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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Comparison of Secondary Metabolites and Essential Oil Content of Some *Origanum* Species

Bazı Origanum Türlerinin Sekonder Metabolitleri ve Uçucu Yağ İçeriklerinin Karşılaştırılması

Muhsin AĞAMİRZAOĞLU[*1], Negar VALIZADEH[2], Amir RAHIMI[3]

Abstract

Origanum genus is one of the most widely used herbs in folk medicine for its biological properties. This study was performed to determine the morphological and phytochemical properties of five species of *Origanum* including *O. majorana*, *O. onites*, *O. syriacum*, *O. vulgare* subsp. *vulgare* and *O. vulgare* subsp. *hirtum* as important ethnomedicinal plants. The study was performed at a Research Farm based at Urmia University, Iran. The plants were collected from various places for determining some quantitative properties, antioxidant compounds, and essential contents. The results showed that the highest plant height (86.4 cm) was observed in *O. vulgare* subsp. *hirtum*. The highest fresh weight and dry weight were observed in *O. onites* (826 and 250 g) and *O. vulgare* subsp. *hirtum* (727.64 and 230 g) species in comparison to others, respectively. However, the highest essential oil, essential oil yield per plant, and essential oil yield per ha were 5.26%, 1.71 g and 114 kg ha^{-1}, respectively, which was observed in *O. vulgare* subsp. *hirtum* species. The quantitative analysis revealed higher content of total phenol (51.12%), flavonoid (6.93%), 2, 2-diphenyl-1-picrylhydrazyl (DPPH), (54.29%), superoxide (50.04%) and radical scavenging activities in *O. vulgare* subsp. *hirtum* species, but the *O. onites* species showed higher (21.60%) nitric oxide radical scavenging activities compared to other species. The essential oil analysis revealed that the thymol (6.90-59.89%), carvacrol (0.83-48.91%), γ-terpinene (6.55-18.20%), p-cymene (0.50-20.94%) and α-terpinene (2.71-4.28%) were the most prominent compounds in the studied species of the genus *Origanum*. Cluster analysis showed two main categories and high similarity between *O. onites* and *O. vulgare* subsp. *hirtum.* The findings of the current research indicate that *O. vulgare* subsp. *hirtum* was the best species in terms of phytochemical properties.

Keywords: Marjoram, Phytochemicals, Secondary metabolites, Thymol

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Öz

Origanum cinsi, biyolojik özelliklerinden dolayı geleneksel tıpta en çok kullanılan şifalı bitkilerden biridir. Bu çalışma, beş *Origanum* türünün, *O. majorana*, *O. onites*, *O. Syriacum*, *O. vulgare* subsp. *vulgare* ve *O. vulgare* subsp *hirtum* morfolojik ve fitokimyasal özelliklerini belirlemeyi amaçlamaktadır. Çalışma, İran Urmiye Üniversitesi araştırma alanında yürütülmüştür. Bitkiler bazı kantitatif özellikleri, antioksidan bileşikleri ve uçucu yağ içeriklerini belirlemek için çeşitli yerlerden toplanmıştır. Sonuçlara göre en yüksek bitki boyu (86.4 cm) *O. vulgare* subsp. *hirtum* gözlenmiştir. En yüksek taze bitki ağırlığı ve kuru ağırlığı diğer türler ile karşılaştırıldığında *O. onites* (826 ve 250 g) ve *O. vulgare* subsp. *hirtum* (727.64 ve 230 g) türlerinde görülmüştür. Fakat en yüksek uçucu yağ, bitki başına uçucu yağ verimi ve hektar başına uçucu yağ verimi sırasıyla %5.26, 1.71 g ve 114 kg/ha ile *O. vulgare* subsp *hirtum* türünde gözlenmiştir. Kantitatif analiz sonuçlarına göre; en yüksek toplam fenol içeriği (%51.12), flavonoid (%6.93), 2, 2-difenil-1-pikrilhidrazil (DPPH), (%54.29), süperoksit (%50.04) içeriği ve radikal yakalama aktiviteleri *O. vulgare* subsp. *hirtum*'da ortaya konmuştur, ancak diğer türlerle karşılaştırıldığında, *O. onites* daha yüksek (%21.60) nitrik oksit radikali yakalama aktiviteleri göstermiştir. Uçucu yağ analizleri, Origanum cinsinin incelenen türlerinde, timol (%6.90-59.89), karvakrol (%0.83-48.91), γ-terpinen (%6.18-55.20), p-simen (%94 0.50-0.20) ve a-terpinenin (%2.71-) temel bileşenler olduğunu göstermiştir. Küme analizi, *O. onites* ve *O. vulgare* subsp *hirtum* arasında iki ana kategori ve yüksek benzerlik göstermektedir. Bu araştırmanın bulgularına göre fitokimyasal özellikler açısından *O. vulgare* subsp *hirtum*'un en iyi tür olduğu belirlenmiştir.

Anahtar Kelimeler: Mercanköşk; Fitokimyasallar; Sekonder Metabolitler; Timol

1. Introduction

Medicinal plants are sources of various secondary metabolites with high pharmaceutical activities (Pandey et al., 2019; Mirzapour et al., 2022; Rahimi et al., 2022; Faridvand et al., 2021; Salvo et al., 2018). Secondary metabolites have high added value depending on their production and supply. The value of raw medicinal herbs and their products is significantly growing in the world markets (Pezzani et al., 2017; Tripathy et al., 2017; Rahimi et al., 2022), with ever increase in their demand and selling (Bhardwaj et al., 2019; Ramakrishna et al., 2019) which emphasis on replacing chemically produced medicines with natural medicines (Duletić-Lašević et al., 2018; Morshedloo et al., 2018; Aktepe et al., 2019). Many flowering and aromatic plant species in the *Lamiaceae* family, that are distributed worldwide, are mainly cultivated for their fragrant leaves and attractive flowers (Amiri et al., 2018; Méabed et al., 2018; Moghrovyan et al., 2019; Pandey et al., 2019; Raudone et al., 2018). The species in the genus are highly valued due to the presence of aromatic compounds present in the external glandular structures that produce volatile oils (Ramakrishna et al., 2019; Spyridopoulou et al 2019). These species are widely utilized as pharmaceutical and flavoring herbs around the world and include biologically active elements such as phenolic glucosides, flavonoids, resins, tannins, terpenoids, and sterols (Pezzani et al., 2017; Tripathy et al., 2017). According to Salvo et al. (2018) and Ramakrishna et al. (2019), carvacrol in *Origanum* essential oil presumably interacts with the release and/or production of inflammatory mediator molecules including prostanoid, hence improving the process of healing stomach ulcers.

Some researchers have demonstrated that oregano essential oil has antioxidant, antibacterial, antifungal, and antimicrobial effects, as well as the ability to treat gastrointestinal ailments (Elshamy et al., 2018; Mirzapour et al., 2022; Marrelli et al., 2018). This explains why such crops are highly sourced by the nourishment, cosmetic, pharmaceutical, and medical industries (Spyridopoulou et al., 2019). These species are also used for seasonings, flavor-enhancing, and increasing the shelf life of foods (Bhardwaj et al., 2019; Koleva et al., 2018) making them very popular in the ethnomedicinal culture of the Middle East including Türkiye (Oke-Altuntas et al., 2018). These plant species are adapted to diverse climates and are frequently utilized in the cosmetics and pharmaceutical industries due to their very diverse aromatic constituents. Medicinal properties of such species are often ascribed to the presence of high contents of volatile compounds. *O. vulgare*, *O. majoran*a, *O. onites*, *O. syriacum* are the most plentiful among the genus *Origanum* (Salvo et al., 2018; Kaplan et al., 2019).

It is possible the pharmaceutical properties and antioxidant effects of different *Origanum* plant species differ from one another (Hassan et al., 2020). Therefore, it is important to explore the detailed phytochemical properties of these plant species for wider utilization. This will encourage their widescale extensive cultivation. Therefore, this study’s key objective was to evaluate the secondary metabolites and morphological properties of five *Origanum* species cultivated in Urmia and to encourage their wide range of commercial products based on scientific standards.

2. Materials and Methods

2.1. Study Area

The study was executed in a Research farm based in the Plant Production and Genetics Department, Urmia University, Iran, during the crop years of 2016–2017. It was carried out in randomized blocks, and replicated thrice. The climate data of the research location (Urmia University, Iran), as well as soil analysis results from the site, were recorded. The plant nursery of five *Origanum* species (*O. onites*, *O.majorana*, *O.syriacum*, *O. vulgare* subsp. *vulgare* and *O. vulgare* subsp. *hirtum* (*Figure 1*) was conducted in a greenhouse. The seeds were planted in wrapped 1-liter plastic pots with equally distributed peat moss, sand, and soil. The pots were regularly watered based on greenhouse situations and the phase of plant growth. Once the seed germinated to form nursery seedlings, they were transplanted to the experimental fields in autumn. The experimental ground was plowed at a proper moisture condition of 70-75% using sentek soil moisture probes (capacity of the field) and smoothed. Phosphorus and potassium fertilizers were added before seeding, following the recommendations of the soil analysis report, and furrowed in 50 cm rows. According to the recommendations in the soil analysis report, nitrogen fertilizer was used during the planting and vegetative phases. Watering was carried out at 60% moisture content in the upper (0-30 cm) soil layer. Harvesting of leaves was done at 50% flowering in the second year two times. The harvested plant leaves were dehydrated at room temperature until they attained a constant 8-10% moisture level by weight.

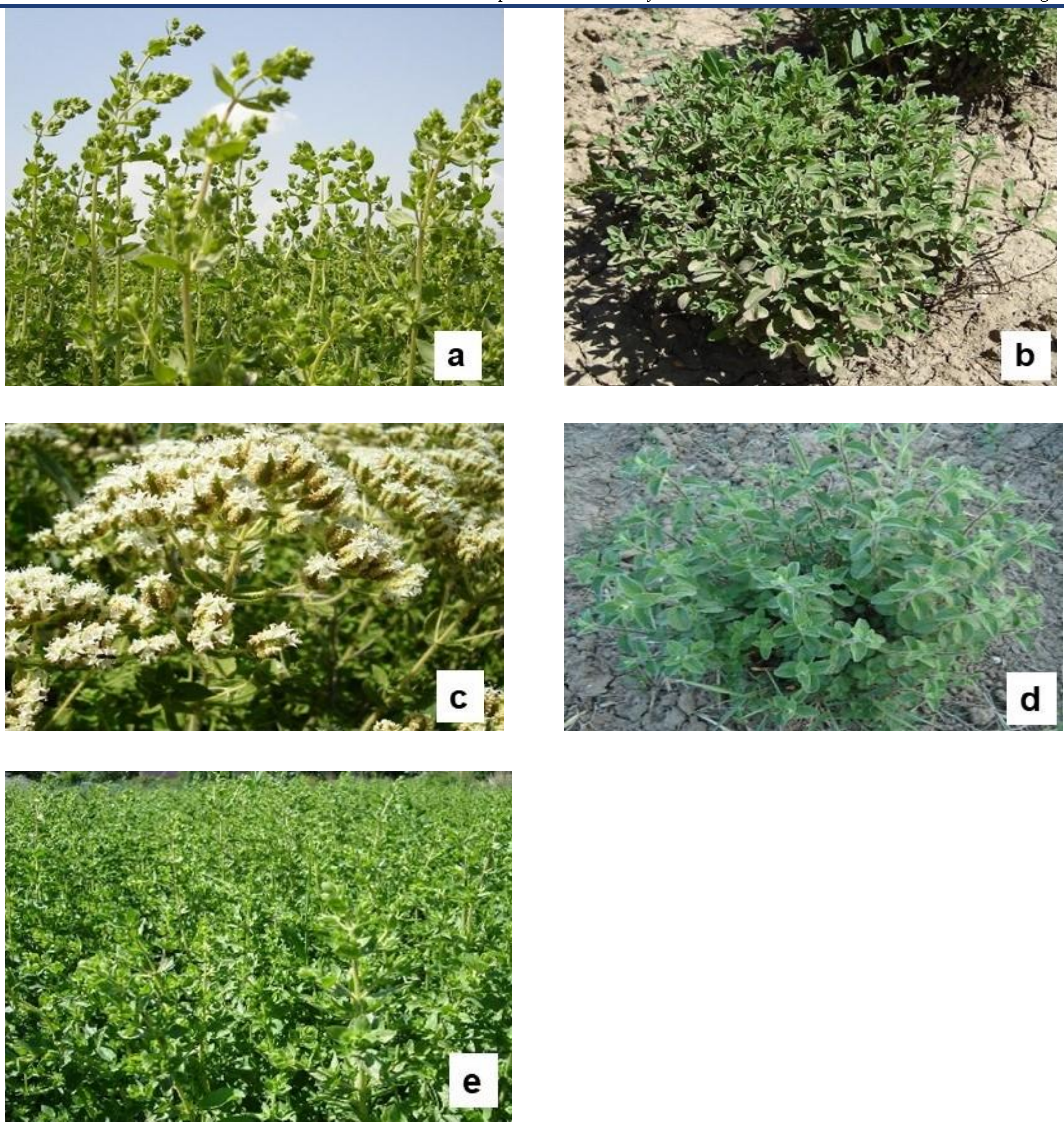

Figure 1. Five species of Origanum. O. vulgare* subsp. *hirtum, a) O. majorana, b) O. onites, c) O. syriacum, d) O. vulgare* subsp. *Vulgare, e) at different stages of growth under field condition

2.1. Soil Physiochemical Characteristics

The climatic parameters of the research region and the physicochemical parameters of the five soils investigated (*Table 1*). The soil pH, was classified as neutral (with a range of 6.5 - 7.5). Due to low EC (less than 2 dS m^{-1}), this soil could not be classified as alkaline. The soil had relatively a loamy texture with high organic carbon (1.15%). These conditions are appropriate for the growing of *Origanum* species. Based on soil nutrient analyses, there was no need of fertilizer application to the soil (K and P concentrations were more than 60 and 15 mg kg^{-1}, respectively). Both organic and inorganic fertilizers are utilized in excess, particularly in Iran, which exceeds the recommended doses (Heydarzadeh et al., 2021a, b). This results in an accumulation of inorganic and organic elements in the soil that eventually degrade with time (Heydarzadeh et al., 2022; Mwadalu et al., 2022; Mirzapour et al., 2022; Amiri et al., 2018).

2.2. Soil Analysis

Five soil samples of studied experimental areas were congregated at random from 0-30 cm deep soil in the experimental fields during autumn using a stainless-steel auger (*Table 2*). The samples were scrupulously mixed and air-dried at a temperature of 25 ^{o}C. This sample was ground and filtered to pass via a two-mm sieve for lab analysis following the methods described by Raudone et al. (2018). Soil electrical conductivity and (EC) pH were evaluated using 1 soil: 5 water (w/v) ratio with a pH meter (specifically the model of the meter was inolab® pH 7110) and a glass electrode (model 712 conductometer) respectively. Organic matter was measured according to organic matter oxidation using H_2SO_4 and $K_2Cr_2O_7$ then titrating with $FeSO_4$. The soil-available phosphorus (P) is the main indicator for determining soil-plant availability (Mirriam et al., 2022). Briefly, in a 50 ml extraction bottle, 20 ml of $NaHCO_3$ (containing 0.5 mol l^{-1} at a pH of 8.51) and a gram of air-dried soil sample were combined, and the bottles were mechanically shaken for 30 minutes. This was followed by filtration, then P was evaluated by spectrophotometer using the colorimetric technique with ascorbic acid at 820 nm. Available K was assessed using 1 M $C_2H_7NO_2$. The hydrometer method was used to measure particle size distribution (Amiri et al., 2018).

Table 1. Outdoor climatic data of the experiment area*

Month	Year	Average relative humidity	Average monthly temperature	Monthly precipitation
January	2016	63.2	-1.1	59.0
	2017	45.7	-4.4	4.4
February	2016	63.1	4	11.0
	2017	65.4	-4.2	39
March	2016	60.1	7.2	31.3
	2017	54.8	6.3	20.4
April	2016	54.7	12.3	57.9
	2017	56	11.6	59.9
May	2016	57.3	16.6	42.8
	2017	52	17.6	11.9
June	2016	51.4	20.6	28.7
	2017	47.3	22.7	0
July	2016	42.1	24.4	5.5
	2017	40.7	26.3	0.1
August	2016	50.1	24.6	0
	2017	52.4	25.2	0.6
September	2016	62	18.5	0
	2017	63	21.1	0
October	2016	73.1	11.5	16
	2017	69.4	12.6	1.8
November	2016	70.6	4	12.2
	2017	73	6.3	38.4
December	2016	50.7	-2.6	65.6
	2017	48.3	1.7	6.8

*Urmia Meteorology Organization, Urmia, Iran

Table 2. Mean physiochemical characteristics of the studied experimental areas

pH	EC (dS m^{-1})	OC (%)	Olsen-P (mg kg^{-1})	Available -K (mg kg^{-1})	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)
7.33	0.07	1.15	37.61	165	9.1	45	32	23

2.3. Plant Analysis

For extract preparation, the leaves of *Origanum* species were harvested from the experimental field ensued by chopping and drying at (23 °C) and thereafter after powdering. The extraction solvent was methanol. The extraction process involved adding 2 grams of the soil sample into 25 mL of the solvent which was then mixed at low rpm for 180 minutes. Thereafter, the extract was sieved via a Whatman filter paper sourced from Whatman Ltd., England. A magnetic stirring was used during different steps of the extraction. Sample solutions were concealed with aluminum foil to avoid exposing the sample which was then kept at 4 °C in dark.

2.4. Total Phenolic Content (TPC)

The cumulative phenolic content in leaves was assessed by employing the Folin-Ciocalteau method as documented by Singleton et al. (1999). In this case, 1600 L of distilled water and 10 L of methanolic extracts were combined and treated at 25°C for 5 min with 200 L of Folin-Ciocalteau reagent. For 30 minutes, the mixture was then kept in the dark while being maintained at 25°C after 200 L of sodium carbonate (which was at 7.5%) was added. This was followed by measurement of the TPC quantitates which was determined by reading the sample's absorbance at 760 nm in a DB-20/DB-20S UV/Visible spectrophotometer. TPC was calculated as mg gallic acid g^{-1} dry weight using gallic acid as an external standard.

2.5. Total Flavonoid Content (TFC)

The $AlCl_3$ colorimetric method was used to evaluate the TFC extracts. In brief, 150 L of $NaNO_3$ (5% W/V) was combined with 30 L of the leaves extract and incubated for 5 minutes. After this, 3 mL of aluminum chloride hexahydrate (this was a 10% W/V solution) was added and it was incubated for another 5 minutes. Thereafter, the mixture was dissolved to the desired concentration by addition of the enough mL of 1.0 M NaOH in deionized water. The solution's absorbance was then evaluated using a spectrophotometer calibrated at 510 nm. This was done during a 30-minute incubation at 25°C in the darkness. The external standard for TFC quantification was Quercetin (QE), and TFC was reported as mg QE g^{-1} dry weight (Gayoso et al., 2016).

2.6. Radical Scavenging Activity (RSA)

By employing the colorimetric method reported by Brand-Williams et al. (1995), the RSA of samples was measured. The combination of 2.0 mL of DPPH solution and 15 μL of methanolic extract was equilibrated for 30 min at 20°C in the darkness. The solution's absorbance was evaluated at 517 nm. The DPPH inhibition was computed using the following formula (Elshamy et al., 2018).

$$\text{Inhibition (\%)} = [(\text{Ab control} - \text{Ab sample}) / \text{Ab control}] \times 100 \quad \text{(Eq. 1)}$$

Where $Ab_{control}$ and Ab_{sample} are the respective absorbance of the control and the sample.

2.7. Superoxide Radical Scavenging Activity (SRSA)

For measurement SRSA (Jing et al., 1995), in 9 ml of 5 mM Tris-HCl (buffered at a pH of 8.2), 1 ml of extract was added. Thereafter, 40 μL of 4.5 mM pyrogallol was added. After shaking for 3 min, the solution's absorption spectrum at 420 nm was evaluated using a spectrophotometer. SRSA was then expressed by the oxidation degree of the test group in relation to that of control. Equation 2 was used to determine the percentage of scavenging activity (Amiri et al., 2018; Méabed et al., 2018).

$$\text{SRSA (\%)} = [(\text{Ab0} - \text{Ab1}/\text{Ab}_0)] \times 100 \quad \text{(Eq. 2)}$$

Where Ab_o is the absorbance of the Tris-HCl buffered with pyrogallol whereas Ab_1 denote the absorbance of the extract.

2.8. Nitric Oxide Radical Scavenging Activity (NORSA)

Griess Illovsoy reaction can be used to evaluate nitric oxide radical inhibition (Garrett, 1964). The Griess Illosvoy reagent was altered by substituting naphthyl ethylene diamine dihydrochloride (this was a 0.1% w/v solution) with 1-napthylamine (5%). About 3 mL of a solution containing phosphate buffer saline (0.5 mL), sodium nitroprusside (10 mM, 2 mL), and Artemisia vulgaris extract (25 to 125 mg/mL), was incubated for 150 min at 25°C. After incubation, 1 mL of sulfanilic acid reagent (containing 20% glacial acetic acid) was mixed with 0.5 mL of the solution and left for 5 minutes to complete diazotization to take place. Before being left for 30 min at 25°C, 1 mL of naphthyl ethylene diamine dihydrochloride was added and mixed thoroughly. In diffused light, a pinkish chromophore was observed. Using a spectrophotometer, the absorbance (at 540 nm) of this solution was recorded in comparison to the corresponding blank solutions. Equation 3 was then used to evaluate the radical inhibition of nitric oxide (Tripathy et al., 2017).

$$\text{NORSA (\%)} = [(\text{Ab control} - \text{Ab sample}) / \text{Ab control}] \times 100 \quad \text{(Eq. 3)}$$

Where Ab_{sample} is the absorbance that was recorded in the presence of the samples of the extracts or standards while $Ab_{control}$ was the absorbance from the control.

2.9. Growth Parameters

The growth parameters that were assessed were plant height, herbage dry weight, and plant fresh weight at the full flowering stage. Theses plant samples were oven-dried at 39°C to constant weight which was achieved after 48 hours.

2.10. Essential Oil (EO) and Essential Oil Yield (EOY)

Extraction of EO was done according to the method of distillation with water and using a Cloninger device. In order to collect the essential oil, after opening the valve and draining the water, the essential oil was collected in a small bottle that was weighed with a digital scale of 0.0001. Then these bottles were weighed and the weight of essential oil per 100 grams of dry leaves was calculated (Adams et al., 2007). EOY was calculated using Equation 4.

$$\mathrm{EOY} = \mathrm{EO} \times \text{herbage dry weight} \qquad \text{(Eq. 4)}$$

2.11. Gas Chromatographic-mass Spectrometric Analysis of Essential Oil

Using a Clevenger-type device, dried aerial portions of the plants were hydro-distilled for 3 hours in 500 mL water. Gas Chromatography (GC) analysis was performed to distinguish different compounds in essential oil. The Hewlett Packard 6890 N GC with FID detector and an HP 5MS 30 m by 0.25 mm by 0.25 µm film thickness capillary column was used for all GC examination. The temperature of the column was controlled to increase from 50°C to 150°C at a frequency of 3°C min^{-1}. Temperatures rise were set at 220 °C and 290 °C for calibration of the injector and detector, respectively. Helium was equally used as a carrier gas at a constant flow rate of 1 mL min^{-1}. Analyses of the gas chromatography-mass spectrometry (GC/MS) were executed using mass selective detector (a Hewlett Packard 5973)-6890 GC/MS system which was operating in the electron ionization structure with 70 eV ionization energy. This was equipped with film thickness capillary column with dimensions of HP 5MS 30 m by 0.25 mm by 0.25 µm. Here the carrier gas used was He (1 mL min^{-1}). The initial temperature of the column was set at 50 °C, with a gradual increase in heat to 150 °C at a frequency of 3 °C min^{-1}. This temperature was maintained for 10 min after which it was escalated to 250 °C min^{-1}. Thereafter, automatic injection of diluted of 1.0 µL of samples (1/100 in acetone, v/v) was done in the spitless mode. The chemical substances identified in this research were identified by comparing their retention durations and mass spectra to those derived from the Flavor 2. L, NIST98.L, and Wiley7n.1 spectral and literature records (Pezzani et al., 2017; Sefeer et al., 2018). FID chromatograms were used to evaluate the relative percentages of the separated substances.

2.12. Statistical Analysis

For this study, Info Stat software, version 2010 was used for data analysis. The standard deviations and means were determined. To discover significant differences between means, ANOVA (analysis of variance) and the LSD (Fisher's multiple range) test were used. Pearson's test was used to do the correlation analysis.

3. Results and Discussion

The various species of *Origanum* were significant for the total phenol, total flavonoid, DPPH radical scavenging capacity, superoxide radicals scavenging capacity, nitric oxide radicals scavenging and chain-breaking capacity, plant height, fresh weight, dry weights, essential oil, and essential oil yield (*Table 3*).

3.1. Total Phenolic Compounds (TPC)

The TPC forms a key diverse group of plant secondary metabolites which are linked to numerous ecophysiological conditions. The TPC of *Origanum* species, determined by the Folin-Ciocalteau colorimetric method, is shown in *Table 4*, which ranged from 36.21 to 51.12 mg GAE g^{-1} dry weight. For TPC, there were considerable variances among the investigated species. The utmost and the lowermost TPC levels were observed in *O. vulgare* subsp. *hirtum* and *O. syriacum* species, respectively. Comparing the results of this study with others noted that TPC in Iranian *Origanum* species was 2 times higher compared to the same species collected under Turkish conditions (Morshedloo et al., 2018; Raudone et al., 2018). Moghrovyan et al. (2019) demonstrated that climate conditions affected the antioxidant activities and TPC contents. Changes in phenolic chemicals in various species may be caused by genetic background and growth circumstances (Elshamy et al., 2018). Environmental variables have a paramount influence on phenolic content (such as rainfall, soil composition, temperature, and UV radiation) (Gayoso et al., 2018). Climate change, predators, disease invasion, nutritional restriction, and excessive irradiation can increase not only the reactive oxygen species (ROS) but also the free radicals (Ngugi et al., 2021). This results in increased antioxidants in plants such as phenolic compounds (Marrelli et al., 2018; Koleva et al., 2018). It is widely presumed that an enzyme which is found in various plant species called phenylalanine ammonia-lyase (PAL) functions as a prominent indicator of environmental stress factors in plants.

Table 3. The results of the analysis of variance for various Origanum species

Sources of variations	df	Total phenol	Total flavonoid	DPPH radical scavenging	Superoxide radicals scavenging	Nitric oxide radicals scavenging	Chain breaking	Plant height	Fresh weight	Dry weights	Essential oil	Essential oil yield per plant	essential oil yield per hectare
Block	2	1.25	0.40	0.42	34.82	6.41	13.82	5.56	5415	695.54	0.08	0.003	17.81
Origanum species	4	87.72**	4.49**	108.82**	330.14**	18.75*	416.26**	1.839,53**	307.655,06**	28.102,64**	4.07**	0.44**	1.999,39**
Error	8	13.39	0.27	13.71	11.67	3.94	10.49	4.12	1.773,16	285.89	0.23	0.02	94.05
C.V (%)		8.89	10.92	7.42	10.16	11.32	11.43	3.19	9.55	12.23	14.49	13.42	13.47

ns, * and ** show non-significance and significance at the $p < 0.05$ and $p < 0.01$ level, respectively.

Table 4. Total phenolic compounds of various Origanum species

Compounds	Species				
	O. majorana	***O. onites***	***O. syracum***	***O. vulgare subsp. vulgare***	***O. vulgare subsp. hirtum***
TPC (%)	41.12±0.56	43.22 ±0.40	36.21±0.61	41.59±0.88	51.12 ±0.32
TFC (%)	4.23 ±0.25	4.43 ±0.33	3.93 ±0.38	4.30 ±0.21	6.93 ±0.44

3.2. Total Flavonoid Contents (TFC)

Flavonoids are plants' bioactive chemical components that can be identified in almost every part of the plant. They are fundamental for floral coloration and fragrance, as well as for protecting plants from UV degradation. Consequently, UV radiation significantly increases flavonoid synthesis (Moreno et al., 2018). There were considerable differences among the investigated species for TFC. In this case, TFC of the five *Origanum* species ranged from 3.93 (in *O. syriacum*) to 6.93 (in *O. vulgare* subsp. *hirtum*) mg QE g^{-1} dry weight (*Table 4*). Differences among the *Origanum* species in TFC may be attributed to variances in the species' genetic background. The results of the current study are in line with previous findings (Amiri et al., 2018; Méabed et al., 2018). Bonea and Urecheam, (2018) determined that the flavonoid content of three *Origanum* species was around 2.14-4.29 mg QE g^{-1} dry weight. These differences are presumed due to the plant genotype and their interaction with the local climatic conditions.

3.3. Total Antioxidant Activity

There are several mechanisms used for measuring antioxidant activities. In the current project, the antioxidant properties of the *Origanum* species were assessed using the DPPH method. The scavenging activity of DPPH radicals in leaf extracts of these species ranged from 39.47 to 53.79% (*Table 5*). In the DPPH assay, the uppermost antioxidant activity was noted in *O. vulgare* subsp. *hirtum* whereas the least activity by DPPH assay was obtained in *O. syriacum.* Analogous results were found during the measurement of nitric oxide and superoxide antioxidant activities. The *O. vulgare* subsp. *hirtum* species showed the highest nitric oxide and superoxide activity among all species at 21.60% and 50.04% (*Table 5*).

Table 5. Total antioxidant activity of different Origanum species

Species	*O. majorana*	*O. onites*	*O. syriacum*	*O. vulgare* subsp. *vulgare*	*O. vulgare* subsp. *hirtum*
DPPH (%)	50.56 ±1.20	54.29 ±1.09	39.47 ±1.35	51.14 ±0.99	53.79 ±1.17
Nitric oxide (%)	15.13 ±0.05	16.62 ±0.08	16.26 ±0.04	18.05 ±0.07	21.60 ±0.04
Superoxide (%)	30.36 ±1.32	35.18 ±1.56	21.29 ±1.11	31.27 ±1.73	50.04 ±2.00

3.4. Plant height

The highest plant height (86.4 cm) was observed in *O. vulgare* subsp. *hirtum.* Also, *O. vulgare* subsp. *Hirtum* and *O. syriacum* species had statistically similar effects on plant height. The lowest plant height (32.6 cm) was obtained in *O. majorana* (*Figure 2*).

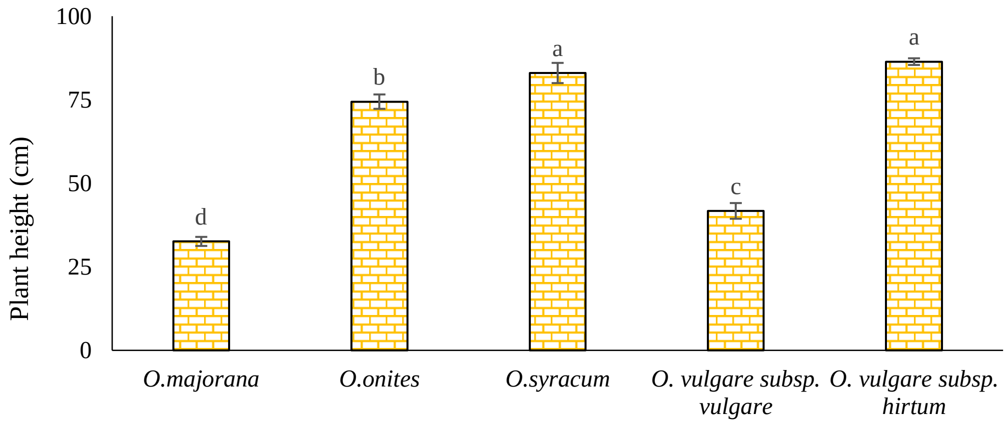

Figure 2. Plant height of 5 Origanum species used in the current study

3.5. Plant fresh weight

The mean comparison for the *Origanum* species revealed that the highest plant fresh weight of 826 g was obtained from *O. onites*, which did not differ significantly from *O. vulgare* subsp. *hirtum* species. The lowest one (92 g) was obtained from the *O. majorana* species (*Figure 3*).

