

Wearable technologies have become one of the trending applications in improving occupational health and safety in construction. Employees' physical conditions and environmental factors can be monitored with sensors integrated into employees' clothing and personal protective equipment. Gyroscopes and accelerometers can capture awkward postures and near miss falls [3]. Some types of smart watch were used as emotion assessment device [4].

Figure 2. Wearable Devices for OHS Management in Construction Sites [3], [4]

2.2. Virtual and Augmented Reality

Virtual and augmented reality technologies aim to create real-life simulations, allowing employees to experience and learn about potential hazards [5]. AR teaches workers how to identify risky areas on the construction site and take precautions by foreseeing risks. In this way, workers who are aware of possible accidents on the site can take safety precautions by noticing the dangers in advance. In virtual reality, the construction site is simulated one-on-one and workers are trained for safety.

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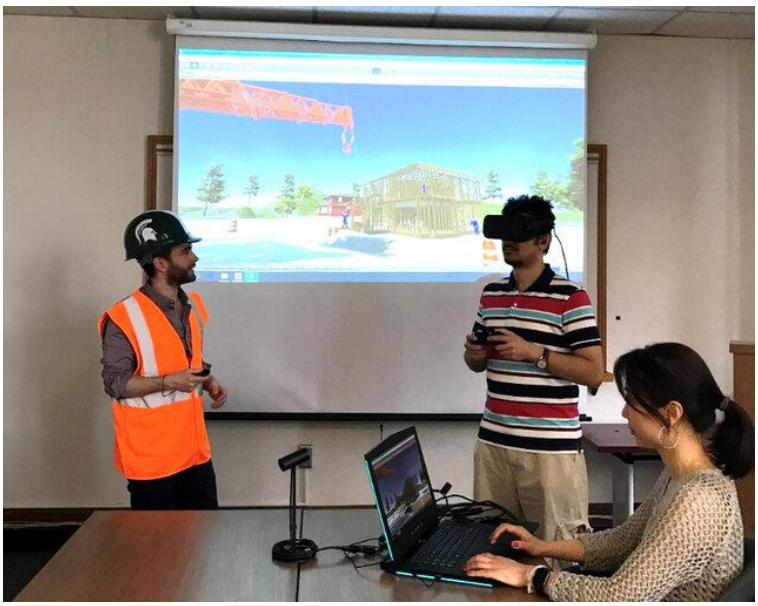

Figure 3. Safety Training with VR [6]

2.3. Data Analysis and Artificial Intelligence

As a result of artificial intelligence and analysis of historical data, it enables risks to be identified in advance and precautions to be taken. Continuous data on movements in the field, use of equipment and environmental conditions are collected and analyzed, and risks that may cause work accidents can be identified in advance. As a result of the continuous collection and analysis of data, a cycle is created in which occupational safety is constantly ensured [7].

2.4. Drone Technologies

It is very difficult to constantly monitor construction sites. Drones are advantageous because they can continuously monitor construction sites. Drones equipped with various sensors and cameras can detect the use of personal protective equipment in the construction site environment, unsecured structures that may cause work accidents, debris, and inappropriate equipment [8].

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Figure 4. Drone application for safety in construction site [8], [9]

3. RESULTS AND DISCUSSION

Developments in technology are seen as an alternative solution in reducing work accidents, which are a significant problem in the construction sector, and creating a safe work environment. Technologies such as sensors, drones, data analysis and artificial intelligence, virtual and augmented reality are expected to be beneficial in reducing employee and equipment-related accidents. In the construction sector, which has a large share in global capital, costs and legal burdens arising from work accidents can be reduced, workers' productivity can be increased and wages can be reduced, and construction workers can be provided with a healthier and safer working environment. There are various difficulties in implementing these technologies to prevent work accidents. These are:

- Adaptation to technology and training
- Increase in initial investment costs
- Traditional aspect of the construction sector

- Data collection and privacy.

Various strategies and methods should be developed and technology adaptation should be ensured against these challenges.

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INSIGHTS INTO THE RESPONSE OF NEIGHBORING BUILDINGS

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ABSTRACT

Understanding the seismic response of adjacent structures is essential for ensuring safety and resilience during seismic events. This study utilizes the concept of response spectra as a tool to evaluate the behavior of adjacent buildings. By simulating various earthquake scenarios and analyzing the interaction between closely spaced structures, the effects of structural pounding to the structural responses has been investigated. The response spectra have been generated for pounding force and acceleration due to different periods and seismic gaps, providing insight into the dynamic behavior of each structure under varying conditions. Key factors, such as the distance between buildings and structural characteristics, are examined to identify potential vulnerabilities. The findings ensure the importance of considering adjacent structures in seismic design and the need for updated building codes that address the risks associated with structural interaction. This research aims to contribute to the development of safer building practices that enhance the resilience of communities facing earthquake threats.

Keywords : response spectra, adjacent building, earthquake

1. INTRODUCTON

Response spectra derived from specific earthquake ground motions provide critical insights into the maximum responses—such as displacement, acceleration, and velocity—that a structure may experience during seismic events. These spectra reflect the possible peak structural responses for a range of natural vibration periods under the action of a specific earthquake.

Seismic pounding is a phenomenon that occurs when adjacent structures or different parts of the same structure collide during an earthquake due to insufficient separation [1]. This typically arises in dense urban areas or in structures with irregular designs, where the buildings or structural sections have distinct dynamic characteristics and natural periods [2]. When subjected

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to seismic excitation, these differences can lead to out-of-phase movements, increasing the risk of collision. Excessive pounding forces can cause severe damage to structural elements, particularly at points of contact, leading to cracking or even collapse.

In this study, the pounding force issue has been addressed in terms of response spectra. Two colliding systems have been designed to present the pounding forces between them considering period variation. One structure is assumed to have constant period, and the other has varied period. As a result, a clear identification has been revealed emphasizing the vibrational differences between two colliding surfaces.

2. NUMERICAL MODEL

Two single degree-of-freedom systems have been modelled to explore the pounding behavior under severe seismic motion. Figure 1 shows the schematic of the systems used. The analysis was conducted on a single-degree-of-freedom (SDOF) system with varying natural periods (structure 2), accompanied by a neighboring structure (structure 1) with periods set at 0.1, 0.5, 1, and 2 seconds, respectively. These varying periods are intended to represent seismic pounding scenarios with different types of structures, ranging from rigid to flexible. In Figure 1, *m*, *k* and *c* are the mass, stiffness and damping coefficients, respectively, while subscripts *1* and *2* are the given numbers for the structures. *d* indicates the gap size.

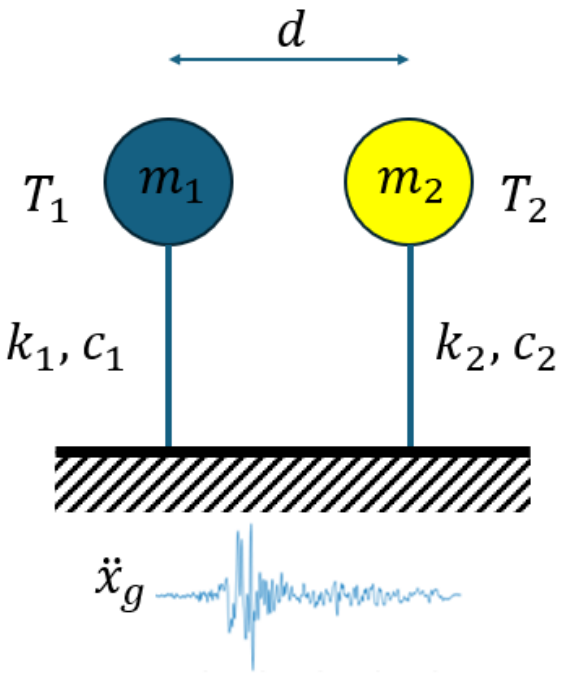

Figure 1. Schematic of Sdof systems

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As an earthquake motion, the acceleration record of 270-degree component of 1999 Kocaeli earthquake has been used to perform numerical analysis. The magnitude is 7.4 whereas the peak ground acceleration is 3.573 m/s^2. The accelerogram is given in Figure 2.

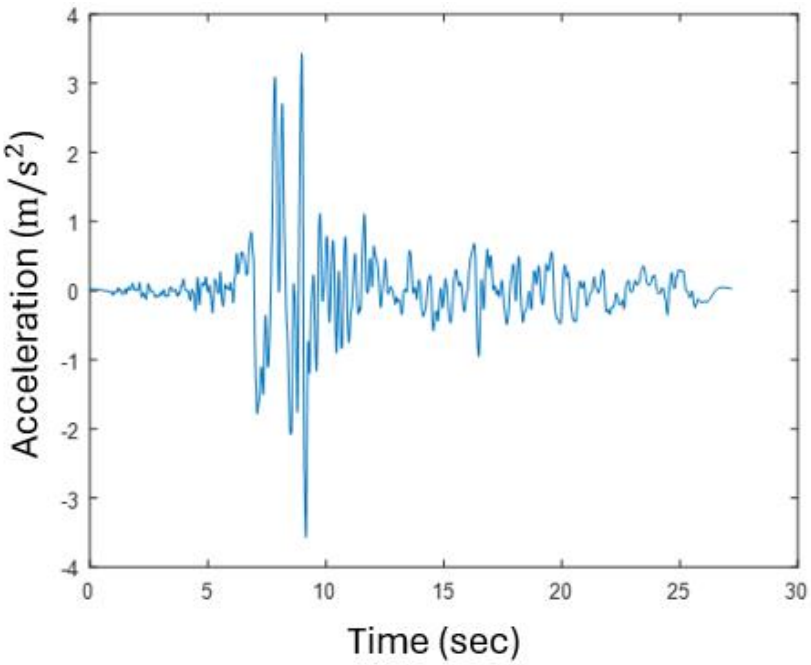

Figure 2. Accelerogram of Kocaeli earthquake

3. RESULTS

In seismic engineering, response spectrum is of great importance in design process to predict the structural behavior under a specific earthquake. The response spectrum is calculated for the structures with different periods to reveal the peak responses corresponding to the structural period. In this paper, the acceleration and displacement response spectra of structure 2 has been calculated and shown in Figure 3. As seen from the figure, the period range is selected between 0.01 sec to 4 sec.

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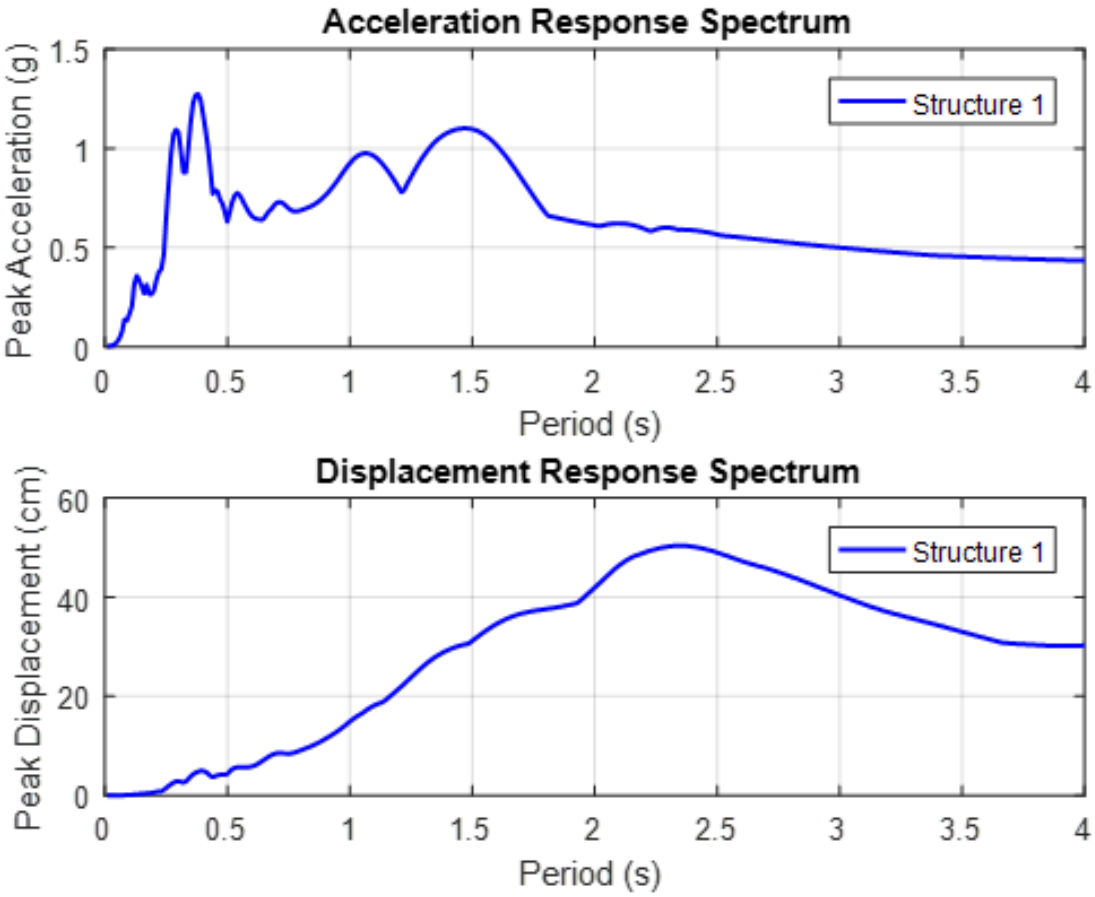

Figure 3. Acceleration and displacement response spectra due to Kocaeli earthquake

Pounding force is the contact force between two surfaces. This force occurs when the gap is closed. And there is no force when the gap is open. In this study, Kelvin-Voigt contact model has been used [1]. This model assumes stiffness and damping contact forces parallel to each other as given in Figure 4. k_p and c_p are contact stiffness and damping coefficients, respectively. When the gap is closed, the force is activated. During the case of open gap, there is no force produced.

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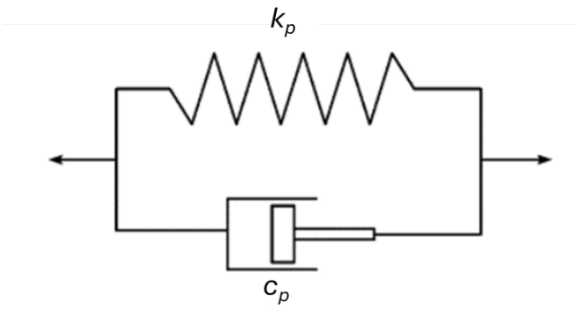

Figure 4. Contact model of colliding surfaces

Two cases have been investigated in terms of seismic gap, 2 cm and 10 cm, respectively. In Figure 5, pounding force spectrum is given for the gap size of 2 cm. The diagram shows the maximum forces occured during collisions with different structures with 0.1 sec, 0.5 sec, 1 sec and 2 sec periods. For the low-period of structures the pounding force is small. For large periods, the poundign force is larger.

Figure 6 has been drawn for the gap size of 10 cm. The pounding forces are larger compared to smaller gap size. This is because the larger the seismic gap, the more displacement and acceleration the structure will have. Thus, the pounding force will become larger. This relationship emphasizes the need for an optimal balance in gap sizing for effective seismic design while seismic gaps are necessary to avoid immediate contact, excessive gaps can lead to stronger collisions. In both figures, common result is when the colliding structure's period is smaller, the pounding force is small. For the structures colliding with stiffer buildings, the pounding force is large. For the structures with same period, there is synchronous behaviour, so there is no pounding force.