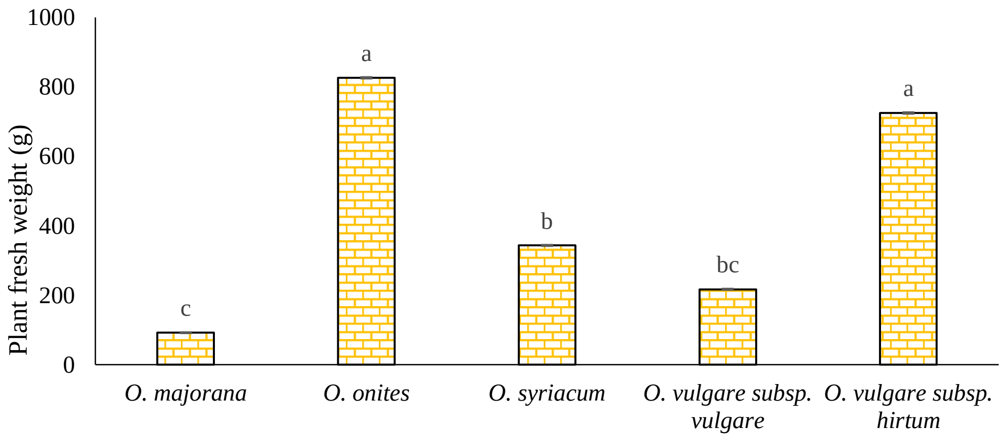

Figure 3. Plant fresh weight of 5 Origanum species used in the current study

3.6. Dry weight

The highest dry weight (250 g) was observed in *O. onites*, Also, *O. onites* and *O. vulgare* subsp. *hirtum* species had statistically similar effects on dry weights. The lowest dry weight (50 g) was obtained in *O. majorana* (*Figure 4*).

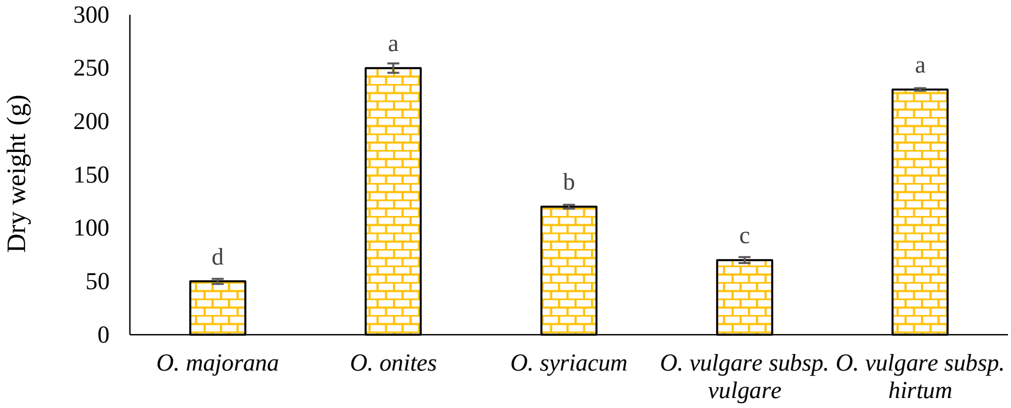

Figure 4. Dry weights of 5 Origanum species used in the current study

Investigated subspecies differed in morphological traits (*Figure 2, 3, 4*). Obtained results indicate on significant differences between examined *Origanum* subspecies and correspond well with the literature data (Węglarz et al., 2020). However, it should be underlined that each subspecies is very variable itself and its morphological features strongly depend on the population/accession origin (Kosakowska et al., 2019). Observed phenotypical plasticity may be related to allogamous way of this plant's reproduction as well as its heterozygous character. Traits such as type of growth habit, lignification degree as well as branching, and foliar density can be important from the practical viewpoint since they affect the yield of herbs and enable their mechanical harvest. In the present study, the plant height, fresh and dry weight of *Origanum* herb species had a significant difference (*Figure 2, 3, 4*). Such results may be related to the temperature requirements of *Origanum* herb species resulting from its origin (Węglarz et al., 2020).

3.7. Essential Oil Percentage

The highest essential oil percentage was 5.26% (*Figure 5*), which was observed in *O. vulgare* subsp. *hirtum* species. The lowest one (2.06%) was obtained from *O. syriacum* species, which did not differ significantly from *O. majorana, O. onites, and O. vulgare* subsp. *vulgare* species (*Figure 5*).

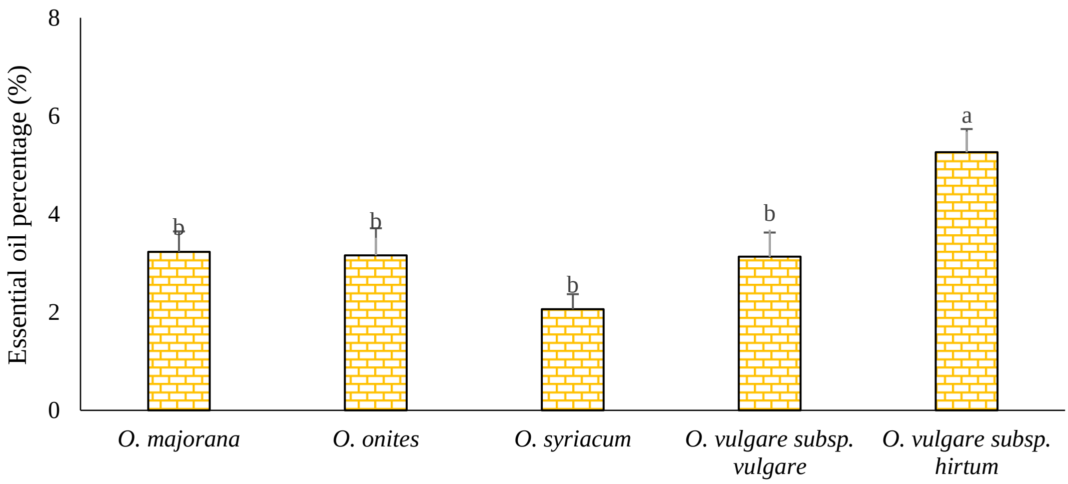

Figure 5. Essential oil percentage of 5 Origanum species used in the current study

3.8. Essential Oil Yield per Plant

The utmost EOY per plant was 1.71 g (*Figure 6*), which was obtained in *O. vulgare* subsp. *Hirtum* species. The lowest one (0.66 g) was obtained from an *O. syriacum* species. Also, *O. majorana*, *O. vulgare* subsp. *vulgare*, and *O. onites* species had statistically similar essential oil yields as that of *O. syriacum* species.

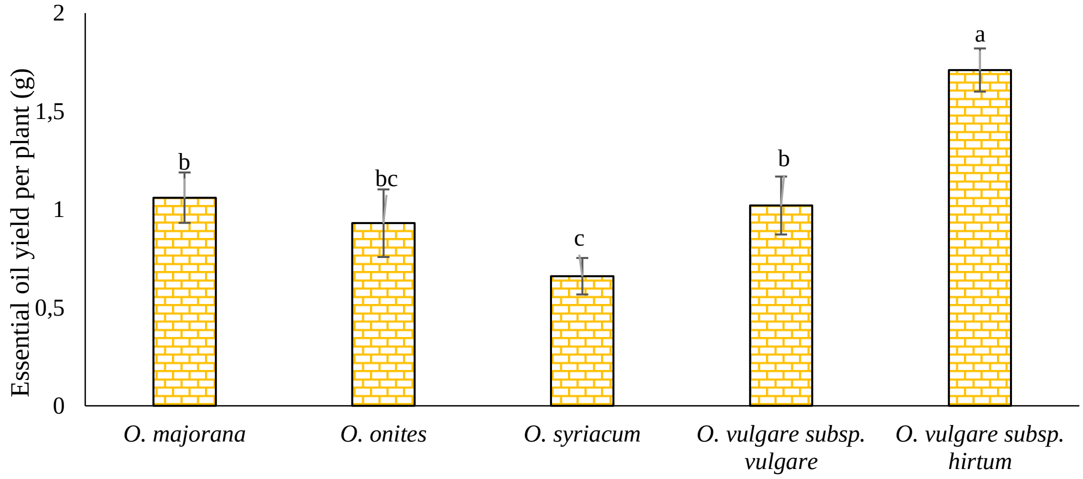

Figure 6. Essential oil yield per plant of 5 Origanum species used in the current study

3.9. Essential Oil Yield per ha

Differences in the essential oil yield were observed in *Origanum* species in the present study. The lowest essential oil yield (44 kg ha^{-1}) was recorded in *O. syriacum* whereas the highest yield (114 kg ha^{-1}) was observed in *O. vulgare* subsp. *hirtum* (*Figure 7*).

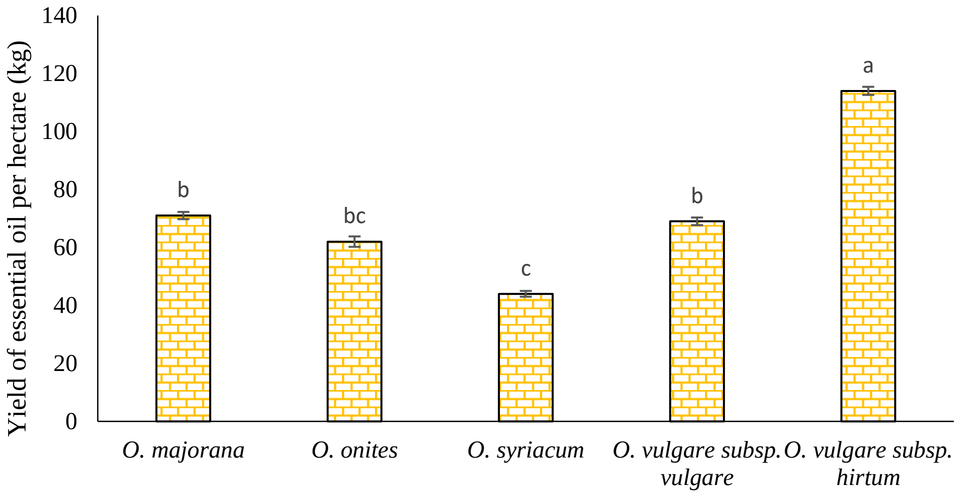

Figure 7. The yield of essential oil per hectare in different Origanum species

In *Origanum* subspecies (as well as in other *Lamiaceae*), glandular trichomes are multicellular epidermal glands responsible for storage of essential oil. Two different types of these glands were recognized on the epidermis of *Origanum* species: peltate and capitate glands (Węglarz et al., 2020). The glandular trichomes are built of one basal cell, one stalk cell and a multi-cellular head, where essential oil is synthesized before being transferred to subcuticular area (Kosakowska et al., 2019). Svidenko et al. (2018) claim that the location of glandular trichomes have valuable taxonomical significance at the species level. In the present work, it is most likely due to the variable formation of glandular trichomes among *Origanum* species, leading to differences in the amount of essential oil (*Figure 5, 6, 7*). This pattern corresponds with studies undertaken earlier by Shafiee-Hajiabad et al., (2014). However, the formation of glandular trichomes is variable and can be controlled by both genetic and environmental factors (Kosakowska et al., 2019), It has led to a difference in the amount of essential oil. It is worth noting that the relationship between the number of glandular trichomes and essential oil content has been found (*Tables 4* and *5*), what refers to results shown by Shafiee-Hajiabad et al. (2014).

3.10. Principal Component Analysis (PCA)

The PCA for the assessed variables on essential oil, antioxidant compounds and quantitative traits for 5 *Origanum* species *O. majorana*, *O. vulgare* subsp. *vulgare*, *O. syriacum*, *O. onites*, and *O. vulgare* subsp. *hirtum*) resulted in 67 and 21% variation being accounted for by the first (PC1) and second (PC2) principal components, respectively (*Figure 8*). The variability in PC1 was mainly due to two groups of variables. The first one consisted of the quantitative traits measured by *O. onites* species form a group characterized by plant height, plant fresh weight, and plant dry weight. The second group consists of *O. vulgare* subsp. *hirtum* species, distinguished by higher amounts of phenolic compounds, flavonoid contents, DPPH scavenging activity radical, nitric oxide, superoxide, essential oil based on percentage, per hectare, and per plant. The second principal component (PC2) was weighted by percentage biomass, and the projection of the variances based on the PCA revealed a significant separation of this variable from the rest along the first axis.

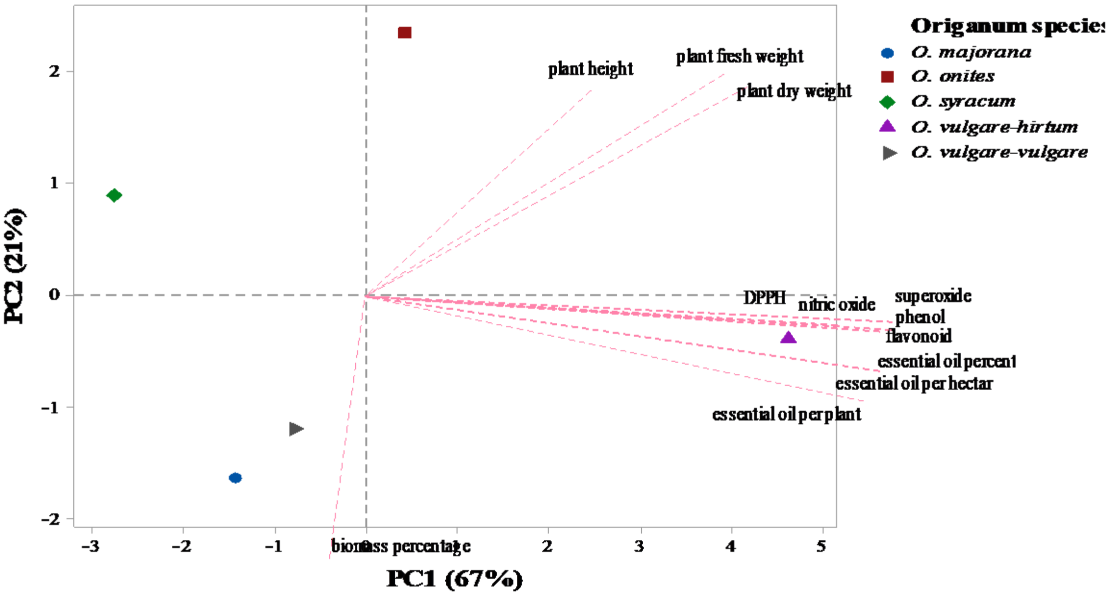

Figure 8. Principal component analysis of various origanum species

3.11. Cluster analysis

The results acquired from the cluster analysis indicated the presence of high inter-production variability in the antioxidant compounds of various *Origanum* species. From the 5 production samples presented to a multivariate evaluation, well-defined groups of antioxidant compounds were distinguished by using cluster analysis (*Figure 9*). According to the information, two subclusters were obtained: The first subset included three *Origanum* species which were *O. vulgare* subsp. *vulgare*, *O. majorana*, and *O. syriacum*, and the second subset had two *Origanum* species: *O. onites*, and *O. vulgare* subsp. *hirtum*.

3.12. Essential Oil Analysis

Various essential oil components were analyzed based on the GC-MS analysis. thymol (6.90-59.89%), carvacrol (0.83-48.91%), γ-terpinene (6.55-18.20%), p-cymene (0.50-20.94%) and α-terpinene (2.71-4.28%) were the most prominent constituents in *Origanum* plants (*Table 6*). The uppermost level of Thymol was detected in *O.majorana* and the lowest amount of it was obtained from *O.vulgare-vulgare*. The peak level of carvacrol (48.91%) was noted in *O. vulgare* subsp. *hirtum* and the lowest amount of it (0.8%) was obtained from *O. syriacum.*

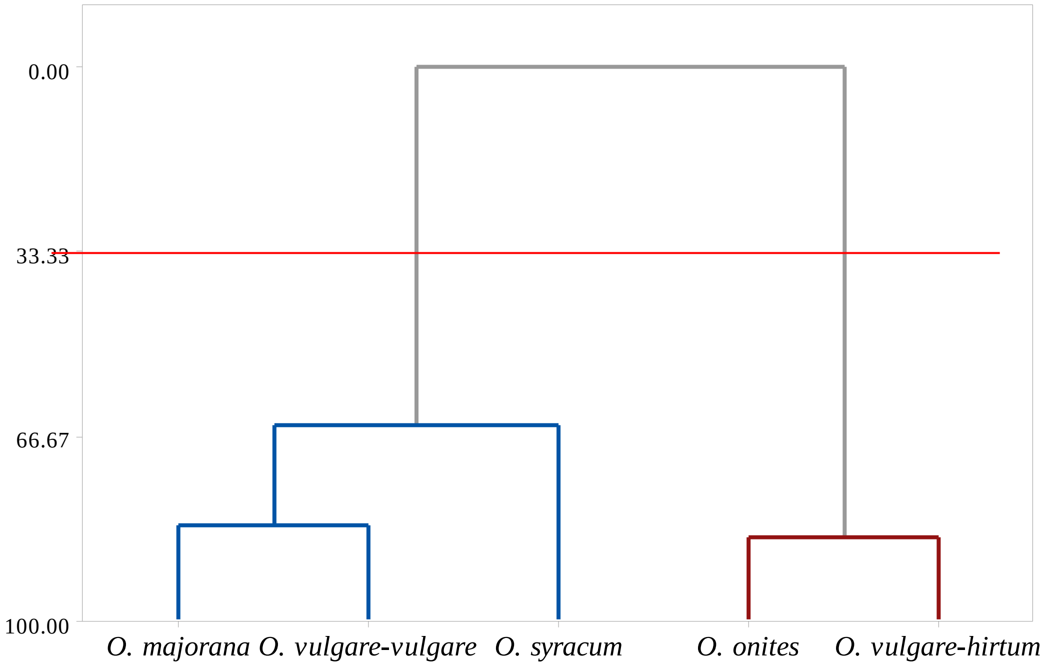

Figure 9. Cluster analysis of 5 Origanum species

As per this study, the antioxidant properties and essential oil content of *Origanum* varied among species (*Table 6*). The density of oil glands involving plant tissues, alteration in the growing environment of plants as the plant matures, and changing allocation of carbohydrates to plant development and growth rather than essential oil synthesis could all cause alterations in essential oil composition. For instance, medicinal plants regulate essential oil production and the attraction of pollinators while repelling herbivores and pests (Moghrovyan et al., 2019; Pezzani et al., 2017). In our study, thymol and carvacrol were the most common component of the essential oil in the *O. majorana* and *O.vulgare* subsp. *hirtum*, respectively. Other *oregano* species including *O. vulgare* subsp.*hirtum* (Moreno et al., 2018), European *O. vulgare* (Duletić-Laušević et al., 2018), *O. vulgare* subsp. *glandulosum* (Gayoso et al., 2018), O. *vulgare* (Pezzani et al., 2017) have similarly showed comparatively high levels of carvacrol. The current study confirms that the highest level of carvacrol (48.91%) was obtained from *O. vulgare* subsp. *hirtum*. Ramakrishna et al. (2019) found carvacrol as a dominant component in the essential oil of *O. vulgare* subsp. *hirtum*. These findings show that the gene for carvacrol generation is preserved. The monoterpenes, g-terpinene, p-cymene, and hydrocarbons operate as progenitors for thymol, and carvacrol thus their rates reduce with an increase in the levels of carvacrol (Sefeer et al., 2018). It is known that many various factors can affect the content and composition of essential oils in aromatic plants, where the most seem to be: genetic, physiological and environmental including temperature, intensity of solar and radiation humidity (Węglarz et al., 2020).

4. Conclusions

The present study investigated the phytochemical properties of five species (*Origanum* species including *O.majorana*, *O. syriacum, O. onites*, *O. vulgare* subsp. *vulgare* and *O. vulgare* subsp. *hirtum*) of marjoram (*Origanum majorana* L.) an important ethnomedicinal plant. Total phenolic compounds, total flavonoid content, total antioxidant activity, and essential oil compounds were determined. The qualitative analysis showed the highest (240 g) dry weight of *O. vulgare* subsp. *hirtum* and *O. onites* species in comparison with others. The quantitative analysis revealed the higher content of total phenol (51.12%), flavonoid (6.93%), DPPH (54.29%), superoxide (50.04%) and radical scavenging activity in *O. vulgare* subsp. *hirtum* species, but the *O. onites* showed higher (21.60%) nitric oxide radical scavenging activity. The essential oil analysis revealed that the thymol (6.90-59.89%), carvacrol (0.83-48.91%), γ-terpinene (6.55-18.20%), p-cymene (0.50-20.94%) and α-terpinene (2.71-

4.28%) were the most prominent constituents in *Origanum* plants. Cluster analysis showed two main categories and high similarity between *O. vulgare* subsp. *hirtum* and *O. onites.* In conclusion, the *O. vulgare* subsp. *hirtum* was the best species in terms of phytochemical constituents.

Table 6. Different compounds of essential oil in various Origanum species.

Component	Peak area ((%)				
	O. majorana	***O. onites***	***O. syriacum***	***O. vulgare* subsp. *vulgare***	***O. vulgare* subsp. *hirtum***
α-phellandrene	1.29	1.41	1.17	0.27	1.35
α-pinene	0.52	0.74	0.68	0.45	0.66
sabinene	-	-	-	3.47	-
1-octen-3-ol	0.47	0.44	-	-	0.24
myrcene	1.77	1.57	1.50	1.22	1.47
3-octanol	-	0.39	-	-	-
δ-3-carene	0.37	0.35	0.50	-	0.30
α-terpinene	3.82	4.28	2.71	3.79	2.78
p-cymene	11.99	20.94	15.52	0.50	10.69
cyclohexene	0.65	0.63	-	1.28	-
beta-Pinene	-	-	-	0.29	0.46
eucalyptol	-	-	-	0.26	-
γ-terpinene	11.65	15.55	18.20	6.55	8.18
trans-sabinene hydrate	-	0.70	-	4.32	0.26
terpinolene	-	-	-	1.49	-
cis-sabinene hydrate	-	-	-	36.38	-
isoborneol	0.61	-	0.56	0.44	0.40
terpinen-4-ol	1.04	0.64	0.43	16.12	0.77
alpha-Terpineol	-	-	-	5.40	-
carvacrol methyl ether	-	-	3.63	-	2.05
tricyclene	-	-	-	2.27	-
thymol	59.89	43.24	51.55	6.90	19.26
Carvacrol	3.55	8.38	0.83	1.76	48.91
β-caryophyllene	1.88	0.76	1.58	1.35	1.77
b-bisabolene	0.51	-	1.14	-	0.43

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Authors contributed equally.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Gebelik Başına Tohumlama Sayısının Süt Sığırlarının Islahında Önemi ve Ekonomik Kayıplar: Siyah Alaca Süt Sığırı Örneği*

Importance of Insemination Number per Pregnancy in Breeding Dairy Cattle and Economic Losses: The Case of Holstein Dairy Cattle

Eyüp TÖRE[1*], Yahya Tuncay TUNA[2], Ahmet Refik ÖNAL[3]

Öz

Süt sığırcılığında, süt ve döl verimi işletmelerin karlılığı üzerinde doğrudan etkili iki ölçüttür. Farklı ölçütler kullanılarak ölçülmeye çalışılan döl verimi dişi sığırlar için kısaca zamanında gebe kalma ve sağlıklı yavruları ileriki yaşlarına kadar doğurma yeteneği olarak tanımlanabilir. Dişi sığırdan beklenen, zamanında gebe kalması ve sürüde kaldığı sürece sağlıklı buzağı doğurma yeteneğini korumasıdır. Gebelik Başına Tohumlama Sayısı, dişilere ait döl verim ölçütlerinden ilkine damızlıkta kullanma yaşı ile dolaylı olarak ilişkili iken servis periyodu, Buzağılama aralığı ve Buzağılama Yılı üzerinde doğrudan etkili olan bir ölçüttür. Bu araştırma ile gebelik başına tohumlama sayısının (GBTS) süt sığırlarının ıslahında önemi ve ekonomik kayıplar ortaya konmaya çalışılmıştır. Tekirdağ İli Damızlık Sığır Yetiştiricileri Birliğine (DSYB) kayıtlı ve halen üretime devam eden süt sığırcılık işletmelerinin 2013-2019 yılları arasındaki 20662 siyah alaca süt sığırına ait (39938 adet) döl verim kayıtları (GBTS) araştırmanın materyalini oluşturmuştur. Buzağılama Yıllarının etkisini ele aldığımızda; farklılığı yaratan yılların en düşük 2014 yılı (1.76 ± 0.022) ortalamasının olduğu, en yüksek ortalama (1.95± 0.020) olarak da 2015 yılı verilerinden kaynaklandığı görülmektedir. ($p<0.01$). Mevsimlerin GBTS'na etkileri irdelendiğinde farklılığın kış (1.81 ± 0.015) ve sonbahar (1.94 ± 0.016) mevsimlerinden kaynaklandığı görülmüştür ($p<0.01$). Laktasyon sırasını değerlendirdiğimizde 1., 2. ve 3. laktasyon sıralarının Gebelik Başına Tohumlama Sayısına etkilerinin önemli olduğu ($p<0.01$) görülmektedir. Araştırmadaki sonuçlar değerlendirildiğin de GBTS ortalaması (1.87 ± 0.01) olarak hesaplanmıştır. GBTS ortalamasına ait ortalama değer ideal sınırlara (1.0-1.7) yakınlık göstermesine rağmen 2013-2019 yılları arasında toplam 39938 tohumlama yapılmıştır. Başarısızlık oranına karşılık gelen maddi kayıp miktarı ise 10.147.200 TL olmuştur. Sonuçlarımızın GBTS'daki mali kayıp miktarı göz ardı edilemeyecek derecede büyük bulunmuştur.

Anahtar Kelimeler: Süt sığırı, Gebelik başına tohumlama sayısı, Ekonomik kayıplar, Hayvan ıslahı

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Abstract

Milk and fertility are two criteria that directly affect the profitability of enterprises in dairy farming. Fertility, which is tried to be measured using different criteria, can be defined as the ability of female cattle to get pregnant on time and give birth to healthy calves until later ages. The expected from female cattle is to become pregnant on time and to maintain the ability to give birth to healthy calves as long as they remain in the herd. the number of inseminations per pregnancy is indirectly related to the first of the fertility criteria of females, the age of use in breeding, while the service period is a criterion that directly affects the calving interval and calving year. The aim of the study was to determine the information and economic losses caused by the deviations from the standard values in the Number of Inseminations Per Conception (NIPC) in our country's dairy cattle. The fertility records (NIPC) of 20662 Holstein Dairy cattle (39938) between 2013-2019 belonging to Tekirdag Province CBA constituted the material of the research. When we consider the effect of calving years; It is seen that the years that created the difference have the lowest average of 2014 (1.76±0.022), and the highest average (1.95±0.020) stems from the 2015 data. ($p<0.01$). When we examine the effects of seasons on NIPC; it was seen that the difference was caused by winter (1.81±0.015) and autumn (1.94±0.016) seasons ($p<0.01$). When we evaluate the lactation order, it is seen that the effects of the 1st, 2nd and 3rd lactation lines on NIPC are significant ($p<0.01$). When we evaluated the results in our study, the NIPC average was calculated as 1.87±0.01. A total of 39938 inseminations were made between 2013-2019. The amount of financial loss corresponding to the failure rate was 10.147.200 TL. Although our results are close to the ideal value, the amount of loss in NIPC in terms of cost is too large to be ignored.

Keywords: Dairy cattle, Number of inseminations per conception, Economic loses, Animal breeding

1. Giriş

Süt sığırcılığında süt ve döl verimi işletmelerin karlılığı üzerinde doğrudan etkili iki ölçüttür. Süt ve döl verim ile birbirlerine etkileri konusunda yapılmış çok sayıda araştırma vardır. Yapılan kaynak taramalarında ülkemizde süt sığırcılığı işletmelerinde döl verimi ölçütleri ile ilgili ekonomik kayıpların saptanması konusunda ise az sayıda araştırmaya (Kumuk ve ark.,1999; Yalçın, 2000; Önal ve Özder, 2007; Sarıözkan ve ark., 2012) rastlanmıştır. Farklı ölçütler kullanılarak ölçülmeye çalışılan döl verimi dişi sığırlar için kısaca zamanında gebe kalma ve sağlıklı yavruları ileriki yaşlarına kadar doğurma yeteneği olarak tanımlanabilir (Kumlu ve ark., 1991., Kumlu ve Akman, 1999, Kumlu, 2000). Dişi sığırdan beklenen, zamanında gebe kalması ve sürüde kaldığı sürece sağlıklı buzağı doğurma yeteneğini korumasıdır.

Tohumlama indeksi olarak da adlandırılan bu özellik tohumlamadaki başarının bir diğer ifade şeklidir. Gebelik Başına Tohumlama Sayısı (GBTS), dişilere ait döl verim ölçütlerinden ilkine damızlıkta kullanma yaşı (İDKY) ile dolaylı olarak ilişkili iken servis periyodu (SP), Buzağılama aralığı (BA) ve Buzağılama Yılı (BY) üzerinde doğrudan etkili olan bir ölçüttür (Tuna ve ark., 2007). Günümüzde sığır ıslahında Suni Tohumlama tekniğinin yaygınlaşması ıslah kavramının ulusal boyuttan, uluslararası boyutlara taşınmasına neden olmuştur. Özellikle ülkemizde son yıllarda Suni Tohumlamaya olan devlet desteği, bu ölçütün kayıt altına alınmasında faydalı olmuştur. İyi koşullarda gebelik başına tohumlama sayısının ideal miktarı 1 adet olması istenir. Ancak bu ölçüt bölge, işletme, tohum kalitesi, ineğin sağlığı, yaşı, kızgınlık süresinin iyi tespiti, spermanın kalitesi, tohumlama tekniği, tohumlayıcının bilgi düzeyi ve deneyimi, yıl, sıcaklık (mevsim) gibi birçok sistematik ve sistematik olmayan çevre faktörlerine bağlı olarak değişmektedir. Ülkemiz koşullarında siyah alaca sığırlarında GBTS nin belirlenmesine yönelik çalışmalardan bir kısmı *Tablo 1*’de verilmiştir.

Tablo 1. Ülkemiz koşullarında siyah alaca sığırlarında döl verim özelliklerinden GBTS’nin belirlendiği çalışmalar

Table 1. Studies in which NIPC was determined from reproductive characteristics in black pied cattle under our country's conditions

Araştırmacılar ve Yıllar	GBTS
Şekerden (1988)	1.50
Soysal ve Özder (1989)	1.70
Kumlu ve ark. (1991)	1.28 ± 0.90
Aslan ve Altınel (1992)	1.51 ± 0.03
İpek (1993)	1.45 ± 0.80
Özcan ve Altınel (1995)	2.40 ± 0.10
Gündal Çörekçi ve ark. (1996)	1.56 ±0.023
Erdem (1997)	1.21 ± 0.42
Kaygısız (1997)	2.198
Bilgiç ve Yener (1999)	1.40 ± 0.05
Özçelik ve Arpacık (2000)	1.72 ± 2.17
Duru ve Tuncel (2002)	1.33 ± 0.02
Bakır ve Çetin (2003)	1.58 ± 1.21
Sehar ve Özbeyaz (2005)	1.68 ± 0.052
Türkyılmaz (2005)	2.01 ± 0.10

Süt sığırcılığında karlılığın yüksek olması için döl verim özelliklerinde yapılan çalışmalarla belirlenmiş bazı ortalama değerlere ulaşılmaya çalışılmaktadır. Aynı zamanda birbirine bağlı olan ve birbirini bütünleyen bu özellikler (*Tablo 2*), bireylerin sürüde kalması (verimli ömür), damızlık olarak seçim, gibi doğrudan ıslah parametresi olarak kullanılmaktadır (Kumlu ve Akman,1999).

Bu çalışmada; süt sığırlarında döl verimi ölçütleri ile ilgili standart değerler özellikle Gebelik Başına Tohumlama Sayısı (GBTS) verilerinin bu standart değerlerden sapmalarının ülkemiz süt sığırcılığı ıslahında yol açtığı bilgi ve ekonomik kayıpların saptanması amaçlanmıştır.

Tablo 2. Dişi sığırda kullanılan döl verim ölçütleri ve standart değerler

Table 2. Reproduction criteria and standard values used in female cattle

Döl Verim Ölçütleri **Reproduction Traits**	**Standart Değerler** **Standard Values**
İlkine Damızlıkta Kullanma Yaşı (İDKY)	15-18 ay
İlkine Buzağılama Yaşı (İBY)	23-25 ay
Buzağılama Aralığı (BA)	12-13 ay
Kuruda Kalma Süresi (KKS)	2 ay
Servis Periyodu (SP)	2-3 ay
Gebelik Başına Tohumlama Sayısı (GBTS)	1 ideal, 1.7 kabul edilir sınır.

2. Materyal ve Metot

2.1. Materyal

Damızlık Sığır Yetiştiricileri Birliğinden elde edilen Tekirdağ İli DSYB'ne ait 2013-2019 yılları arasındaki 20662 siyah alaca süt sığırına ait döl verim kayıtlarından (39938 adet) Gebelik Başına Tohumlama Sayısı (GBTS) araştırmanın materyalini oluşturmuştur.

Kumlu ve Akman (1999)'un bildirdiği kriterlere göre süt ve döl verim özelliklerinde kısıtlamalar yapılmıştır. Bu kısıtlamalar: Laktasyon süresi (220<gün<550), Kuruda kalma süresi (30<gün<90), İlk tohumlama yaşı (14<ay<24), GBTS (1<adet<+5) olarak belirlenmiştir.

Mevsim etkisi olarak: 1-Kış, 2-İlkbahar, 3- Yaz ve 4-Sonbaharı ifade etmektedir.

2.2. Yöntem

GBTS üzerine çevre şartlarının etkileri aşağıdaki doğrusal model (Eşitlik 1) ile değerlendirilmiştir.

$$Yijkl \ = m + BYi \ + Mj + LSk + eijkı \qquad \text{(Eş. 1)}$$

Y_{ijkl} : i.buzağılama yaşı, j.mevsim ve k.laktasyon sırasındaki GBTS,
m: Popülasyon ortalaması,
BY_i : i.buzağılama yaşının etkisi,
M_j: j.mevsimin etkisi,
LS_k: k.laktasyon sırasının etkisi,
e_{ijkl} : hata payının etkisi.

Parametreler arasındaki karşılaştırmalar için Tukey çoklu karşılaştırma testi, GBTS'dan kaynaklanan ekonomik kayıpların belirlenmesinde ise aşağıdaki Eşitlik 2 kullanılmıştır.

$$GBTS'dan\ kaynaklanan\ ekonomik\ kayıplar = Toplam\ gebelik\ sayısı * Gebelik\ için\ kullanılan\ ekstra\ sperma + uygulama\ ücreti * 1\ doz\ sperma\ fiyatı \qquad \text{(Eş. 2)}$$

3. Araştırma Sonuçları ve Tartışma

3.1. Tekirdağ İli 2013-2019 Yılları Arasındaki GBTS Ait Tanımlayıcı İstatistikler

Araştırmanın gerçekleştirildiği Tekirdağ İlinde yetiştirilen Siyah Alaca sığırların GBTS'na ilişkin en küçük kareler ortalamaları üzerine etkili çevre faktörlerinin sonuçları *Tablo 3*'te sunulmuştur.

Çalışmada, toplam 20662 baş Siyah Alaca süt sığırı ve bunlara ait 39938 GBTS'nın genel ortalaması 1.87±0.01 olarak bulunmuştur. Bu değer, Şekerden (1988), Kumlu ve ark. (1991), Aslan ve Altınel (1992), İpek (1993), Gündal Çörekçi ve ark. (1996), Erdem (1997), Bilgiç ve Yener (1999), Duru ve Tuncel (2002), Bakır ve Çetin (2003) ve Sehar ve Özbeyaz (2005)'ın araştırma bulguları olan ve sırasıyla; 1.5; 1.28±0.9; 1.51±0.03; 1.45±0.80; 1.56±0.02; 1.21±.0.42; 1.4±0.05; 1.33±0.02; 1.58±1.21 ve 1.68±0.05'olarak belirlenen değerlerden daha büyüktür. Soysal ve Özder (1989)'in 1.7 ve Özçelik ve Arpacık (2000)'ın ortalamalarına (1.72±2.17) ile benzer iken, Kaygısız (1997)'nin 2,198 ve Türkyılmaz (2005)'in (2.01±0.1) değerlerinden düşük bulunmuştur. GBTS' nın ideal 1.0-1.7 olarak aşım maliyetlerinin buna bağlı olarak açık gün sayının artmaması için gerekli olduğu Sağlam ve

Uğur (2006) tarafından bildirilmesine rağmen bu değerlerin işletmelerde tutturulmasısın zor olduğu Tuncel (1998) ile Özhan ve ark. (2011)'ın GBTS için 1.5-1.8 değerlerinin sığırcılık işletmeleri için kabul edilebilir sınırlar olduğunu bildirmişlerdir. Bu nedenle, Tekirdağ ili için bulduğumuz bu genel ortalamanın (1.87±0.01) kabul edilebilir değer olduğu söylenebilir.

Tablo 3. GBTS'na ait en küçük kareler ortalamaları ve çoklu karşılaştırma sonuçları

Table 3. Least square means and multiple comparison results of NIPC

Faktörler/Factors	n	GBTS/NIPC ($\bar{X} \pm s_{\bar{x}}$)
Genel/Total	20662	1.87±0.01
Buzağılama Yılı/Calving Year		
2013	3916	$1.82{\pm}0.018^{bc}$
2014	2709	$1.76{\pm}0.022^{c}$
2015	3301	$1.95{\pm}0.020^{a}$
2016	3155	$1.94{\pm}0.020^{ab}$
2017	2513	$1.90{\pm}0.023^{ab}$
2018	2037	$1.89{\pm}0.025^{ab}$
2019	3031	$1.88{\pm}0.021^{ab}$
Mevsim/Season		
[1](Kış)	5928	$1.81{\pm}0.015^{c}$
[2](İlkbahar)	4298	$1.86{\pm}0.018^{bc}$
[3](Yaz)	5457	$1.89{\pm}0.017^{ab}$
[4](Sonbahar)	4979	$1.94{\pm}0.016^{a}$
Laktasyon Sırası/Lactation Number		
1	7182	$1.61{\pm}0.013^{d}$
2	5801	$2.12{\pm}0.015^{a}$
3	3618	$1.97{\pm}0.019^{b}$
4	2176	$1.88{\pm}0.024^{c}$
5	1885	$1.80{\pm}0.026^{c}$

([a-b-c-d] Farklı harfler ile ifade edilen ortalamalar arasındaki karşılaştırmalar önemlidir. **p<0.01).

GBTS için yıllarının etkisini değerlendirdiğimizde, yıllar arasındaki fark önemli bulunmuştur (p<0.01). Farklılığı yaratan yılların en düşük değer (1.76±0.022) ile 2014 yılı ortalamasının olduğu, en yüksek ortalama değer (1.95±0.020) olarak 2015 yılında belirlenmiştir. Çalışmada 2013 (1.82±0.018) ve 2014 (1.76±0.022) yıllarının GBTS ortalamaları genel ortalamadan (1.87±0.01) düşük bulunurken, özellikle 2015, 2016 ve 2017 GBTS ortalamaları sırasıyla; (1.95±0.020), (1.94±0.020) ve (1.90±0.023) sürünün genel ortalamasından (1.87±0.01) ve ideal sınırlardan (1.0-1.07) oldukça yüksek çıkmıştır (p<0.01). *Tablo 3*' te Son iki yıla (2018 ve 2019) baktığımızda GBTS ortalamalarının, (1.89±0.025) ve (1.88±0.021) olduğu sürü ortalamasına (1.87±0.01) yaklaşmakla birlikte ideal değerlerden uzak olduğu görülmektedir. GBTS bakımından yıllara göre gözlenen düzenli bir artış ya da azalış olduğu görülmemektedir. Özellikle 2014 yılına baktığımızda hayvan sayısının 3916'dan 2709'a düştüğü ve GBTS'nın ise (1.76±0.022) ideal sınırlara çekildiği benzer eğilimin 2018 yılında da yaşandığı görülmektedir. Yıllar arasında Tekirdağ ili genelinde, yıllar arasında yaşanan süt sığırı sayısındaki düşüş ve özellikle artışın GBTS'nıda artırdığını (2015, 2016 ve 2017) yılları arasında tohumlamada problemler yaşandığını göstermektedir (*Tablo 3*).

Mevsimlere göre GBTS'da artış olduğu ve aralarındaki farklılığın istatistiki olarak önemli olduğu görülmüştür (p<0.01). Mevsim etkilerini irdelediğimizde, en düşük tohumlama sayısı kış (1.81±0.015) ve ilkbahar (1.86±0.01) aylarında görülürken aralarındaki farkın önemli (p<0.01), genel ortalamadan (1.87±0.01) düşük olduğu saptanmıştır. Farklılığın yaz (1.89±0.017) ve sonbahar (1.94±0.016) mevsimlerinden kaynaklandığı ve genel ortalamadan yüksek olduğu ideal değerlerden uzaklaştığı görülmüştür (p<0.01). Sağlam ve Uğur (2007) ile Erdem ve ark. (2007), Tahirova TİM ve Gökhöyük TİM de yaptıkları çalışmalarda GBTS üzerine mevsim etkilerinin etkisiz olduğunu bildirirken, yine Sağlam ve Uğur (2007)'nin bildirişine göre; Ray ve ark. (1992), Bizim çalışmamıza paralel olarak mevsimin GBTS üzerine önemli etkisi olduğunu özellikle yaz mevsiminde sıcaklık etkisinden 1'den fazla tohumlama yapıldığını bildirmişlerdir.

Laktasyon sırasının GBTS'na etkisi önemli bulunmuştur ($p<0.01$). Laktasyon grupları için en düşük değer 1.61±0.013 ile 1. Laktasyonda, en yüksek değerler ise 2. (2.12±0.015) ve 3. (1.97±0.019) Laktasyon sıralarında 4. belirlenmiştir. Dördüncü ve 5+. Laktasyonlarda ise (1.88±0.024) (1.80±0.026) ile düşme eğilimi görülmüştür. Duru ve Tuncel (2002), Türkyılmaz (2005), Sağlam ve Uğur (2007), Erdem ve ark. (2007), bizim bulgumuzun tersine laktasyon sırasının ilerlemesiyle birlikte GBTS'nında artış gösterdiğini bu durumun hayvanların yaşlarının ilerlemesi ile döl tutma sorunlarının artmasının neden olduğunu bildirmişlerdir. Çalışmamızın bir işletmenin değil Tekirdağ İli Damızlık Birliğine kayıtlı tüm işletmelerin verilerini kapsaması ve 3. Laktasyondan sonra süt sığırı sayının hızla azalmasından kaynaklandığını söyleyebiliriz.

3.2. Tekirdağ İli 2013-2019 yılları Arasındaki GBTS'na Ait Başarı Oranları ve Ekonomik Kayıplar

Gebelik Başına Tohumlama Sayısı (GBTS) açısından Tekirdağ İli Damızlık Sığır Yetiştiricileri Birliği (DSYB) 2013-2019 yılı verilerinden 39938 adet GBTS kaydı değerlendirilmiştir. GBTS'nın ideal/hedeflenen değerlere ulaşılamaması neticesinde meydana gelen mali/ekonomik kayıplar *Tablo 4*'te sunulmuştur.

Tablo 4. GBTS'na ait Başarı Oranları ve Ekonomik Kayıp Miktarları (TL)

Table 4. Success Rates and Economic Loss Amounts of NIPC (TL)

Faktörler Factors	Başarılı Success(n)	Başarısız Fail(n)	Toplam Total(n)	Başarı Oranı (%) Success Rate (%)	Başarısız Oranı (%) Fail Rate (%)	Kayıp Miktarı (TL) Loss Amount (TL)
Genel	10946	28992	39938	27	73	10.147.200
Buzağılama Yılı/Calving Year						
2013	2104	5136	7240	29	71	1.797.600
2014	1518	3288	4806	32	68	1.150.800
2015	1715	5033	6748	25	75	1.761.550
2016	1604	4842	6446	25	75	1.694.700
2017	1301	3749	5050	26	74	1.312.150
2018	1088	2843	3931	28	72	995.050
2019	1616	4101	5717	28	72	1.435.350
Mevsim/Season						
[1] Kış	3248	7734	10982	30	70	2.706.900
[2] İlkbahar	2302	5782	8084	28	72	2.023.700
[3] Yaz	2904	7849	10753	27	73	2.747.150
[4]Sonbahar	2492	7627	10119	25	75	2.669.450
Laktasyon Sırası/Lactation Number						
1	4506	7231	11737	38	62	2.530.850
2	2556	10434	12990	20	80	3.651.900
3	1725	5683	7408	23	77	1.989.050
4	1125	3164	4289	26	74	1.107.400
5	1034	2480	3514	29	71	868.000

*Bir doz sperma fiyatı 2023 yılı cari fiyatlarına göre ortalama 150 TL olarak belirlenmiştir. Uygulama fiyatı olarak 200 TL alınmıştır.

GBTS'nda ilk tohumlamada genel başarı oranının %27 olduğu görülmektedir. Toplam 39938 tohumlamanın yapıldığı 2013-2019 yıllarında tohumlamadaki genel başarı oranının %27 gibi bir değerde olması Tekirdağ İli süt sığırcılığında üreme problemlerinin en başta gelen sorunlardan olduğunu göstermektedir.

3.3. 2013-2019 Yıllarına İlişkin GBTS'nın Ekonomik Analizi

Buzağılama yılları olarak *Tablo 4*' incelendiğinde başarısız oranı (%) en düşük 2014 en yüksek ise 2015 ve 2016 yılları olarak hesaplanmıştır. Kayıp miktarını ele aldığımızda ise en düşük 995.050TL ile 2018, en yüksek 1.797.600TL ile 2013 yılında görülmektedir. Mevsimlere göre başarısız tohumlama oranı (%) en düşük kış en yüksek ise sonbahar olarak hesaplanmıştır. Kayıp miktarını ele aldığımızda ise en düşük 2.023.700TL ile ilkbahar, en yüksek 2.747.150TL ile yaz mevsiminde görülmektedir. Laktasyon sırasına göre başarısız tohumlama oranı (%) en düşük 1.laktasyon, en yüksek ise 2. laktasyonda hesaplanmıştır. Kayıp miktarını ele aldığımızda ise en düşük 868.000TL ile 5.laktasyon, en yüksek ise 3.651.900TL ile 2. laktasyonda görülmektedir.

4. Sonuç

Araştırmamızdaki sonuçları değerlendirdiğimizde GBTS ortalaması 1.87±0.01 olarak hesaplanmıştır. Yapılan araştırmalardaki sonuçlarla ideal kabul görülen GBTS ortalaması 1.70 ile parallellik göstermektedir. 2013-2019 yılları arasında toplam 39938 tohumlama yapılmıştır. Başarısızlık oranına karşılık gelen maddi kayıp miktarı ise 10.147.200 TL olmuştur. Sonuçlarımızın ideal değere yakınlık göstermesine rağmen GBTS'daki maliyet açısından kayıp miktarı göz ardı edilemeyecek derecede büyüktür.

Günümüzde düşük karlılıkla çalışan süt sığırcılığı işletmelerinde, döl verimi kontrolünün işletmelerin ve dolaylı olarak ülkemizin ekonomik performansında ki önemi yadsınamaz. Başarılı bir hayvancılık işletmesinde sürünün döl verimine doğrudan veya dolaylı olarak etki eden etmenler yakından izlenerek performansı olumsuz yönde etkileyen faktörlerin, etkisini göstermeden önce elemine edilmesi önem taşımaktadır.

Etik Kurul Onayı

Çalışma Yüksek Lisans Tezinden derlenmiş olup Tez Çalışma Planında Etik Kurul Onayına ihtiyaç duyulmadığına karar verilmiştir.

Çıkar Çatışması Beyanı

Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz.

Yazarlık Katkı Beyanı

Planlama: Tuna, Y.T., Töre, E.; Materyal ve Metot: Tuna, Y.T., Töre, E.; Veri toplama ve İşleme: Töre, E.; Literatür Tarama: Tuna, Y.T., Töre, E. Önal, A.R.; Makale Yazımı, İnceleme ve Düzenleme: Tuna, Y.T., Töre, E., Önal, A.R.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Change of Forage Yield and Quality Characteristics of White Clover (*Trifolium repens* L.) at Different Harvest Time

Ak Üçgülün (*Trifolium repens* L.) Farklı Hasat Zamanlarına Ait Verim ve Kalite Özelliklerinin Değişimi

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Abstract

This study was conducted to determine the yield and quality characteristics of white clover at different harvest time. The study was carried out according to the randomized blocks experimental design in 2021 and 2022, and the Rivendel variety of white clover was used as the plant material in the study. Four different harvest time of white clover, as early bloom, mid-bloom, full bloom, and after-bloom, were considered as the research subject. In the experiment, the plant height, green forage yield, dry matter yield, dry matter ratio, crude protein, crude protein yield, insoluble fiber in acid detergent (ADF), insoluble fiber in neutral detergent (NDF), relative feed value and phosphorus, potassium, calcium, and magnesium contents of white clover were investigated. It has been determined that the differences in all of these examined features in different harvest time of white clover were statistically significant. In the research, white clover reached the highest plant height (32.3 cm and 27.8 cm), green forage yield (38.367 kg ha^{-1} and 52.080 kg ha^{-1}), dry matter yield (10.707 kg ha^{-1} and 13.424 kg ha^{-1}), and crude protein yield (1987 kg ha^{-1} and 2544 kg ha^{-1}) in full bloom in both years. In 2021, the highest crude protein and relative feed value and the lowest ADF and NDF ratios were obtained during early bloom and mid-bloom, while in 2022, the highest values for these characteristics were obtained only from early bloom stages. It was determined that the lowest phosphorus and potassium contents and the highest calcium and magnesium contents were obtained from the after bloom stage in both years. As a result, since the highest yield values and average quality values are obtained from the full bloom stage, it has been concluded that it was more advantageous for the producer to harvest the white clover at this stage.

Keywords: Harvest stage, Hay, Crude protein, Relative feed value, Macro elements

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Öz

Bu çalışma; ak üçgülün farklı hasat zamanlarındaki verim ve kalite özelliklerinin belirlenmesi amacıyla yürütülmüştür. Çalışma, 2021 ve 2022 yıllarında tesadüf blokları deneme desenine göre yürütülmüş ve çalışmada bitkisel materyal olarak ak üçgülün Rivendel çeşidi kullanılmıştır. Araştırma konusu olarak, ak üçgülün erken çiçeklenme, yarı çiçeklenme, tam çiçeklenme ve çiçeklenme sonrası olmak üzere dört farklı hasat zamanı ele alınmıştır. Araştırmada ak üçgülün sahip olduğu bitki boyu, yeşil ot verimi, kuru ot verimi, kuru madde oranı, ham protein oranı, ham protein verimi, asit deterjanda çözünmeyen lif (ADF) oranı, nötr deterjanda çözünmeyen lif (NDF) oranı, nispi yem değeri ile fosfor, potasyum, kalsiyum ve magnezyum oranları incelenmiştir. İncelenen bu özelliklerin tümünün ak üçgülün farklı hasat dönemlerinde gösterdiği farklılığın istatistiksel olarak önemli olduğu belirlenmiştir. Araştırmada ak üçgül, her iki yılda da en yüksek bitki boyuna (32.3 cm ve 27.8 cm), yeşil ot verimine (38.367 kg ha^{-1} ve 52.080 kg ha^{-1}), kuru ot verimine (10.707 kg ha^{-1} ve 13.424 kg ha^{-1}) ve ham protein verimine (1987 kg ha^{-1} ve 2544 kg ha^{-1}) tam çiçeklenme aşamasında ulaşmıştır. 2021 yılında en yüksek ham protein ve nispi yem değeri ile en düşük ADF ve NDF oranları erken çiçeklenme ve yarı çiçeklenme, 2022 yılında ise bu özelliklere ait en yüksek değerler ise sadece erken çiçeklenme aşamalarından elde edilmiştir. Her iki yılda da en düşük fosfor ve potasyum oranları ile en yüksek kalsiyum ve magnezyum oranlarının çiçeklenme sonrası aşamadan elde edildiği belirlenmiştir. Sonuç olarak en yüksek verim değerleri ile ortalama kalite değerleri tam çiçeklenme aşamasından elde edildiğinden, ak üçgülün bu aşamada hasat edilmesinin üretici açısından daha avantajlı olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Hasat dönemi, Kuru ot, Ham protein, Nispi yem değeri, Makro elementler

1. Introduction

Clover species, which are spread in the cool and humid regions of the temperate zone, produce very valuable and high-quality feed for animals because they have thin stems and abundant leaves (Onal Asci, 2016). White clover (*Trifolium repens* L.), which is among the clover species, is an important perennial legume forage plant with a wide distribution area, used for grazing, with very high nutritional value. White clover is highly resistant to grazing and chewing due to its horizontal development and stolon structure and has an indispensable place in forage crop production (Acikgoz, 2001; Acar and Ayan, 2012).

White clover (*Trifolium repens* L.) is a perennial forage legume plant commonly found in pastures, parks, and garden areas of our country (Demirkol and Yilmaz, 2018). At the same time, white clover is a species that can be used in the improvement of meadow and pastures (Röck Okuyucu and Okuyucu, 2006). Since the nutritive value of the white clover is high, the animals grazing in the pastures with the white and meadow clover can provide 40% more live weight gain than the animals grazing in the pastures where perennial grass is dominant (Kemp et al., 2010).

Forage crops can lose their nutritional value over time. In general, as the plant matures, there is a decrease in the protein content of the feed and the degree of digestion of the feed, while there is an increase in the NDF and ADF content. In other words, the quality of the feed decreases with the delay of the harvest time (Bayar and Cacan, 2019; Gursoy and Macit, 2020). Therefore, in order to obtain a quality roughage, it is necessary to determine the harvest time well and to know the quality characteristics of the plants in different developmental periods. In order to reveal the harvest time well, it is necessary to know the chemical composition of the forage crops as well as the yield obtained from the unit area. Because the periods when forage plants give quality forage are not likely to be the periods when they have the highest yield (Karayilanli and Ayhan, 2016). For this reason, it is necessary to know the period when forage crops are at the highest yield and highest quality and to harvest during this period.

The previous studies demonstrated that the effect of harvest time on the yield and quality of legume forage crops is important. In the study, in which the chemical structures of 11 *Astragalus* species were examined at different maturity stages, it was determined that the crude protein ratio decreased and the ratios of ADF and NDF increased from the pre-flowering to the fruit formation period (Cacan et al., 2017). In the study of determining the effect of harvest time on chemical composition of some leguminous plants, the chemical structure of white clover in vegetative, flowering and seed stages was investigated and it was determined that the crude protein ratio, which was 14.76% in the vegetative period, decreased to 12.13 % at the seed stage, the NDF ratio increased from 40.29% to 46.85%, and the ADF ratio increased from 32.45% to 44.01% (Ozkan et al., 2018). Bayar and Cacan (2019) determined that Hungarian vetch (*Vicia pannonica* Crantz.) harvested at different times had ideal values in terms of crude protein, ADF and NDF ratios during the flowering stage, and there was a decrease in grass yield and quality with the formation of pods in Hungarian vetch.

It was determined by previous studies that crude protein ratio, digestible dry matter ratio and relative feed value decreased, green forage and dry matter yield and ADF and NDF ratio increased in forage crops depending on the progress of the harvest time. However, the number of studies revealing the yield and quality characteristics of white clover in different harvest time is quite low. For this reason, the aim of this study is to reveal the yield and quality characteristics of white clover in different harvest time, and as a result, to determine the ideal harvest time.

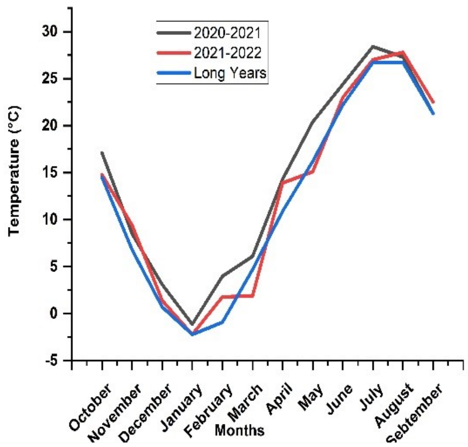
2. Materials and Methods

2.1. Research area and plant material

The research was conducted at Bingöl University Agricultural Application and Research Center between 2020-2022. This area is 15 km away from the city center of Bingöl (Türkiye), located at the coordinates of 38° 32' 41.85" N and 40° 32' 25.58" E and its height above sea level is 1080 m. Rivendel variety of white clover (*Trifolium repens* L.) was used as plant material in the research.

2.2. Climatic characteristics of the research area

In the province of Bingöl, where the research was conducted, the annual average temperature value for many years is 12.3 °C. The average temperature was recorded as 14.5 °C in the years 2020-2021, when the research was conducted, and 13.0 °C in the years 2021-2022. The average annual total precipitation of Bingöl province for many years is 932 mm. The most precipitation is received during the winter months. The average precipitation amount was recorded as 519 mm in the years 2020-2021, in which the research was conducted, and 960 mm in the years 2021-2022. It has been determined that the years 2020-2021 and 2021-2022 are warmer than the long-term average and the year 2020-2021 receives less precipitation than the long-term average (*Figure 1*).



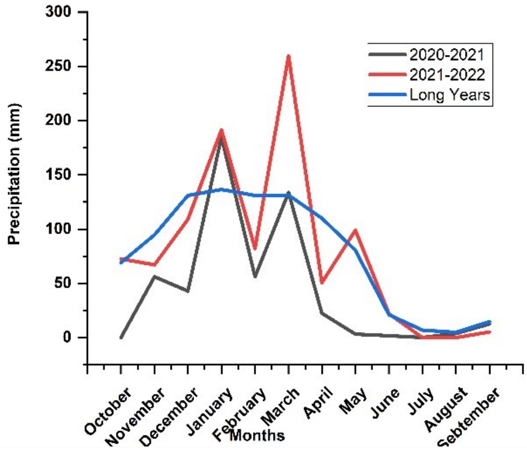


Figure 1. Average temperature and precipitation values for the periods in which the research was conducted

2.3. Soil characteristics of the research area

According to the results of the soil analysis made at the Faculty of Agriculture of Bingöl University; it has been seen that the research area was clay-loam, slightly acidic (pH: 6.26) and calcareous (0.41%), unsalted (0.014%), the amount of organic matter (1.09%) and potassium (18.27 kg da^{-1}) was low and phosphorus (7.60 kg da^{-1}) was medium.

2.4. Methods

The yield and quality characteristics of the hay cut at different harvest time of the white clover were evaluated in this study. For this purpose, the experiment was established on 02 June 2020 according to the randomized blocks design with four replications. In the experiment, 2.5 kg of seeds were used per decare (Marshall et al., 2004) and sowing was done by hand to a depth of 1-2 cm. With sowing, 4 kg of N and 10 kg of P_2O_5 (9 kg da^{-1} DAP) were given (Basbag et al., 2007). Row spacing was set at 40 cm and row length at 20 m in the field experiment. The field experiment was carried out in an area of 20 m x 20 m = 400 m^2. The field experiment was conducted under irrigated conditions and no fertilization was applied except for the fertilization given with sowing. The year 2020 was accepted as the establishment year and no observation or result has been taken. On April 30, 2021, the first flowers began to appear in the trial area. In 2021 and 2022, white clover was harvested twice a year in early bloom, mid bloom, full bloom and after bloom stages. Harvesting was done on the dates and periods given in *Table 1* in 2021 and 2022.

Table 1. Harvest dates of white clover for 2021 and 2022

	2021 Harvest dates		**2022 Harvest dates**	
	1. Harvest	**2. Harvest**	**1. Harvest**	**2. Harvest**
Early Bloom	11.05.2021	09.08.2021	12.05.2022	01.08.2022
Mid Bloom	01.06.2021	19.08.2021	30.05.2022	15.08.2022
Full Bloom	25.06.2021	09.09.2021	16.06.2022	05.09.2022
After Bloom	08.07.2021	23.09.2021	30.06.2022	19.09.2022

The observations in the experiment were made on an area of 1 m^2 determined in the parcels in four replications. Plant height was measured in cm, with 10 plants per replication (Basbag et al., 2007). 1 m^2 area was harvested and the green forage obtained from this area was weighed and green forage yield was obtained. 500 g samples were taken from the green forage obtained from this area and dried at 70 °C for 48 hours. Dry matter yield was calculated by multiplying the results obtained with the green forage yield (Cacan et al., 2018).

Hay samples belonging to the plots whose dry matter content was determined were grinded separately for each plot and made ready for analysis. Crude protein (CP), insoluble fiber in acid detergent (ADF), insoluble fiber in neutral detergent (NDF), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) ratios of ground samples by Near Infrared Reflectance Spectroscopy (NIRS) instrument with #IC-0904FE calibration have determined (Brogna et al., 2009). Relative feed value determined with the help of the formula (Eq. 1);

$RFV = ((120/NDF) \times (88.9 - (0.779 \times ADF)) \div 1.29))$ (Van Dyke and Anderson, 2000) (Eq. 1)

Two harvests were made in both years of the study. The research data were obtained by taking the average of two harvests in each year. Analysis of variance was applied to the obtained data according to the randomized blocks experimental design with JPM statistical program. The differences of the means were compared with the LSD test at the 0.05 level (Acikgoz and Acikgoz, 2001).

3. Results and Discussion

White clover planting was done on 02 June 2020. Since the first year is the establishment year, a harvest was made and no observations were taken. In 2021 and 2022, two harvests were taken in the ecological conditions of the region. In a previous study, it was reported that two harvests of white clover were obtained after the first year in Adana and Hatay provinces (Tukel et al., 2001). Yield and quality characteristics and macro element contents obtained from white clover in 2021, 2022 and two-year average were given in *Table 2*. The green forage and dry matter yields given in *Table 2* were given as the sum of the two cutting made during the year, and the other characteristics were given as the average of the two cutting made during the year.

3.1. Yield characteristics

Yield characteristics obtained from white clover in 2021, 2022 and two-year average were given in *Table 2* and *Figure 2*. It was observed that the difference in plant height, green forage and dry matter yields from the yield characteristics examined in different development periods of white clover in 2021, 2022 and two-year average were statistically significant. Additionally, the differences between years for yield characteristics, and the interaction between year x bloom in terms of green forage and dry matter yields were statistically significant ($P \leq 0.01$).

The lowest values of plant height in white clover were taken from early and mid-bloom periods in 2021, 2022 and two-year average, and the highest plant height was taken from full bloom and after bloom periods. The average plant height of white clover was 27.6 cm in 2021, 23.3 cm in 2022 and 25.5 cm in two-year average, as the average of all developmental stages. From the perspective of two years, it was seen that the white clover elongates a little in the early and mid-bloom periods and reaches the highest plant height in the full bloom period. At the after-bloom stage, it was observed that the plant height decreased due to the plant's water loss, but this decrease was not statistically significant (*Table 2, Figure 2*).

Plant height of white clover in Türkiye was 26.32 cm in average in the ecological conditions of the Eastern Anatolia Region (Aygun and Olgun, 2014), 25-40 cm in ecological conditions of the Black Sea Region (Samsun province) (Basaran et al., 2006), 9.88-14.56 cm in the ecological conditions of the Southeastern Anatolia Region (Basbag et al., 2007) and 18.0-31.0 cm in the ecological conditions of the Mediterranean Region (Antalya province) (Demiroglu and Avcioglu, 2010; Oten et al., 2019). It was seen that the plant height obtained from the white clover was similar to the average plant height obtained from the Eastern Anatolia, Black Sea, and Mediterranean Regions, but higher than the average plant height obtained from the Southeastern Anatolia Region. The probable reason for this height is that the Eastern Anatolia Region receives more precipitation than the Southeastern Anatolia Region. The fact that the region receives more precipitation has led to higher plant height, which is one of the yield elements.

It was seen that the green forage and dry matter yields start to increase after the early bloom period in 2021, 2022 and two-year average, reach the highest level in the full bloom period, and both the green forage yield and the dry matter yield decrease rapidly in the after-bloom stage. It was seen that the difference between full bloom and after bloom stage of green forage yield obtained only in 2021 was statistically in the same group. As the average of the development stages of white clover, the green forage yield was 26.008 kg ha^{-1} in 2021, 38.057 kg ha^{-1} in 2022 and 32.032 kg ha^{-1} in two-year average. Additionally, the dry matter yield was 6.585 kg ha^{-1} in 2021, 9.296 kg ha^{-1} in 2022 and 7.940 kg ha^{-1} in two-year average (*Table 2, Figure 2*).