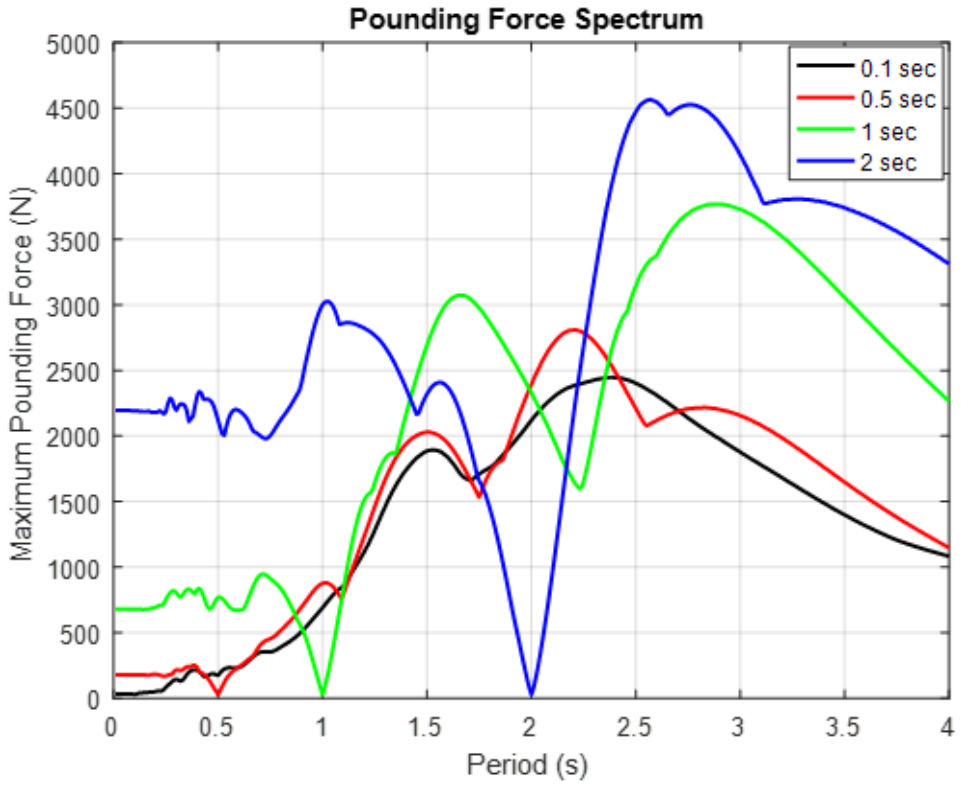

Figure 5. Pounding force spectrum for the gap size of 2 cm

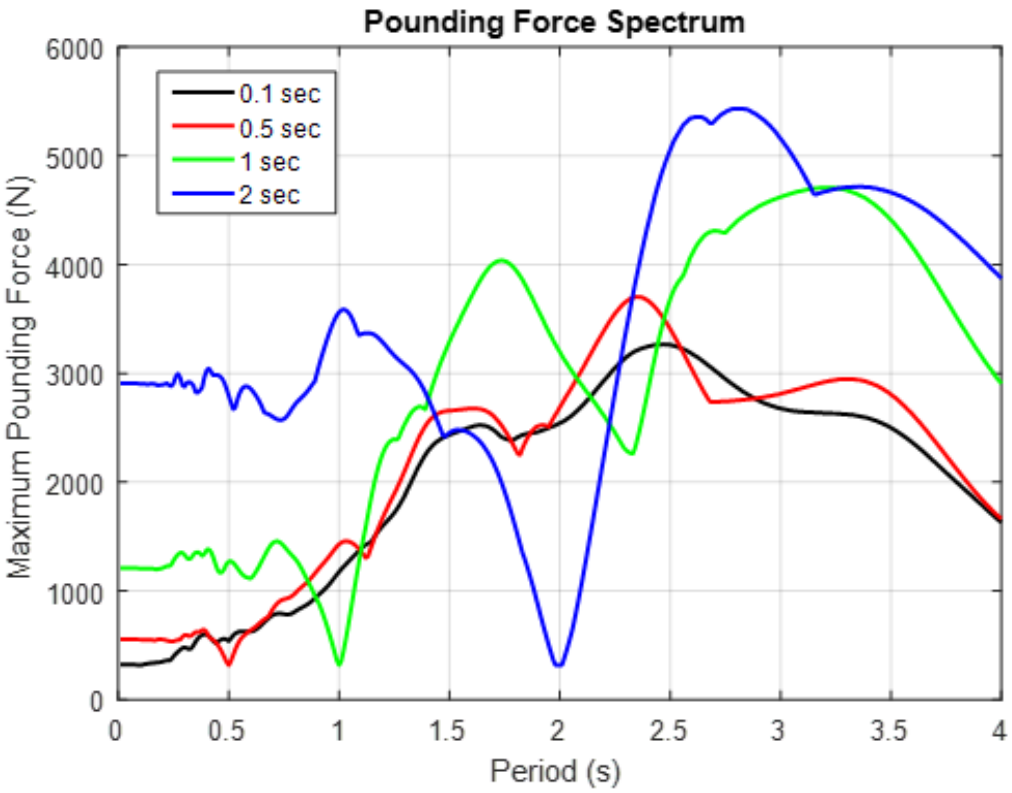

Figure 6. Pounding force spectrum for the gap size of 10 cm

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4. CONCLUSIONS

The conclusions can be summarized as follows,

- The stiffness of neighboring structures are highly effective in the magnitude of impact force. When the neighboring structure is more flexible , the pounding force is smaller. However, when the neighboring structure is stiffer, the pounding force is larger.
- For smaller gap sizes, there will be no pounding force when the structures have same period. Because they vibrate synchronously. As the gap size increases, the pounding is likley to occur since larger gap can allow for unsynchronized movement due to the slight differences which cause differential displacements.
- As the gap size increase between buildings, the pounding force increases. That is because the more displacement and acceleration the structures will have when there is more place to move.
- The findings underscore that an optimization search is required to obtain adequate gap size.

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SEISMIC DAMAGE TO ADJACENT STRUCTURES: A HISTORICAL PERSPECTIVE

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ABSTRACT

Understanding the impact of seismic events on adjacent structures is crucial for improving building safety and resilience, particularly in densely populated city centres with extensive housing. In the past, many instances of damage, and even destruction, were experienced due to severe earthquakes. This study reviews the historical cases of seismic damage to neighboring buildings, highlighting patterns and lessons learned from the events throughout history. The phenomenon of structural pounding, where adjacent buildings collide during seismic motion, is explored in detail, illustrating how design flaws and insufficient spacing can intensify damage. Additionally, advances in building codes and design practices that have emerged in response to these experiences have been discussed.
Keywords: adjacent structures, seismic damage, historical earthquakes.

1. INTRODUCTION

The view of adjacent structures is mostly a typical view in city centres. There are many reasons to have this scene due to high land prices, dense population, including living and workplaces etc. However, during severe earthquakes, adjacent structures are highly susceptible to significant damage or even complete collapse due to the phenomenon known as 'pounding.' This occurs when buildings of different heights, stiffness or natural frequencies vibrate asynchronously, causing them to collide with each other. For instance, during the 1985 Mexico City Earthquake, numerous buildings experienced structural pounding, resulting in extensive damage [1]. Such phenomena have been observed in many recent seismic events, including the 2011 Christchurch Earthquake [2], the 2011 Van Earthquakes [2] and the 2015 Gorkha Earthquake [3], and finally

the 2023 Kahramanmaras Earthquake [4] which affected eleven provinces and caused an unconceivable loss of life and property.

The seismic codes stipulate seismic gap between structures. However, an unexpected magnitude of earthquake can destroy this gap and leads to pounding acting on collided surfaces. Thus, relevant provisions in the codes are regularly reviewed after devastating experiences.

In this study, a recent literature review has been presented to examine a range of issues related to the topic. Recent experiences have been shared and flaws in the construction process of building type structures have been revealed from the real-life examples. The seismic gap formulas included in various earthquake codes have been examined. Besides the pounding forces models addressed in the literature have been investigated.

2. RECENT EXPERIENCES OF STRUCTURAL POUNDING DAMAGES

Due to earthquake motion, different vibrational properties of adjacent structures can cause asynchronous behavior. Thus, the pounding between structures may occur if the seismic gap is inadequate to accommodate the drifts of both structures.

In Figure 1, pictures from the 1985 Mexico earthquake [1], 2011 Christchurch earthquake [2], 2023 Kahramanmaraş earthquake sequence [4], 1999 Athens earthquake [5] and 2009 L'Aquila earthquake [5] are given. The figures are examples for floor-to-column pounding where the story height is different in neighboring buildings. This phenomenon typically arises when neighboring buildings have different story heights or floor levels that do not align. The misalignment causes floors from one building to impact the columns or vertical structural elements of the adjacent building, creating a hammering effect. The floors have hammer effect on columns. Floor-to-column pounding is particularly concerning because columns are crucial structural components responsible for carrying vertical loads. When impacted by the force of a colliding floor, columns

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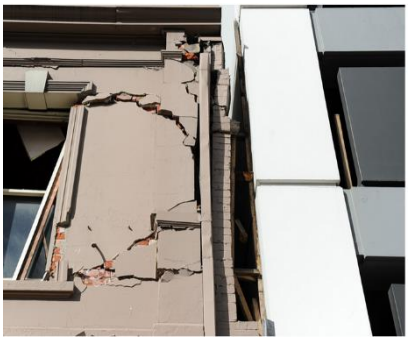
can experience bending, cracking, or even shearing, which may lead to partial or complete failure.

1985 Mexico earthquake [1]



2011 Christchurch earthquake [2]

2023 Kahramanmaraş earthquake sequence [4]

1999 Athens earthquake [5]

2009 L'Aquila earthquake [5]

Figure 1. Floor-to-column damages

In Figure 2, there are examples from 2015 Gorkha earthquake [6] and 2011 Sikkim earthquake [5]. The damages caused by floor-to-floor pounding arises from insufficient seismic gap, especially observed in constructions in densely populated areas. Floor-to-floor pounding can lead to severe damage as the floors absorb and transfer impact forces, which can weaken or even compromise the structural integrity of both buildings.

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2015 Gorkha earthquake [3]

2011 Sikkim earthquake [5]

2015 Gorkha earthquake [6]

Figure 2. Floor-to-floor damages

3. PROVISIONS ABOUT SEISMIC GAP

In seismic codes, there are various definitions to calculate the required seismic gap between adjacent buildings. Some of them are listed as below,

- Eurocode 8 recommends that the minimum separation distance, between two adjacent buildings should be calculated as square root of the sum of peak displacements of both buildings.
- International Building Code (2021) suggests the sum of inelastic displacement of two buildings.
- TBEC 2018 suggest calculating the square root of the sum of the (reduced) squares of the elastic displacements obtained for each floor in the neighboring buildings that shall not be less than the product of the coefficient α. The value of the coefficient α shall be taken as 0.25R/I if the floor levels are equal, and 0.5R/I otherwise (where R is the

structural system behavior coefficient and I is the importance coefficient of the building). Also, the minimum seismic gap should be at least 3 cm for heights up to 6 m, and for every additional height of 3 m beyond 6 m, at least 1 cm shall be added to this value.

- Some codes stipulate total displacement response multiplication with a constant value based on regional seismic characteristics such as Japan Building Code, National Building Code of Canada, Australian Building Code.

4. POUNDING FORCE MODELS

Various impact models have been developed and utilized in numerous structural systems within the literature, including the nonlinear model of Hertz, the linear viscoelastic model by Anagnostopoulos [7], the nonlinear elastic model by Davis [8], and the nonlinear viscoelastic models by Jankowski [9] [10-13]. The linear viscoelastic model is also known as the Kelvin-Voigt model, has been employed. The model consists of a linear spring and a dashpot arranged in parallel.

4. RESULTS AND DISCUSSION

Structural pounding, a phenomenon observed during many past earthquakes, has been identified as a significant factor contributing to the damage and collapse of adjacent buildings and infrastructure. Analysis of historical seismic events reveals that pounding typically occurs when structures of different heights, stiffness, or natural frequencies are located close to each other, leading to asynchronous movements and collisions during ground shaking.

The analysis of past earthquakes has led to the understanding that certain factors increase the risk of pounding, including insufficient separation gaps, structural irregularities, and inadequate design considerations. Effective solutions to mitigate pounding include implementing larger separation gaps, installing energy-absorbing devices, and retrofitting existing structures with enhanced shock-absorbing systems. Furthermore, modern building codes have evolved to address these issues, emphasizing the importance of flexible and resilient designs that can accommodate differential movements during an earthquake. However, there is still a need for ongoing research to develop innovative solutions that can effectively mitigate the risks associated with structural pounding, especially in densely populated urban areas where space constraints limit the feasibility of traditional separation gaps.

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WATER RECYCLING IN SUSTAINABLE HOUSING AND ITS IMPACT ON DESIGN

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ABSTRACT

The continuous increase in the global population has further heightened the importance of water resources. As one of humanity's fundamental needs, water is also utilized in various sectors such as industry, energy production, tourism, and sustainable agriculture. The active and constant use of water is one of the critical drivers of transformation in energy-efficient buildings and environments. This study examines the recycling of water in sustainable housing and its impact on architectural design. Sustainable buildings are certified by international or local commissions. In these buildings, water usage is integrated into passive systems, with rainwater and wastewater being collected. Water collection systems vary in roof design and structure. For the purpose of this study, six buildings were selected. Roof designs and storage units were analyzed and tabulated to assess their impact on design. Climate, precipitation patterns, and solar angles were also considered. According to the study's findings, roof slopes, underground storage areas, and water purification systems provide significant advantages in the use and recycling of water. Water recycling, identified as a crucial factor for sustainability, can help prevent future adverse conditions. Beyond reducing water consumption, it also decreases dependency on external water supplies, promoting self-sufficiency within buildings. Furthermore, integrating water recycling systems into architectural design not only enhances resource efficiency but also contributes to the resilience of buildings in the face of climate change. As cities continue to grow and water scarcity becomes a more pressing issue, these systems will play an essential role in ensuring sustainable urban development.

Keywords: Sustainable housing, Energy-efficient design, Recycling, Water, Roof Design

1. INTRODUCTION

The continuous increase in the global population has significantly heightened the importance of water resources. Water plays a critical role not only in meeting basic human needs but also in various sectors such as energy production, industry, tourism, transportation, and sustainable agriculture. The rising population leads to a decrease in per capita water availability and faster depletion of water sources. Additionally, one adverse effect of population growth is the increased demand for housing, resulting in expanded urbanization. This expansion contributes to the proliferation of impervious surfaces, endangering the sustainability of water resources. In this context, the efficient and effective use of water has become crucial (Temizkan & Tuna Kayalı, 2021).

Architecture is historically regarded as the art of designing and constructing buildings, closely intertwined with artistic expression. However, contemporary architectural trends exhibit a shift in focus from aesthetic considerations to performance, energy efficiency, and technological advancements. Recent designs reflect an increasing awareness of the need to transform buildings into environmentally friendly structures that extend their lifespan (Zengin & Yamaçlı, 2023). This design ethos has led to the emergence of sustainability as a foundational concept in architecture. Sustainable new structures are evaluated for their zero carbon footprint by official institutions through certification processes. Within this study, the impact of water collection channels on architectural design is examined, assessing how effectively and efficiently water is utilized based on selected residential/accommodation units case studies.

2. MATERIAL AND METHOD

To establish a framework for this study, a literature review was initially conducted to define the conceptual underpinnings of water recycling and its influence on sustainable residential design. The primary objective was to analyze the role and integration of water collection channels in architectural design across a selection of diverse case studies. Six residential structures were chosen to represent a range of geographical and climatic contexts, enabling a comparative analysis of water management approaches in varying environmental conditions.

The selection criteria focused on identifying buildings recognized for their sustainable water practices, specifically those designed as water-neutral structures. The chosen cases include the Green Solution House in Denmark, Magney House in Australia, Blue House in Portugal, BedZED House in the United Kingdom, Zero House in the United States, and Green Village in Indonesia. These structures were analyzed for their water collection, recycling systems, and their integration into overall design strategies. Data were systematically organized in a comparative table to evaluate each building's water management system on architectural design and functionality.

3. SUSTAINABILITY IN DESIGN AND CERTIFICATION STANDARDS

The concept of sustainability, first introduced in the 1987 report by the United Nations World Commission on Environment and Development, underscores the importance of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43; Ateş Can & Kurtoğlu, 2017). This foundational principle has led to the development of green

building certifications that assess a building's environmental impact and resource efficiency based on standardized criteria. Certifications such as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and WELL have become prominent benchmarks for evaluating sustainable building practices, especially with regard to energy efficiency and material performance (Yudelson, 2010).

Sustainable building design encompasses both passive and active systems to reduce environmental impact. Passive systems, integrated from the early planning stages, address the building's orientation, spatial design, and climate responsiveness. Key passive strategies include smart facade and double-skin facade systems, courtyard configurations, green roofs, and vegetative building envelopes, which help reduce heat gain and manage stormwater. Rainwater harvesting and greywater recycling systems further support conservation efforts by reusing water for non-potable applications, thus decreasing demand on external resources. Active systems, such as solar energy panels and wind turbines, complement passive strategies by providing renewable energy to reduce reliance on non-renewable sources. Through a balanced combination of passive and active approaches, sustainable buildings aim to minimize their ecological footprint, conserve resources, and meet the high standards set by certification systems. As sustainable construction continues to evolve, these principles will play an increasingly critical role in addressing global environmental challenges like water scarcity, energy demand, and climate change (Kibert, 2016; Uşma, 2023).

4. RAINWATER AND GRAY WATER COLLECTION SYSTEMS IN BUILDINGS

Only about 2.5% of the world's water is potable, highlighting the limited availability of freshwater resources. These resources are increasingly diminishing due to industrialization, irresponsible consumption, rapid population growth, and environmental pollution. One of the major contributors to this depletion is water consumption in buildings. To mitigate this issue, technologies such as rainwater harvesting, and gray water treatment systems have been developed. Rainwater harvesting systems are designed to collect water for later use. This water can be used for irrigation, treated to become potable, or utilized in various applications as needed. Gray water treatment systems, on the other hand, involve the purification of domestic wastewater from sources such as showers, sinks, and kitchens for reuse. Rainwater harvesting systems can be categorized into two main types: underground and above-ground options. These categories are commonly referred to as cisterns and storage tanks. Each method has specific advantages and disadvantages. When deciding which method to implement in system design, several factors must be considered, including precipitation patterns, storage capacity, material types, costs, and the availability of necessary labor. These factors are critical for selecting the most suitable system. In the cistern method, rainwater is collected in specialized storage tanks known as cisterns, which are typically placed underground and constructed to be waterproof. Before entering the cistern, the rainwater must be filtered, commonly using silica sand. An ideal approach in the cistern system involves layering the bottom third of the cistern with gravel and covering the upper section with fine sand, creating a sand filter approximately one meter high (Lasage & Verburg, 2015; Campisano et al., 2017; Temizkan & Tuna Kayalı, 2021).

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In the storage method, harvested rainwater is usually stored in external tanks that may be placed above ground or, when necessary, underground. The size of a storage tank is determined by various factors, including:

- The area of the collection surface,
- Local rainfall and weather conditions,
- The required volume of water,
- The maximum amount of rainwater that can be collected,
- The presence of alternative water sources,
- The suitability of the area.

When installing above-ground storage tanks, it is crucial to ensure that the ground is level and firm to mitigate the risk of settling over time. Additionally, the foundation of the tank must be flat. The position of the tank is determined by its size, shape, available space, climate, and soil conditions. Tanks that can be partially or completely installed underground or above ground should be placed as close as possible to minimize piping and pump requirements (Temizkan & Tuna Kayalı, 2021).