Table 2. Yield and quality characteristics of white clover at different harvest time

	Year 2021	Early Bloom	Mid Bloom	Full Bloom	After Bloom	Average
Yield	Plant height, cm	23.4 b**	23.5 b	32.3 a	31.1 a	27.6
	Green forage yield, kg ha^{-1}	13.013 b**	15.960 b	38.367 a	36.693 a	26.008
	Dry matter yield, kg ha^{-1}	3.064 b**	4.622 b	10.707 a	7.946 a	6.585
Quality	Dry matter, %	89.5 c**	89.8 b	89.8 b	90.1 a	89.8
	Crude protein, %	21.4 a*	20.0 ab	18.6 bc	17.4 c	19.4
	Crude protein yield, kg ha^{-1}	657 c**	924 bc	1987 a	1385 b	1238
	ADF, %	21.3 c**	21.0 c	26.5 b	28.2 a	24.3
	NDF, %	29.7 b**	28.8 b	34.5 a	35.8 a	32.2
	RFV	227 a**	235 a	184 b	174 b	205
	Phosphorus, %	0.34 a*	0.31 ab	0.31 ab	0.29 b	0.31
	Potassium, %	2.25 a**	2.12 a	2.07 a	1.59 b	2.01
	Calcium, %	1.81 c**	1.92 b	1.92 b	2.05 a	1.93
	Magnesium, %	0.39 c**	0.40 c	0.42 b	0.47 a	0.42
	Year 2022	**Early Bloom**	**Mid Bloom**	**Full Bloom**	**After Bloom**	**Average**
Yield	Plant height, cm	19.3 b**	20.1 b	27.8 a	26.0 a	23.3
	Green forage yield, kg ha^{-1}	35.880 c**	40.293 b	52.080 a	23.973 d	38.057
	Dry matter yield, kg ha^{-1}	7.143 c**	9.743 b	13.424 a	6.873 c	9.296
Quality	Dry matter, %	89.0 c**	89.3 b	89.3 b	89.5 a	89.3
	Crude protein, %	23.8 a**	21.8 b	19.0 c	18.3 c	20.7
	Crude protein yield, kg ha^{-1}	1702 c**	2121 b	2544 a	1259 d	1906
	ADF, %	17.6 c**	20.9 b	23.2 a	24.6 a	21.6
	NDF, %	26.5 c**	30.0 b	31.5 a	32.1 a	30.0
	RFV	264 a**	226 b	209 c	202 c	225
	Phosphorus, %	0.36 a**	0.32 b	0.30 c	0.30 c	0.32
	Potassium, %	2.39 a**	2.22 ab	2.05 b	1.68 c	2.09
	Calcium, %	1.85 c**	1.93 b	1.91 bc	2.06 a	1.94
	Magnesium, %	0.38 b**	0.38 b	0.40 b	0.45 a	0.40
	Two-Year Average	**Early Bloom**	**Mid Bloom**	**Full Bloom**	**After Bloom**	**Average**
Yield	Plant height, cm	21.4 c**	21.8 c	30.1 a	28.6 b	25.5
	Green forage yield, kg ha^{-1}	24.447 b**	28.127 b	45.223 a	30.333 b	32.032
	Dry matter yield, kg ha^{-1}	5.104 c**	7.182 b	12.065 a	7.409 b	7.940
Quality	Dry matter, %	89.3 c**	89.6 b	89.6 b	89.8 a	89.5
	Crude protein, %	22.6 a**	20.9 b	18.8 c	17.9 c	20.0
	Crude protein yield, kg ha^{-1}	1180 b**	1522 b	2265 a	1322 b	1572
	ADF, %	19.4 c**	20.9 c	24.9 b	26.4 a	22.9
	NDF, %	28.1 b**	29.4 b	33.0 a	33.9 a	31.1
	RFV	245 a**	230 b	197 c	188 c	215
	Phosphorus, %	0.35 a**	0.32 b	0.30 bc	0.30 c	0.32
	Potassium, %	2.32 a**	2.17 ab	2.06 b	1.64 c	2.05
	Calcium, %	1.83 c**	1.92 b	1.91 b	2.05 a	1.93
	Magnesium, %	0.39 c**	0.39 c	0.41 b	0.46 a	0.41

*: P≤0.05, **: P≤0.01, LSD (Years): **, LSD (Bloom): **, LSD (Years x Bloom): **

Year x bloom interaction was found significant only for green forage and dry matter yields. In terms of interactions, the highest green forage and dry matter yields were obtained from the full bloom period of 2022, while the lowest values were obtained from the early bloom period of 2021.

The green forage yield (26.008 kg ha^{-1}) obtained in 2021 increased by 46% to 38.057 kg ha^{-1} in 2022, and the dry matter yield (6.585 kg ha^{-1}) obtained in 2021 increased by approximately 41% in 2022 to 9.296 kg ha^{-1} (*Figure 2*). Perennial legume forage crops show poor growth in the first year. Therefore, the first year is considered the plant year and is not evaluated in terms of yield or quality. Perennial legume forage crops start to show their main yield after the second year and give higher yields in the following years (Acar and Onal Asci, 2006). There is a similar situation in this study. This year of the white clover, which was sowing in 2020, was accepted as the year of establishment and no observations were taken. In 2021, the first observations began to be taken. Due to its nature, higher values were obtained in 2022 from white clover, which is a legume forage plant.

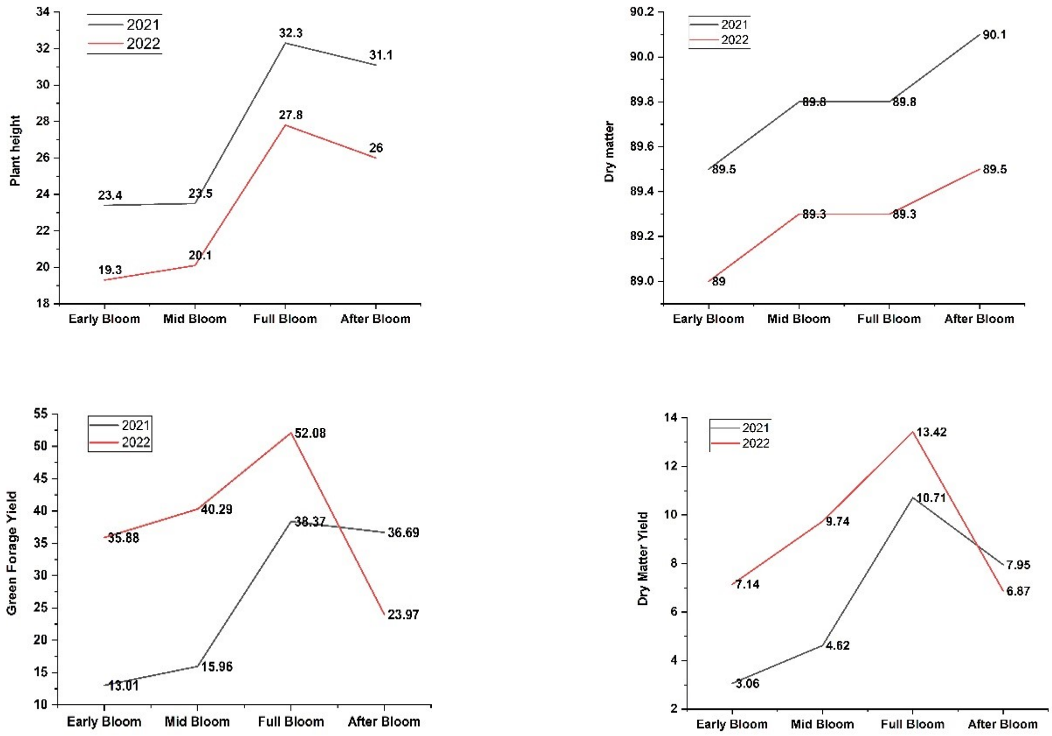


Figure 2. Changes in plant height, green forage yield, dry matter yield and dry matter ratios of white clover in 2021 and 2022

When the studies on green forage and dry matter yields in white clover were examined; under Mediterranean and Southeastern Anatolia Region conditions (Adana, Hatay and Şanlıurfa), green forage yield 993-4159 kg ha^{-1}, dry matter yield 150-696 kg ha^{-1} (Tukel et al., 2001), in Black Sea Region (Samsun province) ecological conditions green forage yield 1784 kg ha^{-1} and dry matter yield 432 kg ha^{-1} (Acar and Onal Asci, 2006), in Southeastern Anatolia Region conditions (Diyarbakır province) green forage yield 17713-28490 kg ha^{-1} and dry matter yield 4501-7574 kg ha^{-1} (Basbag et al., 2007), in Mediterranean Region climate conditions green forage yield 1061-1735 kg ha^{-1} and dry matter yield 204-343 kg ha^{-1} were reported (Demiroglu and Avcioglu, 2010). In a similar study, it was reported that in the experiment conducted in the Black Sea region, two harvests were taken and the dry matter yield of white clover was 549 kg ha^{-1} in the first year and 463 kg ha^{-1} in the second year (Can and Ayan, 2020). In a three-year study conducted in England (Marshall et al., 2003), the dry matter yield of *Trifolum repens* was determined as 4556-5928 kg ha^{-1}. It was seen that the green forage and dry matter yields obtained from this study showed partial similarities with the previous studies.

3.2. Quality characteristics

The quality characteristics (dry matter, crude protein, crude protein yield, ADF, NDF and relative feed value) of white clover determined in 2021, 2022 and two-year average were given in Table 2 and Figure 3. It was seen that the difference between dry matter, crude protein, crude protein yield, NDF, ADF ratios and relative feed value from the properties of white clover examined in different development periods is statistically significant in 2021, 2022 and two-year average. Additionally, the differences between years for quality characteristics, and the interaction between year x bloom in terms of crude protein yield, NDF, ADF and relative feed value were statistically significant (P≤0.01).

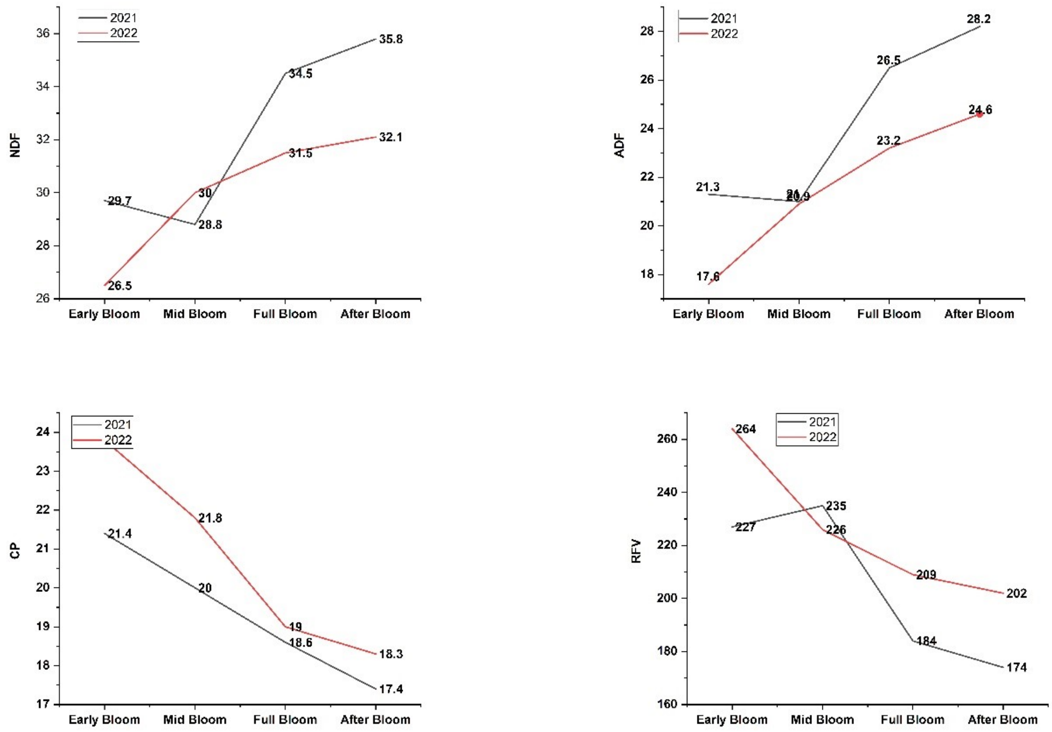


Figure 3. Changes in NDF, ADF and CP ratios and relative feed value of white clover in 2021 and 2022

Dry matter is dehydrated feed. It is obtained by subtracting the moisture content from 100 and its average value in feeds varies between 85-92% (Rivera and Parish, 2010). It was seen that the dry matter ratio increased continuously from early bloom to after bloom in both years and reached its highest values after bloom. As the average of the development stages of white clover, the dry matter ratio was 89.8% in 2021, 89.3% in 2022 and 89.5% in two-year average. It was seen that the dry matter ratio increased after early bloom in white clover, did not change in half and full bloom periods, and increased again after bloom. The dry matter ratio is related to the water loss of the white clover. It was found out that as the plant matures, the amount of water it contains decreases (*Table 2, Figure 2*). Similar to the study findings Demirel et al. (2010) reported that dry matter rate of white clover is 92.58%. Kurt et al. (2022) observed that dry matter ratio in white clover is 91.8%. Also, Ozkan et al. (2018), reported that the dry matter ratio increased from the vegetative period (92.96%) to the seed stage (94.01%) in white clover.

In 2021, 2022 and two-year average, it was observed that the white clover has the highest crude protein ratio in the early bloom period, the crude protein ratio decreases in the mid-bloom stage and has the lowest crude protein ratio in the full bloom and after bloom. As the average of the developmental stages of white clover, the crude protein ratio was 19.4% in 2021, 20.7% in 2022 and 20.0% in two-year average. It is understood that as the plant matures, the crude protein content decreases regularly. The highest crude protein yield was obtained from the full bloom stage in both years and two-year average. The average crude protein yield from white clover was 1238 kg ha^{-1} in 2021, 1906 kg ha^{-1} in 2022 and 1572 kg ha^{-1} in two-year average (*Table 2, Figure 3*). Year x bloom interaction was found significant for crude protein yield. The highest crude protein yield was obtained from the full bloom period of 2022, while the lowest value was obtained from the early bloom period of 2021.

Similar to the findings of the study, the crude protein ratio in white clover; Marshall et al. (2004) 16.9-23.6% in England, Acar and Onal Asci (2006) %20.38 in the Black Sea region, Basaran et al. (2006) %18.93, Basbag et al. (2007) %16.52-19.00 and Basbag et al. (2011) %19.41 in the conditions of the Southeastern Anatolia Region, Ergon et al. (2016) %16.3-22.6 in Norway and Kurt et al. (2022) %17.9 in the conditions of the Eastern Anatolia Region have been detected. These findings obtained by the researchers are similar to the findings of the current study. Also, in a previous study, it was determined that the crude protein ratio in white clover decreased regularly from the vegetative period to the seed stage (Ozkan et al., 2018).

The lowest NDF and ADF contents in white clover were taken from early bloom and mid bloom in both years and two-year average, and the highest NDF and ADF contents were from full bloom and after-bloom stages. In general, it was found out that NDF and ADF contents increase as the plant matures. As the average of the developmental stages of white clover, the NDF content was 32.2% in 2021, 30.0% in 2022, %31.1 in two-year average and the ADF content was 24.3% in 2021, 21.6% in 2022 and 22.9% in two-year average (*Table 2, Figure 3*). Year x bloom interaction was found significant for NDF and ADF contents. The highest NDF and ADF contents were obtained from the full and after bloom period of 2021, while the lowest values were obtained from the early bloom period of 2021.

In the white clover; in Southeastern Anatolia Region conditions, ADF rate 24.71%, NDF rate 35.0% (Basbag et al., 2011), in the conditions of the Eastern Anatolia Region, the ADF rate 28.08% and the NDF rate 43.62% (Cacan et al., 2015), in a study conducted in Norway, NDF rate 36.9-43.8%, ADF rate 26.9-29.3% (Ergon et al., 2016), in Black Sea conditions, ADF content 23.8%-26.4%, NDF content 33.2%-37.6% (Can and Ayan, 2020), in the conditions of the Eastern Anatolia Region, the ADF rate 24.7% and the NDF rate 36.7% (Kurt et al., 2022) was determined. It was observed that the NDF and ADF ratios obtained in white clover are partially similar to the findings of other studies.

Relative feed value is a parameter that describes the response of animals to feed quality. Relative feed value provides an estimate of the expected feed intake and energy value from a feed. Relative feed value is calculated based on the ADF and NDF ratio of alfalfa in full bloom and a value above 151 is considered “prime” (Rivera and Parish, 2010). The highest relative forage value in white clover was obtained from early bloom and mid-bloom stages in 2021, and only from early bloom stage in 2022 and two-year average. It was observed that higher relative feed value was obtained from the early stages of white clover, the relative feed value decreased as the plant matured, and the lowest values were obtained after bloom. It was determined that the relative feed values obtained even in the after-bloom stage, where the lowest values were obtained, were above 151 and included in the "prime" group. As the average of the development stages of the white clover, the relative feed value was obtained as 205 in 2021, 225 in 2022 and 2015 two-year average (*Table 2, Figure 3*). Year x bloom interaction was found significant for relative feed value. The highest relative feed value was obtained from the early bloom period of 2022, while the lowest value was obtained from the after bloom period of 2021.

Can and Ayan (2020) determined the relative feed value in white clover in the range of 153-211. Kurt et al. (2022), reported that white clover has a higher value in terms of digestibility and relative feed value than other leguminous forage plants, and that they have determined the relative feed value as 176. These values obtained from the white clover were found close to the findings obtained from the study. The relative feed value obtained as 142 by Bozkurt Kiraz (2011) and as 143 by Cacan et al. (2015) was found to be lower than the finding obtained from the experiment.

The macro element contents obtained from white clover in 2021, 2022 and two-year average were given in *Table 2* and *Figure 4*. It is seen that the difference between phosphorus, potassium, calcium and magnesium contents of macro elements examined at different developmental levels of white clover was statistically significant in 2021, 2022 and two-year average. It was observed that only the difference in Mg content was statistically significant in terms of years. Year x bloom interaction was found insignificant for all macro elements.

In white clover, the highest phosphorus and potassium contents and the lowest calcium and magnesium contents were obtained from the early, mid and full bloom stages, and the highest calcium and magnesium contents and the lowest phosphorus and potassium contents were obtained from the after-bloom stage in 2021. In 2021, the average of the developmental stages of the white clover was phosphorus 0.31%, the potassium was 2.01%, the calcium was 1.93%, and the magnesium was 0.42% (*Table 2*). In white clover, in 2022, the highest phosphorus ratio was obtained from early bloom, the highest potassium was obtained from early and mid-bloom, and the highest calcium and magnesium contents were obtained from the after-bloom stages. The lowest phosphorus was obtained from full and after bloom, the lowest potassium was obtained after bloom, the lowest calcium was obtained from early bloom and the lowest magnesium was obtained from early, mid, and full bloom stages. In 2022, the average of the developmental stages of white clover was phosphorus of 0.32%, potassium of 2.09%, calcium of 1.94% and magnesium of 0.40%. In the two-year average, the highest phosphorus and potassium contents were obtained from early bloom stages and highest calcium and magnesium contents were obtained from the after bloom stages. In the two-year average, the average of the developmental stages of white clover was phosphorus of 0.32%, potassium of 2.05%, calcium of 1.93% and magnesium of 0.41% (*Table 2*). In both years, it was observed that the phosphorus and potassium contents of white clover tend to decrease as the plant matures, while the calcium and magnesium contents tend to increase with the maturation of the plant (*Figure 4*).

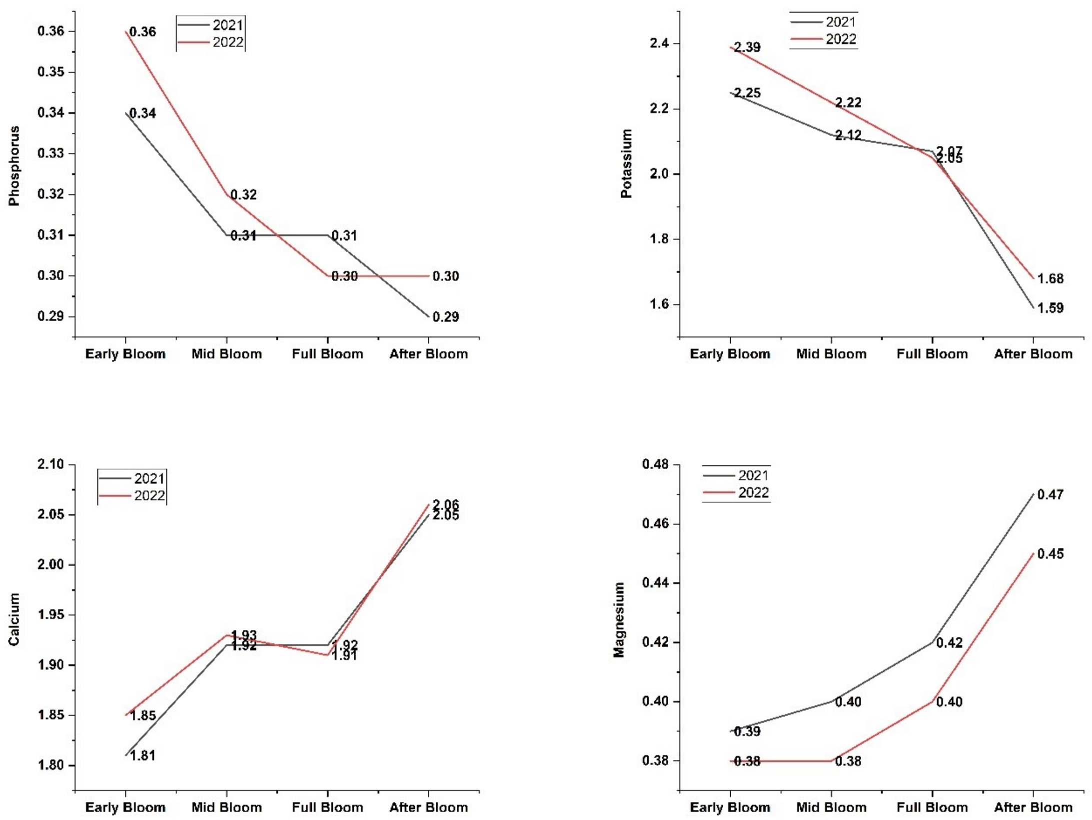


Figure 4. Changes in P, K, Ca and Mg content of white clover in 2021 and 2022

It was observed that the research findings were similar to the contents of phosphorus (0.41%), potassium (2.70%), calcium (1.48%) and magnesium (0.31%) obtained from white clover in the Southeastern Anatolia Region conditions (Basbag et al., 2011), the ratios of phosphorus (0.63%), calcium (1.34%) and magnesium (0.29%) obtained from white clover in the conditions of the Eastern Anatolia Region (Cacan et al., 2015), the ratios of phosphorus (0.38-0.41%), potassium (2.44-2.86%), calcium (1.57-1.58%) and magnesium (0.29-0.30%) obtained from alfalfa in the conditions of the Middle Anatolia Region (Engin and Mut, 2018) and the ratios of phosphorus (0.27%), potassium (1.49%), calcium (1.63%) and magnesium (0.36%) obtained from Astragalus taxa in the conditions of Eastern Anatolia Region (Çaçan et al., 2023).

The contents of P, K, Ca and Mg obtained from white clover were found to be in line with the optimal ratios of 0.2-0.5% for phosphorus, 1.0-5.0% for potassium and 0.1-0.4% for magnesium, reported by Motsara and Roy (2008). However, the calcium contents obtained from white clover in 2021, 2022 and two-year average were found to be higher than the 0.1-1.0% calcium content reported as the optimal ratio reported by Motsara and Roy (2008). In terms of the health of animals, there must be a balance between the minerals in the feed. In this study, the high Ca ratio causes an imbalance between Ca:P. In general, a 2:1 ratio of Ca:P in feeds is ideal and its excess causes milk fever in animals (Acikgoz, 2001). However, if the animals receive enough vitamin D, this ratio can be tolerated up to 7:1 (Barnes et al., 1990; Buxton and Fales, 1994). In this respect, the Ca:P ratio obtained was found to be tolerable.

4. Conclusions

This study investigated the effect of different harvest time of white clover on yield and quality, as the average of two years, it was observed that the highest values in terms of yield were taken from the full bloom stage. The highest crude protein, relative feed value, phosphorus and potassium ratios and the lowest dry matter, NDF and ADF contents were obtained from the early bloom period. Although the early bloom stage gave higher values in terms of these characteristics, it is clear that up to 70% yield loss will occur in the harvest made at this stage. However, it was found out that even in a harvest to be made at the full bloom stage, white clover will be in the "prime" group in terms of relative feed value and the highest values will be obtained in terms of yield. For this reason, it was concluded that it would be more advantageous to harvest at the stage of full bloom, which has the highest yield and can be considered ideal in terms of quality.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Cacan, E., Ozdemir, S., Kokten, K., Ucar, R., Mokhtarzadeh, S., Ekmekci, M., Kutlu, M. A.; Design: Cacan, E., Ozdemir, S., Kokten, K., Ucar, R., Mokhtarzadeh, S., Ekmekci, M., Kutlu, M. A.; Data Collection or Processing: Ozdemir, S., Ucar, R., Ekmekci, M.; Statistical Analyses: Cacan, E., Kokten, K.; Literature Search: Mokhtarzadeh, S., Kutlu, M. A.; Writing, Review and Editing: Cacan, E., Ozdemir, S., Kokten, K., Ucar, R., Mokhtarzadeh, S., Ekmekci, M., Kutlu, M. A.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

İklim Değişikliğine Karşı Tarım İşletmelerinin Geçim Kaynakları Etkilenebilirliğinin Sermaye Unsurları Açısından Değerlendirilmesi: Türkiye'de Üzüm Üreticileri Örneği

Assessing the Livelihood Effect of Agricultural Enterprises to Climate Change in Terms of Assets: The Case of Grape Producers in Turkey

Betül BAHADIR[1*], Şener UYSAL[2]

Öz

Türkiye'de iklim değişikliğinin olumsuz etkilerinden, tarımın diğer üretim biçimlerinde olduğu gibi, üzüm yetiştiriciliği de doğrudan etkilenmektedir. Türkiye'de 4,2 milyon ton üzüm üretimi ile bağcılık Türkiye ekonomisi için önem arz etmektedir. Ancak Türkiye'de bağcılık sektörü, üreticilerin geçim kaynaklarını tehdit eden kuraklık da dahil olmak üzere iklim kaynaklı risklerle karşı karşıyadır. Bununla birlikte, üreticilerin hanehalkı geçim kaynaklarının iklim değişikliği karşısında ne düzeyde kırılgan (savunmasız) olduğu ve bu kırılganlığın bölgeler arasında ne düzeyde farklılaştığı konusunda bilgi eksikliği vardır. Bu çalışma ile bu boşluğun doldurulması amaçlanmıştır. Türkiye'de gerek genel olarak tarım işletmelerinin gerekse üzüm üreticileri özelinde iklim değişikliğine karşı geçim kaynakları kırılganlığını ölçmeye yönelik yapılmış çalışmaya rastlanılmamış olması çalışmayı özgün kılmaktadır. Çalışmanın birincil verileri, Türkiye'nin önemli üzüm üreticisi 6 bölgedeki 8 ilde 35 ilçede üretim yapan 466 üzüm üreticisi ile yüz yüze görüşülerek anket formları aracılığıyla toplanmıştır. Geçim kaynakları kırılganlıklarının hesaplanmasında LEI (Livelihood Effect Index) indekslerinden faydalanılmıştır. LEI indeksinin hesaplanmasında işletmelerin sahip oldukları sermaye unsurları insan sermayesi, sosyal sermaye, doğal sermaye, finansal sermaye ve fiziksel sermaye unsurları açısından ayrı başlıklar altında değerlendirilmiştir. Bununla birlikte işletmelerin iklim değişliğine maruziyet düzeyleri de değerlendirilmiştir. Çalışma sonucunda, işletmelerin karşılaştıkları iklim olayları arasında en fazla aşırı kuraklık (2.25) ve sıcaklık artışları (2.01) orta düzeyin üzerinde gerçekleşirken, yağmur sezonunda gecikme (1.94), don olayları (1.77) ve yağmur sezonunda kısalma (1.70) ve dolu olayları (1.68) işletmelerin karşılaştıkları diğer iklim olayları arasında yer aldığı görülmüştür. Bununla birlikte, üzüm üreticilerinin iklim değişikliğine karşı geçim kaynakları kırılganlığı (LEI) değeri 0.44 olarak hesaplanmış ve bu sonuç üreticilerin iklim değişikliği gibi şoklar karşısında geçim kaynaklarının orta düzeyde bir etkilenebilirliğe sahip olduğunu göstermektedir. İşletmelerin iklim değişikliği gibi afetler karşısında en fazla kırılgan sermaye unsurunu fiziksel sermayeleri oluşturduğu görülmüştür (0.790). İşletmelerin sahip oldukları finansal sermaye (0.582) ve doğal sermaye unsurları (0.436) ise geçim kaynakları etkilenebilirlik düzeyi üzerinde orta düzeyde etkilemektedir. Geçim kaynakları kırılganlığı fazla olan Malatya (0.495), Adıyaman (0.490) ve Elazığ (0.475) illerinde uyum düzeylerini artırıcı faaliyetlere ihtiyaç vardır. Çalışmadan elde edilen sonuçlar ile tarım sektöründe bölgesel farklılıklar dikkate alınarak iklim değişikliğinin yaratmış olduğu farklı boyutlardaki maruziyetler ve işletme yapılarının farklı hassasiyet düzeyleri göz önüne alınarak işletmelerde hangi alanların güçlendirilmesi gerektiği konusunda ilgili paydaşlara ve politika yapıcılara uyum stratejilerinin geliştirilmesinde yol gösterici olacağı düşünülmektedir.

Anahtar kelimeler: Bağcılık, İklim değişikliği, Sürdürülebilir geçim kaynakları, Uyum kapasitesi, Kırılganlık

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Abstract

In Turkey, grape cultivation is directly affected by the adverse effects of climate change. Viticulture has an important for the Turkish economy with a production of approximately 4.2 million tons. However, the viticulture sector is facing climate-related risks, including drought, which threaten the livelihoods' producers. Additionally, there is a lack of information regarding the extent to which livelihoods 'producers, both in general agricultural enterprises and specifically grape producers, are vulnerable to climate change and how this vulnerability varies among regions. This study aims to fill this gap. There has been no prior study that measures livelihood vulnerability to climate change in Turkey, neither in general for agricultural enterprises nor specifically for grape producers. The primary data for this study were collected through face-to-face interviews with 466 grape producers who operate in 35 districts of 8 provinces, which are among the major grape producers in 6 regions of Turkey. The Livelihood Effect Index (LEI) was used to calculate livelihood vulnerability. In the calculation of the LEI index, the capital elements possessed by enterprises were evaluated under separate headings, such as human capital, social capital, natural capital, financial capital, and physical capital. In addition, the exposure levels of enterprises to climate change were also assessed. As a result of the study, among the climate events faced by enterprises, extreme drought (2.25) and temperature increases (2.01) were found to be above the moderate level, while other climate events faced by enterprises included delayed rainfall season (1.94), frost events (1.77), shortened rainfall season (1.70), and hail events (1.68). Additionally, the Livelihood Effect Index (LEI) value for grape producers was calculated as 0.44, indicating that producers have a moderate susceptibility to the effects of shocks such as climate change on their livelihoods. It was observed that physical capital element constituted the most vulnerable capital element (0.790) for enterprises when faced with disasters such as climate change. Financial capital (0.582) and natural capital (0.436) had a moderate impact on the vulnerability of livelihoods. In provinces with higher livelihood vulnerability, such as Malatya (0.495), Adıyaman (0.490), and Elazığ (0.475), there is a need for activities to increase adaptation levels. The results may guide relevant stakeholders and policymakers in developing adaptation strategies, considering the different sensitivity levels of enterprise structures and the varying dimensions of exposure of climate change.

Keywords: Viticulture, Climate change, Sustainable livelihoods, Adaptation capacity, Vulnerability

1. Giriş

Küresel düzeyde en büyük çevresel tehditlerden biri haline gelen iklim değişikliği, dünya genelindeki sıcaklık, yağış düzeni, deniz seviyeleri ve ekstrem hava olayları gibi iklim parametrelerindeki uzun süreli değişiklikleri ifade etmektedir. Sanayileşmeyle birlikte artan sera gazı emisyonlarının ortalama sıcaklığın artmasına neden olarak, 1850-2020 arasında sıcaklığın yaklaşık 1.3℃ yükseldiği bildirilmektedir. Bununla birlikte, sera gazı emisyonlarının 1980 yılından bu yana çok daha hızlı bir şekilde artmıştır (IPCC, 2022).

Bu durum tarım, su kaynakları, ekosistemler, insan sağlığı ve ekonomik faaliyetler gibi birçok alanda ciddi etkilere neden olmaktadır. Bununla birlikte, kuraklık, sel, deniz seviyesinin yükselmesi, bitki hastalıkları ve ekstrem hava olayları gibi sonuçlar tarımsal verimlilik, su kaynakları, doğal yaşam ve sosyo-ekonomik dengeler açısından büyük tehditler oluşturmaktadır.

Türkiye'nin içinde bulunduğu Akdeniz kuşağı iklim değişikliğinden en fazla etkilenen ve giderek daha fazla etkileneceği düşünülen bölgeler arasında yer almaktadır. IPCC (2022) raporuna göre, başta Türkiye olmak üzere Balkanlar, İber Yarımadası ve Kuzey Afrika'nın ısınma oranlarının küresel yıllık ısınma oranlarına kıyasla %40 ile %50 arasında daha yüksek değerlere ulaşacağı tahmin edilmektedir (IPCC, 2022). Türkiye özelinde değerlendirildiğinde ise, IPCC'nin belirlediği dünya genelinde sıcaklıkların 1.5℃, 2℃, 3℃ ve 4℃ artacağı dört farklı senaryonun her biri için Türkiye'yi daha zorlu koşulların beklediği anlaşılmaktadır.

Türkiye'de uzun dönem mevsimlik ortalama hava sıcaklıklarındaki değişimlerin incelenmesi sonucunda ilkbahar ortalama hava sıcaklıklarının Türkiye'nin büyük bir kesiminde artış gösterdiği ve Marmara, Ege, Akdeniz, İç Anadolu, Güneydoğu Anadolu bölgelerinde gerçekleşen ısınmanın istatistiksel olarak anlamlı olduğu tespit edilmiştir (Türkeş, 2019). Elde edilen bu sonuçlar bölgesel iklim değişikliğinin giderek arttığını göstermektedir. Türkiye yağışlarındaki uzun dönem değişiklikler değerlendirildiğinde ise kış döneminde Ege, Akdeniz ve Güneydoğu Anadolu bölgelerinde gerçekleşen kuraklaşmanın istatistiki açıdan önemli olduğu saptanmış, Akdeniz Bölgesi'nde ise yıllık toplam yağış miktarının azalacağı tahmin edilmektedir (Türkeş, 2020; Ozturk ve ark., 2015). Bununla birlikte sıcak mevsimlerde eriyen karla beslenen nehirlerdeki su seviyesinin sıcaklık artışına bağlı olarak azalacağı ve böylece tarım sektörünün de olumsuz yönde etkileneceği ifade edilmektedir (Sen ve ark., 2012). Sonuç itibariyle, iklim değişikliği ile ortaya çıkabilecek tarımsal üretimdeki değişiklikler ise geçimini tarımdan sağlayan kesimin ekonomik, sosyal yapısında olduğu kadar, ülke ekonomisinde de önemli yansımalara neden olabilecektir (ÇŞB, 2012).

Sistemlerin iklim değişikliği etkilerine, özellikle aşırı hava ve iklim olayları ve afetlerine hangi ölçüde dayanabileceği ve bunlarla nasıl baş edebileceği, belirli bir tehlikenin ciddiyetine, tehlikenin sistemi etkileme ve afete dönüşme olasılığına ve tehlikeye tamamen maruz kaldığı varsayıldığında sistemin etkilenebilirliğine bağlıdır. Bununla birlikte, sistemin uyum kabiliyetini farklı uygulamalar yoluyla oluşturulmuş bir kapasite olarak düşünmek, bireylere, topluluklara ve hatta hükümetlere karşı karşıya kaldıkları iklim değişikliğinin belirli etkilerine karşı direngenliklerini geliştirmek için hangi önlemlerin en mantıklı olduğuna karar verme esnekliği de verebilir. Bu nedenle, zayıf uyum kapasiteleri nedeniyle kırsal kesimdeki hanehalkında iklim değişikliğinin etkilerini anlamak ve potansiyel risklerini tanımlamak, hanelerin daha sürdürülebilir ve dirençli bir yaşam sürmelerine yardımcı olması bakımından önemlidir. Bu kapsamda, iklim değişikliği sonucu geçim kaynaklarında bozulan dengeyi sağlayabilmek için mevcut kaynaklar içerisinde hangilerinin güçlendirilmesi gerekliliğinin ortaya konulması ihtiyacı vardır. Böylece iklim değişikliği nedeniyle hanehalkı gelirinin korunmasına yönelik yapılacak uyum çalışmalarının da daha kolay ve etkili bir şekilde uygulanması sağlanabilecektir. Kırılganlık analizi, geçim kaynaklarının dayanıklılığına katkıda bulunan faktörlere dair iç görü sağlamaktadır. Bu faktörleri anlayarak, uyum stratejileri yalnızca riskleri azaltmayı değil aynı zamanda toplulukların iklimle ilgili zorluklar karşısında genel dayanıklılığını artırmayı da hedefleyebilir.

Sonuçta, geçim kaynakları hassasiyetini analiz etmenin temel amacı uyum stratejilerinin etkinliğini arttırmaktır. Farklı toplulukların karşılaştığı benzersiz zorlukların anlaşılmasıyla, değişen iklim karşısında olumlu sonuçlar elde etmek için uyum önlemleri daha iyi tasarlanabilir, uygulanabilir ve izlenebilir hale gelebilmektedir. İklim değişikliği kırılganlığının değerlendirmesi alanı, toplulukların değişen çevre koşullarına nasıl uyum sağlayacağını ölçme ihtiyacını karşılamak için ortaya çıkmıştır. Çeşitli araştırmacılar sosyal, doğal ve fiziksel bilimler arasındaki boşluğu doldurmaya çalışmış ve bu zorluğun üstesinden gelecek yeni metodolojilere katkıda bulunmuşlardır

(Polsky ve ark., 2007). Bunların birçoğu büyük ölçüde IPCC'nin maruz kalma, duyarlılık ve uyarlanabilir kapasitenin bir fonksiyonu olarak çalışma hassasiyeti tanımına dayanmaktadır (IPCC, 2001; Hahn ve ark., 2009)

Bu kapsamda iklim değişikliğinin olumsuz etkilerine karşı farklı bölge ve farklı tarımsal üretim faaliyetlerine yönelik işletme düzeyinde geçim kaynaklarının kırılganlığını araştıran uluslararası literatürde birçok çalışma bulunmaktadır (Hahn ve ark., 2009; Sujakhu ve ark., 2018; Xu ve ark., 2020; Khan ve ark., 2021; Yang ve ark., 2021; Rai ve ark., 2022; Fahad ve ark., 2023). Türkiye'de ise iklim değişikliğinin tarım üzerine etkisi konusunda çalışmalar sınırlı olup çalışmalar daha çok iklime bağlı verimdeki değişmelerin Türkiye'nin tarımsal üretim deseni, ürün verimi, tarım ürünleri fiyatları, ihracat ve ithalat miktarı, tüketici, üretici ve sosyal refaha etkileri (Dellal ve ark., 2007; Dellal ve ark., 2011; Dudu ve Çakmak, 2013; Alpas ve ark., 2018; Konukçu ve ark., 2020) üzerine yoğunlaşmaktadır.

İklim değişikliğinin olumsuz etkilerinden, tarımın diğer üretim biçimlerinde olduğu gibi, üzüm yetiştiriciliği de doğrudan etkilenmektedir. Türkiye, bağ alanı ve üzüm üretiminde dünyanın önemli ülkeleri arasında yer almaktadır. İklim koşullarının ve yetiştirme şartlarının uygunluğu nedeniyle bağcılık ülke genelinde birçok üreticinin geçim kaynağını oluşturmaktadır (Semerci ve ark., 2015). Ancak, çiftçiler iklim değişikliğini geçim kaynaklarına bir tehdit olarak algılamazlarsa, çiftçilerin iklim değişimine uyum davranışları veya zararını azaltma eylemleri yapması da olası değildir (Arbuckle ve ark., 2013). Bu çalışma ile Türkiye'de üzüm üreticileri özelinde işletmelerin karşılaştıkları iklimsel olaylar ve işletme üzerindeki etki düzeyleri ortaya konulması, hanehalkı sürdürülebilir geçim kaynakları kırılganlığının işletmelerin sermaye unsurları göz önüne alınarak söz konusu iklimsel olaylar karşısında hangi sermaye unsurları açısından ve ne düzeyde farklılaştığı bölgeler arası karşılaştırmalı olarak değerlendirilmesi amaçlanmıştır. Bu açıdan, Türkiye'de tarım işletmelerinin iklim değişikliğine karşı hanehalkı düzeyinde geçim kaynakları kırılganlığını ölçmeye yönelik çalışmaya rastlanılmamış olması çalışmayı özgün kılmaktadır.

Çalışmadan elde edilecek sonuçların, Türkiye'de tarım sektöründe bölgesel farklılıklar dikkate alınarak iklim değişikliğinin yaratmış olduğu farklı boyutlardaki maruziyetler ve işletme yapılarının farklı hassasiyet düzeyleri göz önüne alınarak belirlenen kırılganlık seviyeleri ile, işletmelerde yapısal olarak hangi alanlarda öncelikli olarak uyum stratejilerine odaklanılması gerektiği konusunda ilgili paydaşlara ve politika yapıcılara yol gösterici olacağı düşünülmektedir. Ayrıca araştırmacılar tarafından farklı tarımsal faaliyet alanları için benzer değerlendirmelerin yapılabilmesi için referans bir çalışma olması da beklenmektedir.

2. Materyal ve Metot

2.1. Verilerin Toplanmasında ve Örneklemede Kullanılan Yöntem

Araştırmanın materyalini, Türkiye'deki üzüm üretimi yapılan, gayeli olarak seçilen 8 ildeki (Adıyaman, Denizli, Elazığ, Malatya, Manisa, Mersin, Nevşehir, Tekirdağ) üzüm yetiştiriciliği yapan işletmelerden anket yoluyla elde edilen verilerden oluşmaktadır.

2017 yılı TÜİK (Türkiye İstatistik Kurumu) verilerine göre Türkiye'de 73 ilde, çekirdekli ve çekirdeksiz çeşitlerle sofralık, kurutmalık ve şaraplık üretim amacıyla 4.169.068 da alanda bağcılık yapılmaktadır. Örnekleme sayısının belirlenmesinde, Türkiye'de üzüm üretimin yaygın olduğu Ege, Marmara, İç Anadolu, Akdeniz, Doğu Anadolu ve Güneydoğu Anadolu Bölgeleri (6 Bölge) seçilmiştir. Araştırmanın yapılacağı illerdeki bağ alanları, toplam bağ alanlarının %46'sini (1.916.680 da) temsil etmektedir. Bu araştırmada Türkiye'de 2015 yılı Tarım ve Orman Bakanlığı Çiftçi Kayıt Sistemine (ÇKS) kayıtlı üzüm üreticisi sayısı 231.494 kişidir. Araştırmanın yapılacağı 8 ilde üzüm üreticisi sayısı toplam 85.089 olup Türkiye üzüm üreticilerinin yaklaşık %37'sini oluşturmaktadır. Ana kütleyi temsil edebilecek örnek hacminin belirlenmesinde oransal örnekleme yöntemi kullanılmıştır. Bu yöntem doğrultusunda anket sayısı aşağıdaki formüle göre hesaplanmıştır (Newbold, 1995):

$$n = \frac{N*p(1-p)}{(N-1)*\sigma_p^2+p*(1-p)} \qquad \text{(Eş. 1)}$$

Formülde; n örnek büyüklüğünü, N ana kütleyi, p tahmin oranını (0.5 maksimum örnek büyüklüğü için), σ_p^2 oran varyansını (maksimum örnek hacmine ulaşmak için % 95 güven aralığında çizelge değeri 1.96 ve % 5 hata payı ile) ifade etmektedir. Ana kitleyi oluşturan üreticilerin özellikleri başlangıçta bilinmediğinden, örnek hacmini azami düzeye çıkarmak için p değeri 0.5 olarak alınmış ve örnek hacmi 384 olarak bulunmuştur. Bölgede yer alan üzüm üreticilerinin illere göre dağılımı esas alınarak il bazında anket sayısı belirlenmiştir. Ancak Elazığ, Malatya ve Tekirdağ illerinde verilerin analizine yönelik yeterli büyüklüğü elde etmek için en az 40 örneklem sayısı belirlenerek, örneklem sayısı 466 işletmeye çıkarılmıştır. Araştırma alanı ile ilgili üzüm üreten işletme sayıları, ekim alanı ve üretim miktarı ile yapılan anketlerin illere göre dağılımı aşağıda *Tablo 1*'de verilmiştir.

Tablo 1. İllere göre üzüm üreten işletme sayısı, üretim miktarı ve anket dağılımı (2021 yılı)

Table 1. Number of grape enterprises, production amount and survey sample distribution by province (2021)

İller	**İşletme Sayısı (adet)**	**Bağ Alanı (da)**	**Üzüm Üretim Miktarı (ton)**	**Anket Sayısı (adet)**
Adıyaman	8.212	106.449	66.384	40
Denizli	14.280	341.611	324.974	71
Elazığ	6.382	108.254	71.076	40
Malatya	4.314	36.348	19.304	40
Manisa	29.810	858.919	1.308.370	140
Mersin	7.977	178.340	343.308	55
Nevşehir	11.417	189.436	90.751	40
Tekirdağ	2.687	35.115	33.916	40
Toplam	85.089	3.902.211	3.670.000	466

2.2. Verilerin Analizi Aşamasında İzlenen Yöntem

Çalışmada, Türkiye'de iklim değişikliğine karşı üzüm üreticileri özelinde işletmelerin geçim kaynakları kırılganlığını sermaye unsurları açısından değerlendirmek için DFID (2001)'a dayanan Urothody ve Larsen (2010) tarafından kullanılan Geçim Kaynakları Etkilenebilirliği İndeksi (LEI) yöntemlerinden faydalanılmıştır. Geçim Kaynakları Etkilenebilirliği İndeksi, belirli bir bölgenin veya topluluğun geçim kaynakları sürdürülebilirliğini ve insanların çeşitli risklere ve stres faktörlerine karşı duyarlılığını değerlendirmek için kullanılan bir araçtır. Bu indeks ile geçim kaynaklarına dayalı sürdürülebilirlik analizlerinde sermaye unsurları dikkate alınmaktadır. Sermaye unsurları, insanların ve toplulukların geçim kaynaklarını sürdürmelerine ve krizlere karşı daha dirençli hale gelmelerine yardımcı olan kaynakları ifade etmektedir. Bu kaynaklar beş farklı sermaye unsuru altında toplanır ve bunlar beşerî, sosyal, doğal, fiziki ve finansal sermayedir (DFID, 2001).

Geçim kaynakları etkilenebilirlik indeksi (Livelihood Effect Index-LEI) hesaplanmasında oluşturulan göstergeler, literatür taraması ve odak grup çalışması sonucu çalışma alanına özgü belirlenmiş ve iklim değişikliği kırılganlığı ile arasındaki fonksiyonel ilişki belirtilmiştir (*Tablo 2*). Bu kapsamda Hahn ve ark. (2009), Eriksen ve Kelly (2006), ve Selvaraju ve ark. (2006) tarafından yapılan çalışmalardan faydalanılarak çalışmada kullanılacak üzüm yetiştiriciliği ile ilgili araştırma bölgesine özgü olabilecek göstergelerin listesi belirlenmiştir. Bununla birlikte araştırma alanında birçok çiftçi, kötü hava koşulları nedeniyle ürün kaybı, tek çeşit gelir kaynağı olarak tarıma yüksek bağımlılıkları, tarımsal yapılarındaki ve üretim uygulamalarındaki farklılıklar, eğitim yetersizliği nedeniyle farklı istihdam türlerine erişim sağlayamama gibi çeşitli nedenlerle geçim sorunları yaşadıkları saha çalışması öncesi anket yapılacak illerde Tarım ve Orman Bakanlığı ve üretici birlikleri ile yapılan görüşmeler ile belirlenmiştir. Bu nedenle, çalışma alanındaki kırılganlığı daha iyi yansıtabilmek amacıyla söz konusu literatür taramasına dayalı belirlenen göstergelere ilave olarak *Tablo 2*'de belirtilen bağ verimi azalan işletme oranı (DS2), arazi eğimi (DS3), toprak yapısı (DS4), arazi mülkiyet durumu (DS6), sulama durumu (DS14), toplam gelirde tarımın payı (FNS5), damlama sulama yapma durumu (FKS6) değişkenleri de bu çalışmaya özgü olarak belirlenmiştir.

Ancak, göstergelerin her biri farklı bir ölçekte ölçüldüğü için, öncelikle her birinin bir indeks olarak standartlaştırılması gerekmektedir. Ancak bunu yapmadan önce, göstergeler ile kırılganlık arasındaki fonksiyonel ilişkiyi dikkate almak önemlidir. İki tür işlevsel ilişki mümkündür: göstergenin değerindeki artış ile kırılganlık artar veya azalmaktadır. Değişkenle kırılganlık arasında pozitif fonksiyonel ilişkiye sahip ise normalleştirme Eşitlik (2) kullanılarak yapılır.

$$Index_i = \frac{s_i - s_{min}}{s_{max} - s_{min}} \quad \text{(Eş. 2)}$$

Eşitlikteki, s_i ile i iline ait alt bileşen ortalamasını ve s_{min} ve s_{max}, her bir alt bileşen için sırasıyla minimum ve maksimum değeri ifade etmektedir. Öte yandan, değişkenler ile kırılganlık arasında negatif fonksiyonel ilişkiye sahip olduğunda normalleştirme Eşitlik (3) yardımıyla yapılmaktadır.

Tablo 2. Geçim kaynakları etkilenebilirlik (LEI) sermaye unsurları ve göstergeleri

Table 2. Livelihood Effect Index (LEI) assets and indicators

Kod	Sermaye Unsuru	Fİ*	Kod		Fİ
	Beşeri Sermaye				
BS1	Hastalık nedeniyle okul/işe gidemeyen hane %	+	BS7	Temel gıda ihtyaçlarını hane dışından karşılayan haneler	+
BS2	Hanehalkı reisi eğitim indeksi (tersi)	-	BS8	Bir yılda aile tüketimi için satin alınan hububat miktarı (kg)	+
BS3	Hanehalkı reisi tarımsal deneyim	-	BS9	Temel gıda alışverişi için hanenin en yakın pazara uzaklığı (km)	+
BS4	İklim ile ilgili bilgi/eğitim desteği alamayan haneler	+	BS1 0	Aile bireylerinden bir veya fazlası çalışmak için göç eden haneler (%)	-
BS5	Öğün azaltan haneler	+	BS11	Toplam işgücü içerisinde aile bireylerinin tarım dışı işlerde geçirdiği süre (%)	-
BS6	Hanehalkı beslenmesi için yiyecek temin etmede zorluk çekilen ay sayısı				+
	Sosyal Sermaye				
SS1	Hane reisi kadın haneler (%)	+	SS6	İhtiyaç durumunda köyde yaşayanlardan yardım alamayacağını düşünen haneler (%)	+
SS2	Bağımlı nüfus oranı (%)	+	SS7	Köyde yaşayanlar arasında borç alma ve verme konularında sorun yaşayan haneler (%)	+
SS3	Hane reisi yaşı (yıl)	+	SS8	Kooperatif ortaklığı veya birlik üyeliği bulunmayan haneler (%)	+
SS4	Aile birey sayısı (kişi)	+	SS9	Tarımsal konularda bilgi desteği alamayan haneler (%)	+
SS5	Köyde yaşayanlar arasında güven eksikliği olduğunu düşünen haneler (%)				+
	Doğal Sermaye				
DS1	Ekilen toplam tarım arazisi (da)	-	DS9	Sulama kaynağına erişemeyen haneler (%)	+
DS2	İklim değişikliği nedeniyle bağ verimi azalan işletmeler (%)	+	DS10	Bölgedeki su kaynağı düzenli olarak ihtiyacını karşılamayan haneler (%)	+
DS3	Arazi eğimi orta veya dik eğime sahip işletmeler (>%7 eğimli)) (%)	+	DS11	Doğal su kaynaklarının su seviyesinin azaldığın belirten haneler (%)	+
DS4	Toprak yapısı (kıraç arazi yüzdesi)	+	DS12	Sulama kaynağına yatırım riski olduğunu düşünen haneler (%)	+
DS5	Pazara uzaklık (km)	+	DS13	Sulama kaynağına uzaklık (km)	+
DS6	Kira ve ortakçılıkla işlenen arazi (%)	+	DS14	Sulama yapılamayan bağ alanı oranı (%)	+
DS7	Toprak erozyonu yaşayan haneler (%)	+	DS15	Tarımsal üretimde çeşitlendirme	-
DS8	Yetiştirilen bağ ürünü çeşitliliği (n) indeksi (1/(1+n)				-
	Finansal Sermaye				
FNS1	Tarımsal desteklerden faydalanamayan haneler (%)	+	FNS4	Tasarruf yapamayan haneler (%)	+
FNS2	Tarımsal kredi kullanamayan haneler (%)	+	FNS5	Toplam gelirde tarıma bağımlılık (%)	+
FNS3	Tarım Sigortası yaptıramayan haneler (%)				+
	Fiziksel Sermaye				
FKS1	Bina sermayesi (TL)	-	FKS4	Bağ alanı büyüklüğü (da)	
FKS2	Tarımsal alet makine sermayesi (TL)	-	FKS5	Toplam işlenen tarım alanı içerisinde bağcılık payı (%)	
FKS3	Hayvan sürü büyüklüğü (BBHB)	-	FKS6	Damlama sulama yapamayan işletmeler (%)	

** Fİ: Fonksiyonel ilişki*

$$Index_i = \frac{S_{max} - S_i}{S_{max} - S_{min}} \quad \text{(Eş. 3)}$$

Farklı birimlerde ölçülen her bir değişken, 0 ile 1 arasında değer alan bir indeks ile ifade edildikten sonra, önce her bir sermaye alt unsurlarının skorlarının kendi içerisinde ağırlıklı ortalamaları alınıp her bir sermaye unsurunun kırılganlık değeri hesaplanmıştır (Eşitlik 4).

$$LVI_{Ci} = \frac{\sum_{j=1}^{n} index_{si_j}}{\mathrm{n}} \quad \text{(Eş. 4)}$$

Eşitlikteki, LVI_{Ci}, her bir il için çalışma kapsamında incelenen kırılganlık alt bileşenlerden birini, $index_{sij}$ her bir alt bileşeni oluşturan gösterge indeks değerini ve *n* ise ana bileşende yer alan gösterge sayısını ifade etmektedir.

Her bir geçim kaynağı sermayesinin kırılganlık değerlerini hesaplamak için, Eşitlik (5)'deki denklem kullanılarak her bir sermaye unsurunu oluşturan ana göstergelerin ortalaması alınmıştır:

$$LEI = \frac{\sum_{i=1}^{5} w_{Ci} LVI_{Ci}}{\sum_{i=1}^{5} w_{Ci}} \quad \text{(Eş. 5)}$$

LEI, geçim kaynağı etkisi indeksini; LVI_{ci}, her bir sermaye unsurunu oluşturan göstergenin kırılganlık değerini; w_{ci}, her bir sermaye unsuruna katkıda bulunan alt gösterge sayısı tarafından belirlenen gösterge ağırlığını ifade etmektedir. Çalışmada, tüm alt bileşenlerin geçim kaynakları kırılganlık indeksine eşit şekilde katkıda bulunduğu varsayılmıştır (Sullivan ve ark., 2002). LEI değeri, 0 (en az kırılgan) ile 1 (yüksek derecede kırılgan) arasında değişmektedir.

3. Araştırma Sonuçları ve Tartışma

3.1. İşletmelerin Genel Özellikleri

Araştırmaya dahil olan işletmelerde hane reisinin tamamına yakınını (%99) erkeklerden oluşmakta olup, görüşme yapılan üreticilerin ortalama yaşı 54.44 ve ortalama tarımsal üretimdeki deneyimi ise 33 yıldır. İşletmecilerin, %72'si (338 kişi) ilköğretim mezunu ve %78.3'ünün (365 kişi) bir yılda tarımda kendi işinde çalışma süresi 6 ay ve üzeri bireylerden oluşmaktadır. Bağcılık yapan işletmelerde ortalama aile birey sayısı 3 kişidir.

3.2. İşletmelerin Karşılaştıkları İklimsel Olaylar ve Etkileri

İncelenen işletmelerde doğa olayları ve iklim değişikliği maruziyetlerini ölçmek için, işletmelere son 10 yılda işletmelerinin bulunduğu bölgede aşırı yağmur, aşırı kuraklık, don olayı, dolu, sel, sıcaklık artış ve azalışları, yağmur sezonunda kısalma ve gecikme, yağmurlu ve kurak mevsimde gecikme nedeniyle üretim dönemindeki değişiklik, iklime bağlı arazi kayması ve fırtına hortum gibi olayların gerçekleşme sıklıkları sorulmuş ve *Tablo 3*'de sonuçlar verilmiştir. Buna göre işletmelerin karşılaştıkları iklim olayları arasında en fazla aşırı kuraklık (2.25) ve sıcaklık artışları (2.01) orta düzeyin üzerinde gerçekleşirken, yağmur sezonunda gecikme (1.94), don olayları (1.77) ve yağmur sezonunda kısalma (1.70) ve dolu olayları (1.68) işletmelerin en fazla karşılaştıkları diğer iklim olayları arasında yer aldığı görülmüştür. İşletmelerin maruz kaldıkları iklimsel olaylar karşısında ise en fazla sıcaklık artışı (1.73) ve aşırı kuraklık (1.71) ile başa çıkmada zorlandıklarını belirtmişlerdir (*Tablo 3*). İşletmeler tarafından aşırı kuraklık durumunun şiddeti ve olumsuz etkisi sıcaklık artışlarına göre daha yüksek değerlendirilse de sulama imkanı olan işletmeler kuraklıktan diğer üreticilere göre daha az etkilenmekte ve kuraklıkla başa çıkmada zorlanma düzeyleri daha düşük olduğu görülmüştür. Bununla birlikte, her ne kadar bazı iklimsel olayların görülme sıklığı ve etkisi düşük değerlendirilmesine rağmen bazı iklimsel olayların etkileri bölgelere ve ilçelere göre değişebileceği de göz önüne alınmalıdır.

3.2. İklim Değişikliğinin İşletmelerin Sürdürülebilir Geçim Kaynakları Sermaye Unsurlarına Etkisi Açısından Değerlendirilmesi

Geçim kaynağı, insanları, yeteneklerini ve yiyecek, gelir ve varlıkları da içeren yaşam araçlarını içermektedir. Bir geçim kaynağı, stresler ve şoklarla baş edebildiği ve bunları toparlayabildiği ve doğal kaynak tabanına zarar vermeden hem şimdi hem de gelecekte yeteneklerini ve varlıklarını geliştirmeyi başarabildiği zaman sürdürülebilirdir (Chambers ve Conway, 1992).

İklim değişikliğinin incelenen işletmelerde beşeri, sosyal, fiziksel, doğal ve finansal sermaye unsurlarını kapsayan geçim kaynakları etkilenebilirlik indeksi *Tablo 4* ve *Şekil 1*'de verilmiştir. Buna göre tüm işletmeler için genel geçim kaynakları etkilenebilirlik indeksi (LEI) 0.440 olarak hesaplanmış olup, bu değer iklim değişikliği ve afetler gibi şoklar karşısında üzüm üreticilerinin geçim kaynaklarının orta düzeyde etkilenebilir olduğunu ifade etmektedir. Geçim kaynakları kırılganlık düzeyleri bakımından iller arasında hesaplanan değerler birbirine yakın olmakla birlikte, en çok etkilenebilirlik Malatya (0.495) ve en az etkilenebilirlik Manisa (0.392) ili için hesaplanmıştır.

Tablo 3. Üzüm üreticilerinin karşılaştıkları iklimsel olaylar ve etkilerine yönelik görüşleri

Table 3. Opinions of grape producers on the climatic events they encounter and their effects

İklimsel Olaylar	Olayın gerçekleşme sıklığı*	Olayın şiddeti*	Olayın işletme üzerine olumsuz etkisi*	Bu tehlikeyle başa çıkmada zorlanma*
Aşırı kuraklık	2.25	2.41	2.38	1.71
Sıcaklığın artması	2.01	2.23	2.23	1.73
Yağmur sezonunda gecikme	1.94	1.97	1.95	1.50
Don olayları	1.77	1.76	1.76	1.50
Yağmur sezonunda kısalma	1.70	1.72	1.72	1.34
Dolu olayları	1.68	1.82	1.83	1.49
Yağmurlu ve kurak mevsimdeki değişiklikler; dikim, budama, hasat vb. dönemlerde değişikliklere yol açar	0.88	0.92	0.92	0.73
Fırtına dalgası, hortum, kuvvetli rüzgar	0.54	0.66	0.65	0.48
Sıcaklığın azalması	0.25	0.25	0.26	0.07
Aşırı yağmur	0.22	0.32	0.32	0.29
Sel	0.15	0.21	0.21	0.21
İklim ile ilgili arazi veya çamur kayması	0.03	0.04	0.04	0.03

**İklimsel olayların etkileri; 0:Hiç; 1:Düşük; 2:Orta; 3:Yüksek*

Geçim kaynağı etkilenebilirlik indeksini oluşturan her bir sermaye unsurunun kırılganlığının düzeyinin bilinmesi, dış şoklar karşısında alternatif stratejiler yoluyla işletmelerde dirençliliğin güçlendirilmesi açısından önemlidir. Bu kapsamda çalışmada işletmelerin iklim değişikliği gibi afetler karşısında en fazla kırılgan sermaye unsurunu fiziksel sermayeleri oluşturduğu görülmüştür (0.790). İşletmelerin sahip oldukları finansal sermaye (0.582) ve doğal sermaye unsurları (0.436) ise geçim kaynakları etkilenebilirlik düzeyi üzerinde orta düzeyde etkilemektedir.

Fiziki sermaye unsurunu işletmelerin aktif sermaye unsurlarından bina sermayesi, toprak varlığı, hayvan sermayesi, tarımsal alet makine sermayesi ve arazi ıslahı (sulamaya yönelik yatırımlar) oluşturmaktadır. Literatürde, işletmelerde fiziki sermayenin, hanehalkının tarımsal faaliyetlere katılımını kolaylaştıran ve geçim kaynaklarını güvence altına almayı sağlayan önemli bir unsur olduğunu göstermektedir (Aryal ve ark., 2014; He ve Ahmed, 2022). Bununla birlikte tarım işletmelerinde fiziksel sermaye unsurlarından herhangi birinin yetersizliği ya da fazlalığı, işletmelerin başarılı çalışmalarını olumsuz yönde etkilemektedir. Rantabl çalışabilmek için gerekli sermaye unsurlarından her birinin belirli oranlarda bulunması gerekmektedir (Erkuş ve ark., 1995). Çalışma kapsamında incelenen işletmelerdeki tarımsal üretim faaliyeti içerisinde hayvan varlığının düşük olması (0.976), işletmelerin sahip oldukları tarımsal alet ve makine sermayesinin düşüklüğü (0.937) ve işlenen bağ alanlarının küçük ölçekte olmasının (0.885) fiziksel sermaye kırılganlığını yüksek düzeyde artıran unsurlar olduğu bulunmuştur.

İncelenen işletmelerde tarımsal üretim faaliyeti içerisinde hayvansal üretime yer veren işletmelerin oranı %10.51 olup, ortalama sürü büyüklüğü 0.645 BBHB olarak hesaplanmıştır. İller bazında işletmelerde en fazla hayvan varlığı 2.02 BBHB ile Malatya ilinde en az ise 0.10 BBHB ile Tekirdağ ilinde bulunmaktadır. İşletmelerde bitkisel üretim faaliyetinin yanı sıra hayvancılık faaliyetine de yer verilmesi, bitkisel üretimdeki iklimsel risklere karşı gelir istikrarı sağlayarak hanehalkı geçim kaynaklarını güvence altına alınması açısından önemlidir (Aryal ve ark., 2014; Aribi ve ark., 2021)

İşletmelerin sahip oldukları tarımsal alet makine sermayesi ise fiziksel sermaye unsurlarının değerlendirilmesinde önemli bir göstergedir. Kullanılan teknoloji uygulamalarının işletmelerde verimliliği artırarak geçim kaynaklarına olumlu bir şekilde yansıması açısından önemli bir unsurdur. Bu açıdan incelenen illerde tarımsal alet makine varlığı bakımından en kırılgan il Malatya (0.969) ve en az kırılgan il ise Manisa (0.909) hesaplanmıştır. Tüm işletmeler için çiftlik varlıkları kapsamında, en fazla varlık işletme başına 0.893 adet ile traktör, 0.678 adet pülverizatördür ve 0.660 adet ile toprak işleme aletleri (pulluk ve kültivatör) oluşturmaktadır.

Manisa ilindeki üzüm üreticilerinin diğer bölgelerden farklı olarak üzüm serme ve toplama makinesi (işletme başına 0.157 adet), üzüm savurma makinesine (0.300 adet) sahip olduğu tespit edilmiştir. Üzüm üreticilerinin sadece %29'su depo, %12'si hayvancılık faaliyetlerine yönelik ahır varlığına, %0.6'sı samanlık ve %0.8'si su tankına sahiptir.

Fiziksel sermaye unsurları arasında kırılganlığı artıran diğer bir faktör ise işletmelerin sahip olduğu bağ alanı büyüklüğü (0.885) bulunmuştur. İşletmelerde ortalama işlenen tarım arazisi 73.27 dekar olup, bağ alanı ise 35.39 dekardır. Diğer bir ifade ile işletmeler tarım arazilerinin %48.29'unu üzüm üretimine ayırmaktadır. İller bazında işletme başına ortalama bağ alanı en düşük 11.62 dekar ile Malatya ilinde, en yüksek ise 45.97 dekar ile Elazığ ilindedir.

İşletmelerin üretimlerinde daha yüksek verim sağlamaları amacıyla modern sulama sistemlerinden yararlanmaları bakımından da kırılganlıkları yüksek düzeydedir (0.627). Tekirdağ ilinde görüşme yapılan işletmelerin tamamında bağ alanlarında sulama yapılmamaktır. Bu bulgu Durgut ve Arın (2005) yaptıkları çalışma sonucu ile de uyumludur. Adıyaman ilinde görüşme yapılan üzüm üreticileri arasında damlama sulama sistemi kullanan işletmelerin oranı %2.5, Nevşehir ilinde %10.0, Malatya ilinde ise %20 olduğu tespit edilmiştir. Tüm işletmeler için damlama sulama sistemi kullanım oranı ise %37.34 olarak hesaplanmış olup en yüksek damlama sulama sistemi kullanım oranı %83.64 ile Mersin ilinde hesaplanmıştır.