5. FINDINGS

5.1. Green Solution House (Denmark)

Green Solution House includes accommodation units and a conference center Thanks to its systems, it is a carbon-neutral, water-neutral, and energy-positive building. As a water-neutral structure, the rainwater harvesting system is integrated with the collection channels located on the inverted V-shaped roof, which direct water to storage pipes. The collected water is utilized in facilities such as toilets, urinals, and bathrooms. Water-saving fixtures are also employed to reduce consumption rates. Household wastewater that cannot be used as drinking water is repurposed for applications such as irrigation and toilet flushing (Figure1) (Silva, 2024).

Figure 1. Green Solution House (Silva, 2024)

5.2. Magney House (Australia)

The residence, designed by Pritzker Prize-winning architect Glenn Murcutt, features an asymmetrical V-shaped roof with vertical collection pipes at the ends, which channel rainwater into a storage tank for drinking and heating purposes. The elevated roof wing on one side creates a window section that allows controlled natural light to enter the interior space (Figure 2) ("Features | Architecture & Design," n.d.).

Figure 2. Magney House ("Features | Architecture & Design," n.d.)

5.3. Blue House (Portugal)

Designed according to passive house principles, this self-sufficient home harmonizes with the environment through the use of natural building materials, thereby reducing its carbon footprint and chemical impacts. Despite having a flat roof, it collects rainwater in a storage system located in the garden. The collected water is then treated for use in the pool and drainage systems (Figure 3) (Caballero, 2024).

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Figure 3. Blue House (Caballero, 2024)

5.4. BedZED (UK)

Beddington Zero Energy Development (BedZED) is a residential project located in London that promotes sustainable living. Within this development, rainwater harvesting systems have been implemented to enhance water efficiency. The collected water is utilized for irrigation of green spaces and in toilet cisterns (Figure 4) ("BedZED | Zedfactory," n.d.).

Figure 4. BedZED House ("BedZED | Zedfactory," n.d.)

5.5. Zero House (US)

Zero House is a fully independent home designed to achieve zero energy and water waste. This house meets its water needs through a rainwater harvesting system. The rainwater collected from the roof is filtered and treated before being stored, and it is used for all of the house's water requirements (Figure 5) ("House Zero," 2023).

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Figure 5. Zero House ("House Zero," 2023)

5.6. Green Village (Indonesia)

Green Village is a sustainable living project located in Bali. The houses in this village utilize rainwater harvesting systems to ensure the effective use of water. The collected rainwater meets the needs for drinking water and garden irrigation in the homes (Figure 6) ("Home - Green Village Bali," 2022).

Figure 6. Green Village ("Home - Green Village Bali," 2022)

6. COMPARISON AND CONCLUSION

As shown in Table 1 below, rainwater harvesting systems utilize different design forms based on regional data such as rainfall, climate, and soil conditions rather than adhering to a single design system. Depending on the needs, some residential buildings use harvested rainwater for drinking, while others utilize it solely for garden irrigation and toilet flushing. A common design feature across all structures is the integration of rainwater channels and storage areas into the design, making them unobtrusive. In multi-unit housing, the storage system is typically implemented as a cistern, whereas single-family homes often utilize a tank system for storage.

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Table 1. Comparison of Buildings Utilizing Rainwater Harvesting Systems

	Blue House (Portugal)	**Zero House (USA)**	**Green Solution House (Denmark)**	**Magney House (Australia)**	**BedZED (UK)**	**Green Village (Indonesia)**
Roof Type	Flat	Flat	V or Inverted V	V or Inverted V	V or Inverted V	V or Inverted V
Rainwater Storage	✔	✔	✔	✔	✔	✔
Uses of Recycled Water	For pool and drainage	For all water needs	For toilets, urinals, and bathrooms	For drinking and heating	For irrigation of green areas and toilets	For drinking water and garden irrigation
Water Collection System	Storage	Storage	Storage	Storage	Cistern	Cistern

As observed in the examined buildings, factors such as climate, sun angle, and rainwater have significantly influenced their designs. The positioning of roofs in V and inverted V shapes, along with their sloped designs, has facilitated the efficient collection of rainwater. Additionally, the water storage system is strategically located underground, thereby concealing it from view.

Water is not only essential for meeting human needs but also plays a crucial role in the development of nations. Despite being a renewable resource, the unconscious consumption of water negatively impacts its future availability. The rapid population growth and urbanization exacerbate this issue, while technological advancements present potential solutions to water-related challenges. Rainwater harvesting systems are of paramount importance in terms of sustainability and water conservation.

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YOĞUN BAKIM ÜNİTESİNDE TELE-TIP UYGULAMALARI

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ÖZET

Yaşlı nüfusunun artmasıyla yoğun bakımlara artan talebin yanı sıra, ihtiyaç duyulan sağlık personeli sayısında azalma bir tezat oluşturmaktadır. Tele-tıp bu konuya bir çözüm olabilme umudunu taşımaktadır. Yoğun bakım hekimine destek olarak çeşitli uzaktan tıbbi çözümler geliştirilmiştir. Yoğun bakım ünitesi için geliştirilen yeni tele tıp modellerinde, tele tıp en iyi uygulama yönergelerine ve süreç kalitesi göstergelerine uyumu artırmak için kullanılabilir. Ayrıca, süreç kalitesi göstergeleri, işlevsel sonuçlar ve yaşam kalitesi ölçümleri sonuçların değerlendirilmesine dahil edilmelidir. Bu araştırma ile, mevcut modellerin incelemesi ve her yoğun bakım kliniğinin ihtiyacına göre tele tıp modeli geliştirilmesi hedeflenmiştir.

Anahtar Kelimeler: Yoğun bakım, tele-tıp, yaşam kalitesi ölçümleri, hastane yatış süresi

1. GİRİŞ

Almanya'da her yıl 2,1 milyondan fazla yoğun bakım ünitesine yatış ve ABD'de 4,4 milyon yoğun bakım ünitesine yatış gerçekleşmektedir (1). Yaşlanan nüfus ve tıbbi gelişmeler nedeniyle önümüzdeki yıllarda önemli ölçüde artacağı tahmin edilen yoğun bakımlara olan talep zaten yüksek durumdadır (2). Bu durum ABD'de yoğun bakım için yıllık yaklaşık 82 milyar dolarlık harcama ve 1994 ile 2004 yılları arasında %36'lık bir maliyet artışı ile karşımıza çıkmaktadır (3). Aynı zamanda, kritik hastaların yaşları ve hastalık şiddetlerinin artmasına rağmen, komplikasyonlar ve ölüm oranları düşmektedir (4). Ölüm oranlarındaki azalmanın yeterli yoğun bakım personeli kadrosuna bağlı olduğu gösterilmiştir (5). Bu nedenle, eğitimli yoğun bakım uzmanları ve hemşirelerin mevcut eksikliği düşünüldüğünde, gelecekte bu açık büyük ihtimalle daha da kötüleşebilir ve elde edilen başarıları tehlikeye atabilir (6). Bu bağlamda, yoğun bakımda tele-tıp, kaliteyi ve verimliliği aynı anda artırarak yoğun bakım kapsamını genişletmek için bir çözüm olarak duruyor (7). 2010 yılı itibarıyla ABD'deki yoğun bakım yataklarının %7,9'una tele tıp yoluyla ulaşılmaktadır, bu çoğunlukla büyük, kentsel hastanelerde gerçekleşmektedir (8). Ancak telemedikal gerçekten yoğun bakım kalitesini artırıyor mu? Bu çalışmanın aşağıdaki iki bölümünde, kritik derecede hasta hastalar için

telemedikalin mevcut uygulama modellerini açıklayacağız ve telemedikal programların sonuçlar üzerindeki etkisini inceleyeceğiz. Ardından, telemedikal programlara uygulanabilen yoğun bakımda bakım kalitesi kavramlarına ışık tutacağız. Son bölümde, telemedikalin faydalarından yararlanarak yoğun bakım ünitesinde bakım kalitesini ölçmenin ve iyileştirmenin yollarını ele alacağız.

2. YOĞUN BAKIMDA TELE TIP: UYGULAMA MODELLERİ

Son yıllarda yoğun bakımda sayısız telemedikal program ortaya çıktı. En tipik model, "tele-ICU" olarak adlandırılan bir telemedikal kokpit ve kamera donanımlı bir araba veya robot teknolojisine sahip uzak bir siteden oluşur (9). Tele-Yoğun Bakım Üniteleri genellikle deneyimli yoğun bakım uzmanları, yoğun bakım hemşireleri ve idari veya büro personeli gibi ek personel ile donatılmıştır (10). Genellikle, tele-ICU ile uzak bölgeler arasında görsel-işitsel bir bağlantı vardır. Bunun ötesinde, yoğun bakım uzmanları gerçek zamanlı hayati bulgulara, ventilatör ayarlarına, hasta dosyalarına, laboratuvar parametrelerine, karar destek araçlarına, not paylaşımına, uyarılara ve X-ışını ve ekokardiyografi gibi görüntüleme araçlarına erişebilir (11,12). Telemedikal programlar tele-ICU'ya atanan yetkinlik ve sorumluluklarda önemli farklılıklar göstermiştir. Bazı programlarda tele-ICU yoğun bakım uzmanları hasta bakımının hemen hemen tüm yönlerine dahil olmuştur. Yatak başı doktoru ve hastalarla iletişim kurabilmiş, yerindeki doktorları denetlemiş, gecelik hasta kabul yönetimi sırasında destek olmuş, uyarılara yanıt vermiş, hastaları periyodik olarak incelemiş, ilk bakım planının uygulanmasını sağlamış ve uygun görüldüğü takdirde bakım planlarını değiştirmişlerdir (12, 13). Diğer telemedikal programlarda, yerinde bulunan hekim, uzaktaki tele-Yoğun Bakım Ünitesi yoğun bakım uzmanına, yalnızca yaşamı tehdit eden durumlarda müdahalede bulunmaktan, tedavi planında değişiklik yapma ve emir verme konusunda tam yetkiye kadar tanınan özerklik derecesine kadar değişen ölçüde yetki vermiştir (10, 11, 14).

3. TELEMEDİKAL PROGRAMLARIN HASTA İLE İLGİLİ SONUÇLAR ÜZERİNDEKİ ETKİSİ VE UYGULAMA ENGELLERİ

Bugün itibariyle, yoğun bakım ünitesinde tele-tıbba ilişkin çalışmaların çoğu, yoğun bakım ünitesi ve hastane ölüm oranını, yoğun bakım ünitesinde ve hastanede kalış süresini (HKS), maliyetleri ve maliyet etkinliğini değerlendiren kontrollü olmayan öncesi ve sonrası çalışmalardır (15). Rosenfeld ve diğerleri ile Breslow ve diğerleri tarafından yapılan çalışmalar, hastane ve yoğun bakım ünitesi ölüm oranlarında, yoğun bakım ünitesinde kalma sürelerinde ve ayrıca mali faydalarda azalmalar buldu. Daha yakın tarihli bir çalışmada, Lilly ve diğerleri önlenebilir komplikasyonların azaldığını ve en iyi klinik uygulamaya uyumun arttığını buldu. İlginç bir şekilde, ölüm oranlarındaki azalmaların dörtte birinden üçte birine kadar olan kısmı daha iyi uygulamaya atfedilebilir (12). Ölüm oranlarındaki azalmaların yanı sıra, McCambridge ve diğerleri telemedikal bir programın uygulanmasından sonra mekanik ventilasyon kullanımında önemli azalmalar olduğunu gösterebildiler (16). Kahn ve arkadaşları tarafından farklı bir yaklaşım benimsendi. Telemedikal yoğun bakım programları uygulayan ve uygulamayan ABD hastanelerini eşleştiren büyük, ülke çapında bir retrospektif vaka kontrol çalışması gerçekleştirdiler ve telemedikal programlara sahip hastanelerde 90 günlük ölüm oranının biraz daha düşük olduğunu gösterdiler. Etki, büyük kentsel ortamlarda daha belirgindi (8). Bu bulguların aksine, Thomas ve diğerleri ölüm oranında veya HKS' de azalmalar bulamadı. Ancak, daha şiddetli hastalar telemedikal programdan daha fazla fayda gördüler ve yazarlar bunu kritik olaylara hızlı yanıtla açıkladılar ve program yalnızca en ağır hastalar için maliyet açısından etkiliydi (11). Benzer şekilde ne Morrison ve diğerleri ne de Nassar ve diğerleri ölüm oranında veya HKS' de önemli azalmalar bulamadı (14, 17).

Thomas ve diğerleri, personel kabulünün uygulamanın ana itici gücü olduğunu belirlemiştir (11). Uzaktaki merkez personeli tele-Yoğun Bakım ünitesi doktorunu tıbbi ekibin bir parçası olarak kabul etmeye isteksizse, etkinlik büyük olasılıkla azalacaktır. Kolaylaştırıcıların ve uygulamaya yönelik engellerin bu özel yönü Young ve diğerleri tarafından yapılan sistematik bir incelemede araştırılmıştır (18). Kabul için olası engeller olarak, tesis içi ve tesis dışı yoğun bakım uzmanının çelişkili tavsiyelerini, tele-Yoğun Bakım Ünitesi'nin iş yükünü artırdığı ve yerleşik iş süreçlerini kesintiye uğrattığı algısını ve telemedikal destekten düşük fayda hissiyatını belirlediler. Ayrıca, tele-Yoğun Bakım Ünitesi tarafından izlenip incelendiği hissi ve teknik arızalar uygulamayı engelledi. Uygulamanın, iyi işleyen teknoloji, tele-tıbbın hasta bakımı üzerinde olumlu bir etki gösterdiğine dair his, tele-YBÜ ile yerinde doktorlar arasındaki iyi iletişim ve tele-YBÜ'nün iş yükünü gerçekten azaltıp azaltmadığı ile kolaylaştığı görüldü (19).

Chen ve diğerlerinin çalışmaları (20), Young ve diğerleri (21) ve Wilcox ve Adhikari (22)ölüm oranında ve HKS' de (yoğun bakım veya hastane HKS' de) genel azalmalar buldu. Ancak, maliyet etkinliği konusunda hiçbir sonuca varılmadı. Özellikle, Wilcox ve Adhikari, sürekli, gerçek zamanlı izleme ile müdahaleler ve yalnızca uzaktan danışmanlık ile müdahaleler arasında fark bulamadılar. Bu fark, Ramnath ve diğerleri tarafından yapılan sistematik bir incelemede daha da ayrıntılı olarak açıklanmıştır (23). Telemedikal programları sürekli, gerçek zamanlı izleme veya yalnızca danışmanlık sağlanması temelinde gruplandırdılar. Her iki kategoride de, azalmalar bulan çalışmalar olduğu gibi, mortalite ve HKS'de hiçbir fark bulan çalışmalar da vardı. Sistematik incelemelerine yalnızca iki çalışmayı (12,24) dahil eden Mackintosh ve meslektaşları (15), katılımcı yoğun bakım ünitelerine ilk saat içinde yoğun bakım uzmanı incelemesi, düzenli disiplinler arası turlar ve en iyi uygulamaya uyma gibi faktörlerin daha iyi sonuçlarla ilişkili olduğunu ortaya koyan bir anket yayınladılar.

Yazarlar, telemedikal müdahaleler, kullanılan teknolojiler, müdahaleden önceki yoğun bakım ünitesi bakımı (açık ve kapalı yoğun bakım üniteleri), örneklem büyüklüğü ve müdahale dönemleri ile ilgili çalışmalardaki tutarsızlıkları vurgulayarak farklı sonuçları açıkladılar. Ayrıca, düşük metodolojik kalite, telemedikal müdahalelerin yetersiz açıklaması ve sonuçların yetersiz raporlanması birçok çalışmada eleştirildi. Ayrıca yazarlar, uzun vadeli sonuçları değerlendiren randomize çalışmalara olan ihtiyacı vurguladılar. Yoğun bakım ünitesinde tele-tıbbın etkinliğine ilişkin karışık kanıtlar göz önüne alındığında, geniş çaplı uygulama riskler taşır. Bir tele-tıbbi programın uygulanması önemli miktarda kaynak yatırımı gerektirir (para, personel, teknik ekipman, eğitim, vb.). Tele-tıp tedaviyi ve sonuçları önemli ölçüde iyileştirmiyorsa, bu kaynaklar hasta sonuçlarını açıkça iyileştirdiği gösterilen diğer programlara harcanmalıdır. Bu açıdan, yoğun bakım ünitesinde tele-tıbba ilişkin sağlam bir kanıt tabanı oluşturmak son derece önemlidir. Dahası, mevcut çalışmalar çoğunluğu yalnızca Amerika Birleşik Devletleri'nde yürütülmüştür. Farklı sağlık sistemlerinde ve kültürel bağlamlarda, tele tıp farklı algılanabilir ve farklı etkinlik dereceleri gösterebilir. Özellikle yoğun bakım uzmanlarının daha da fazla olduğu düşük-orta gelirli ülkelerde, tele tıbbın tedavi sonuçları üzerinde büyük bir etkiye sahip olma potansiyeli vardır. Bu nedenle, gelecekteki çalışmalar Amerika Birleşik Devletleri dışında yapılmalıdır.