İşletmelerde fiziksel sermaye unsurlarından sonra ikinci en yüksek kırılganlığa sahip sermaye unsurunu ise finansal sermaye (0.582) oluşturmaktadır Pandey ve ark. (2017) yaptıkları çalışmada daha fazla finansal sermayeye sahip olan işletmelerin iklim değişikliğinin etkilerine karşı daha fazla uyum sağlama kapasitelerine sahip olduklarını ortaya koymuştur. Çünkü finansal varlıklar hanehalkı nakit ihtiyacını kolayca karşılayabileceğinden iklim değişikliğinin hanehalkı geliri üzerindeki olumsuz etkilerini kısa süre içerisinde azaltmada kilit bir role sahiptir (Sujakhu ve ark., 2019) Bu bulgu çalışma sonuçları ile de uyumludur. İncelenen işletmelerde finansal sermaye unsurunu oluşturan göstergeler olarak kişi başı hanehalkı geliri, toplam gelirde tarımın payı, tarımsal desteklerden faydalanma, tarımsal kredi kullanımı, tarım sigortası yaptırma ve tasarruf yapabilme açısından değerlendirilmiştir. İncelenen göstergeler arasında, geçim kaynakları kırılganlığını en fazla artıran göstergeler arasında, kişi başı gelir (0.869) ve hane gelirinin tarımsal faaliyetlere bağımlılığı (0.765) bulunmuştur. Hinkel (2011), kırsal hanelerin gelirlerinin tarıma bağımlı oluşunun, iklim değişikliğine karşı ürün hasadındaki azalışlar nedeniyle gelirdeki kırılganlıklarını artırarak nakit ihtiyaçları için onları borçlanmaya zorlayabileceğini ifade etmiştir. Ancak bu durum tarımsal faaliyetlerden elde edilen gelirin hanehalkının tasarruf yapmasına olanak sağladığı sürece geçim kaynakları etkilenebilirliğinin azaltıcı bir etkisi olacağı da göz önüne alınmalıdır. Diğer bir ifade ile toplam gelirde tarımsal gelire bağımlılık yüksek olsa bile, tarımsal gelir tasarruf ve yatırımlar için yeterli ise geçim kaynaklarının daha az kırılgan olmasına neden olacaktır. Çalışmada bu durum, iller düzeyinde diğer kırılganlık göstergeleri ile incelendiğinde net bir şekilde görülmektedir. İncelenen işletmelerde, tarımsal gelire bağımlılık bakımından kırılganlığın en yüksek olduğu Mersin (0.886) ve Manisa (0.858) illerinde tasarruf yapabilen hane oranı sırasıyla %60 ve %74.3 olarak hesaplanmıştır. Bununla birlikte tarımsal gelire bağımlılık bakımından kırılganlığı en düşük il olan Malatya'da (0.505) ise görüşme yapılan hanelerin sadece %20'si tasarruf yapabilmektedir. Bu illerde kişi başı gelir kırılganlığı en yüksek Malatya (0.957), en düşük ise Manisa (0.794) ve Mersin (0.816) illeri hesaplanmıştır. Söz konusu illerde, sırasıyla tarım sigortası yaptırma oranı ise Malatya ilinde %22.5 iken, bu değer Mersin ilinde %72.7 ve Manisa ilinde %70.7 olarak hesaplanmıştır. Benzer şeklide Malatya ilinde işletmelerin tarımsal kredi kullanım oranı %17.5 iken, Manisa ilinde %56.4 ve Mersin ilinde %52.7'dir. Dolayısıyla araştırma kapsamında incelenen illerde, Malatya ili tarımsal gelire bağımlılığı en düşük il olmasına rağmen finansal sermaye kırılganlığı (0.765) en yüksek il olarak bulunurken, tarımsal gelire bağımlılığı en yüksek fakat finansal sermaye kırılganlığı en düşük iller arasında Manisa (0.477), ve Mersin (0.541) illeri olduğu görülmüştür.

Diğer bir geçim kaynağı sermaye unsurunu oluşturan doğal kaynaklar sermayesi ise çalışmada işletmelerdeki toprak, su ve tarımsal üretim çeşitliliği bakımından ele alınmıştır. Bu açıdan işletmelerin sahip olduğu bağ alanı büyüklüğü, toprak yapısı (eğimli ve kıraç), işletmenin pazara yakınlığı, toprak erozyonuna maruz kalma, sulama imkanları ve yatırımları, su kaynaklarında bozulma, sulama kaynağına uzaklık, yetiştirilen tarımsal ürün ve üzüm çeşitliliği, iklim nedeniyle bağ veriminde azalma göstergeleri geliştirilerek doğal kaynak sermayesi indeks değeri hesaplanmıştır. Buna göre, tüm işletmeler için doğal kaynaklar sermayesi kırılganlığı 0.436 olarak hesaplanmış, orta derecede kırılganlığa sahip olduğu söylenebilir.

İşletmelerin doğal kaynaklar sermayesi kırılganlığının artmasında yüksek düzeyde etkisi olan unsurlar arasında, işlenen tarım arazilerinin küçük ölçekte oluşu (0.945), iklim değişikliği nedeniyle bağ veriminde azalma yaşayan hanelerin yüksekliği (0.927) ve yetiştirilen bağ ürünü çeşit sayısının azlığı (0.892) gelmektedir. Bununla birlikte, işletme genelinde tarımsal üretim faaliyetinde çeşitliliğin az olması (0.694), işletmelerin kıraç toprak yapısına sahip olması (0.613), kuru koşullarda bağcılık yapılan alanlar (0.494), arazilerin eğimli olması (0.462), sulama kaynağına uzaklık (0.436) faktörlerinin geçim kaynakları kırılganlığını orta düzeyde etkilemektedir.

İklim değişikliğinin geçim kaynakları üzerindeki kırılganlığı, sahip olunan kaynakların büyüklüğüne, kullanımına ve üretkenliğine atfedilir (Asrat ve Simane, 2017). Çalışmalar, sınırlı doğal kaynaklara sahip ve tarıma bağımlılığı yüksek küçük ölçekli tarım işletmelerinin, daha fazla üretim çeşitliliği ve sulama imkanına sahip daha büyük işletmelere kıyasla daha savunmasız olduğunu göstermektedir (Abid ve ark. 2016; Khan ve ark., 2020; Khan ve ark., 2021). Çünkü, daha az kaynak ve teknolojiye sahip küçük ölçekli işletmelerde, iklimsel değişkenlikler ve bunlarla ilgili oluşan zararlar nedeniyle, ürünlerin kalitesi, verimi ve fiyatı üzerinde dalgalanmalara neden olabilir ve bu durum, küçük çiftliklerin pazar erişimini kısıtlayarak geçim kaynaklarını etkileyebilmektedir. Bununla birlikte, sınırlı kaynakları nedeniyle adaptasyon stratejilerini uygulamak ve yeni teknolojileri benimsemek için yeterli finansal ve teknik destek alamama sorunları da yaşayabilirler.

İncelenen işletmelerde son üç yılın bağ verimi ortalaması dekara 1.05 ton olarak hesaplanmıştır. Adıyaman ilinde anket çalışmasının yapıldığı işletmelerde, sofralık üretim yapılan bağların verimden düşmüş olması nedeniyle ortalama üç yıllık verim dekara 0.36 ton ile incelenen iller içerisindeki en düşük verim değeri olarak hesaplanmıştır. Bununla birlikte iklimsel faktörlere bağlı olarak işletmelerin %92.7'si ortalama bağ veriminde son yıllarda azalma yaşadıklarını belirtmişlerdir.

Bu bakımdan, kırsal kesimdeki hanelerin riskler ve buna bağlı savunmasızlığını yönetme perspektifinden ve bazı durumlarda gelirleri artırma arzusundan, tarımsal ürünleri çeşitlendirmesi bir politika hedefi olarak uygulanmaktadır (Kimenju ve David, 2008). İncelenen işletmelerde tarımsal üretim faaliyeti büyük oranda bitkisel üretim ağırlıklı olup, toplam tarımsal üretim deseninde işletmelerin en fazla altı farklı üretim branşına yer verdiği görülmüştür. Buna göre tarımsal üretimlerinde en fazla iki çeşit üretim faaliyetine yer veren işletmelerin oranı %66.74, üç çeşit üretim faaliyetine yer veren işletmeler %20.82 ve dört çeşit ve üzeri üretim faaliyetine yer veren işletmelerin oranı ise %12.44 olarak hesaplanmıştır. Tüm işletmeler için toplam ekilen tarım arazisinin %48.29'unu bağ alanına ayırırken, işletmelerin üretim deseninde en fazla üretimine yer verdiği diğer ürünlerin başında %12.65 ile buğday, %7.66 ile arpa ve %6.71 ile silajlık mısır üretimi gelmektedir. Geriye kalan %24.69'luk alanda ise, incelenen bölgelerin iklim koşullarına uygun olarak 30'un üzerinde farklı ürünün yetiştiriciliği tespit edilmiştir. Bununla birlikte yetiştirilen bağ çeşit sayısı bakımından ise işletmelerin %69.96'sı bir çeşit, %27.9'u iki çeşit ve %2.15'i ise üç veya dört çeşit üzüm üretimine yer vermektedir. İller bazında ise, Mersin (%98.18), Manisa (%91.43) ve Elazığ (%87.5) illeri ağırlıklı olarak işletmelerinde tek çeşit üzüm üretimine yer verirken, Nevşehir ilinde üreticilerin %82.5'i iki veya üç çeşit üzüm üretimine yer vermektedir.

Doğal kaynak sermayesi açısından önemli bir diğer husus ise, işletmelerdeki toprak yapısı ve sulama imkanları açısından kırılganlıklarıdır. Tekirdağ ilinde görüşme yapılan işletmelerin tamamında bağ alanlarında sulama kaynağına erişim olmadığı ve bu nedenle üzüm üretiminde sulu tarımın yapılamaması nedeniyle, Tekirdağ ili diğer iller içerisinde doğal kaynaklar sermayesi en kırılgan il (0.523) olarak hesaplanmıştır. Türkiye'de yeterli sulama alt yapısının oluşturulamamış olması ve sulanan alanlarda ise diğer tarımsal ürünlerden elde edilen gelirin daha yüksek olması nedeniyle, bağcılığın daha az tercih edilen bir bitkisel üretim metodu olması, yeterli yağışın düştüğü yörelerde bağcılığın susuz olarak sürdürülmesine neden olmaktadır (Odabaşıoğlu ve ark., 2021). Bununla birlikte, Türkiye'de bağcılık üretim faaliyetinin kuru koşullarda yaygın yapılıyor olması hem üzüm verimini hem de kalitesini düşürmektedir. Türkiye'de yürütülen birçok araştırmada, bağlarda yeterli sulamanın yapılması halinde üzüm veriminin %35 ile %86 arasında artabileceği ortaya konulmuştur (Topuz ve Dağdelen, 2017; Çolak ve ark., 2019; Pekmezci ve Dardeniz, 2020).

Ek olarak bağcılığın yapıldığı arazilerin Manisa ili hariç oldukça yüksek kıraç toprak yapısına sahip olmaları da işletmelerde verimlilik ve hanehalkı geçim kaynakları açısından diğer bir sorun oluşturmaktadır. Üzüm üreticilerinin işlediği toplam bağ alanının toprak yapısına göre %41'ini taban, %27'si kır taban ve %32'si kıraç araziden oluşmaktadır. Bağ alanlarının arazi eğimine göre %53.8'i düz eğimli, %46.2'ü orta ve dik eğimlidir.

Bununla birlikte, diğer göstergelerle kıyaslandığında işletmelerin doğal kaynak sermayesinin daha dirençli olduğu unsurları arasında ise, işletmelerin sulama kaynağına (0.034) ve pazara (0.068) yakın olması, mülk arazi sahipliliğinin yüksek oluşu (0.138), su kaynağının su seviyesinde azalma yaşayan işletmelerin nispeten az olması (0.162), işletmelerde toprak erozyonunun daha az yaşanması (0.204) gelmektedir.

İncelenen tüm sermaye unsurları arasında işletmelerin dış şoklar ve risklere karşı geçim kaynakları açısından beşeri (0.261) ve sosyal (0.341) sermayelerinin daha dirençli olduğu bulunmuştur. Khan ve ark. (2020) daha güçlü beşeri ve sosyal sermayenin, işletmelerin şoklara dirençli risk yönetimi kapasitesini artırdığını bildirmiştir. Ancak çalışma kapsamında söz konusu sermaye unsurunu oluşturan göstergeler arasında en kırılgan unsurlarını ise, hanelerin tarımsal konularda bilgi alamama düzeyi (0.837), hanehalkı reisinin iklim ile ilgili konularda eğitim veya bilgi desteği alamaması (0.602), hanehalkı reisi yaşı (0.572), hanehalkı reisinin tarımsal deneyimi (0.543), hanehalkı reisi eğitim durumu (0.467), köyde yaşayan bireyler arasında parasal konularda borç alma ve verme konularında güven eksikliği yaşayan hanelerin varlığı (0.496) gelmektedir.

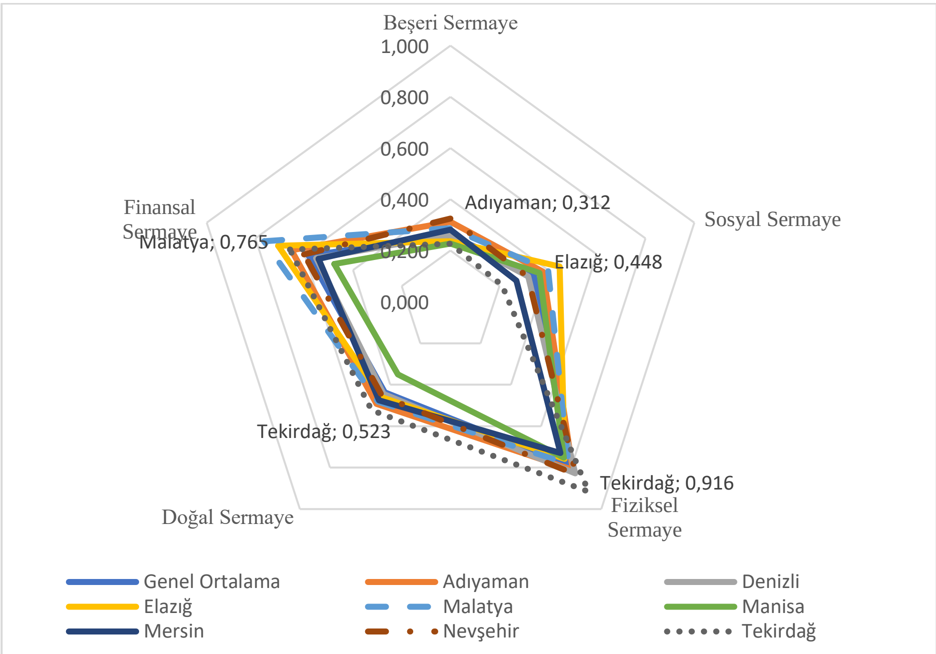

Figure 1. Vulnerability of livelihood assets by provinces

Şekil 1. İllere göre geçim kaynakları sermaye unsurlarının kırılganlık düzeyleri

Benzer şekilde, çalışmalar, güncel tarımsal bilgilere erişebilen ve tarımsal faaliyetlerini iklim değişkenliğine nasıl uyarlayacağını bilen çiftçilerin, üretim risklerine karşı daha yüksek çiftlik yönetimi becerilerine sahip olduğunu, daha fazla ürün verimi elde ettiğini ve sonuçta işletmelerin uyum sağlama kapasitesini geliştirdiğini göstermektedir (Khan ve ark., 2019; Khan ve ark., 2021; Moser ve Luers, 2008).

Hanehalkı reisinin yaşının iklim değişikliği üzerindeki etkisi çok yönlü olabilmekte ve bu nedenle tarım sektöründeki genç ve yaşlı çiftçilerin her birinin farklı güçlü ve zayıf yönleri bulunmaktadır. Çalışmalar, çiftçi yaşının artışı ile daha fazla deneyime sahip olmalarına ve bu sayede iklim değişikliğiyle başa çıkma konusundaki riskleri azaltacak daha iyi uyum becerileri ve bilgi birikimine sahip olduklarını ortaya koymaktadır (Mugari ve ark., 2020; Karki ve ark., 2020; Mugari ve ark., 2023). Bununla birlikte, genç çiftçilerin, iklimsel uyum becerilerinin daha esnek ve yeni tarım teknolojilerine daha kolay uyum sağlayabilme, iklim değişikliğiyle mücadelede modern tarım araçları ve iklim dostu yöntemleri benimsemeye daha yatkın olabilirler. Bu durum literatürde benzer çalışmalar ile de ortaya konulmuştur (Mabe ve ark., 2014; McCarthy ve ark., 2001).

Tablo 4. Geçim kaynakları etkilenebilirliği indeksini oluşturan sermaye bileşenleri indeks değerleri

Table 4. Index values of capital components of livelihood effect index

Göstergeler	Genel Ortalama	Adıyaman	Denizli	Elazığ	Malatya	Manisa	Mersin	Nevşehir	Tekirdağ
Beşeri Sermaye	**0.261**	**0.312**	**0.261**	**0.237**	**0.288**	**0.227**	**0.282**	**0.325**	**0.227**
Hastalık nedeniyle okul/işe gidemeyen haneler	0.378	0.425	0.268	0.325	0.525	0.400	0.364	0.525	0.225
Hanehalkı reisi eğitim indeksi	0.467	0.531	0.413	0.474	0.454	0.465	0.450	0.515	0.487
Hanehalkı reisi tarımsal deneyim	0.543	0.523	0.557	0.541	0.567	0.560	0.559	0.495	0.483
İklim ile ilgili bilgi/eğitim desteği alamayan haneler	0.602	0.750	0.613	0.613	0.538	0.575	0.582	0.575	0.638
Hanehalkı beslenmesi için yiyecek temin etmede zorluk çekilen ay sayısı	0.078	0.155	0.037	0.110	0.240	0.023	0.047	0.040	0.150
Öğün azaltan haneler	0.073	0.325	0.042	0.025	0.125	0.043	0.036	0.075	0.025
Temel gıda ihtyaçlarını hane dışından karşılayan haneler	0.190	0.273	0.151	0.156	0.273	0.046	0.283	0.544	0.158
Bir yılda aile tüketimi için satin alınan hububat miktarı	0.216	0.136	0.176	0.110	0.159	0.323	0.228	0.141	0.209
Temel gıda alışverişi için hanenin en yakın pazara uzaklığı	0.036	0.029	0.015	0.077	0.030	0.009	0.144	0.023	0.008
Aile bireylerinden bir veya fazlası çalışmak için göç eden hane oranı	0.139	0.100	0.310	0.000	0.075	0.064	0.236	0.300	0.050
Toplam işgücünde aile bireylerinin tarım dışı işlerde geçirdiği süre	0.145	0.111	0.256	0.068	0.122	0.101	0.182	0.268	0.056
Sosyal Sermaye	**0.341**	**0.380**	**0.319**	**0.448**	**0.400**	**0.365**	**0.270**	**0.318**	**0.210**
Hane reisi kadın	0.006	0.000	0.000	0.025	0.025	0.007	0.000	0.000	0.000
Bağımlı nüfus oranı	0.150	0.124	0.167	0.221	0.168	0.170	0.073	0.128	0.118
Hane reisi yaşı	0.572	0.585	0.620	0.663	0.543	0.526	0.540	0.596	0.589
Aile birey sayısı	0.290	0.209	0.306	0.219	0.263	0.335	0.268	0.388	0.213
Bu köyde yaşayan insanlara güvenmeyen hane oranı	0.217	0.200	0.141	0.250	0.250	0.307	0.182	0.175	0.075
Yardımlaşma alamayacağını düşünen hane oranı	0.260	0.375	0.183	0.550	0.375	0.264	0.200	0.125	0.075
Borç alma ve verme konularında güven sorunu yaşayan haneler	0.496	0.475	0.493	0.625	0.475	0.671	0.345	0.375	0.125
Kooperatif ortaklığı veya birlik üyeliği bulunmayan haneler	0.240	0.600	0.169	0.525	0.725	0.093	0.055	0.225	0.025
Tarımsal konularda bilgi desteği alamayan hanelerin oranı	0.837	0.850	0.789	0.950	0.775	0.914	0.764	0.850	0.675
Fiziksel Sermaye	**0.790**	**0.811**	**0.828**	**0.758**	**0.782**	**0.752**	**0.729**	**0.833**	**0.916**
Bina sermayesi	0.631	0.579	0.678	0.650	0.488	0.579	0.606	0.650	0.921
Tarımsal alet makine sermayesi	0.937	0.962	0.937	0.917	0.969	0.909	0.954	0.949	0.957
Hayvan sürü büyüklüğü (BBHB)	0.976	0.985	0.972	0.980	0.925	0.979	0.980	0.989	0.996
Bağ alanı büyüklüğü	0.885	0.926	0.861	0.850	0.964	0.858	0.897	0.882	0.923
Toplam işlenen tarım alanı içerisinde bağcılık payı	0.684	0.438	0.771	0.599	0.546	0.751	0.777	0.628	0.699
Damlama sulama yapamayan işletmeler oranı	0.627	0.975	0.746	0.550	0.800	0.436	0.164	0.900	1.000

Tablo 4 (devam)

Table 4 (continued)

Göstergeler	**Genel Ortalama**	**Adıyaman**	**Denizli**	**Elazığ**	**Malatya**	**Manisa**	**Mersin**	**Nevşehir**	**Tekirdağ**
Doğal Sermaye	**0.436**	**0.492**	**0.445**	**0.460**	**0.482**	**0.350**	**0.475**	**0.454**	**0.523**
Ekilen toplam tarım arazisi ortalaması	0.945	0.956	0.959	0.883	0.975	0.937	0.965	0.916	0.974
İklim değişikliği nedeniyle ortalama bağ verimi azalan işletmeler	0.927	0.950	0.958	0.975	0.925	0.850	0.982	0.975	0.950
Arazi eğimi orta veya dik eğime sahip işletme sayısı (>%7 eğimli))	0.462	0.502	0.461	0.605	0.735	0.113	0.619	0.658	0.816
Toprak yapısı (kıraç arazi yüzdesi)	0.613	0.975	0.674	0.600	0.905	0.153	0.835	0.925	0.851
Pazara uzaklık	0.068	0.095	0.069	0.031	0.132	0.018	0.126	0.075	0.105
Kira ve ortakçılıkla işlenen arazi oranı	0.138	0.067	0.163	0.039	0.035	0.183	0.130	0.189	0.173
Yetiştirilen bağ ürünü çeşitliliği	0.892	0.817	0.869	0.950	0.833	0.971	0.994	0.667	0.817
Toprak erozyonu yaşayan haneler	0.204	0.350	0.197	0.300	0.125	0.164	0.127	0.075	0.425
Sulama kaynağına erişemeyen haneler	0.436	0.925	0.606	0.525	0.700	0.000	0.145	0.650	1.000
Bölgedeki su kaynağı düzenli olarak ihtiyacını karşılamayan haneler	0.313	0.050	0.155	0.450	0.250	0.457	0.655	0.125	0.000
Doğal su kaynaklarının su seviyesinin azaldığını belirten haneler	0.162	0.025	0.103	0.158	0.083	0.279	0.267	0.092	0.000
Sulama kaynağına yatırım riski olduğunu düşünen haneler	0.157	0.000	0.127	0.175	0.100	0.293	0.200	0.025	0.000
Sulama kaynağına uzaklık	0.034	0.000	0.027	0.012	0.042	0.046	0.084	0.014	0.001
Sulama yapılamayan bağ alanı oranı	0.494	0.970	0.622	0.525	0.765	0.056	0.269	0.820	1.000
Tarımsal üretimde çeşitlendirme	0.694	0.696	0.682	0.675	0.621	0.723	0.732	0.611	0.732
Finansal Sermaye	**0.582**	**0.653**	**0.551**	**0.707**	**0.765**	**0.477**	**0.541**	**0.601**	**0.659**
Tarımsal desteklerden faydalanamayan hane oranı	0.322	0.400	0.197	0.475	**0.725**	0.221	0.400	0.300	0.175
Tarımsal kredi kullanamayan hane oranı	0.573	0.550	0.563	0.750	**0.825**	0.436	0.473	0.600	0.775
Tarım Sigortası yaptıramayan hane oranı	0.479	0.500	0.521	0.750	**0.775**	0.293	0.273	0.475	0.750
Tasarruf yapamayan haneler	0.483	**0.875**	0.394	0.600	0.800	0.257	0.400	0.550	0.650
Toplam gelirde tarıma bağımlılık	0.765	0.640	0.752	0.749	0.505	0.858	**0.886**	0.745	0.674
Kişi başı yıllık gelir	0.869	0.951	0.876	0.917	0.957	0.794	0.816	0.935	0.928
LEI	**0.440**	**0.490**	**0.440**	**0.475**	**0.495**	**0.392**	**0.432**	**0.465**	**0.461**

Benzer şekilde çiftçilerin eğitim düzeyi artıkça, bilgi, beceri ve teknoloji açısından daha donanımlı ve bu sayede daha sürdürülebilir ve dirençli tarım uygulamalarına yönlendirilebilirler. Bu durum Williams ve ark. (2018) ve Rai ve ark. (2022) yaptıkları çalışmanın sonuçlarıyla da uyumludur

4. Sonuç

Bu çalışmada, tarım üreticilerin iklim krizi gibi dış şoklar karşısında hanehalkı geçim kaynaklarının ne düzeyde kırılgan olduğu ve bu kırılganlığın bölgeler arasında ne düzeyde farklılaştığı, üzüm üreticileri özelinde ortaya konulmaya çalışılmıştır. Üzüm üreticilerinin sürdürülebilir geçim kaynaklarını oluşturan beş sermaye unsuru açısından dayanıklılığı incelenerek, işletmelerde hangi alanların güçlendirilmesi gerektiği konusunda ilgili paydaşlara ve politika yapıcılara uyum stratejilerinin geliştirilmesinde yol gösterici olması hedeflenmiştir.

Çalışmadan elde edilen bulgular doğrultusunda, Türkiye'de incelenen iller ortalamasına göre üzüm üreticilerinin iklim değişikliğinin olumsuz etkilerine uyum sağlama kapasitelerinin ve tarımsal yapılarının zayıf olması nedeniyle iklim değişikliğinin işletmelerde yarattığı maruziyet geçim kaynaklarını orta düzeyde etkilemektedir. Bununla birlikte çalışma sonucunda incelenen illerdeki bağcılık işletmelerinin iklimsel olaylara maruziyetleri ve hassasiyetlerindeki farklılıkları nedeniyle, uyum stratejilerinin de bu farklılıkları gözeterek geliştirilmesi gerekliliğini ortaya koymaktadır. Genel olarak değerlendirildiğinde ise işletmeler iklimsel olaylardan en fazla aşırı kuraklık, sıcaklık artışları, yağmur sezonundaki gecikmeler ve yağmur sezonundaki kısalmalardan olumsuz etkilenmiştir. Bununla birlikte, hanehalkı gelirinin tarıma bağlılığı, arazilerin toprak yapısı ve sulama imkanları nedeniyle bu iklimsel faktörler karşısında hassasiyetleri daha da artmaktır. Ancak, bu maruziyet ve hassasiyetler ile başa çıkmada, işletmelerin sahip olduğu hanehalkı aktif nüfus varlığı, tarımsal desteklerden faydalanma düzeyi ve kooperatif ortaklığı veya birlik üyeliği gibi unsurların katkısı daha fazladır. Bununla birlikte, uyum kapasitelerini daha güçlü kılacak işletmelerin sahip oldukları sermaye unsurları genel olarak zayıf bulunmuştur. Bu kapsamda değerlendirilen, işletmelerin geçim kaynaklarını oluşturan sermaye unsurları arasında fiziksel sermayeleri, işletmelerin dış şoklara karşı en fazla kırılgan sermaye unsurudur. İşletmelerin sahip oldukları finansal sermaye ve doğal sermaye unsurları ise geçim kaynakları etkilenebilirlik düzeyi üzerinde orta düzeyde etkilemektedir. İşletmelerin beşeri sermaye ve sosyal sermayeleri bakımından dış şoklara karşı daha dayanaklı oldukları sonucuna varılmıştır.

Çalışma kapsamında incelenen işletmeler içerisinde küçük ölçekli, hayvan sermayesi ve tarımsal alet makine sermayesi düşük, sulama imkanı bulunmayan verimliliği düşük, hane geliri büyük oranda tarıma bağlı olup kişi başı düşen geliri düşük, tarımsal üretimde çeşitlendirme yapma imkanı olmayan ve tarımsal üretim ve iklim değişikliği ile ilgili konularda eğitim veya bilgi desteği alamayan hanelerde daha yüksek geçim kaynakları kırılganlık değerine sahip oldukları görülmüştür. Araştırma kapsamında incelenen iller arasında geçim kaynakları kırılganlığı en yüksek Malatya ve en düşük Manisa ilinde bulunmuştur.

Çalışma sonuncunda incelenen tüm bu sermaye unsurları ve tespit edilen yüksek kırılganlık göstergelerinin, iklim değişikliğinin olumsuz etkilerine karşı uyum becerisini artırma ve işletmelerin hassasiyet düzeyini daha dirençli hale gelmesinde birbiriyle bağlantılı unsurlar oldukları söylenebilir. Bu nedenle, tarım işletmelerinin iklim değişikliğiyle mücadelede başarılı olması için fiziksel, finansal, doğal, sosyal ve beşeri sermaye unsurları arasında uyumun önemli olduğu ve tüm sermaye unsurlarının güçlendirilmesinde bütüncül bir yaklaşımın benimsenmesi önemli bir rol oynamaktadır.

Araştırma bölgesindeki işletmelerde fiziksel sermayenin düşük olması, bu işletmelerde modern teknolojilerin yeteri kadar kullanılamadığını ve nakit sıkıntısının yaşandığını göstermektedir. Bu nedenle, özellikle küçük ölçekli finansal sermayenin yetersiz olduğu işletmelerde, devlet teşvikleri, hibe programları veya düşük faizli krediler gibi finansal desteklerle tarım işletmeleri desteklenebilir. Sürdürülebilir tarım uygulamaları, su yönetimi sistemleri, toprak iyileştirme ve erozyon kontrol yöntemleri, erken uyarı sistemleri, işletmelerde biyoçeşitliliğin korunması ve artırılması gibi fiziksel ve doğal sermaye yatırımları ve bunlara yönelik desteklemeler ile iklim değişikliğinin kırsal hanehalkının geçim kaynaklarına olumsuz etkileri azaltabilir. Özellikle küçük ölçekli işletmelerde üretim teknolojilerini geliştirecek finansal destekler önem arz etmektedir. Diğer sermaye unsurlarının geliştirilmesine yönelik geliştirilen tüm stratejilerin ve politika uygulamalarının ise beşeri sermaye ile desteklenmesi önemlidir. Yetkin ve bilinçli beşeri sermayeye sahip tarım işletmelerinin, sürdürülebilir tarım uygulamalarını benimseme ve uygulama konusunda daha istekli olmasına, yenilikçi çözümlerin geliştirilmesine ve tarım sektöründe sürdürülebilirlik adımlarının daha etkin bir şekilde uygulanmasına yardımcı olacaktır.

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Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz

Yazarlık Katkı Beyanı

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Assessment of Crop Water Stress Index (CWSI) of Sorghum Irrigated by Surface and Subsurface Drip Irrigation Methods under Mediterranean Conditions

Akdeniz Koşullarında Yüzeyüstü ve Yüzeyaltı Damla Sulama Yöntemleriyle Sulanan Sorgumun Bitki Su Stresi İndeksinin Değerlendirilmesi

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Abstract

In recent years, subsurface drip irrigation has become increasingly important in view of the increasing drought. As it is a newly developed method, the effects of subsurface drip irrigation (SSDI) and surface drip irrigation (SDI) need to be compared in terms of plant growth and yield parameters as well as water savings. The CWSI is an important index that indicates the water status in the plant and is closely related to yield and plant development parameters. The aim of the study is to compare the CWSI calculated with the SDI and SSDI methods in sorghum. The relationship between CWSI and physiological parameters (leaf number (LN), leaf area index (LAI), chlorophyll content (CC)), as well as bioethanol and juice yield are also evaluated in the study. The study was designed in a randomized complete block design to include two drip irrigation methods (SDI and SSDI) and five different irrigation treatments (I_0, I_{25}, I_{50}, I_{75}, and I_{100}) in three replications in Antalya in 2017. The full irrigation treatment was applied when 40% of the available soil water capacity in the soil profile of 0-90 cm was depleted, while the deficit irrigation treatments were applied at 75%, 50% and 25% of the full irrigation treatment. Consequently, the upper limit value was calculated as 5.5ºC and the lower limit equation was determined as T_c-T_a = -1.96*VPD-0.08 under Mediterranean conditions for the sorghum plant. Compared to the SDI treatments, lower CWSI values were calculated for the SSDI treatments. Additionally, it was determined that as the CWSI increased in sorghum, leaf number, leaf area index, and chlorophyll content values decreased and as a result, juice and bioethanol yield decreased. It was determined that there was a high level of exponential relationship and a strong negative correlation between CWSI-irrigation, CWSI-ET, CWSI-leaf number, CWSI-LAI, CWSI-CC, CWSI-Juice yield, CWSI-bioethanol yield, and CWSI-IWP for both irrigation methods in sorghum. Considering the lower CWSI and higher bioethanol yield, it was concluded that the SSDI method is more suitable for sorghum.