4. YOĞUN BAKIMDA TELEMEDİKAL KULLANIMIYLA BAKIM KALİTESİNİN ÖLÇÜLMESİ VE KOLAYLAŞTIRILMASI

Yoğun bakımda telemedikal programlara ilişkin önceki çalışmalar, öncelikle hastane ve yoğun bakım ünitesi ölüm oranlarındaki ve hastane ve yoğun bakım ünitesinde kalma sürelerindeki azalmaları değerlendirerek bakım kalitesindeki iyileştirmeleri değerlendirmiştir. Bu ölçümler,

yoğun bakım ünitesinden sağ kurtulanların yaşam kalitesindeki ve işlevsel yönlerindeki karmaşık, uzun vadeli değişiklikleri kavrama yeteneğine sahip değildir. Bu, bu çalışmaların sonuç değerlendirmelerinin heterojen olmasının nedenlerinden biri olabilir. Uzun vadeli sekelleri olan yoğun bakım ünitesinden sağ kurtulanların giderek artması, araştırmaların ölüm oranının ötesinde işlevsel sonuç ölçümlerini içermesini zorunlu kılmaktadır (25). Ancak, uzun vadeli takipleri içeren çalışmaların zahmetli ve kaynak tüketen çabalar olduğu unutulmamalıdır. Bu nedenle, ölüm oranı gibi geleneksel sonuç ölçümlerinin yerini almayacaklardır, ancak tamamlayıcı olarak görülebilirler. Ek olarak, bakımın yapısal kalitesinin yönleri telemedikal programların sonuçları olarak kullanılmalıdır. Kumpf ve diğerleri tarafından geliştirilen akut bakım kalite göstergeleri seti, ölçülebilirlikleri, alakaları ve sağlam kanıt temelleri nedeniyle bu amaç için uygun bir çözümdür (26).

Şimdiye kadar, birçok telemedikal müdahale, yoğun bakım ünitesindeki telemedikal programların özellikle gece saatlerinde daha iyi yoğun bakım uzmanı izleme ve kapsamı sağladığı ve böylece yoğun bakım uzmanı eksikliğini giderdiği fikrine ağırlık kazandırdı (27). Tele-tıp, yoğun bakım uzmanının fiziksel varlığının basit bir ikamesi olarak algılanıyor ve tele-tıbbın bu özelliğine, ölüm oranı ve hastanede kalma süresi üzerindeki olumlu etkiler atfediliyor. Bu mantıkla, telemedikal yapısal kaliteyi artırır. Personel eksikliği veya multidisipliner yaklaşım uygulama sorunları gibi acil sorunlarla karşı karşıya olan yoğun bakım üniteleri için, telemedikal programlara yönelik bu yaklaşım yeterli ve en uygun maliyetli olabilir. Young ve diğerleri tarafından vurgulandığı gibi, farklı yoğun bakım ünitelerinin halihazırda ne kadar iyi işlediğine ve personel sayısına bağlı olarak farklı ihtiyaçları vardır (18). Bununla birlikte, personel sorunlarının ötesinde, telemedikal programlar süreç kalitesini artırmak ve en iyi uygulamaya ve kılavuz uygulamasına uyumu güçlendirmek için bir araç olarak kullanılabilir. Örneğin, yoğun bakım ünitesi liderlerinin günlük olarak rutin bir kontrol listesi kullanmaları yönünde teşvik edilmesinin antibiyotik kullanımı ve sütten kesme konusunda en iyi uygulamaları artırdığı gösterilmiştir (28). Farklı bir çalışmada, örneğin stres ülseri profilaksisi veya sedasyonun kesilmesi gibi iyi uygulamaların uygulanmasına ilişkin bağımsız uzak bir siteden günlük yoğun bakım hemşiresi değerlendirmeleri, iyi uygulamaya uyumu artırdı (29). Carrothers ve ark., dört yoğun bakım ünitesinde deliryum ve kas güçsüzlüğünün önlenmesi için ABCDE paketinin uygulanmasını değiştiren faktörleri araştırırken, iş başında eğitimin CAM-ICU'nun en hızlı ve en yüksek uygulamasını sağladığını buldu (30). Uygulama oranı, daha geleneksel öğrenme konseptlerine göre çok daha iyiydi. Telemedikal programlar, ICU personelinin en iyi uygulamaya uyum konusunda sürekli iş başında eğitim sunma şansına sahiptir. Lilly ve diğerleri tarafından yapılan çalışma telemedikal bir programın derin ven trombozunun önlenmesi gibi en iyi uygulamalara uyumu artırdığını ve kateterle ilişkili kan dolaşımı enfeksiyonları gibi komplikasyonları azalttığını gösterdi; bu da müdahalenin ölüm oranındaki azalmanın %25-30'unu açıkladı (12). Wilcox ve diğerleri. ayrıca, ölüm oranını azaltmak için en iyi uygulamayı iyileştirmek amacıyla telemedikal programların önemini vurguladılar, ancak bu varsayım için yetersiz bir kanıt temeli olduğunu kabul ettiler. En iyi uygulamaya ulaşmak için bir araç olarak telemedikal özellikle önemlidir, çünkü en iyi uygulamaya daha iyi uyumun hasta sonuçları üzerinde önemli bir olumlu etkisi olabilir.

5. SONUÇ

Yoğun bakım ünitesinde telemedikal tedavi, öncelikle yoğun bakım uzmanı kıtlığını karşılamak için yoğun bakım uzmanı işlevlerinin yerine kullanılmıştır. Sonuç ölçütleri olarak, çoğu çalışma ölüm oranını ve HKS'u kullanmıştır. Bilişsel, fiziksel ve ruhsal sağlık ile yaşam kalitesi ölçütleri telemedikal programların değerlendirilmesine dahil edilmeli ve buna ek olarak, telemedikal programlar Kumpf ve diğerleri tarafından örneklendirildiği gibi süreç kalitesi göstergelerine göre değerlendirilmelidir (26). Yoğun bakım personeli eksikliğini gidermek bazı amaçlar için

yeterli olsa da, yoğun bakım ünitesinde tele-tıbbın yeterince değerlendirilmeyen avantajları, en iyi uygulamaya, kılavuzlara ve süreç kalitesi göstergelerine uyumu artırma potansiyelinde yatmaktadır. Bireysel yoğun bakım ünitelerinin ihtiyaçlarına göre ayarlandığında, tele-tıp, eğitimler ve öğretimler içeren en iyi klinik uygulama için daha geniş uygulama konseptlerinin önemli bir bileşeni olabilir.

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AVRUPA'DA DİŞ HEKİMLİĞİ EĞİTİMİ

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ÖZET

Bu tezde Avrupa'daki diş hekimliği eğitiminin nasıl işlediği, müfredatındaki temel şeyler ve korona sürecinde diş hekimliği eğitiminin nasıl devam ettiği anlatılmakla birlikte diş hekimliği eğitimini iyileştirmek için yapılabilecek bazı eylemlerle ilgili tavsiyeler verilmiştir. Sağlığımızı emanet edeceğimiz hekim meslektaşlarımızın bilim ve bilim eğitimi açısından gelişmiş olan Avrupa'da nasıl eğitim gördüğü öğrenilerek, bu eğitimden kendi ülkemizde yapılan diş hekimliği eğitimine hangi yönde düzenlemeler yaparak ülkemizdeki diş hekimliği eğitimini geliştirebileceğimiz anlamak amaçlamıştır.

Anahtar kelimeler: Diş hekimliği, eğitim, Avrupa, denklik, uyum

SUMMARY

This thesis aims to explore how dental education functions in Europe, including its curriculum and the continuation of dental education. Additionally, recommendations are provided for actions that can be taken to improve dental education. By examining how our fellow healthcare professionals, whom we trust with our health, receive education in scientifically advanced Europe, the goal is to understand how we can enhance dental education in our own country by implementing appropriate modifications.

Key words: Dentistry, education, Europe, equivalence, harmony

GİRİŞ

Avrupa'da diş hekimliği eğitimi, yüksek kalite standartlarına sahip ve uluslararası tanınırlığı olan bir eğitim sürecini içerir. Avrupa'da diş hekimliği eğitimi genellikle 5 ila 6 yıl sürer ve bir lisans derecesi ile tamamlanır. Bazı ülkelerde, öğrencilerin bir ön lisans derecesi alması gerekebilirken, diğer ülkelerde doğrudan diş hekimliği programına girebilirler. Eğitim süresi ülkelere ve üniversitelere göre değişiklik gösterebilir. Diş hekimliği eğitimi, genellikle

temel bilimlerin yanı sıra diş hekimliği ile ilgili dersleri de kapsar. Öğrenciler, anatomi, fizyoloji, biyokimya, mikrobiyoloji, farmakoloji gibi temel bilimlerin yanı sıra diş hastalıkları, ağız cerrahisi, protetik diş tedavisi, pedodonti, ortodonti, periodontoloji ve endodonti gibi diş hekimliği konularında da eğitim alırlar. Diş hekimliği eğitimi hem teorik dersleri içerirken hem de klinik uygulamaları kapsar. Öğrenciler, klinik becerilerini geliştirmek için hasta tedavileri gerçekleştirir ve klinik ortamlarda deneyim kazanır. Bu, hasta ile etkileşimde bulunma, teşhis koyma, tedavi planlama ve dental prosedürleri gerçekleştirme becerilerini içerir. Avrupa'daki diş hekimliği eğitimi genellikle ulusal ve uluslararası akreditasyon kuruluşları tarafından denetlenir ve belirli standartlara tabidir. Bu sayede, mezun olan diş hekimleri, uluslararası düzeyde kabul edilen bir eğitim aldıklarını kanıtlayabilirler [1].[2] [3]

Sonuç olarak, Avrupa'daki diş hekimliği eğitimi, uluslararası düzeyde tanınan bir eğitim sürecidir. Öğrencilere teorik bilgi, klinik beceriler ve araştırma fırsatları sunar. Bu sayede, mezunlar, diş hekimliği alanında başarılı bir kariyere sahip olma potansiyeline sahiptir. Avrupa'da diş hekimi geliştiren yaklaşık olarak 200 tane diş hekimliği fakültesi vardır, bunların 141 tanesi Avrupa Ekonomik Alanı (European Economic Area) bünyesinde bulunmaktadır. Bu diş hekimliği fakültelerinin öncelikli amacı yetiştirdiği diş hekimlerinin; ahlak anlayışına sahip, gerektiğinde sorumluluk alabilen kişiler olmasıdır. Avrupa ülkeleri arasında; hastalık deneyimleri, kültürel normları ve sağlık politikaları açısından oldukça çeşitlilik vardır. Buna bağlı olaraktan ülkelerdeki diş hekimliği eğitimlerinde farklılıklar vardır [4].

AVRUPA ÜLKELERİNDEKİ DİŞ HEKİMLİĞİ FAKÜLTELERİNDEKİ MÜFREDAT ÇEŞİTLİLİKLERİ

1996'da Shanley Avrupa ülkelerindeki diş hekimliği fakültelerinin Dişhekimliği Sektörel Yönergelerinin şartlarına ne kadar uyduğunu öğrenmek için bir araştırma yapıp makale yayınladılar [5]. Elde ettikleri sonuçlara bakıldığında endişe verici olduğu görüldü. Avrupa'da ne durumda olduğunu öğrenmek istedikleri 127 okuldan sadece 30 tanesi geri dönüş yaptı. Geri dönüş yapan okullar karşılaştırıldığında düşünülünden çok daha yüksek oranda müfredatta farklılık olduğu görüldü. Geri dönüş yapan okulların yöneticilerinin verdiği bilgilere bakıldığında, işlenen ders saatleri karşılaştırıldığında; en düşük ders saati olan fakülte ile en yüksek ders saati olan fakülte arasında on kattan fazla fark olduğu görüldü. Üstelik bu fark protetik diş hekimliği, periodontoloji gibi temel ve önemli derslerde de görülüyordu. Ders saatleri arasında bu kadar büyük bir fark olduğunu düşünürsek teorik bilgileri öğrenmek için daha az ders saati alan öğrencilerin öğrenmek için daha fazla çaba göstermesi gerektiğini düşünebiliriz.

Klinik akademik kadroya baktığımızda sayı olarak ondan seksene kadar farklılık olduğu görüldü. Okulların her yıl aldığı yeni öğrenci sayısını karşılaştıracak olursak yine çok yüksek bir fark olduğunu görüyoruz. Yıllık en az öğrenci alan okulun 20 civarında öğrenci en fazla öğrenci alan okulun ise yıllık yaklaşık 170 öğrenci aldığını görüyoruz. Okulların bütçesine baktığımızda ise öğrenci sayısı ile alınan bütçe arasında doğru orantı olmadığını görüyoruz.

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Öğrenci sayısıyla bütçenin doğru orantıda olmamasını ele aldığımızda ya öğrencilerin eşit düzeyde eğitim almadığını ya da aradaki bütçe farkını kendilerine ayırdıkları bütçeden karşıladığı sonucuna varabiliriz.

Bu karşılaştırmada tüm okullardan geri dönüş alamadığımızı düşünürsek, daha fazla okulun geri dönüş yapması durumunda aradaki farkın daha fazla artacağını düşünebiliriz. Bu okullardan mezun olan diş hekimlerini ele aldığımızda ise klinik deneyim ve teorik bilgi açısından aynı seviyede olmadığını düşünürsek yanılmış olmayız. Aynı seviyede olmayan diş hekimleri açısından karşılaşabileceğimiz en büyük sorun tedavi esansında karşılaşabileceğimiz malpraktislerdir.

MESLEKİ EĞİTİM VE SONRASINDA DEVAM EDEN GELİŞİM

Mesleki eğitimdeki yönergelerin asıl amacı eğitim sürecinin doğru denetleyiciler ile denetlenmesiyle Avrupa genelindeki her yerde bağımsız olarak çalışabilecek kaliteli diş hekimlerinin eğitiminin sağlanmasıdır. Bunlara ek olarak mezun olmuş diş hekimlerini üniversitelerde desteklemek için yönergelerde bazı düzenlemelerin yapıldığı da bilinmektedir. Avrupa'daki diş hekimliği okullarına bakıldığında bu alanda da eğitimdeki zorlama dereceleri, eğitimin içeriği, denetim düzeyleri açısından burada da farklılıklar olduğu görülebilmektedir [6].

Örnek verecek olursak İngiltere'de Ulusal Sağlık Hizmetlerinde (National Health Service) müdür olarak çalışmak isteyenler için mesleki eğitim zorunludur. Mesleki eğitim içeriği, tam zamanlı maaşlı olarak onaylı bir diş hekiminin yanında 1 yıl boyunca çalışmış olmaktır. Bunların organizasyonu ise genel diş hekimliği pratisyenliği yapan, on iki diş hekiminden sorumlu olan atanmış bir mesleki eğitim eğitmeni tarafından düzenlenir [7]. Yeni mezun olmuş diş hekimlerinin değerlendirilmesi ve mesleki seyir defterinin kaydının tutularak değerlendirilmesi bölgesel lisansüstü dekanlar (Regional Postgraduate Deans) tarafından yapılmaktadır. Bölgesel lisansüstü dekanlar yeni mezun diş hekimlerinin aldıkları eğitimin ulusal standartlara uygun olup olmadığını denetleyen kimselerdir. Bölgesel lisansüstü dekanların bir diğer görevi de verilen eğitimin yıl sonunda tamamlanmış olduğunu belgelemeleridir. Uygulanan bu programlarının tamamı ulusal olarak organize edildiği için diş hekimliği okullarının sorumluluğunda değildir [8].

Diğer Avrupa ülkelerinde farklı varyasyon tiplerinde programlar vardır. Örnek verecek olursak İskandinav ülkelerinin bazılarında Devlet Sağlık Kurumları ile istihdam yaratmayı amaçlayan bir program vardır. Bu program dahilinde yeni mezun olan diş hekimleri okuldan sonraki ilk yılını devletin sağlık kurumlarında geçirirler. Almanya'da ise daha gayri resmi ama zorunlu bir sistem vardır. Buradaki sistemde ise sağlık sigortacıları tarafından tanınmak isteyen yeni mezun olmuş diş hekimlerinin 2 yıl boyunca bulunduğu eyaletin diş hekimleri odasının verdiği eğitimi almalıdırlar. Pratik anlamda çalışmak isteyen diş hekimlerinin bu odalara üyeliği zorunlu tutulmuştur. Fransa'da ise bir diş hekimliği muayenesinde 6 yıl deneyim sahibi olmak gereklidir. Macaristan'da ise Birleşik Krallık'takine benzer olan 2 yıl olan bir plan uygulanmaktadır. Bazı doğu ve orta Avrupa ülkelerinde, yeni mezun olmuş diş hekimlerinin ülkelerin kendisinin belirlemiş olduğu bir süre boyunca Devlet Sağlık Hizmetlerinde çalışması

[6] Brown, A., & Keep, E. (Eds.). (2000). Review of vocational education and training research in the United Kingdom. Brussels: Office for Official Publications of the European Communities.
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şartı vardır. Bu uygulamanın resmi bir eğitim programına dahil olup olmadığı bilinmemektedir [9] [10].

Diş hekimliği fakültesindeki müfredatta olması gereken temel şey kanıta dayalı olmasıdır. Avrupa Diş Hekimliği Eğitimi Birliği (Association for Dental Education in Europe, ADEE), diş hekimliği eğitimindeki çeşitliliği korumaya yönelik adımlar atmaktadır, bunu yapmasındaki amaç ise farklı Avrupa ülkelerinde farklı eğitim gören diş hekimleri arasında tartışma ortamını sağlamaktır. Tüm bunlar yapılırken yine de verilen eğitimin ortak bir çerçeve içinde kanıta dayalı bilgiler ile olmalıdır. Bologna tavsiyesine göre yükseköğretim için "3-5-8" modeli (Lisans- Yüksek Lisans- Doktora) tavsiye edilmiştir.

2005 yılında verilip 2011 yılında revize edilen bu yönergeye göre diş hekimliği eğitiminin, en az beş yıllık bir süre boyunca devam etmesi ve bu süre boyunca tam zamanlı olarak teorik ve klinik çalışmalardan oluşması gerektiği bildirilmiştir. Şu anda diş hekimliği fakültelerinin çoğunda bölünmemiş 5 yıllık bir diş hekimliği eğitim programı mevcuttur, ancak akademi dahilinde Bologna 3+2 sistemini yüksek lisans düzeyinde takip etmek gibi bir opsiyon vardır. Bu programın uygulanması ile uygun olan AKTS (Avrupa Kredi Toplama ve Transfer Sistemi) kredileriyle 5 yıllık tam zamanlı eğitim ile diş hekimliği yüksek lisans derecesine ulaşılmış olunur. 3+2 modelinde ilk 3 yıllık eğitimin başarılı olması sonucunda lisans derecesinin verilmesini ifade eder [11].

5 yıl süren diş hekimliği eğitiminden sonra diş hekimliği okulu ile diş hekimi mesleği arasında bir köprü görevi görecek şekilde, devlet tarafından finanse edilmesi ile 1 veya 2 yıllık mesleki eğitim programının uygulanmasını şart koşan bazı Avrupa ülkeleri vardır ancak tüm Avrupa ülkeleri bu uygulamayı yapmamaktadır. Bu uygulamanın zorunlu tutulamamasındaki temel gerekçelerden biri 5 yıllık eğitimin sonunda zorunlu bir görev verilmesi sonucunda hareket özgürlüğü kısıtlanır [12].

MÜFREDAT YAPISI

Diş hekimliği fakülteleri, üniversite ve fakülte birleşimi ve değişkenleri kapsamında bağımsız olan bir diş hekimliği müfredatı geliştirme hakkına sahip olması istenen bir durumdur. Bologna tavsiyelerini baz alırsak, diş hekimliği müfredatını hazırlarken modüler bir şekilde olan müfredat hazırlanmalıdır.

Modülü, disiplin ya da departman kavramlarından bağımsız olan bir öğrenme birimi şeklinde tanımlayabiliriz. Modül, bütün haliyle müfredat için gereklidir ve müfredatın yeterliklerini açık bir şekilde ifade etmelidir. Bunlara ek olarak modül, iyi tanımlanmış öğrenmeye dayalıdır. Her bir modülde; modülün açıklamasını içeren bir başlık, AKTS değeri, ve öğrenme çıktılarını içermelidir [13].

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Öğrenme çıktıları, düşünülen genel kanı olan öğrencilere nelerin sağlandığı bilgisinin aksine; öğrenme modülünün tamamının yapılması sonrasında bir öğrencinin neleri anlamış olması, bilmesi gerektiğinin ifadesidir. Öğrenme çıktılarının bilişsel, duyusal ve psikomotor alanlardaki gereksinimlerin hepsini kapsamalıdır [14].

İlk olarak yapılacak modül için temel olarak öğrenilecekleri ve bir öğrencinin geçmesi için gerekli olan kriterler belirlenmelidir. Öğrenme çıktısının çok sayıda ve yüzeysel olmaması gerekir bunun yerine daha az sayıda ama daha fazla önem arz eden öğrenme çıktısı olmalıdır. Öğrenme çıktısı tanımlanırken basit ve açık bir şekilde tanımlanmalı ve hazırlanmış öğrenme çıktısı değerlendirilebilir olmalıdır. Öğrenme çıktılarını yazarken uygun fiil seçiminde; vurgu, bilgi ve becerinin uygulanmasını gösterebilecek, kesin ve ölçülebilir bir fiil kullandığımıza dikkat etmeliyiz [15].

MÜFREDAT YAPISI İÇİN ÖNERİLER

- Diş hekimliği fakültesinin etkin bir eğitim verebilmesi için bir tıp fakültesi ve bir üniversite ile veya geniş tabanlı bir sağlık bilimleri fakültesi ile koordine bir durumda olmalıdır.
- Diş hekimliği okullarının diş hekimliği eğitimi için kendilerinin müfredat geliştirebilme yetkisi olmalıdır. Aynı zamanda diğer sağlık eğitimi programlarının dekanları veya müdürleri ile denk statüye sahip bir dekanı ya da müdürü olmalıdır.
- Diş hekimliği okulunun etkili bir şekilde idaresinin sağlanması için, yetki gücünün ve sorumluluklarının açık bir şekilde tanımlanmış olması gereklidir.
- Diş hekimliği müfredatının oldukça yoğun olduğunu düşünürsek, diş hekimliği öğrencilerinin hepsinin etkin bir eğitim alabilmesi için yeterli sayıda klinik ve akademik eğitimci ile yeterli sayıda idari personel bulunmalıdır.
- Diş hekimliği eğitiminin müfredatını belirlerken öğrenci ve hasta merkezli hazırlanmalıdır.
- Bölümün yapısı klinik öğrenme ortamına engel olacak şekilde değil klinik öğrenime katkıda bulunacak şekilde olmalıdır.
- Tüm hastaların ağız bakımının öğretilmesini kolaylaştıracak şekilde olmalıdır.
- Diş hekimliği okulunun, eğitim düşünce yapısını; müfredat yapısını; eğitimin içeriğini ve değerlendirilmesinin bulunduğu güncel olan bir müfredat el kitabı bulunmalıdır.
- Her modül, modülün başlığını; AKTS değerini ve öğrenme çıktılarını içeren bir el kitabına sahip olmalıdır. Bu el kitabında müfredatın kısa bir açıklaması, öğretme ve öğrenme yöntemleri ve modülün sonunda hangi yöntemlerle değerlendireceği yazmalıdır.
- Bir modül en az 5 AKTS'den oluşmalı ve öğrenmenin etkin bir şekilde yapılabilmesi için otuz AKTS'yi geçmemelidir.
- Fakültenin idaresi, fakülte ve öğrencilerin globalleşmesini desteklemelidir. Bunu öğrencilerin Erasmus gibi öğrenci değişim programlarının uygulanması ve uygun kredi sistemlerinin (ECTS) kullanılması ile sağlayabilir.
- Ulusal sağlık politikaları, bölgesel ve ulusal oral bakım gerekleri kursların ve içeriğinin geliştirilmesinde temel altyapı olmalıdır.

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[14] Movchun, V., Lushkov, R., Pronkin, N. Prediction of individual learning style in e-learning systems: opportunities and limitations in dental education. Educ. Inf. Technol. 2021; 26, 1–15.
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- Bir diş hekimliği fakültesi, ilgili kaynaklara erişebilmeli ve yıllık iş planını eğitim hedefleriyle ilişkilendirerek oluşturmak veya en azından katkıda bulunmak için yetkilendirilmelidir. Devredilmiş diş hekimliğindeki bütçe şeffaf olmalıdır.
- Komite yapısı kapsayıcı ve destekleyici olmalıdır. Farklı kademe personel ve öğrencilerden temsilciler içermelidir.
- Beş yıllık programın tamamlanması genel lisans derecesi olarak kabul edilebilir, ancak bu kesinlikle diş hekimi veya herhangi bir ağız sağlığı profesyoneli olarak kayıt olma şansı vermemelidir.
- Diş hekimliği fakültelerinde öğretimli lisansüstü programlar önerilir, ancak bu programlar diş hekimliği lisans programını zayıflatmamalıdır.

MÜFREDAT İÇERİĞİ İÇİN ÖNERİLER

• Diş hekimliği müfredatının içeriği, Avrupa Diş Hekimi Profili ve Yetkinlikleri ile doğrudan ilişkili olmalı ve katkıda bulunmalıdır.

• Okullar, müfredatın içeriğinin kanıta dayalı olmasını ve tüm program boyunca güncel en iyi uygulamaları yansıtmasını sağlamalıdır.

• Hastalarla erken temas, diş hekimliği öğrencileri arasında gerçekleşmelidir. Birinci veya ikinci sınıftan itibaren diş hekimliği öğrencilerinin hastalarla teması sağlanmalıdır.

• Etkili enfeksiyon kontrolü, tüm klinik faaliyetlerin ayrılmaz bir parçası olmalıdır.

• Entegre hasta bakımı, klinik eğitimin temel bir parçası olmalıdır.

• Temel ve biyomedikal konular eksiksiz bir şekilde öğrenilmelidir.

• Temel yaşam desteği becerileri de dahil olmak üzere eğitim, düzenli olarak ve değerlendirilerek verilmelidir.

• Hastaların tedavilerinde diş hekimlerinin ilgili olduğu tıbbi ve diğer durumlar eğitimde eksiksiz olarak verilmelidir.

• Davranışsal ve sosyal bilimler eğitimi, diş hekimlerinin hastalarıyla, takım üyeleriyle ve diğer sağlık profesyonelleriyle etkili iletişim kurmalarını sağlamak için önerilmektedir.

• Diş hekimliği halk sağlığı, koruyucu diş hekimliği ve toplum diş hekimliği eğitimi teşvik edilmelidir.

• Etik ve mesleki davranış eğitiminde uygulamalı bir yaklaşım önerilmektedir.

• Takım çalışmasına ve farklı diş hekimliği takım üyeleri için eğitim programları arasında bazı entegrasyon unsurlarına daha fazla önem verilmelidir.

• Seçmeli derslerin lisans müfredatının ayrılmaz bir parçası olması sağlanmalıdır

TARTIŞMA VE SONUÇ

Elde ettiğimiz veriler sonucunda Avrupa'daki ülkelerde üniversitelerin diş hekimliği eğitimi verebilmesi için belirli bazı koşulları sağlaması gerektiği görülmüştür. Bu koşullarda Covid-19 sürecinde pandemi nedeniyle bazı değişiklikler olmuştur ama öğrenciler genel olarak yüz yüze olan pandemi öncesinde uygulanan sistemi tercih etmişlerdir. Verimli bir diş hekimliği eğitimi için verilen derslerin uygulamalı olması ve uygulama saatinin yeterli olması gerekmektedir. Bunlara ek olarak her anabilim dalı için yeterli sayıda akademisyenin üniversitesi bünyesinde diş hekimliği öğrencilerinin derslerine girmelidir. İlk üç yıllık teorik ve uygulamalı derslerden sonra diş hekimliği öğrencilerinin hoca kontrolünde yeterli sayıda hasta

bakabilmeli ve mezun olduklarında kimsenin yardımı olmadan hastalara doğru endikasyonu koyabilecek ve gerekli işlemleri uygulayabilecek becerilere sahip olmalıdır. Mezun olan diş hekimlerinin ilk yılında yaşayacakları şehirde bulunan deneyimli diş hekimlerinin yanında 1 yıl boyunca çalışarak hastalara kimsenin yardımına gerek olmadan doğru endikasyon koyabildiğinden ve gerekli olan tedavileri yapabildiğinden emin olunduktan sonra yeni mezun diş hekimlerinin çalışma hayatına tam geçişi olması gereklidir. Diş hekimleri çalışma hayatına geçtikten sonra öğrenme sürecini sonlandırmamalı ve güncel gelişmeleri takip etmelidir. Çalışma hayatında diş hekimlerinin güncel bilgilerle kendini geliştirdiğinden ve güncel tedavi yaklaşımlarına hakim olduğundan emin olmak için diş hekimlerine beş yılda bir sınav yapılabilir. Covid-19 sürecinde görüldüğü üzere online eğitimin bazı avantajları bulunmaktadır. Online eğitimin avantajları ve yüz yüze eğitimin avantajları birleştirilerek örgün bir eğitim sistemi sağlanarak diş hekimliği öğrencilerinin daha iyi bir eğitim alması sağlanabilir.

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ADÖLESANLARA YÖNELİK AFET OKURYAZARLIĞI: BİR ÖLÇEK GELİŞTİRME ÇALIŞMASI

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ÖZET

Amaç: Araştırmamızın amacı hem ülkemizde hem de dünya genelinde adelosan çağdaki bireylerin afet okuryazarlığı becerisini değerlendirip gelecek kuşakların afetler konusunda farkındanlığını arttırmak için adölesanlara yönelik afet okuryazarlığı ölçeği geliştirmektir.

Materyal ve Metot: İki aşamadan oluşan bu çalışmanın ilk aşamasında madde havuzun oluşturulması ve uzman görüşünün alınması yer alırken ikinci aşamasında ölçeğin psikometrik değerlendirilmesi yer almaktadır. İki aşamadan oluşan bu çalışmanın ilk aşamasında madde havuzun oluşturulması ve uzman görüşünün alınması yer alırken ikinci aşamasında ölçeğin psikometrik değerlendirilmesi yer almaktadır. AFA analizi için SPSS 27, DFA analizi için de AMOS 21 paket programları kullanılmıştır. Verilerin analizinde, adölesanların özellikleri frekans, yüzde, ortalama ve standart sapma gibi tanımlayıcı istatistikler yapılırken, AFA ve DFA grupları arasındaki farklar ki-kare ve t-testi kullanılarak analiz yapılmıştır.

Bulgular: Alanyazının incelenmesi ve uzman görüşleri doğrultusunda oluşturulan 5'li Likert şeklinde hazırlanan 53 maddelik (AYAOÖ) taslağı, yapılan analizler sonucunda 29 madde ve 4 alt boyut olarak son halini almıştır. Faktör analizi sonucunda açıklanan toplam varyansın %53.237 olduğu belirlenmiştir. Adölesan Afet Okuryazarlık Ölçeğinin tüm maddelerinin güvenirlik katsayısı 0.944 olduğu belirlenirken alt boyutların Cronbach α değerleri 0.88 ile 0.95 arasında değişti görülmüştür. 29 maddelik Adölesan Afet Okuryazarlık Ölçeği'nin aritmetik ortalamasının 109.71±21.69 olduğu belirlenmiştir. Tüm bu bulgular 29 maddeden oluşan Adölesan Afet Okuryazarlık Ölçeğinin içyapı tutarlılığının yüksek olduğunu göstermektedir. Doğrulayıcı faktör analizi sonrası 29 maddelik ölçeğin standardizasyon katsayılarının 0.50'nin üzerinde olduğu belirlenmiştir. CFA uyum indekslerinin kabul edilebilir düzeyde olduğu tespit edilmiştir. CMIN/DF=2.523, RMSEA= 0.048, CFI= 0.937, TLI=0,931, NFI=0.900, AGFI=0.894 ve GFI=0.910 olarak belirlenmiştir.

Sonuç: Adelosanlara yönelik afet okuryazarlığı ölçeği, geçerlilik ve güvenilirlik analizleri, kapsam geçerliliği, iç tutarlığı ve yapısal özellikleri açısından kabul edilebilir ve geçerli nitelikte olduğunu göstermiştir. Gelecekte yapılacak Adelosanlara yönelik afet okuryazarlığını

ölçme ve değerlendirme çalışmalarında önemli bir ihtiyacı karşılayıp alanda ki bir boşluğu dolduracağı değerlendirilmektedir.

Anahtar kelimeler: Adölesan, Afet, Okuryazarlık

1.GİRİŞ

Afetler uzun vadede halk sağlığı ve psikolojisini tehtit eden, acil tıbbı sorunlar nedeniyle kitlesel acılara yol acan oldukça karmaşık olaylardır (Singh, 2020). Brown ve ark. (2014) Afet okuryazarlığını, ‘’bireylerin bir afetin zarar azaltma, hazırlık, müdahale ve iyileştirme bağlamında bilinçli kararlar almak ve talimatları izlemek için bilgiyi okuma, anlama ve kullanma derecesi’’ olarak tanımlanmaktadır. Sözcü ve Aydınözü (2019) Afet okuryazarlığını, ‘‘bir bireyin karşılaştığı veya karşılaşabileceği bir afet sorununun detaylı bir şekilde anlaşılması, analiz edilmesi, sentezlenmesi ve değerlendirilmesi sonucunda doğru ve bilinçli kararlar alma süreci’’ olarak tanımlamıştır. Afetlere hazırlıkta afet okuryazarlıgı oldukca önemli bir yer tutmaktadır (Asshiddiqi vd., 2021). Afet risklerini azaltmak, toplumun farkındalığını arttırarak biliçlenmesini sağlamak için afet okuryazarlığı becerisine ihtiyaç vardır (Bulut, 2023).

Adolesan dönem, yaşamın çocukluk ile yetişkinlik arasındaki, 10 ila 19 yaş arasındaki evresi ve insan gelişiminin ve sağlığın temellerinin atılması için önemli, eşsiz bir zamandır (WHO,2024). Ülkemizdeki adelosan çağdaki (10-19 yaş) birey sayısı Sağlık Bakanlığı (2022) verilerine göre 12.949.817 (%15,1) dir. Dünya nufusunda bu oran %16’dır (UNFPA, 2021). Afetlerle ilgili yapılan çalışmalarda sıklıkla yaş ve bireylerin afet okuryazarlık düzeyleri arasında pozitif yönde anlamlılık tespit edilmiştir (Erdogan ve Kaya, 2024; Bulut, 2023 ; Genç vd., 2022 ; Sözcü ve Aydınözü, 2019). Bu sebeple, yetişkinliğe geçmeden önceki erken yaşlarda afetler hakkında farkındalık oluşturmayı hedefleyen eğitimler, afet riskini azaltmada oldukça önemlidir. Dünya genelinde afet ülkesi olarak bilinen Japonya afet okuryazarlığı açısından oldukça iyi bir örnektir. Japonya’da yıllık eğitim programlarının uygulanması (Shiroshita ve Manyena, 2011) ve okul müfredatına afet öz yeterlilik eğitimini dahil edilmesi nedeniyle afet müdehale bilgisi kapsamının %100’e yakın olduğu tespit edilmiştir (Xu vd., 2014).

Literatür taramasında dünyada hem de ülkemizde afetlere hazırlık ve afet yönetimi konusunda toplumun afet farkındalığını ölçmeye yönelik yetişkinler için ölçme araçları ve çalışmalar mevcut olsa da Dünya nüfusunun %16’sını kapsayan adelosan çağdaki bireylerin bilgilerini ölçmeye yönelik bir değerlendirme aracına rastlanmamıştır. Bu görüşten hareketle planlanan çalışmada; afetler konusunda toplumun gelecek nesillerinin farkındalıgını arttırmak, afet okuryazarlık becerisini değerlendirmek ve gelecekte yapılması planlanan egitimlere yön vermesi amacıyla “Adolesanlara Yönelik Afet Okuryazarlığı Ölçeği Geliştirme Çalışması” planlanmıştır.