Keywords: Bioethanol yield, Juice yield, Leaf number, Leaf area index, Chlorophyll content

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Öz

Son yıllarda artan kuraklığın olumsuz etkilerinden dolayı, yüzey altı damla sulama yöntemi önem kazanmıştır. Yeni geliştirilen bir yöntem olduğu için yüzey altı ve yüzey üstü damla sulama yöntemlerinin etkisinin hem bitki gelişimi ve verim parametreleri hem de su tasarrufu açısından karşılaştırılması gerekmektedir. Bitki su stresi indeksi (CWSI), bitkideki su durumunu gösteren önemli bir indeks olup, verim ve bitki gelişim parametreleri ile yakından ilişkili olduğu belirlenmiştir. Sorgumun biyoetanol üretim amacı ile yetiştirildiği düşünüldüğünde, su kaynaklarını verimli kullanan ve su kullanım etkinliğini arttıran bir sulama yöntemi üretiminin sürdürülebilir olmasını sağlayacak en önemli uygulama olarak görülmektedir. Bu çalışmanın amacı, sorgumda yüzey (SDI) ve yüzeyaltı (SSDI) damla sulama yöntemlerinde hesaplanan bitki su stres indeksinin (CWSI) karşılaştırılmasıdır. Çalışmada CWSI ile bazı fizyolojik parametreler (yaprak sayısı, yaprak alanı indeksi, klorofil içeriği) ve biyoetanol, özsu verimi arasındaki ilişkiler değerlendirilmiştir. Çalışma, Antalya bölgesinde 2017 yılında tesadüf bloklarında bölünmüş parseller deneme desenine göre üç yinelemeli olarak yürütülmüştür. Deneme konuları, kullanılabilir su tutma kapasitesinin farklı oranları olacak şekilde beş farklı (%100, %75, %50, %25 ve %0) su uygulama düzeyi yüzey (SDI) ve yüzeyaltı (SSDI) damla sulama yöntemlerinde oluşturularak belirlenmiştir. Sonuç olarak sorgum bitkisi için Akdeniz koşullarında üst sınır değeri 5.5^{o}C, alt sınır denklemi ise T_c-T_a = -1.96*VPD-0.08 olarak hesaplanmıştır. Deneme süresince, SDI yöntemi ile karşılaştırıldığında SSDI yönteminde hesaplanan CWSI değerlerinin daha düşük olduğu gözlemlendi. Ayrıca sorgumda CWSI arttıkça yaprak sayısı, yaprak alan indeksi ve klorofil içeriği değerlerinin azaldığı ve bunun sonucunda özsu ve biyoetanol veriminin azaldığı saptanmıştır. Bu çalışmada, sorgumda sulama suyu seviyesi (I)-CWSI, bitki su tüketimi (ET)-CWSI, bitkinin fizyolojik özellikleri (yaprak sayısı, yaprak alan indeksi, klorofil içeriği)-CWSI arasında, özsu verimi-CWSI, biyoethanol verimi-CWSI arasında yüksek düzeyde üstel ilişki ve negatif korelasyon olduğu belirlenmiştir. Düşük CWSI ve yüksek biyoetanol verimi dikkate alındığında, sorgum bitkisi için SSDI yönteminin daha uygun olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Biyoetanol verimi, Özsu verimi, Yaprak sayısı, Yaprak alan indeksi, Klorifil içeriği

1. Introduction

In recent years, the use of bioethanol among renewable energy sources has increased (Azadi et al., 2012; Sarkar et al., 2012; Aksoy et al., 2023). In 2030, it is estimated that bioethanol production will increase by 132 billion liters under current conditions in the world (OECD-FAO, 2021). The most important feature of bioethanol is that plants reuse the CO_2 released during its use and consumption and thus do not cause global warming (Kadam et al., 2002; Lal, 2008). Irrigation is the most important input limiting the environmental sustainability of bioethanol. Energy crops to be grown for this purpose will increase the pressure on water resources during cultivation, as they will constitute a separate area in the agricultural sector that continues to feed people in agriculture. Sorghum is considered the energy plant of the future (Reddy et al., 2005; Almodares et al., 2007; Davila-Gomez et al., 2011; Zegada-Lizarazu and Monti, 2012; Mullet et al., 2014) because it has been determined in many studies that it is a more drought-resistant plant than wheat, corn, and sugar cane used for bioethanol production. Additionally, compared to these plants, the cultivation time is shorter and the production cost is lower (Lueschen et al., 1991; Hunter, 1994; Assefa et al., 2010; Davila-Gomez et al., 2011; Fracassoa et al., 2016). As irrigation water is limited, especially in arid and semi-arid countries, sorghum's drought-tolerant characteristics make its bioethanol cultivation sustainable.

Although sorghum has been identified as a drought-tolerant plant, its response to water stress is unclear in the literature. In studies of deficit irrigation in sorghum, it has been found in some studies that up to a certain level of water deficiency there is no change in yield (Smith and Buxton, 1993; Howell et al., 2007; Miller and Ottman, 2012; Xie and Su, 2012; Campi et al., 2014) while in other studies there is a reduction in yield due to water stress (Sakellariou–Makrantonaki et al., 2006; Sakellariou-Makrantonaki et al., 2007; Dercas and Liakatas, 2007; Mygdakos et al., 2009; Mastrorilli et al., 2011; Vasilakoglou et al., 2011; Klocke et al., 2012; Wani, 2012; Tolk et al., 2013; Jahansouz et al., 2014; Jabereldar et al., 2017; Bell et al., 2018; Polat, 2022). In addition, although bioethanol yield is evaluated in some of the studies (Smith and Buxton, 1993; Sakellariou-Makrantonaki et al., 2007; Vasilakoglou et al., 2011; Miller and Ottman, 2012), there are more studies in which biomass yield is evaluated. More studies are needed to examine the effect of water stress on bioethanol yield in sorghum varieties grown for bioethanol production.

Accurately monitoring the water status of the plant and understanding the plant's response to water stress is very important for optimizing irrigation systems and saving water (Yazar et al., 1999; Gu et al., 2021). The water status of plants can be measured by methods based on plants, soil, and climate indicators, or a combination of these (Jones, 2014; Alves and Pereira, 2000). Direct measurement of the plant's water status is a more useful method because it can directly determine the plant's response to stress, and more accurate information can be obtained since plants can respond to both soil and climatic factors. (Jones, 1990; Khorsandi et al., 2018; Simbeye et al., 2023). Methods such as stomatal conductance, photosynthetic rate, leaf water potential, and stem water potential are commonly used to determine plant water status. However, these methods take a long time and require high labor. Additionally, leaf water potential and stem water potential measurements may cause damage to plants (Ballester, 2013; Khorsandi et al., 2018; Gu et al., 2021). For this reason, water status should be measured with a method that does not harm the plant, is not laborious, and is continuous.

Canopy temperature (T_c), measured via infrared thermometers or thermal cameras, is an ideal physiological indicator for monitoring plant water status (Moller et al., 2006; Ballester et al., 2013; Kullberg et al., 2017). With this method, the plant's water stress can be monitored for a long time without damaging the plant (Jones, 2004; Leinonen and Jones, 2004; Gu et al., 2021). When there is a water deficiency in the root zone of plants, the water potential gradient in the stem decreases. This change reduces stomatal conductance in leaves, causing a decrease in transpiration and consequently an increase in leaf temperature (Hsiao, 1973; Idso, 1982; Jones, 1999; Leinonen and Jones, 2004; Jones, 2004). Therefore, infrared radiation emitted by the canopy can be used as an indicator of plant water stress (Idso et al., 1981; Jackson, 1982; Jones, 1999; Alves and Pereira, 2000; Irmak et al., 2000; Payero et al., 2005; Payero and Irmak, 2006; O'Shaughnessy et al., 2011; Taghvaeian et al., 2012; Ballester, 2013; Bozkurt Çolak et al., 2015). However, canopy temperature is not only affected by water deficiency in the soil, but can also vary depending on meteorological conditions such as air temperature and wind, and morphological characteristics of the plant such as leaf shape and size (Maes et al., 2012). Therefore, canopy temperature needs to be standardized so that it can be used as an indicator of water stress (Gu et al., 2021). Idso et al. (1981) and Jackson et al. (1981) proposed the CWSI and developed empirical and theoretical models to calculate it.

Among CWSI calculation methods, the empirical model has gained importance because it can be calculated using fewer parameters and is more practical. Empirical method has been used to determine water status and schedule irrigation in many plants and consistent results have been obtained O'Shaughnessy et al. (2012) in sorghum, Veysi et al. (2017) in sugarcane, Yuan et al. (2004) in wheat, Payero and Irmak (2006) in corn and soybean, Taghvaeian et al. (2012) in corn. The basic graph on which the non-water stress baseline (NWSB) (lower limit) and non-transpiring baseline (upper limit) are constructed is the key to forming an empirical CWSI model (Idso, 1982). Defining the NWSB is the most important and distinctive stage in constructing the basic graph (Gardner et al., 1992). Studies in the literature have determined that NWSB varies in growth stages and may vary depending on the plant and climate (Idso, 1982; Taghvaeian et al., 2014; De Jonge et al., 2015). However, once reliable NWSB was determined, it was determined that CWSI could be accurately predicted in similar climatic conditions and the same plant, moreover, in the same growth periods (Gu et al., 2021). In many studies conducted under different plant and climate conditions, it has been determined that CWSI is strongly associated with plant physiological characteristics such as leaf water potential, stomatal conductance, and photosynthesis (Xu et al., 2016; Erdem et al., 2010; Sezen et al., 2014; Lena et al., 2020; King et al., 2020; Gonzalez-Dugo et al., 2020; Gu et al., 2021) and with yield (Yazar et al., 1999; Irmak et al., 2000; Wanjura et al., 2000). However, in sorghum, it is not yet clear whether CWSI can predict physiological and yield parameters in the plant or the relationships between them. In sorghum, there are very few studies on the possibilities of using CWSI in irrigation programming and its relationship with plant physical parameters. O'Shaughnessy et al. (2012) theoretically calculated the CWSI values in grain sorghum irrigated with the furrow irrigation method and reported that irrigation in sorghum could be programmed with the CWSI time threshold (CWSI-TT) method. They evaluated the yield as dry grain yield-biomass yield. Olufayo et al. (1996) calculated CWSI values (empirical method) in grain sorghum irrigated with the sprinkler irrigation method. They explained that grain yield can be estimated from average CWSI values. Wanjura et al. (1990) calculated CWSI values in grain sorghum irrigated with furrow irrigation with a theoretical method and determined a linear relationship between mean CWSI and grain yield. Ajayi and Olufayo (2004) explained that grain sorghum yield and ET values can be estimated from canopy temperature data and this can be used in optimum irrigation strategies on a local scale. Karataylı (2021) calculated CWSI values in grain sorghum according to the experimental method. The author determined a linear inverse relationship between the hay yield obtained from different irrigation levels and CWSI and concluded that the CWSI value could be used in irrigation scheduling. Keten (2020) obtained the lower limit and upper limit equations using the experimental method for silage sorghum irrigated with the drip irrigation method.

When the studies on sorghum are examined, it is seen that the studies examining the CWSI change in drip irrigation method are quite limited. While it has been determined that drip irrigation in sorghum both increases yield and saves water, studies comparing surface and subsurface drip irrigation methods have reported that more yields are achieved in SSDI and that this method increases water saving (Sakellariou-Makrantonaki et al., 2006; Sakellariou-Makrantonaki et al., 2007; Mygdakos et al., 2009; Aydinsakir et al., 2021). However, there is no study comparing CWSI obtained from SDI and SSDI methods. In addition, in these studies, the relationship between CWSI and biomass and hay yield values were examined. More studies are needed to examine the relationship between bioethanol yield and CWSI.

The aim of this study is, 1- to calculate the lower and upper limit equations for sorghum under Antalya conditions, 2- to assess mean CWSI values calculated by using experimental methods in SDI and SSDI drip irrigation methods for sorghum, 3- to use a non-linear exponential relationship to describe the relationships between CWSI and irrigation, evapotranspiration (ET), physical characteristics of the plant (leaf number, leaf area index, chlorophyll content), bioethanol and juice yield and irrigation water productivity (IWP).

2. Materials and Methods

2.1. Research area, soil, irrigation water and meteorological parameters

This research was conducted at the Batı Akdeniz Agricultural Research Institute (BATEM), Antalya, between July and September 2017. The physical and chemical properties of the soil are shown in *Table 1*. Na, K, Ca, Mg, HCO_3, SO_4, pH, and EC_w values of the irrigation water used in the study were determined as 0.49, 4.23, 1.85, 5.03, 0.53, 1.06 me L^{-1}, 7.3, and 0.56 dS m^{-1}, respectively. The Monthly average values of meteorological data and long-term measurements in Antalya during the experimental period are given in Table 2. During the research, all meteorological data belonging to the experimental area were taken from the 07.01 coded meteorological station of the Agricultural Monitoring and Information System (TARBIL), which is located at longitudes 36.9411°N, 30.891°E, 250 m away from the experiment side. Detailed information about fertilizer applications and crop protection measures in the research area is also given in Aydinsakir et al. (2021).

Table 1. Physical and chemical characteristics of the soil

Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture	$CaCO_3$ (%)	ECw (dS m^{-1})	pH	Field Capacity (%, g g^{-1})	Permanent Wilting Point (%, g g^{-1})	Bulk Density (g cm^{-3})
0-30	29.18	21.2	49.6	Loam	24.0	0.63	7.50	24.04	12.78	1.35
30-60	32.65	17.3	50.1	Loam	29.7	0.44	7.70	23.52	12.81	1.30
60-90	36.59	15.3	48.2	Loam	30.1	0.38	7.80	21.67	11.30	1.32

Table 2. Monthly mean climatic data throughout the growing season of the sorghum at the experimental site for the long-term and the experimental year.

Years	Months	Temperature (°C)	Rainfall (mm)	Evaporation (mm)	Wind (m s^{-1})	Relative humidity (%)
1954-2016	May	20.4	30.0	143.2	2.0	66.2
	June	25.5	7.6	177.5	1.9	55.2
	July	28.3	3.4	195.5	1.9	54.3
	Aug.	28.2	1.8	172.4	1.7	56.7
	Sep.	24.4	12.3	134.4	1.8	58.8
	Oct.	20.0	80.1	150.6	2.0	61.0
2017	May	21.3	59.6	108.2	1.9	67.7
	June	26.3	-	125.6	1.8	63.1
	July	30.5	-	161.1	1.9	57.4
	Aug.	29.0	-	155.2	1.9	64.4
	Sep.	26.9	-	137.3	1.8	62.8
	Oct.	22.2	12.6	111.5	1.7	53.2

2.2. Plant material, planting, irrigation systems and statistical design

The plant material used was the Sorghum variety (*Sorghum bicolor* L.), which is widespread under 5 Mediterranean conditions. The sorghum seeds were planted in May 2017 with a row spacing of 45 cm and a row depth of 3-5 cm. As a result of the infiltration tests in the field, the average infiltration rate of 12 mm h^{-1} was determined. Accordingly, the distance between the drippers in the rows was 45 cm and the flow rate was determined to be 2.1 L h^{-1}. For SSDI irrigation, laterals were placed at a depth of 45 cm below the soil surface.

Table 3. Irrigation methods and treatments used in the study

Irrigation methods		Irrigation treatments
Irrigated	Surface drip irrigation (SDI)	SDI_{25}
		SDI_{50}
		SDI_{75}
		SDI_{100}
	Subsurface drip irrigation (SSDI)	$SSDI_{25}$
		$SSDI_{50}$
		$SSDI_{75}$
		$SSDI_{100}$
Rainfed		I_0

The study was designed in randomized complete block design to include two irrigation methods (SDI and SSDI) and five different irrigation treatments (I_0, I_{25}, I_{50}, I_{75}, and I_{100}) in three replications. The full irrigation treatment was performed when 40% of the available water capacity in the 0-90 cm soil profile was depleted. In comparison, the deficit irrigation treatments were applied at 75%, 50%, and 25% of the full irrigation treatment. Irrigation methods and treatments are shown in *Table 3*. Details regarding the experimental design of the study can be found in Aydınsakir et al. (2021) article.

2.3. Measurements

The method used to calculate evapotranspiration (ET), leaf number (LN), leaf area index (LAI), chlorophyll content (CC), bioethanol, juice yield, and irrigation water productivity (IWP) values is explained in detail in Aydinsakir et al., (2021). The statistical method used is also detailed in this article. Therefore, information on measuring the parameters required to determine CWSI is given here.

CWSI was calculated according to Idso et al. (1981) by using measured crop canopy temperature (T_c) – air temperature (T_a) and vapor pressure deficit (VPD). Empirical CWSI was calculated using Equation 1.

$$CWSI = \frac{(T_c - T_a)_m - (T_c - T_a)_{ll}}{(T_c - T_a)_{ul} - (T_c - T_a)_{ll}} \quad \text{(Eq. 1)}$$

Where $(T_c\text{-}T_a)_m$ is the measured difference between crop canopy temperature and air temperature, $(T_c - T_a)_{ll}$ is the lower limit representing the temperature difference for a fully irrigated crop, and $(T_c - T_a)_{ul}$ is the upper limit representing the temperature difference between the crop canopy and ambient air when the plants are severely stressed. Canopy temperatures were measured with an infrared thermometer (Spectrum Technologies Inc., Aurora, IL 60504, USA) held in a 90º angle to the soil surface between 12:00 and 15:00 hours, from four directions in each plot. The average of canopy temperatures measured every hour between 12:00 and 15:00 was used to calculate CWSI. To obtain the lower bound, canopy temperatures were measured hourly between 07:00 and 19:00 on August 20, 2017 and September 6, 2017 at full irrigation (I_{100}) in both methods, and their averages were used in the base graph. To increase water stress, three replicate plants were randomly selected from the rainfed treatment (I_0), and one day before the measurement, these plants were separated from their roots and tied with a stick (Sammis, 1988). Canopy temperatures were measured hourly between 12:00 and 15:00 and these values were used to establish a lower limit line. Measurements were taken on August 26 and 27 and on September 6, 7, and 11, 2017 to determine the lower limit.

Vapor pressure deficit (VPD) was calculated using the following equations depending on air temperature and RH values (Allen et al., 1998):

$$e_s = 0.6108 \times exp\left[\frac{17.27T}{T + 237.3}\right] \quad \text{(Eq. 2)}$$

$$e_a = e_s \times \left(\frac{RH}{100}\right) \quad \text{(Eq. 3)}$$

$$VPD = e_s - e_a \quad \text{(Eq. 4)}$$

Where, es is the saturation vapor pressure (kPa), T is the mean air temperature (°C), RH is the relative humidity of the air (%), and, VPD is the vapor pressure deficit (kPa). T and RH values were taken from the meteorological station.

To calculate the CWSI values obtained in this study, the average of canopy temperatures measured every hour between 12:00 and 15:00 was used. Canopy temperatures were measured on July 16, 17, 19, and on August 15, 20, 22, 26, and September 4,6, 7, 11 in 2017.

3. Results and Discussion

3.1. Soil water storage

Soil water storage values during the 2017 growing periods for each treatment (SDI and SSDI) are given in *Figure 1*.

Different irrigation water applications were started on June 10, 2017, and a total of 18 and 16 irrigations were conducted on the SDI and SSDI respectively, depending on soil moisture. With the exception of the rainfall treatment (I_0), soil moisture storage was between the field capacity and wilting point for all treatments in both SDI and SSDI methods. Soil moisture storage decreased below the wilting point from the 60th day after sowing in rainfed treatment (I0). With both irrigation methods, it can be is seen that soil water storage increases with decreasing water deficit (SDI-SSDI). Soil moisture storage flucted near the wilting point throughout the growing season in the SDI_{25} and $SSDI_{25}$ treatments. While soil moisture storage decreased from the 70th day after sowing to the end of the growing period in SDI_{25}, it showed a decreasing change before irrigation and a decrease after irrigation in $SSDI_{25}$. The reason for this is probably that the plant benefits more from the irrigation water supplied to the plant in the SDI method and some of the irrigation water applied in the SDI method evaporates from the soil surface. On the other hand, the SDI_{50} treatment showed a change in soil moisture storage compared to the $SSDI_{50}$ treatment, which was closer to I_0 throughout the growing season. Soil moisture storage changed closer to 50% of available water, especially after the irrigation days in the $SSDI_{50}$ treatment. On the other hand, soil moisture storage decreased below 50% of available water, especially before the irrigation days in SDI_{75}, while the soil moisture storage was generally above 50% of available water throughout the growing season. In addition, soil moisture storage changed between field capacity and 50% of available water in SDI_{100} and $SSDI_{100}$ treatments throughout the growing period, but while the soil moisture storage did not decrease and showed a more stable change in $SSDI_{100}$ treatment, it decreased to 50% available water before irrigation in SDI_{100}.

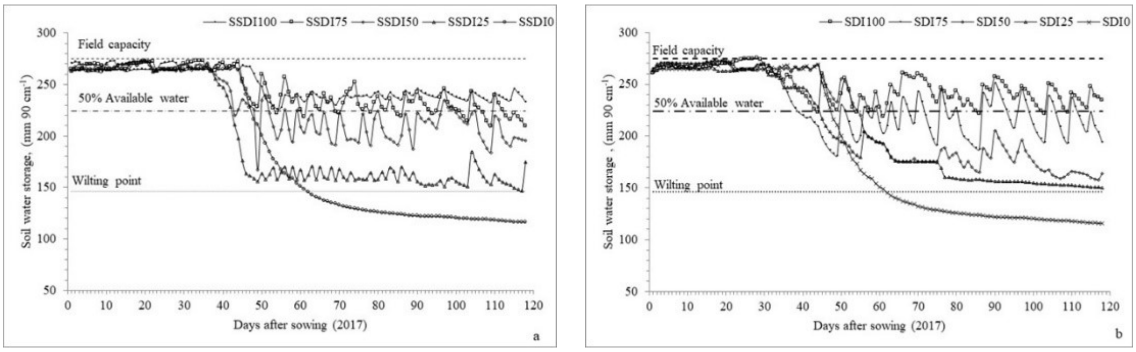

Figure 1. Soil water storage (mm) in 0–90 cm depth in the experiment (a: Subsurface drip irrigation, SSDI; b: Surface drip irrigation, SDI)

3.1. Upper and lower limit baselines

As explained in the material method section, T_c values were measured between 07:00 and 19:00 from I100 for the lower limit, and between 12:00 and 15:00 from the I0 for the upper limit. T_c-T_a values are plotted against VPD and when deriving the regression equation, it is assumed that the plant is not exposed to any environmental stress other than water stress Idso et al. (1981). The basic graph is given in *Figure 2*.

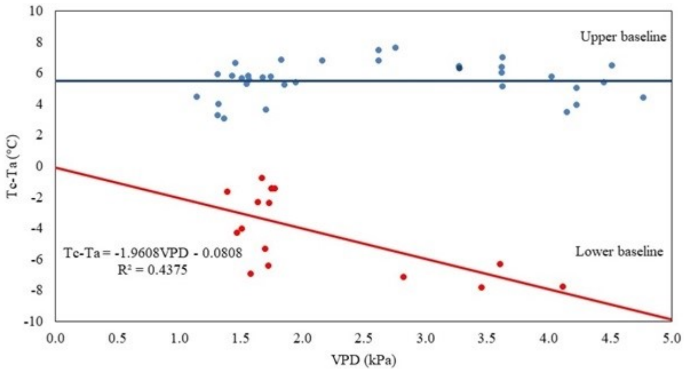

Figure 2. Relationships between canopy temperature and air temperature (T_c-T_a) and vapor pressure deficit (VPD) of sorghum at Antalya

When examining the graph, it becomes clear that the VPD range for the lower limit is between 1.0 and 4.5. Gardner and Shock (1989) suggested that the VPD range should be between 1 and 6, for better use in other studies. In our study, measurements were taken in a wider VPD than in other studies, even though it was not between 1 and 6. As can be seen in Figure 2, the lower baseline changes as a function of VPD, while the upper baselines does not depend on VPD. The resulting lower baseline (No Water Stress Baseline: NWSB) was defined by the linear equation T_c-T_a =-1.96 VPD-0.08 (R^2=0.44). Significant differences were found between the baselines we developed for sorghum and the previously developed baselines. Olufayo et al. (1996) found this baseline for grain sorghum as T_c-T_a=-2.51VPD+3.76 in France, while Keten (2020) determined the lower limit baseline for silage sorghum as T_c-T_a=-1.44VPD+0.4095 in 2018 and T_c-T_a=-1.51VPD-1.18 in 2019 in Kahramanmaraş, Karataylı et al. (2021) determined the lower baseline equation of sweet sorghum plant as $T_c - T_a = -1.7763$ VPD + 3.3395 under Adana conditions. The slope and intercept of a linear relationship in these studies and our study are different. Many researchers have emphasized that slope and intercept may vary according to plant type and different climatic conditions (Idso, 1982; Taghvaeian, 2014; De Jonge et al., 2015). When we compare Karatayli et al. (2021) and Keten (2020), we think that this difference is due to the plant variety. It is known that sweet sorghum, grain sorghum, and silage sorghum show different morphological and biochemical responses to water stress (Massacci et al., 1996; Zegada-Lizarazu and Monti, 2012). Slope and intercept values may vary depending on the plant species or even different genotypes of the same plant (Gu et al., 2021; Godson-Amamoo et al., 2022). For example, Candogan et al. (2013) suggested that the reason for the difference between the slopes and intervals obtained by Nielsen (1990) in soya plants is due to the plant variety and climate conditions. This difference may also be due to the difference in leaf areas between varieties. Kanbar et al. (2020) explained that under the same conditions, there is a difference between the leaf areas (green) obtained from sweet, grain, and forage sorghum genotypes. Since leaf size affects leaf temperature (Smith, 1978), it may have caused the lower limit values obtained from different genotypes to differ. Moreover, the lower limit is also differentiated by the fact that the study was not carried out under similar climatic conditions, irrigation practices, and soil types (Erdem et al., 2012). On the other hand, Olufayo et al. (1996) obtained grain yield in his study. When sorghum is grown for bioethanol, it is harvested immediately after the flowering period, while it is harvested after grain filling for grain yield. Taking measurements during different growth periods may change the NWSB. Although there have been previous studies in which the same NWSB was used successfully in different plants in different growing seasons and did not change according to the growth period (Grimes and Williams, 1990; Candogan et al., 2013; Bellvert et al., 2014; De Jonge et al., 2015; Bozkurt Çolak and Yazar, 2017; Zhang et al., 2023), there are also studies in which it was determined that NWSB varies considerably according to the growth periods and cannot be used (Nielsen et al., 1994; Orta et al., 2003; Cui et al., 2005; Gontia and Tiwari., 2008; Taghvaeian et al., 2014; Veysi et al., 2017; Alghory and Yazar, 2019; Khorsand et al., 2019; Ru et al., 2020; Gu et al., 2021). When these studies are examined, it is a remarkable result that this change occurs mostly in corn plants according to growth periods. For example, Khorsand et al. (2019) determined that the slopes and intercept of the lower limit values obtained in different growth periods of the corn are different. Gu et al. (2021) reported that the slope and intercept values of the lower line change severely as the growth period changes in both corn varieties. Taghvaeian et al. (2013) and De Jonge et al. (2015) obtained different slope values in the same country and city. Although there is no study comparing growth periods in sorghum, we think that similar findings can be obtained with corn plants. Since the sorghum plant is harvested in different growing periods depending on the yield to be calculated, it should be specifically stated in which period the measurements were taken when establishing the lower limit. Since the lower limit values in our study were taken towards the end of the flowering period and the leaf morphology differs during the growth periods of sorghum, we thought that T_c values might also be different.

When we compare the upper limit, Olufayo et al. (1996) calculated it as 0.5-4.5, Keten (2020) calculated it as 0.34-1.13, and Karataylı (2021) calculated it as 3.48. When these studies are examined, it is seen that our upper limit (5.5) is closer to the value found by Olufayo et al. (1996). Since the upper limit line does not depend on the VPD, plant type is more important than the same climate and region. Since the upper limit value was determined in the generative period in this study, this difference may also be due to the difference in the growth period. For instance, Khorsand et al. (2019) determined the upper limit value for corn as 4.69 in vegetative phase-floral initiation, 2.83 in flowering-pollination, and 10.01 in seed seating-seed filling.

For sorghum, in particular studies are required in which both the lower and upper limits are determined and compared separately in different growing seasons as, otherwise the accuracy of the use of the base graphs determined decreases. Idso (1982) stated that taking canopy development into account when developing baselines helps to reduce errors associated with the natural spatial variability of field crops. Furthermore, the use of the graph is limited when the climate changes, even in the same region (Jackson et al., 1981; Jackson, 1982; Payero et al., 2005; De Jonge et al., 2015). Taking measurements under the same climatic conditions, on the same plant species, and during the same growing seasons increases the accuracy of the graph. In addition, the high measurement frequency also has an effect. Payero and Irmak (2006) compared the lower and upper limit lines of corn and soybean by calculating them every 10 minutes. They explained that the baselines varied throughout day and from day to day, and observed a daily variation of about 5 degrees.

3.2. Relationships between mean CWSI and crop growth and yield parameters

The effects of the interaction between the drip irrigation methods and irrigation levels on sorghum parameters are shown in *Table 4*. The relationships among between mean bioethanol yield, juice yield, leaf number, LAI, CC, irrigation, ET, IWP, and mean CWSI for different irrigation treatments in SDI and SSDI methods are given in Figure 3. The correlation coefficients indicating the direction and strength of the relationship between bioethanol yield, juice yield, leaf number, LAI, CC, irrigation, ET, IWP, and mean CWSI are given in *Table 5*. Since this article aims to compare the CWSI values obtained by different methods, we have not discussed the effect of the interaction of irrigation methods and irrigation levels on physiological parameters and yield parameters. More detailed information can be found available in Aydinsakir et al. (2021).

Table 4. Irrigation, evapotranspiration, leaf number, leaf area index, chlorophyll content, juice yield bioethanol yield, hay yield, irrigation water productivity, and crop water stress index in the experiment

Treatments	I (mm)	ET (mm)	LN	LAI (m^2 m^{-2})	CC	Juice yield (L ha^{-1})	Bioethanol yield (L ha^{-1})	Hay yield (t ha^{-1})	IWP (kgm^{-3})	Seasonal average CWSI
SDI_{100}	468.2	553.6	11.0	14.0 b	47.0	44890 a	1799 ab	20.52 b	2.7	0.32
SDI_{75}	346.6	495.8	10.7	11.0 e	38.1	37260 b	1603 bc	15.07 c	2.1	0.34
SDI_{50}	252.0	412.2	10.7	10.6 f	26.7	26260 c	1447 c	13.37 cd	2.3	0.40
SDI_{25}	140.0	312.9	9.7	9.8 h	14.2	24793 d	1412 c	9.15 f	1.2	0.49
I_0	30.5	206.0	9.3	9.0 i	5.8	1596.3 e	90.3 d	7.44 f	-	0.58
$SSDI_{100}$	429.0	526.4	11.0	15.0 a	51.4	51322 a	2085 a	23.67 a	3.1	0.27
$SSDI_{75}$	335.2	450.1	11.0	11.9 b	33.3	50462 a	2045 a	21.07 ab	3.3	0.29
$SSDI_{50}$	232.5	361.4	10.7	11.2 d	20.2	40903 b	1684 bc	15.96 c	2.5	0.35
$SSDI_{25}$	130.2	278.4	10.3	9.9 g	11.5	25574 b	1569 bc	12.11 de	1.6	0.41
			NS	**	NS	*	*	*		-

SDI: Surface drip irrigation, SSDI: Subsurface drip irrigation, I: Irrigation water applied, ET: Evapotranspiration, IWP: Irrigation water productivity, LN: Leaf number (number $plant^{-1}$) LAI: Leaf area index, CC: Chlorophyll content.
*, ** and N.S., Significant at the $p < 0.05$, $p < 0.01$ level and not significant, respectively.

The means indicated with the same small letter in the same column are not significantly different ($p < 0.05$).