2.YÖNTEM

İki aşamadan oluşan bu çalışmanın ilk aşamasında madde havuzun oluşturulması ve uzman görüşünün alınması yer alırken ikinci aşamasında ölçeğin psikometrik değerlendirilmesi

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yer almaktadır. Adölesan Afet Okuryazarlık Ölçeğinin (AYAOÖ) psikometrik özelliklerini ortaya koymak amacıyla AFA ve DFA analizi yapılmıştır. Bu bağlamda örneklem belirlenirken AFA (362) ve DFA (301) analizi için ayrı ayrı iki veri toplanmıştır. Veriler Eylül 2024 tarihinde Erzurum ilinde merkez ilçedeki Milli Eğitim Müdürlüğüne bağlı okullardaki 10-19 yaş aralığındaki ögrencilerden çalışmaya dahil edilme kriterlerine uyan ve çalışmaya katılmayı kabul eden 663 öğrenciyle sosyo-demografik veri formu ve Adelosanlara yönelik afet okuryazalığı ölçek taslağı aracılığıyla yüz yüze olarak uygulanıp toplanmıştır. AFA analizi için SPSS 27, DFA analizi için de AMOS 21 paket programları kullanılmıştır. Verilerin analizinde, adölesanların özellikleri frekans, yüzde, ortalama ve standart sapma gibi tanımlayıcı istatistikler yapılırken, AFA ve DFA grupları arasındaki farklar ki-kare ve t-testi kullanılarak analiz yapılmıştır.

Araştırma izni: T.C. Millî Eğitim Bakanlığından 17.09.2024 tarihinde gerekli kurum izinleri alınmıştır (Başvuru No: MEB.TT.2024.001527).

Madde havuzunun oluşturulması: Literatür taraması ve 80 öğrenci ile afetler ile ilgili bilgilerini aktardıkları kompozisyon çalışması sonucu 58 maddeye ulaşılmıştır.

Uzman Görüşü: Oluşturulan madde havuzu alanında uzman 10 farklı kişinin görüşüne sunulmuştur. Öneriler ve düzeltmeler sonrasında soru sayısı 53'e düşmüş ve 5'li Likert yapıda hazırlanan madde havuzu son halini almıştır.

Örnekleme uygulaması:800 ögrenciye uygulanan taslak formunlarının tam ve doğru şekilde cevaplanan 663 tanesi degerlendirilmeye alınmıştır.

3.BULGULAR

Araştırmada AFA ve DFA grubunda yer alan adölesanların tanıtıcı özelliklerinin karşılaştırılması Tablo 1'de verildi. Gruplar arasında istatistiksel olarak anlamlı fark olmadığı saptandı (Çizelge 1).

Çizelge 1. *Adölesanların Tanıtıcı Özelliklerinin Dağılımı*

Characteristics	**Participants in EFA (n=362)**		**Participants in CFA (n=301)**		**t / χ^2 (*p*)**
Yaş Ortalama	13.35±1.45		13.25±2.05		0.036 (0.661)
Cinsiyet					
Kadın	201	55.5	159	52.8	0.483 (0.487)
Erkek	161	44.5	142	47.2	
Gelir Düzeyi					
Kötü	3	0.8	5	1.7	2.108 (0.103)
Orta	246	68.0	167	54.9	
İyi	113	31.2	129	43.4	
Afet Yaşama Durumu					

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Evet	208	57.6	161	54.2	0.769 (0.381)
Hayır	154	42.4	140	45.8	
Afet Eğitimine Katılma Durumu					
Evet	205	56.6	152	50.8	3.548 (0.170)
Hayır	157	43.4	149	49.2	
Afet Kaynaklı Mal Kaybı Yaşama Durumu					
Evet	14	3.9	11	3.7	0.016 (0.899)
Hayır	348	96.1	289	96.3	
Afet Kaynaklı Yaralanma Durumu					
Evet	8	2.2	8	2.7	0.145 (0.703)
Hayır	354	97.8	293	97.3	
Afet kaynaklı Yakınını Kaybetme Durumu					
Evet	31	8.6	34	11.3	1.421 (0.233)
Hayır	331	91.4	267	88.7	

3.1. İçerik Geçerliliği

Adölesan Afet Okuryazarlık Ölçeği, adölesanlara içerik açısından uygun olup olmadığını incelemek için, çocuk sağlığı ve halk sağlığı konularında deneyimi olan uzmanlardan oluşan toplam 10 uzmana gönderildi. Uzmanlar madde içerik geçerlilik indeksi (I-CVI) ve ölçek içerik geçerlilik indeksini (S-CVI) değerlendirmek için davet edildi. Maddelerin uygun olup olmadığını 4 puanlık bir ölçekle değerlendirdiler. I-CVI, her bir maddeyi üç puan veya dört puan ile sıralayan uzman sayısının toplam uzman sayısına oranıdır. Madde-İçerik Geçerlilik İndeksi (I-CVI) ve Ölçek-İçerik Geçerlilik İndeksi/Ortalama (S-CVI) kullanılarak analiz edildi ve maddenin I-CVI'sı 0.80'den küçükse veya S-CVI/Ave 0.90'dan küçükse madde modifikasyonu veya silinmesi düşünülmüştür (Polit ve Beck, 2006). Uzman yanıt oranı %100 olarak değerlendirildi. I-CVI değeri 0.80'in altında kalan 5 madde ölçekten çıkarıldı. 53 madde için I-CVI 0.885 ile 1.000 arasında ve S-CVI 0.925 olarak bulundu.

3.2. Açımlayıcı Faktör Analizi (AFA) Bulguları

Geliştirilmek istenen Adölesan Afet Okuryazarlık Ölçeğinin yapı geçerliğini sınamak için açımlayıcı faktör analizi tekniklerinden olan temel bileşenler analizi yapılmıştır. Başlangıç olarak verilerin faktör analizine uygun olup olmadığını görebilmek için Kaiser Meyer Olkin (KMO) örneklem yeterliği katsayısına ve Barlett Küresellik testi anlamlılık değerine bakıldı. Yapılan analiz sonucunda, Kaiser Meyer Olkin (KMO) örneklem yeterliği katsayısı .948, Barlett Küresellik testi değeri de anlamlı olduğu saptandı ($\chi2= 5505.466$, $p<0.001$). Ulaşılan bu değerler örneklemden elde edilen verilerin faktör analizine uygun olduğunu göstermiştir. Faktör yükleri .30'un altında olan maddelerle birden fazla faktöre yük veren ve faktör yükleri arasında .10'dan az olan 22 madde sırayla atılmıştır (Çokluk vd., 2010; Hair vd., 2009). Tekrarlanan faktör analizi sonucunda açıklanan toplam varyansın %53.237 olduğu belirlendi. AFA sonucunda öz değeri 1'i aşan dört faktörlü yapı elde edildi.

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3.3 Doğrulayıcı Faktör Analizi (DFA) Bulguları

DFA 31 madde ve dört faktörlü yapı üzerinde, AFA da dahil edilmeyen 301 adölesan ile gerçekleştirildi. 31 maddelik ölçeğin standardizasyon katsayılarının iki maddede (7. ve 41. Madde) 0.50'nin altında olduğu belirlendi. Son hali verilen ölçekte, bu maddeler çıktığında 2. Faktörün altı madde, 3. Faktörde 4 maddeden oluştuğu belirlendi. 29 maddelik Adölesan Afet Okuryazarlık Ölçeği için CFA tekrarlandı. 29 maddelik ölçeğin standardizasyon katsayılarının 0.50'nin üzerinde olduğu belirlendi. CFA uyum indekslerinin kabul edilebilir düzeyde olduğu belirlendi. CMIN/DF=2.523, RMSEA= 0.048, CFI= 0.937, TLI=0,931, NFI=0.900, AGFI=0.894 ve GFI=0.910 olarak belirlendi. Uyum değerleri Byrne'nin (2011) belirttiği referans değerleri dikkate alınarak değerlendirildi. Modele ilişkin path diyagramı Şekil 1'de verilmiştir.

3.4. Benzeşme Geçerliliği Bulguları

Adölesan Afet Okuryazarlık Ölçeği benzeşme geçerliğini görebilmek için açıklanan ortalama varyans (AVE) değerleri ile birleşik güvenirlik değeri (CR) hesaplandı. Yapılan hesaplama sonucunda ölçeğin AVE değerleri (0.31-0.60) arasında değişti. CR değerlerinin (0.64-0.93) arasında olduğu belirlendi. Adölesan Afet Okuryazarlık Ölçeğinin benzeşme geçerliliği değerlerinin yeterli olduğu söylenebilir. Ayrıca faktörler arası korelasyon katsayıları için korelasyon analizi yapıldı. Faktörler arası yüksek düzeyde pozitif yönde ilişki olduğu saptandı ($p<0.001$).

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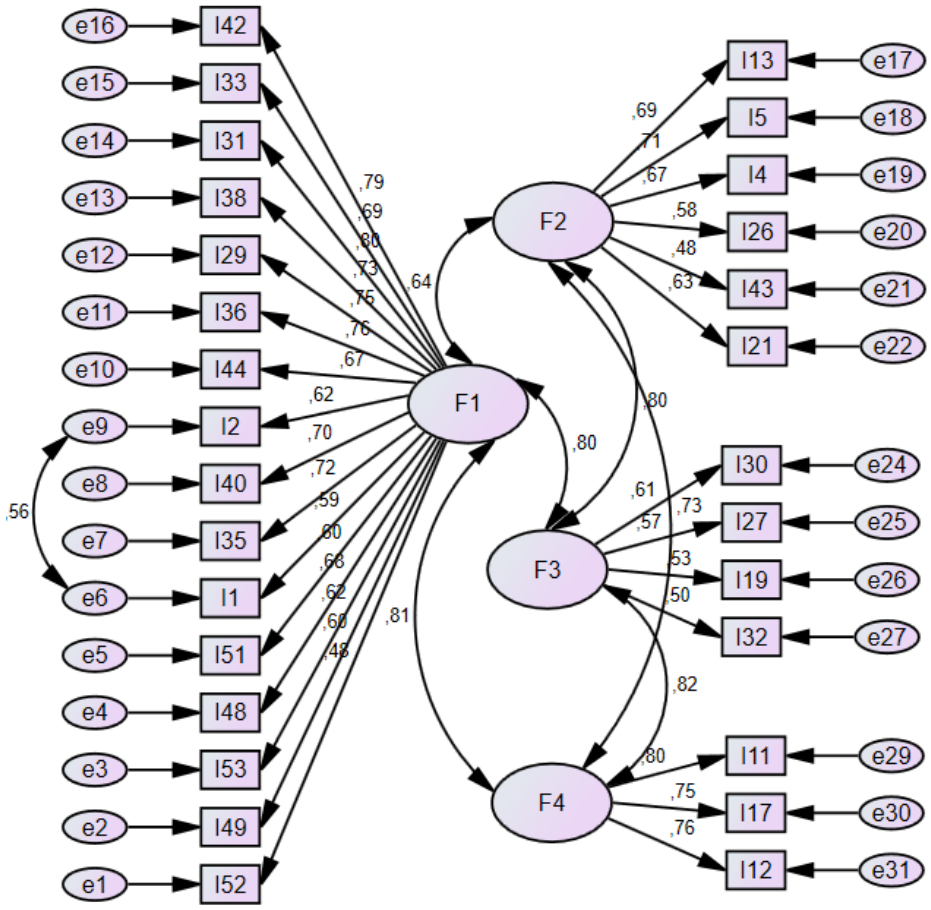

Görsel 1. Adölesan Afet Okuryazarlık Ölçeğine ait Path Diyagramı

3.5.İç tutarlılık

Adölesan Afet Okuryazarlık Ölçeği ’ne ait maddelerdeki iç tutarlılık güvenirliği ve homojenlik kanıtı olarak madde toplam puan korelasyon katsayıları incelendi. Adölesan Afet Okuryazarlık Ölçeğinin tüm maddelerinin güvenirlik katsayısı 0.944 olduğu belirlendi. Alt boyutların Cronbach α değerleri 0.88 ile 0.95 arasında değişti. Madde-toplam test korelasyonunun yeterli olabilmesi için gerekli minimum değerin 0.30 olması gerektiği belirtilmektedir. Düzeltilmiş madde toplam korelasyon katsayısı eğer 0.20’nin altındaysa maddeler ölçme aracından çıkarılmalıdır. Ancak bu katsayı 0.20 ila 0.30 arasında ise maddeler zorunlu ölçme aracına alınabilir, 0.30 ya da daha üstündeyse maddeler iyidir (Şencan, 2005) Adölesan Afet Okuryazarlık Ölçeği incelendiği zaman madde-toplam puan korelasyonunun 0.292-0.675 arasında olduğu görülmektedir. Bu çalışmada da 0.30’un altında bir madde olduğu ancak ölçekte kalması gerektiğine karar verilmiştir. 29 maddelik Adölesan Afet Okuryazarlık Ölçeği’nin aritmetik ortalamasının 109.71±21.69 olduğu belirlendi. Tüm bu bulgular 29

maddeden oluşan Adölesan Afet Okuryazarlık Ölçeğinin içyapı tutarlılığının yüksek olduğunu göstermektedir.

4.SONUÇ

Adelosanlara yönelik afet okuryazarlığı ölçeği, geçerlilik ve güvenilirlik analizleri, kapsam geçerliliği, iç tutarlığı ve yapısal özellikleri açısından kabul edilebilir ve geçerli nitelikte olduğunu göstermiştir. Gelecekte yapılacak Adelosanlara yönelik afet okuryazarlığını ölçme ve değerlendirme çalışmalarında önemli bir ihtiyacı karşılayıp alanda ki bir boşluğu dolduracağı değerlendirilmektedir.

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FOTODEDEKTÖRLERİN TARİHSEL GELİŞİMİ

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ÖZET

Fotodedektörler, elektromanyetik radyasyonu algılamak için kullanılan sensörlerdir. Çeşitli tipleri arasında fototransistörler, fotodiyotlar ve fotomürekkep hücreleri bulunur. Bu dedektörler, genellikle ışığa maruz kaldıklarında elektriksel sinyaller üreterek çalışırlar.

Fototransistörler, ışığa maruz kaldıklarında transistörün iletkenliğini değiştirir ve bu değişiklik elektriksel bir sinyal olarak ölçülerek algılanır. Fotodiyotlar ise ışığa duyarlı yarıiletken malzemelerden yapılmıştır ve ışığa maruz kaldıklarında malzemenin elektriksel direnci değişir, bu da dedektör tarafından algılanan bir sinyale dönüşür. Fotomürekkep hücreleri ise içerdikleri fotoreseptörlere bağlı olarak rengi değişen mürekkep içerir; bu renk değişikliği ölçülerek dedektörün tepkisi belirlenir [1].

Fotodedektörleri, yüksek hassasiyetleri ve hızlı tepki süreleri nedeniyle birçok teknolojik uygulamada önemli bir rol oynar. Ancak, belirli dalga boylarında hassasiyetleri ve çevresel koşullara duyarlılıkları gibi sınırlamalar da dikkate alınmalıdır. Bu dedektörler, günümüzde sensör teknolojisinin temel bir bileşeni olarak kabul edilir ve sürekli olarak geliştirilmektedir.

Bu dedektörlerin çeşitli uygulama alanları bulunmaktadır. Optik iletişimde ışığın modülasyonu ve demodülasyonunda, güvenlik sistemlerinde hareket dedektörleri ve güvenlik kameralarında, tıbbi görüntüleme cihazlarında ve astronomide uzaydaki elektromanyetik radyasyonu ölçmede kullanılırlar. Bu çalışmada 19. Yüzyıl ve 21. Yüzyıl aralığında fotodedektörlerin tarihsel gelişimi hakkında çalışma yapıldı. Kullanıldığı yerler araştırılarak, gelecek nesillerde ne tür yenilikler yapılacağı hakkında araştırmalar yapıldı [2].

Anahtar Kelimeler: Foto dedektörler, Fotodiyotlar, Fotomürekkep, Fototransistörler, Sensör

1. GİRİŞ

Fotodedektörler, ışığı veya elektromanyetik radyasyonu algılayan ve bu bilgiyi elektriksel sinyallere dönüştüren sensörler olarak bilinir; bu özellikleri sayesinde birçok alanda, optik iletişimden güvenlik sistemlerine, tıbbi görüntülemeden astronomiye kadar geniş bir uygulama yelpazesinde kullanılmaktadırlar.

Bu dedektörler, temelde çeşitli fotoelektrik etkileşim prensiplerine dayanarak çalışır ve çeşitli türleri arasında fototransistörler, fotodiyotlar ve fotomürekkep hücreleri bulunur. Fototransistörler, ışığa maruz kaldıklarında transistörün iletkenliğini değiştirir, fotodiyotlar ise ışığa duyarlı yarıiletken malzemeler kullanarak direnç değişikliklerini algılar. Diğer yandan, fotomürekkep hücreleri içerdikleri fotoreseptörlere bağlı olarak rengi değişen mürekkepleri kullanarak ışığı algılar [3].

Bu sensörlerin geniş uygulama alanları arasında optik iletişim sistemleri, güvenlik sistemleri, tıbbi görüntüleme cihazları ve astronomik gözlemler bulunmaktadır. Optik iletişimde, foto dedektörler ışığın modülasyonu ve demodülasyonunda önemli bir rol oynarlar; güvenlik sistemlerinde ise hareket dedektörleri ve güvenlik kameraları gibi temel unsurlardan biridirler.

Yüksek hassasiyetleri, hızlı tepki süreleri ve geniş spektrumda çalışma yetenekleri, foto dedektörlerini modern teknolojideki birçok uygulamada vazgeçilmez kılar. Ancak, belirli dalga boylarında hassasiyet ve çevresel koşullara duyarlılık gibi bazı sınırlamalar göz önünde bulundurulmalıdır. Foto dedektörleri, bilimsel araştırmalardan endüstriyel kullanıma kadar geniş bir yelpazede yaygın olarak kullanılmakta ve sürekli olarak geliştirilmektedir.

2. UYGULAMALAR

2.1. Fotodedektör Teknolojisinin Doğuşu

Fotodedektörlerin keşfi, 19. yüzyılın sonlarına doğru gerçekleşmiş ve elektriğin ışıkla etkileşimi üzerine yapılan çalışmalarla gelişmiştir. Bu cihazlar, ışığı elektrik sinyallerine dönüştürme prensibine dayanır ve genellikle fotoelektrik etki, fotoiletkenlik veya fotovoltaik prensiplerle çalışır. Fotodedektörlerin keşfi, Albert Einstein'ın 1905'te açıkladığı ve ona Nobel Fizik Ödülü'nü kazandıran **fotoelektrik etki** kuramına dayanır. Ancak bu etki, ilk olarak

Heinrich Hertz ve Wilhelm Hallwachs gibi bilim insanlarının 1880'lerde yaptığı deneylerde gözlemlenmiştir.

2.2. Modern Fotodedektörlerin Gelişimi

Modern fotodedektörlerin gelişim süreci, elektronik ve malzeme bilimi alanlarındaki büyük ilerlemelerle şekillenmiştir. Temel amaç, fotonları daha hassas, hızlı ve düşük enerji tüketimiyle elektrik sinyaline dönüştürebilmektir. İşte modern fotodedektörlerin gelişim sürecindeki önemli aşamalar:

2.2.1. Katı Hâl Fotodedektörlerin Gelişimi (1940'lar - 1950'ler)

İlk Katı Hâl Fotodedektörler: 1940'larda, özellikle II. Dünya Savaşı sonrası dönemde, katı hâl fiziği alanında büyük bir ilerleme kaydedildi. Silikon (Si) ve germanyum (Ge) gibi yarı iletkenler keşfedilerek fotodedektörlerde kullanılmaya başlandı. Bu malzemelerin ışığa olan duyarlılığı, fotodedektörlerin daha küçük ve daha dayanıklı hale gelmesine olanak sağladı.

Fotodiyotlar: 1950'lerde, silikon ve germanyum tabanlı ilk fotodiyotlar geliştirildi. Fotodiyotlar, hızlı tepki verebilen ve geniş bir spektral duyarlılığa sahip olmalarıyla özellikle telekomünikasyon alanında popüler hale geldi.

2.2.2. PIN ve APD fotodedektörlerin Ortaya Çıkışı (1960'lar - 1970'ler)

PIN Diyotlar: 1960'larda geliştirilen PIN fotodiyotlar (p-tipi, iç bölge ve n-tipi katmanlardan oluşur), yüksek hızlı iletişim sistemlerinde kullanıldı. Bu diyotlar, iç bölge sayesinde düşük gürültü seviyelerine ulaşarak ışık sinyallerini daha hassas bir şekilde elektrik sinyaline çevirebildi.

Avalanche Fotodiyotlar (APD): 1970'lerde geliştirilen APD'ler, düşük ışık koşullarında çalışabilme kabiliyetiyle öne çıktı. Bu diyotlar, bir "çığ" etkisi yaratarak zayıf foton sinyallerini güçlendirebilir. Dolayısıyla, özellikle düşük ışık seviyeleriyle çalışmak gereken uygulamalarda tercih edilir hale geldi.

2.2.3. Fiber Optik Haberleşme ve Yüksek Hızlı fotodedektörlerin Gelişimi (1980- 1990)

Fiber Optik Teknolojinin Yükselişi: 1980'lerde fiber optik iletişimin gelişimi, daha hızlı ve yüksek duyarlılığa sahip fotodedektör ihtiyacını ortaya çıkardı. Bu dönemde indiyum-galyum-arsenit (InGaAs) gibi yeni yarı iletken malzemeler kullanılarak optik alıcıların dalga boyu duyarlılığı genişletildi.

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Yüksek Hızlı fotodedektörler: Telekomünikasyon alanındaki talepler doğrultusunda, gigahertz (GHz) düzeyinde çalışan hızlı fotodedektörler geliştirildi. Bu tür fotodedektörler, optik sinyallerin yüksek hızlarda dönüştürülmesi gereken fiber optik sistemlerde kullanılmaya başlandı.

2.2.4. CMOS Tabanlı fotodedektörler (2000'ler - Günümüz)

CMOS Görüntü Sensörleri: 2000'li yıllardan itibaren CMOS tabanlı fotodedektörler, düşük maliyetleri, düşük enerji tüketimleri ve kolay üretilebilir olmaları nedeniyle yaygınlaştı. CMOS sensörler, cep telefonu kameralarından güvenlik kameralarına kadar birçok alanda kullanılmaktadır.

CCD'den CMOS'a Geçiş: CCD (Charge-Coupled Device) tabanlı fotodedektörler, 1970'lerden 2000'lere kadar görüntüleme teknolojisinde yaygındı. Ancak CMOS teknolojisinin gelişmesiyle birlikte, CCD teknolojisi yerini büyük ölçüde CMOS'a bıraktı. CMOS sensörler, daha hızlı tarama hızları ve düşük enerji tüketimi sunar.

2.2.5. Gelişmiş Malzemeler ve Yeni Nesil fotodedektörler (2010'lar - Günümüz)

Grafen ve 2D Malzemeler: Grafen ve diğer iki boyutlu (2D) malzemeler, fotodedektörler için yeni fırsatlar sundu. Grafen tabanlı fotodedektörler, geniş spektral duyarlılığa sahip olmaları ve yüksek hızda tepki verebilmeleri ile dikkat çekmektedir. Bu tür malzemeler, esnek ve hafif yapılarıyla giyilebilir teknolojilerde de kullanılabilir.

Kuantsal Nokta (Quantum Dot) fotodedektörler: Kuantum noktalar, belirli dalga boylarındaki ışığa yüksek duyarlılık sağlayan nanoparçacıklardır. Kuantum nokta fotodedektörler, özellikle kızılötesi (IR) algılama uygulamalarında popüler hale gelmiştir.

Gece Görüş ve Kızılötesi Teknolojiler: Günümüzde gece görüş ve kızılötesi görüntüleme sistemlerinde kullanılan fotodedektörler, askeri ve güvenlik alanlarında oldukça gelişmiştir. Bu dedektörlerde genellikle HgCdTe (cıva kadmiyum tellür) gibi malzemeler kullanılır. Çizelge 1. de fotodedektörlerin tarihsel gelişii toplu olarak görülmektedir.

2.2.6. Yapay Zeka Destekli fotodedektör Sistemleri (Gelecek Perspektifi)

Yapay Zeka Entegrasyonu: fotodedektör sistemlerine yapay zeka ve makine öğrenimi algoritmalarının entegre edilmesi, örneğin görüntü işleme ve nesne tanıma gibi ileri düzey analizlerin doğrudan cihaz üzerinde yapılmasına olanak tanır. Bu, özellikle güvenlik, sağlık ve otomotiv sektörlerinde büyük önem taşır.

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Modern fotodedektörlerin gelişim süreci, bilim ve teknolojinin ilerlemesiyle devam etmektedir. Yeni malzemeler ve gelişmiş algoritmalar, fotodedektörlerin daha hassas, hızlı ve enerji verimli hale gelmesini sağlamaktadır.

2.3. Fotoelektrik Etkinin Gelişimi

Fotoelektrik etkinin gelişimi, ışığın doğasının anlaşılmasında ve kuantum mekaniğinin temellerinin atılmasında kritik rol oynamıştır. Bu olay, ışığın metaller gibi yüzeylere çarptığında elektronların salınmasına neden olduğunu gösterir. Fotoelektrik etki üzerindeki çalışmalar, fizik ve mühendislik alanlarında devrim yaratmış ve fotodedektörler gibi teknolojilere yol açmıştır.

2.4. Fotodedektörlerin Çalışma Prensibi

Fotodedektörlerin çalışma prensibi, ışık enerjisini (fotonları) elektriksel sinyale dönüştürmeye dayanır. Bu cihazlar, gelen ışığı algılayarak fotoelektrik etki, fotoiletkenlik veya fotovoltaik etki gibi mekanizmalar yoluyla elektriksel bir yanıt üretirler.

2.5. Fiber Optik İletişimde Fotodedektörler

Fiber optik iletişimde fotodedektörler, optik sinyalleri (ışık sinyalleri) elektrik sinyallerine dönüştürerek iletişim sistemlerinde kritik bir rol oynar. Fiber optik kablolar üzerinden taşınan ışık sinyalleri, veriyi yüksek hızda ve uzun mesafelerde kayıpsız şekilde iletir. Bu iletim sistemlerinde fotodedektörler, optik sinyalin iletim sonunda elektrik sinyaline dönüştürülmesi için gereklidir.

Fiber optik iletişimde kullanılan fotodedektörlerin hızlı, duyarlı, düşük gürültülü ve çeşitli dalga boylarına duyarlı olmaları gerekir. Bu nedenle fiber optik sistemlerde özellikle PIN fotodiyotlar ve çığ etkili diyotlar (APD'ler) gibi yüksek hızlı ve hassas cihazlar tercih edilir.

3. SONUÇLAR VE DEĞERLENDİRME

Fotodedektörlerin tarihsel gelişimi, teknolojinin evrimini ve optik algılamadaki önemli dönüm noktalarını göstermektedir. Başlangıçta bilimsel bir merak olan fotodedektörler, günümüzde günlük hayatın ve modern endüstrinin önemli bir parçası haline gelmiştir [4].

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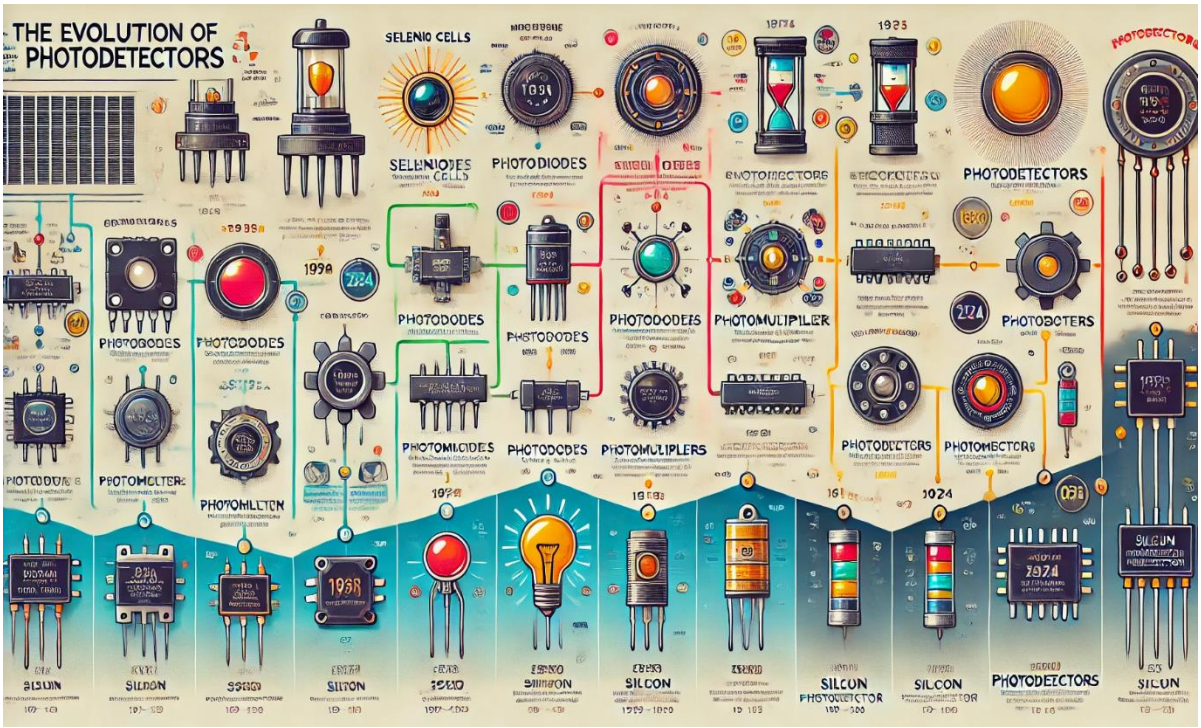
4. GENEL DEĞERLENDİRME VE SONUÇLAR

Fotodedektörler, ışık enerjisini elektrik sinyallerine çevirerek modern teknolojinin vazgeçilmez unsurlarından biri haline gelmiştir. İlk olarak 19. yüzyılda fotoelektrik etkinin keşfiyle temelleri atılan bu teknoloji, Albert Einstein'ın çalışmaları sayesinde teorik bir dayanak kazanmış ve kuantum fiziği açısından önemli bir gelişim noktası oluşturmuştur. Zamanla, fotodiyotlar, fototransistörler ve fotomultiplier tüpleri (PMT) gibi farklı fotodedektör türleri geliştirilmiş, böylece cihazların hassasiyetleri ve hızları artarken maliyetleri de düşmüştür [5].

Telekomünikasyon ve fiber optik iletişimde bilgi iletimine katkıda bulunan fotodedektörler, ayrıca tıbbi görüntüleme, güvenlik sistemleri, endüstriyel otomasyon gibi birçok alanda yaygın kullanım alanına sahiptir. Günümüzde, düşük ışık koşullarında dahi yüksek performans sunabilen gelişmiş fotodedektörler, çeşitli sektörlerde güvenilir veri elde etme aracı olarak kullanılmaktadır [6]. Görsel 1. de kullanım alanları birarada görülmektedir.



Görsel 1. fotodedektörlerin Gelişim Süreci

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Çizelge 1. Fotodedektörlerin Tarihsel Gelişimi

Yıl	Gelişme
1839	William Fox Talbot, fotokimyasal etkileri keşfetti.
1873	Wilhelm Röntgen, ilk fotodedektör olan katot ışını tüpünü geliştirdi.
1888	George Eastman, ilk taşınabilir fotokamera ve film geliştirdi.
1904	John Ambrose Fleming, ilk vakum tüpü olan "Fleming Tüpü"nü icat etti.
1947	William Shockley, transistörün geliştirilmesi ile fotodedektörlerin elektroniğe entegrasyonu.
1960	Lazerin icadı ile fotodedektörlerin hassasiyeti ve uygulama alanları genişledi.
1980'ler	CCD (Charge-Coupled Device) teknolojisinin geliştirilmesi, görüntüleme alanında devrim yarattı.
2000'ler	CMOS (ComplementaryMetal-OxideSemiconductor) teknolojisinin yaygınlaşması, enerji verimli fotodedektörlerin ortaya çıkmasını sağladı.
2020'ler	Kuantum nokta teknolojisi ve grafen tabanlı fotodedektörler gibi yeni nesil fotodedektörler geliştirilmeye başlandı.

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SUSTAINABLE ARCHITECTURE IN THE MEDITERRANEAN BASIN: COMPARATIVE INSIGHTS INTO VERNACULAR PRACTICES IN ALBAICÍN AND KALEİÇİ

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ABSTRACT

Climate change, intensified by anthropogenic activities and resulting with extreme weather events, has necessitated the development of sustainable buildings that harmonize with natural ecosystems. Vernacular architecture is a type of building approach characterized by sustainable qualities, particularly its use of climatic data and adaptation to local conditions through elements such as topography, layout, and material selection. The Mediterranean basin, a region where the impacts of climate change are concretely observed, contains numerous examples of climate-responsive and sustainable designs within its vernacular architectural heritage. This study examines the Albaicín neighborhood in Spain which is protected by UNESCO and also Kaleiçi in Türkiye within the Mediterranean basin which has a rich vernacular architectural heritage and protected by the Committee on Conservation of Cultural Assets in Türkiye. Aim of this study is examining two regions unique climate-sensitive architectural approaches. The Albaicín reigon, located at the northeast part of Granada, features examples of vernacular architecture and urban landscape which stands as a testament to the enduring presence of Andalusí culture. This area represents the medieval Moorish settlement, which retained its essence even after adaptation to the Christian way of life. Its main characteristics have been preserved, representing a Moorish town from the Nasrid dynasty. This rich historical layering led to the inclusion of Albaicín on UNESCO's World Heritage List in 1994 which expanded the current protection boundaries at the time. Kaleiçi, is also an area of significant historical value, with roots extending to antiquity and containing traditional Turkish houses adapted to hot and humid climate. The Kaleiçi area is protected as an urban conservation site and a third-degree archaeological conservation site by the Committee on Conservation of Cultural Assets in Antalya, which is the regional part of the general conservation committee in Türkiye. The buildings in both cities were assessed based on vernacular architectural sustainability criteria established through an extensive literature review. For this evaluation, criteria such as urban planning, building form, spatial organization, opening dimensions, color, building materials and thermal mass, landscape and water elements, microclimate creation, adaptation to topography, orientation, shading, and ventilation methods were selected. The evaluation results were tabulated to highlight the contribution of unique architectural styles of both regions to

sustainability, as well as to identify their similarities and differences. In this context, this study aims to contribute to the literature by examining the role of vernacular architectural heritage in the Mediterranean basin in promoting sustainability. Overall, traditional buildings in both regions were found to share similarities in terms of topography usage, spatial organization, orientation, building stock density, material choices and application methods, the use of courtyards, and units located within the courtyards. However, elements specific to traditional Turkish houses, such as usage of bay windows and shading provided by wide eaves are absent in Albaicín region architecture. The findings are discussed in detail in the results section.

Keywords: Sustainability, Climate change, Vernacular architecture, Mediterranean basin, Sustainable development

1. INTRODUCTION

Economic development models that rely on energy production from fossil fuels have gradually led to significant environmental issues. The construction sector is one of the highest consumers of non-renewable energy sources. According to a report by the United Nations Environment Programme, energy used in buildings constitutes approximately 30-40% of total global energy consumption (UNEP, 2007). Following the energy crises of the 1970s, World Commission on Environment and Development, which had been set up in 1983, published a report in 1987, concerning the concept of “sustainable development’’, offered an alternative economic development model that also handle environmental concerns. Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland Report, 1987). In buildings, energy is primarily used for climate controlling systems, which are designed mainly for the comfort of users such as; heating, cooling, lighting, and ventilation systems. Recent challenges related to environmental pollution and economic constraints have brought energy efficiency to the forefront, emphasizing the importance of renewable energy sources and also the passive solutions to reduce energy consumption (Daly, 2017). Various passive systems and design choices exist to reduce the reliance on these systems, thereby minimizing energy consumption. Vernacular architectural examples often incorporate climate-appropriate design solutions that effectively reduce energy demand.

In this study, which examines building decisions specific to vernacular architecture, selected sustainable building criteria—identified through a comprehensive literature review—are evaluated using examples from the Mediterranean Basin. The vernacular architectural heritage of cities selected from Spain and Türkiye are assessed based on sustainability criteria drawn from studies such as "Comparative Evaluation of Ecological and Energy-Efficient Buildings within the Framework of Sustainable Architecture using a Simple Additive Weighting Method" (Beşiroğlu & Özmen, 2022) and "The Influence of the Mediterranean Climate on Vernacular Architecture: A Comparative Analysis between the Vernacular Responsive Architecture of Southern Portugal and Northern Egypt" (Fernandes et al., 2014).

2. MATERIALS AND METHODS FOR VERNACULAR ARCHITECTURE ANALYSIS

In this study, Spain and Türkiye were selected from countries within the Mediterranean Basin, focusing specifically on the cities of Granada and Antalya, respectively. The name "Granada" may have been derived either from the Spanish word "pomegranate," or from the Maghrebi word "Karnattah" which means "city of travelers" as well as "hill of foreigners" (The Editors of Encyclopaedia Brittanica, 2024). The city's southern area consists of administrative and commercial buildings, while the western section is primarily composed of modern residential structures. Northeast area of Granada is named as Albaicín district, a medieval settlement with historical layers stemming from its periods of occupation by Roman, Visigothic, Iberian, and Arab populations. Due to this rich historical layering, the Albaicín was inscribed on UNESCO's World Heritage List in 1994, and the area was further protected by extending the preservation zone, to be included as the Alhambra and Generalife, which have been under preservation since 1984 (UNESCO World Heritage Centre, n.d.). The district is characterized by cobbled streets and includes examples of vernacular Arab architecture from the Maghreb period. Within the study, the vernacular building stock in Albaicín is assessed based on specified sustainability criteria.

Similarly, Kaleiçi, located in the Muratpaşa district of Antalya, is included in the scope of this study. In antiquity, Kaleiçi was enclosed by horseshoe-shaped walls, both inside and out. Within these walls, which span multiple historical periods, there are approximately three thousand houses with distinctive tile roofs. The unique structures of these houses provide insight not only into Antalya's architectural history but also into the lifestyle of the region. The area also contains numerous historical buildings, including the Tekeli Mahmut Pasha Mosque, Karatay Madrasa, and İskele Mosque. The Kaleiçi houses, which have been adaptive reused with new functions, are evaluated in this study according to the identified sustainability criteria.

The original design decisions inherent to vernacular architecture are analyzed through examples from two different geographical locations. Sustainability criteria adapted from the articles "Comparative Evaluation of Ecological and Energy-Efficient Buildings within the Framework of Sustainable Architecture using a Simple Additive Weighting Method" (Beşiroğlu & Özmen, 2022) and "The Influence of the Mediterranean Climate on Vernacular Architecture: A Comparative Analysis between the Vernacular Responsive Architecture of Southern Portugal and Northern Egypt" (Fernandes et al., 2014) were used to assess these buildings (Table 1).

Table 1. Criteria for Assessing Vernacular Architecture Sustainability in the Mediterranean Basin (Adapted from Fernandes et al., 2014; Beşiroğlu & Özmen, 2022)

Criteria	Options
Urban Planning	Dense Building Stock - Non-Dense
Building Form	Compact Building Form - Excessive Openness
Shading Method	Building Density, Plant Usage, Shutter Usage, Eave Usage
Natural Ventilation Method	Mashrabiya, Orientation, Plan Typology, Ventilation Chimney

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Opening Dimensions in Buildings	Large – Small
Utilization of Water's Microclimatic Qualities	Present – Absent
Plants Used for Landscaping	Present – Absent
Color of Buildings	Light – Dark
Building Materials and Thermal Masses	High Thermal Mass - Low Thermal Mass Material
Topography-Compatible Settlement	Compatible – Incompatible
Visual Relationship with Outdoor Spaces	Present – Absent
Use of Operable Windows	Present – Absent
Preference for Sustainable Resources in Material Selection	Yes – No
Orientation and Plan Typology	North- South / Courtyard Present – Absent

3. EXAMINATION OF ALBAICÍN DISTRICT STRUCTURES IN THE CONTEXT OF SUSTAINABILITY CRITERIA

3.1. Urban Planning

The dense urban fabric of the Albaicín district reduces the exposure of building surfaces to sunlight. Consequently, the buildings do not require active cooling systems typically employed during hot summer months. The narrow, shaded streets protect pedestrians from harsh effects of the sun, resulting in high density of buildings in the area (Figure 1).

Figure 1. Albaicin Region's fabric. Source: (andaluciamia.com, n.d.)

3.2. Building Form

The building forms are compact. Openings in the structures are oriented to the south according to their topographical placements and remain consistently sized and repetitive. Additionally, the south-facing orientation of the buildings is significant for heating and energy efficiency during winter.

3.3. Shading Method

The use of shutters on windows provides a solution to the harsh effects of sunlight. The high courtyard walls of the Carmen-type houses create shade in the narrow streets. In the narrow and organic street layout, the facades of the buildings play an important role in creating shade. Wooden shutters, positioned to protect against changing sunlight throughout the day, are utilized in these structures. (Figure 2).

Figure 2. Wooden shutters are common within the region, positioned to protect interior spaces against the changing sunlight. Source: (andaluciamia.com, n.d.)

3.4. Natural Ventilation Method

Similarly, the Mashrabiya, also known as Meşrebiye, is an architectural element unique to vernacular architecture, originating from Islamic geometric art (Figure 3). It is used in the region, notably in the Moorish period, Nasrid dynasty. The Mashrabiya is a type of window element designed to allow viewing the outside without being seen, while simultaneously facilitating natural air circulation. Its three-dimensional geometry and lace-like woodwork have made the art of Mashrabiya, known for its intricate window and balcony latticework, a symbolic representation of Arab art (Esmer, n.d.)

Figure 3. Mashrabiya, intricate window and balcony latticework. Dar al-Horra Palace. Source: (legadoandalusi.es, n.d.)

3.5. Opening Dimensions in Buildings

The buildings in the Albaicin region are organically positioned along the slope of the topography. In this regard, the structures do not obstruct each other in terms of views and natural light. Openings are oriented towards the south and maintained within specific proportions.

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Generally, the openings are small to prevent overheating in summer and heat loss in winter periods. (Figure 4).

Figure 4. Opening dimensions. Source: (andaluciamia.com, n.d.)

3.6. Utilization of Water's Microclimatic Qualities

The courtyards, aligned along the north-south axis, ensures an optimal air-light ratio for the surrounding living spaces. It generally features a water-filled tub that creates a comforting microclimate, utilizing evaporative cooling and the courtyard effect (Figure 5), (Caponetto & Giuffrida, 2018).

Figure 5. Pools in courtyards. Dar al-Horra Palace. Source: (alhambra-patronato.es, n.d.)

3.7. Plants Used for Landscaping

The region is characterized by its plants and trees native to Andalusia. Notable sites such as the Alhambra Palace, Generalife, and their gardens exhibit similar plant selections and landscaping arrangements. The use of plants helps the air get cooler through evaporation/transpiration before it reaches the buildings, as well as contributing to shading. This is a significant element in regions with Mediterranean climate.

3.8. Color of Buildings

The buildings are mostly plastered with lime and have cream/terracotta shades of exposed bricks, rammed earth materials which are dominating the facades.

3.9. Building Materials and Thermal Mass

Soil, which stands out for its availability and harmony with nature, has been used in the construction of many buildings in the past (Olğun et al., 2019). A sustainable material must not contain toxic elements that threaten human health, must be recyclable or reusable, and must return to nature without leaving harmful effects on the ecosystem after its use. An important characteristic of sustainable materials is that they can be sourced locally, from the region (Tufan & Özel, 2018). The city of Granada has an architectural heritage of rammed earth and brick materials. Among these are the Alhambra Palace complex and, according to recent research conducted by the CRAterre Centre (International Centre for Earth Construction), there are such structures characteristic to Moorish vernacular architecture and traditional Arab construction techniques in the historic Albaicin area (Caponetto & Giuffrida, 2018). The building materials used in the region are primarily river stones, compressed earth, fire bricks, wooden posts, and lime mortar. The use of these natural building materials, which have high thermal mass, ensures that the buildings remain cool during the day and warm at night through the heat stored in the building envelope.

3.10. Topography-Compatible Settlement

The Albaicin region is situated on hilly terrain north of the Darro River. The area has a sloping topography, featuring organically arranged streets and residences. This reflects a design philosophy that is compatible with the topography.

3.11. Visual Relationship with Outdoor Spaces

Archetype of the Albaicin houses were compact which had less openings and visual relationship with outdoor spaces, especially on the ground floor level. Demografic increase resulted this primary plan type to change. Especially openings are increased and privacy which was an important element in Moorish plan type was spoiled.

3.12. Use of Operable Windows

Operable windows are utilized in the region. They are an important element for ensuring natural ventilation and maintaining indoor air quality.

3.13. Preference for Sustainable Resources in Material Selection

Natural building materials such as stone, brick, rammed earth and wood have been used. The use of these materials, which are compatible with the local climate, has been found beneficial due to their excellent thermal retention capabilities, keeping interiors cool during the day and warm at night.

3.14. Orientation and Plan Typology

North-south orientation of a settlement, a trend that continued throughout the Middle Ages in both the Byzantine cities of the Eastern Mediterranean and the Islamic cities of the West can be also seen in Albaicin region. The buildings are positioned along the slope in a north-south orientation (Pica, 2018). The city's compact form, characterized by dead-end streets, along with the widely used courtyard typology, are the works of bioclimatic masters from Al-Andalus and ancient times. The salons, which serve as the principal spaces for living and representation, are located in the larger rooms on the shorter sides of the courtyard (Caponetto & Giuffrida, 2018).

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4. EXAMINATION OF KALEİÇİ DISTRICT STRUCTURES IN THE CONTEXT OF SUSTAINABILITY CRITERIA

4.1. Urban Planning

The houses in Antalya's Kaleiçi are constructed in a contiguous arrangement, ensuring that their sun-facing surfaces connect while being shaded from the sun's effects. The buildings cast shadows on each other, result of varying building heights. Consequently, the area has a high building density (Figure 7).

Figure 7. High building density. Source: (pixabay.com, n.d.)

4.2. Building Form

The houses in Kaleiçi cannot be described as having a compact building form. The need for cooling is addressed through external porches and courtyards oriented toward prevailing winds.

4.3. Shading Method

The Kaleiçi houses provide shade on the streets with their contiguous and eaved configurations and narrow streets (Figure 8). Additionally, the use of wooden shutters for shading purposes is observed in the buildings (Figure 9).

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Figure 8. Contiguous and eaved configurations in the buildings. Source: (pixabay.com, n.d.)

Figure 9. Left, wooden shutters for shading and privacy. Source: (pixabay.com, n.d.)

4.4. Natural Ventilation Method

Although mashrabiya elements are not present in the buildings, ventilation has been considered in terms of orientation and plan typology.

4.5. Opening Dimensions in Buildings

In accordance with the climate, the Kaleiçi structures predominantly feature long, rectangular openings. The dimensions vary from facade to facade. Some facades have relatively small openings, while others incorporate larger windows to maximize sunlight. Also in Traditional Turkish Houses, usage of external sofa is common and this area, Kaleiçi, consists such examples which helps ventilation as well as daylight utilization.

4.6. Utilization of Water's Microclimatic Qualities

The Kaleiçi houses utilize pool and well water to cool the courtyard. The evaporation of well water due to heat cools the courtyard, and this cool air subsequently flows into the interior spaces, helping to maintain a comfortable temperature indoors.

4.7. Plants Used for Landscaping

The courtyards of the Antalya Kaleiçi houses are surrounded by high walls and feature trees that are well-suited to the local environment and climate.

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4.8. Color of Buildings

The structures reflect the characteristics of traditional Turkish house architecture, with their facades and colors showcasing the essence of Turkish homes. Natural building materials used in the region result in lighter colors.

4.9. Building Materials and Thermal Mass

The presence of high thermal mass, characteristic of natural building materials, is also found in the buildings of this region.

4.10. Topography-Compatible Settlement

Kaleiçi has a sloping topography, featuring organically arranged streets and residences. This reflects a design philosophy that is compatible with the topography similar to Albaicin district.

4.11. Visual Relationship with Outdoor Spaces

Kaleiçi houses possess the qualities of traditional Turkish houses. The functional planning of these traditional homes is reflected in their connection to the outdoors, as seen in the facade arrangements. Consols and cumbas (bay windows) and openings in them are particularly important for street-facing facades.

4.12. Use of Operable Windows

The houses feature operable windows and include a primary skylight that allows sunlight to enter in a controlled manner, facilitating natural ventilation.

4.13. Preference for Sustainable Resources in Material Selection

The materials used in the Kaleiçi houses include stone and wood. These materials can be easily sourced locally and do not contain additives that could harm the environment. Depending on the climate characteristics, the materials should sustain interior temperature comfort. In cold climates, materials must provide thermal insulation, while in hot climates, they should help keep the interior cool. The ground floors in Kaleiçi are constructed with stone walls, preventing outside heat from entering the interior. The building materials in Kaleiçi align with climatic data, further emphasizing their sustainability.

4.14. Orientation and Plan Typology

The houses in Kaleiçi exhibit the plan characteristics of traditional Turkish houses. In response to Antalya's hot and humid climate, a ‘house with external sofa’ plan type has been implemented. Which allows interior and exterior spaces to form a unity by creating an easy access. Also the plan orientations are similar to Albaicin district and many other Mediterranean settlements which is typically north-south axis. Courtyard usage and function is similar to Albaicin region. Ground floor has less opening and compact compared to the upper floors which was also seen in the Albaicin region.

5. RESULT

The existing houses in the studied areas have been evaluated based on sustainability criterias. In both regions, there is a dense building stock and an organic settlement pattern that utilizes the slope. The buildings are positioned along north-south axis, making use of the prevailing winds for ventilation. The use of courtyards, along with plants and water features within these

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courtyards, is observed in both areas. The ground floors in both regions are mostly constructed using a masonry system. The materials used are local and natural.

The openings in the buildings located in the Albaicin area are relatively smaller compared to those in Kaleiçi; this is believed to be influenced by the microclimatic characteristics of the geographical contexts. The facades in the Albaicin region, feature mashrabiya, whereas Kaleiçi houses are the examples of traditional Turkish architecture. The consols and cumbas (bay windows) present in the facades are not seen in the Albaicin region. Additionally, the eaves characteristic to traditional Turkish houses are present in Kaleiçi which provide shading to the streets. However, the buildings in the Albaicin area do not exhibit the wide eaves found in the traditional Turkish house examples of Kaleiçi. The use of slope and topography is similar in both areas. The orientation of openings to the courtyard aims to provide ventilation and cooling. The visual relationship established with the outdoor environment and the provision of shading through shutters on the facades are observed in both regions. There is a tendency towards using natural building materials, and the procurement of local materials is sustainable (Table 2, Table 3).

Table 2. Albaicin region sustainability assessment

Urban Planning	Dense Building Stock		Non-Dense	
Building Form	Compact Building Form		Excessive Openness	
Shading Method	Building Density	Plant Usage	Shutter Usage	Eave Usage
Natural Ventilation Method	Orientation	Plan Typology	Mashrabiya	Ventilation Chimney
Opening Dimensions in Buildings	Large		Small	
Utilization of Water's Microclimatic Qualities	Present		Absent	
Plants Used for Landscaping	Present		Absent	
Color of Buildings	Light		Dark	
Building Materials and Thermal Masses	High Thermal Mass		Low Thermal Mass	
Topography-Compatible Settlement	Compatible		Incompatible	
Visual Relationship with Outdoor Spaces	Present		Absent	
Use of Operable Windows	Present		Absent	
Preference for Sustainable Resources in Material Selection	Yes		No	
Orientation - Plan Typology	North- South Axis		Courtyard Present.	

Table 3. Kaleiçi region sustainability assessment

Urban Planning	Dense Building Stock		Non-Dense	
Building Form	Compact Building Form		Excessive Openness	
Shading Method	Building Density	Plant Usage	Shutter Usage	Eave Usage
Natural Ventilation Method	Orientation	Plan Typology	Mashrabiya	Ventilation Chimney
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Color of Buildings	Light		Dark	
Building Materials and Thermal Masses	High Thermal Mass		Low Thermal Mass	

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Topography-Compatible Settlement	Compatible	Incompatible
Visual Relationship with Outdoor Spaces	Present	Absent
Use of Operable Windows	Present	Absent
Preference for Sustainable Resources in Material Selection	Yes	No
Orientation - Plan Typology	North- South Axis	Courtyard Present

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