Table 5. Correlation coefficients indicating the direction and power of the relationship between irrigation-CWSI, ET-CWSI, leaf number-CWSI, LAI-CWSI, CC-CWSI, Juice yield-CWSI, bioethanol yield-CWSI, IWP-CWSI of sorghum depending on the amount of irrigation water

Parameters	Irrigation methods	Correlation coefficients (r)
CWSI-Irrigation	SDI	-0.980
	SSDI	-0.945
CWSI-ET	SDI	-0.976
	SSDI	-0.956
CWSI-Leaf number	SDI	-0.972
	SSDI	-0.997
CWSI-LAI	SDI	-0.835
	SSDI	-0.836
CWSI-CC	SDI	-0.981
	SSDI	-0.853
CWSI-Juice yield	SDI	-0.938
	SSDI	-0.994
CWSI-Bioethanol yield	SDI	-0.937
	SSDI	-0.994
CWSI-IWP	SDI	-0.883
	SSDI	-0.976

(CWSI: Crop water stress index, ET: Evapotranspiration, LAI: Leaf area index, CC: Chlorophyll content, IWP: Irrigation water productivity, SDI: Surface drip irrigation, SSDI: Subsurface drip irrigation)

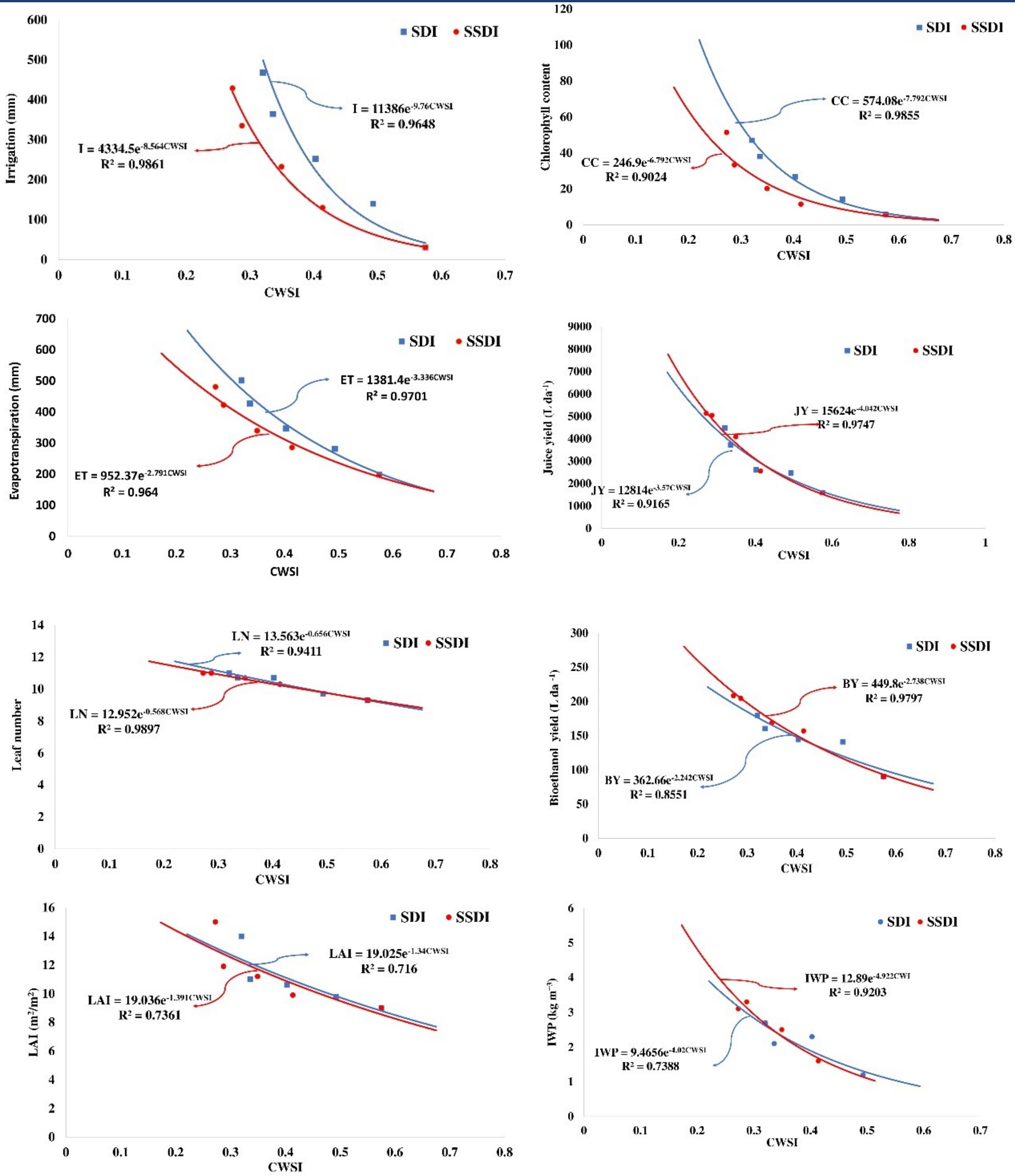

Figure 3. Relationships between CWSI and irrigation, CWSI and ET, CWSI and Leaf number, CWSI and LAI, CWSI and CC, CWSI and Juice yield, CWSI and bioethanol yield, CWSI and IWP (CWSI: Crop water stress index, ET: Evapotranspiration, LAI: Leaf area index, CC: Chlorophyll content, IWP: Irrigation water productivity, SDI: Surface drip irrigation, SSDI: Subsurface drip irrigation)

The seasonal average CWSI in treatments I100, I75, I50 and I25 is calculated as 0.32, 0.34, 0.40, and 0.49, respectively, in the SDI method, while it is calculated as 0.27, 0.29, 0.35 and 0.41, respectively in the SSDI method (*Table 4*). It is a noteworthy that a lower CWSI is calculated for the SSDI method in all treatments with the SSDI method same amount of irrigation. Although less irrigation water was applied at the same levels in the SSDI method, we thought that the lower CWSI value was obtained in all treatments as a result of the plant benefiting more from irrigation water in the root zone in this method. Although there is no statistical difference, the higher IWP values in the SSDI method with the same irrigation levels support this hypothesis. It can be assumed that, the plant uses the water more efficiently with the SSDI method and the amount of transpiration is higher than with the SDI method. It can be assumed that as the amount of transpiration increases, the canopy temperature decreases and, accordingly, CWSI values decrease.

There are only a few studies that compare the CWSI values determined using different methods. Similar to our study, Bozkurt Çolak et al. (2015) compared the SSDI and SDI methods in eggplant and found that the SDI method reduced CWSI values. Similarly, Sezen et al. (2014) reported that the CWSI value calculated by the drip irrigation method in red pepper (*Capsicum annuum L.*) was lower than the furrow irrigation method. On the other hand, Bozkurt Çolak et al. (2021) found that they could not detect any difference between the CWSI values determined by these two methods in the quinoa plant. For sorghum, there is no study in the literature that compares the CWSI values obtained with these methods. For sorghum production to be sustainable, the most appropriate irrigation method must be determined. In our study, the lower CWSI values of the SSDI method prove that this method is more advantageous. However, further studies are needed, especially to compare the CWSI values of the SDI and SSDI methods.

It can be seen that there is no statistical difference between the LN and CC values of the different treatments, but there is a difference between the LAI values (*Table 4*). Again, although higher LAI values were obtained with the SSDI method, lower CWSI values were calculated. The relationship between LAI and CWSI appears to be stronger than the relationship between LN and CC. Although there are studies in which the SSDI method increases LAI values in sorghum (Sakellariou et al., 2007) there is a need for studies investigating the relationship with CWSI.

The highest bioethanol yield values were obtained with $SSDI_{100}$, $SSDI_{75}$ and SDI_{100} and no statistical difference was found between these treatments. In addition, the CWSI value for these treatments was calculated to be 0.27, 0.29, and 0.32, respectively. The lower CWSI calculation for $SSDI_{75}$ than for SDI_{100} indicates that $SSDI_{75}$ is advantageous to achieve the highest bioethanol yield in sorghum while water savings. Also, Aydinsakir et al. (2021) suggested that in cases where water resources are limited, SSDI75 can be used to save water. CWSI values obtained in this study support this result.

When *Figure 3* and *Table 5* were considered together, it was found that there was a high degree of exponential relationship and a strong negative correlation between irrigation-CWSI, ET-CWSI, leaf number-CWSI, LAI-CWSI, CC-CWSI for both irrigation methods in sorghum. In both methods, as the amount of irrigation water applied increases, the water consumption of the plant also increases and thus the transpiration of the plant. Canopy temperature decreases and correspondingly CWSI values decrease. Similarly, Yazar et al. (1999) obtained a linear inverse relationship between applied irrigation (mm) and CWSI in corn. It has been determined that CWSI values increase as water deficit increases in different plants (Sezen et al., 2014; Bahmani et al., 2017; Bozkurt Çolak and Yazar, 2017; Yetik and Candogan, 2023).

Decreasing ET values reduce transpiration values, which increases causing the canopy temperature and thus the CWSI value. Our result is consistent with studies from the literature. Olufayo et al. (1996) observed common and strong relationships between baseline indices canopy surface temperature and relative ET in sorghum under different weather conditions. Furthermore, the researchers stated that ET can be predicted from crown temperature data obtained at different time points. Yazar et al. (1999) identified a linear inverse relationship between ET and CWSI in maize. Braunworth and Mack (1989) found a significant correlation between ET and CWSI (in sweet corn). Yetik and Candogan (2023) found the relationship between ET and CWSI significant in the sugar beet and calculated the determination coefficient of the relationship between ETc and CWSI as $R^2 = 0.9902$. Moreover, the researchers explained that regression equations obtained by graphing ET against CWSI can be used to predict ET. Gu et al. (2021) determined a significant linear correlation between ET and CWSI in corn. In our study, we determined that ET values can be estimated by using CWSI values and $ET = 1381.4e^{-3.336\ CWSI}$ (SDI), $ET = 952.37e^{-2.791CWSI}$ (SSDI) equations. Of course, more studies are needed to support this finding.

The decrease in the number of leaves is due to a lack of moisture in the soil (Sanchez et al., 2002). The decrease in soil moisture reduces carbon assimilation, stomatal conductance, and cell turgor, and leads to stomatal closure. As water stress increases, stomata closure causes leaves to wilt and leaf number to decrease (Prasad et al., 2021). Consequently, when the stomata close, the canopy temperature increases and the CWSI value of the plant increases. In sorghum, the decrease in soil moisture content has been found to reduce the number of leaves (Rostampour, 2013; Mahinda, 2014). In this study, the decrease in the number of leaves was found to increase the CWSI.

In both irrigation methods, LAI decreased when CWSI values increased. Decreasing the number of leaves over soil moisture also decreases LAI. In addition, the transpiration rate of the plant decreased with decreasing irrigation amount, which led to increased temperatures in the tree canopy and growth losses. While CWSI values increased, leaf area decreased due to the decrease in growth, and as a result, LAI values also decreased. An inverse relationship between CWSI and LAI has been identified in many different plants (Erdem et al., 2010; Sezen et al., 2014; Alghory and Yazar, 2019; Kirnak et al., 2019; Bozkurt Çolak et al., 2021; Gu et al., 2021). Although many studies have found that LAI values decrease with increasing irrigation water deficit or water stress in sorghum (Sakellariou-Makrantonaki et al., 2006; Sakellariou-Makrantonaki et al., 2007; Dercas and Liakatas, 2007; Zegada et al., 2012; Mahinda, 2014) no study investigating the relationship between CWSI and LAI was found.

Water stress reduces CC in sorghum (Xu et al., 2000). In both methods, an increase in CWSI leads to a significant decrease in CC and thus impairs efficiency. When plants are under stress, chlorophylls decrease during leaf senescence (Merzlyak et al., 1999). When the plant closes its stomata under stress, transpiration decreases, T_c increases and consequently CWSI increases. CC and CWSI are related to each other, but the correlation test is designed to strengthen the degree of this relationship. In addition, from the equations obtained in our study (*Figure 3*), it was determined that CWSI values can be estimated by measuring the CC value.

Juice yield and bioethanol yield are linked. In different sorghum varieties, bioethanol yield has been determined to be positively correlated with juice yield in various studies (Rono et al., 2018; Suwarti et al., 2018; Güden et al., 2021). Therefore, in this study, we evaluated the relationship of both yield parameters with CWSI. It was determined that there was a high level of exponential relationship (R^2=0.917 in SDI, R^2= 0.975 in SSDI) and a strong negative correlation (r = -0.938 in SDI, r =-0.994 in SSDI) between juice yield and CWSI. In addition, it was determined that there was a high level of exponential relationship (R^2=0.855 in SDI, R^2= 0.980 in SSDI) and a strong negative correlation (r = -0.937 in SDI, r =-0.994 in SSDI) between bioethanol yield and CWSI.

Additionally, by measuring CWSI values, juice yield was determined with the equations $y = 12814e^{-3.57CWSI}$ in the SDI method, $y = 15624e^{-4.042CWSI}$ in the SSDI method, bioethanol yield was determined with the equations $y = 362.66e^{-2.242CWSI}$ in the SDI method, $y = 449.8e^{-2.738CWSI}$ in the SSDI method. These equations can be used to determine the harvest time in sorghum plants grown for bioethanol purposes. When the bioethanol yield values are compared and confirmed by field studies with the help of these equations in all grown periods of sorghum, the harvest time can be decided at a certain threshold value.

It is seen that as CWSI values increase, both juice yield and bioethanol yield decrease. A strong inverse relationship between CWSI and yield has been determined in different plants (Abdul-Jabbar et al., 1985 for alfalfa; Braunworth and Mack, 1989 for sweet corn; Candogan et al. 2013 for soybean; Wang et al., 2005 and Alghory and Yazar, 2019 for wheat; Irmak et al., 2000 and Gu et al., 2021 for corn; Yetik and Candoğan, 2023 for sugar beet). There are studies that a negative linear relationship between grain yield and CWSI in sorghum. Researchers stated that as CWSI value increases in sorghum, grain yield decreases (Wanjura et al., 1990; Olufayo et al., 1996; Karataylı, 2021). Wanjura et al. (1990) emphasized that yield can be estimated using CWSI values in grain sorghum. In our study, we established the relationship between bioethanol yield and CWSI. More studies are needed to examine the relationship between CWSI and bioethanol yield in varieties grown for bioethanol yield.

Additionally, when *Figure 3* and *Table 4* are examined together, there is no statistical difference in terms of bioethanol yield between SDI_{100} (0.32) and SDI75 (0.34), also between $SSDI_{100}$ (0.27) and SSDI75 (0.29). The yield started to decrease after I_{50} (0.40) in the SDI method and after I50 (0.35) in the SSDI method. Here, the threshold CWSI value can be considered as 0.40 in the SDI method and 0.35 for SSDI. In other words, the yield decreases after the CWSI 0.40 in the SDI method, while 0.35 in the SSDI method.

It was determined that there was a high level of exponential relationship (R^2=0.739 in DI, R^2= 0.920 in SDI) and a strong negative correlation (r = -0.883 in SDI, r =-0.976 in SSDI) between IWP and CWSI. As CWSI values increased, IWP values decreased. In other words, we can say that the increase in water stress in the plant reduces the efficiency of the plant per unit of water. As CWSI increased, yield decreased and, as a result, IWP values decreased. Since one of the purposes of determining CWSI is to determine the water status in the plant, it is important to know the relationship between IWP and CWSI. The exponential relation developed between IWP and CWSI is obtained as $IWP= 9.4656e^{-4.02CWSI}$ in SDI, and $IWP = 12.89e^{-4.922CWSI}$ in SSDI.

4. Conclusion

In this study, the upper limit value was calculated as 5.5°C and the lower limit equation was determined as $T_c-T_a = - 1.96\ VPD - 0.08$ in Antalya conditions for the sorghum plant. Additionally, we thought that determining the lower limit values of sorghum in different growth periods could increase the accuracy of using the graph in more areas. In sorghum, we recommend that lower limit values be determined and compared in the same growth periods. In sorghum, we calculated lower CWSI in the subsurface drip irrigation method. More studies are needed to support our finding, comparing CWSI values obtained from surface and subsurface irrigation methods. It was determined that there was a high level of exponential relationship and a strong negative correlation between irrigation-CWSI, ET-CWSI, leaf number-CWSI, LAI-CWSI, CC-CWSI, Juice yield-CWSI, bioethanol yield-CWSI, IWP-CWSI for both irrigation methods in sorghum. More studies are needed to examine the variation between bioethanol yield and CWSI in sorghum, especially in varieties grown for bioethanol production.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Polat, B., Aydinşakir, K., Büyüktaş, D.; Design: Polat, B., Aydinşakir, K., Büyüktaş.; Data Collection or Processing: Polat, B., Aydinşakir, K., Büyüktaş.; Statistical Analyses: Polat, B., Aydinşakir, K., Büyüktaş.; Literature Search: Polat, B., Büyüktaş, D.; Writing, Review and Editing: Polat, B., Aydinşakir, K., Büyüktaş, D.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of The Prevalence of Honey Bee Diseases and Parasites in Samples from Sivas Province

Sivas İli Örneklerinde Bal Arısı Hastalıkları ve Parazitlerin Yaygınlığının Belirlenmesi

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Abstract

Honey bees, *Apis mellifera* L. (Hymenoptera: Apidae), are the most important pollinators of agricultural products and plants in the natural environment. Honeybees are an important ecosystem component due to their role in nature and agricultural production. Bacterial, fungal, viral, and parasitic factors in bee farms are among the most important causes of honey bee colony losses. Honey bee diseases (bacterial, fungal and viral) and parasites are among the most important factors limiting beekeeping development and production efficiency in Türkiye. In addition to diseases caused by bacterial and fungal agents, diseases caused by viral agents are very diverse. Viruses, especially mixed infections, cause colony losses and are the most important factors in the decline of honey bee colonies. In this study the presence and prevalence of honey bee pathogens (*Varroa destructor*, *Nosema ceranae*, *Paenibacillus larvae*, and nine viruses) in suspicious samples with colony losses were investigated in Sivas province. For this purpose, microscopic, microbiological, and molecular methods were investigated on larvae and adult bee. The results showed that the most common viral pathogens in samples from Sivas province were Deformed Wing Virus (70%), *Apis mellifera* Filamentous Virus (60%), Black Queen Cell Virus (60%), Sacbrood Virus (55%) and *Varroa destructor* virus-1 (40%), respectively. In some samples, it was observed that there was a double (17.5%), triple (30%), quadruple (22.5%), or even quintuple (17.5%) association of viral agents. The viral infection/varroa coexistence rate was determined to be 50%. It was determined that 22.5% of the samples examined contained *Nosema* spores, while 12.5% were positive for *P. larvae*. Revealing the distribution of bee diseases will help beekeepers in disease-fighting and taking measures. This study showed the presence of the *Am*FV and the *Varroa destructor* virüs-1 in the Sivas province of Türkiye for the first time.

Keywords: *Apis mellifera* L., Honey bee pathogens, Virus, *Varroa destructor*, Sivas

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Öz

Bal arıları, *Apis mellifera* L. (Hymenoptera: Apidae), doğal ortamdaki tarım ürünleri ve bitkilerin en önemli tozlayıcılarıdır. Bal arıları doğadaki ve tarımsal üretimdeki bu rolleri nedeniyle ekosistemin önemli bir bileşenidir. Arı çiftliklerinde bakteriyel, fungal, viral ve paraziter faktörler bal arısı koloni kayıplarının en önemli nedenleri arasında yer almaktadır. Bal arısı hastalıkları (bakteriyel, fungal ve viral) ve parazitleri Türkiye'de arıcılığın gelişmesini ve üretim verimliliğini sınırlayan en önemli faktörler arasında yer almaktadır. Bakteriyel ve fungal etkenlerin neden olduğu hastalıkların yanı sıra viral etkenlerin neden olduğu hastalıklar da oldukça çeşitlidir. Virüsler, özellikle de karışık enfeksiyonlar koloni kayıplarına neden olur ve bal arısı kolonilerinin azalmasındaki en önemli faktörlerdir. Bu çalışmada Sivas ilinde koloni kayıpları olan şüpheli örneklerde bal arısı patojenlerinin (*Nosema ceranae*, *Varroa destructor*, *Paenibacillus larvae* ve dokuz virüs) varlığı ve yaygınlığı araştırılmıştır. Bu amaçla larva ve ergin arılarda mikroskobik, mikrobiyolojik ve moleküler yöntemlerle araştırmalar yapılmıştır. Sonuçlar Sivas ilinden alınan örneklerde en sık görülen viral patojenlerin sırasıyla Deformed Wing Virus (%70), *Apis mellifera* filamentous virus (%60), Black Queen Cell Virus (%60), Sacbrood Virus (%55) ve *Varroa destructor* virus-1 (%40) olduğunu göstermiştir. Bazı örneklerde viral etkenlerin ikili (%17.5), üçlü (%30), dörtlü (%22.5) ve hatta beşli (%17.5) birlikteliği olduğu görülmüştür. Viral enfeksiyon/varroa birlikteliği oranı %50 olarak belirlenmiştir. İncelenen örneklerde *Nosema* spor varlığı %22.5, *P. larvae* pozitiflik oranı ise %12.5 olduğu belirlenmiştir. Arı hastalıkları dağılımının ortaya çıkarılması arıcılara hastalıklarla mücadele ve önlem alma konusunda yardımcı olacaktır. Bu çalışma ile Türkiye'nin Sivas ilinde ilk kez *Am*FV ve *Varroa destructor*-1 virüsünün varlığını gösterilmiştir.

Anahtar Kelimeler: *Apis mellifera* L., Bal arısı patojenleri, Virus, *Varroa destructor,* Sivas

1. Introduction

Honey bees, *Apis mellifera* L. (Hymenoptera: Apidae), are the most important pollinators of agricultural products and plants in the natural environment. Worker bees, which constitute most of the honey bee population, produce a wide variety of products with high economic value, such as honey, pollen, propolis, royal jelly, bee venom, and beeswax. However, parasites and diseases seen in honey bees negatively affect the development and progress of beekeeping activities. Many pathogens and parasites that affect honey bees also have a worldwide distribution. These pathogens (bacteria, fungi, and viruses) and parasites can be found alone or in groups (Steinhauer et al., 2018; Beaurepaire et al., 2020; Nanetti et al., 2021). Nosemosis and varroosis, common and harmful infectious diseases in honey bee and larvae, play an important role in low honey yield (Salkova and Gurgulova, 2022). Varroosis is one of the diseases that directly or indirectly causes bee loss in beekeeping. Varroosis is so common that it has been reported in almost every part of the world today (Doğanay and Aydın, 2017). *Varroa destructor* causes loss of development by sucking hemolymph in the larval and pupal stages of the honey bee. In addition to causing an average 7% weight loss in the pupa, varroa can act as a biological vector for many viruses and transmit viral agents horizontally and vertically. Nosemosis is one of the most important and common diseases of beekeeping, seen in the digestive system of adult honey bees and causing both colony losses and low honey yield. According to new studies, Nosemosis disease is of fungal origin and is caused by two species, *Nosema apis*, and *N. ceranae*, which belong to the *Nosema* genus in Microspora (Grupe and Quandt, 2020). Many factors play a role in the spread of nosemosis, such as climatic conditions, inadequate care conditions, diseases such as amoebiasis, and insufficient nutritional supplements during the winter (Mayack and Hakanoğlu, 2022). American Foulbrood (AFB) disease is a contagious infection that causes severe losses to the larvae of the honey bee *Apis mellifera* L. and other *Apis* species. *Paenibacillus larvae*, the causative agent of AFB, is a Gram-positive, dangerous, and contagious bacterium whose spores are highly resistant to adverse environmental conditions (Pernal and Clay, 2013). The spore form germinates in honey bee larvae and causes disease. The spore form, which is pathogenic for larvae, does not cause pathogenicity in adult bees. The spore form is highly resistant to environmental conditions, heat, and chemicals. AFB disease occurs after germinating spores in the midgut due to hatched larvae consuming food contaminated with bacterial spores, leading to septicemia (Chioveanu et al., 2004).

One of the problems in beekeeping is symptomatic and asymptomatic infections caused by viral disease. Bee viruses can be transmitted to bees horizontally, vertically, or via vectors (Beaurepaire et al., 2020). *Varroa destructor* is a biological or mechanical vector for many bee viruses and is accepted as an ectoparasite of honey bees in vector-mediated transmission (Yañez et al., 2020). It is known that there is a close mutualistic relationship, especially between the Deformed Wing Virus (DWV) and *Varroa* mite, and even for a long time, the clinical symptoms of DWV were mistakenly associated with *Varroa destructor* (Gebremedhn et al., 2020). Bee viruses can cause wing deformations, loss of body hair, paralysis, tremors, developmental disorders in larvae, the short lifespan of bees, or death in different life forms in honey bees. While most viruses known to exist in honeybees, showing symptomatic or asymptomatic symptoms, carry RNA genetic material, a small portion carry genetic material in DNA. The research on viral infections in honey bees has focused chiefly on RNA viruses (Beaurepaire et al., 2020). Acute Bee Paralysis Virus (ABPV), *Varroa destructor* virus-1 (VDV1), Black Queen Cell Virus (BQCV), Chronic Bee Paralysis Virus (CBPV), Deformed Wing Virus (DWV), Kashmir Bee Virus (KBV), Sacbrood Virus (SBV), and Israeli Acute Paralysis Virus (IAPV) are some of the most studied honeybee RNA viruses (Beaurepaire et al., 2020). *Apis mellifera* Filamentous Virus (*Am*FV) is a double-stranded DNA virus that infects honey bees. *Am*FV is thought to be the most common and least harmful bee virus (Bailey, 1982).

The study aimed to identify the presence and distribution of parasitic and disease-causing pathogens in honeycomb, adult bees, and larvae samples taken from suspicious beehives in different districts of Sivas province. The study determined the distribution of honey bee disease pathogens and parasites and the viral factor-induced multiple infection rates.

2. Materials and Methods

2.1. Collection of suspicious samples and microscopic diagnosis of parasitic diseases

The study was conducted with suspected samples from Sivas province, where bee enterprises are practiced

(*Figure 1*). Suspicious samples were taken from the hives in the bee enterprises. Samples from different hives (honeycomb and adult bees) were examined for *Varroa destructor* positivity and *Nosema ceranae* positivity in adult bees. *V. destructor* identification was carried out according to the instructions described in the OIE Terrestrial Manual (OIE, 2021). Morphological identification of *V. destructor* was performed by detection with the alcohol washing method (Oliver, 2020). Both larval and adult bee samples were examined to investigate the presence of varroosis in the hives. All pupae, larvae, and honeybee samples collected from each hive were examined separately, and all containers were placed at -20°C overnight, and the surviving bees were allowed to die or dorm. The container with bees was poured into a petri dish, and 50-500 adult bees were examined under the stereomicroscope for *Varroa* spp., presence. The spaces between the abdominal segments and under the wings of all bees were especially checked. *V. destructor* samples were first examined morphologically. All positive samples were stored at -20°C (Doğanay and Aydın, 2017; OIE, 2021). The abdomens of 20 bees were separated and crushed in 3 mL of SF (serum physiologic) to diagnose nosemosis. For direct examination, approximately 3 drops of the resulting suspension were taken and placed on a microscope slide, a coverslip was applied, and the spores were examined under a light microscope (400X magnification). Samples found positive for *Nosema* spores were photographed (Tel et al., 2021).

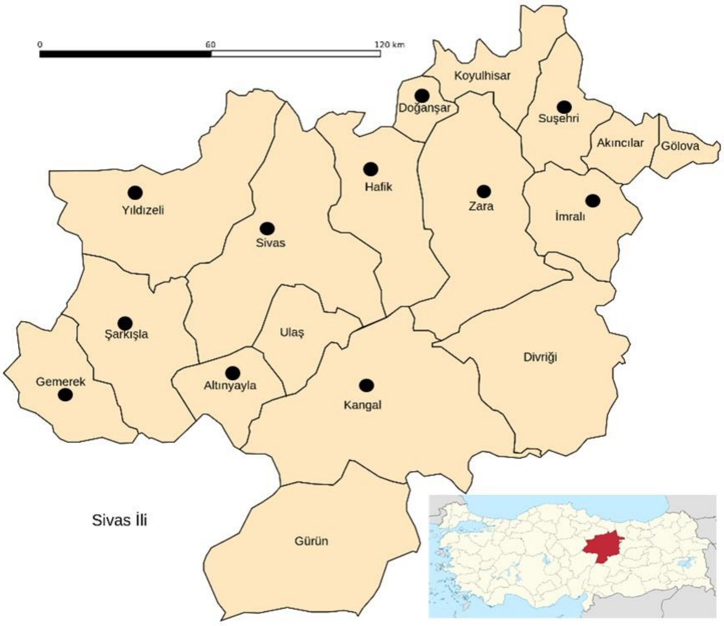

Figure 1. Districts where suspicious samples were collected in Sivas province

2.2. Investigation of American Foulbrood disease by culture method

In the diagnosis of AFB, 3-5 honey bee larvae selected from each comb were suspended in 9 ml of PBS (phosphate-buffered salt solution). Approximately 15 adult bee samples were transferred to a cryotube in 3 ml PBS and disrupted in a homogenizer (Bead Ruptor Elite, Bead Mill Homogenizer, USA). All prepared solutions were heated in a water bath at 80°C for 10 minutes to eliminate vegetative bacteria. The basic honeycomb sample weighing 1.5 grams was dissolved in 10 ml chloroform. Two millilitres of this solution were mixed with six millilitres of physiological saline. Following this, a direct inoculation of 100 microliters solution was carried out. For the isolation of *Paenibacillus larvae*, Brain Heart Infusion agar (BHIA, Thiamine added), Colombia sheep blood agar (CSA 5% sterile defibrinated sheep blood, Nalidixic acid/Pipedimic acid added) and MYPGP agar (Mueller-Hinton broth, yeast extract, K_2HPO_4, glucose, sodium pyruvate, agar and nalidixic acid/pipedimic acid added) were used. All cultured media were incubated at 37°C in an incubator with 5-7% CO_2 for 3-5 days. Petri dishes on which no microorganism growth was observed were incubated under the same conditions for one week. Gram and nigrosin staining were performed and examined under a light microscope to identify the observed microorganism colonies. Additionally, catalase testing was performed on bacterial cultures for diagnosis (OIE, 2018).

2.3. Total Nucleic Acid Extraction and One-step RT-PCR Analysis

Adult bees and larvae taken from each hive were homogenized separately. Fifteen larvae samples from the same hive were transferred to 7 mL cryotubes, and 3 mL of PBS (Sigma, 806544, USA) was added. Larval and adult bee samples were homogenized in an automatic homogenization device (Bead Mill Homogenizer SKU 19-042E, OMNI International, USA). After homogenization, the samples were centrifuged at 4000 rpm at 4 °C for 15 min, and the supernatants were collected. The supernatant was used for RNA extraction. RNA extraction was performed using a commercial kit (High Pure Viral Nucleic Acid Kit, Roche, Germany) according to the company's protocol.

RNA extracts obtained from larval and adult bee samples were tested separately with One-step RT-PCR for nine viruses that are thought to cause honey bee diseases. The list of primers used for each disease is given in *Table 1*. Reaction mixtures and thermal conditions were applied the same for one-step RT-PCR testing in all viral diseases. The one-step RT-PCR method specified by Chen et al. (2006) was used for this purpose. A commercial kit (RT-PCR Kit, QIAGEN, Germany) was used for the one-step RT-PCR assay. The reaction mixture was prepared by adding 12.5 µL of RT-PCR Master Mix, 0.8 µL of each of 10 pmol of forward and reverse primers, 0.25 µL of RT Mix, and 5.65 µL of ultrapure water. By adding 5 µL of the suspicious RNA sample, the total reaction volume became 25 µL. The reaction mixtures were transferred to the Thermal Cycler device (T100 Thermal Cycler, BIO-RAD, Singapore). Thermal conditions were applied in the Thermal Cycler, so RT and PCR steps were performed as one. It was kept at 50 °C for 30 minutes to convert the RNAs into cDNA and then at 95 °C for 15 minutes to inactivate the reverse transcriptase enzyme. Following this process, 60 seconds at 94 °C for pre-denaturation, 60 seconds at 55 °C for annealing, and 60 seconds at 72 °C for extension were applied in 40 repetitions. Finally, the reaction was terminated by a final extension at 72 °C for 10 minutes. After the PCR reaction, PCR samples were run on a 2% agarose gel containing ethidium bromide for 45 minutes at 75 Volts and visualized under UV light. Positive virus DNA samples and accession numbers used in the study, respectively, ABPV (OP504103), BQCV (OK345070), DWV (OP504101), *Am*FV (OP642035), CBPV (EU122229), KBV (OP504105), SBV (OP504108), IAPV (OP504110), and VDV1 (OP504112). These positive virus DNAs were used as positive controls in PCR.

Table 1. Primers used in this study

Viruses *	Primer sequences	(bp)	References
ABPV	ABPV-F: 5’- CATATTGGCGAGCCACTATG -3’ ABPV-R: 5’-- CCACTCCACACAACTATCG3’	398	(Benjeddou et al., 2001)
IAPV	IAPV-F: 5’-CGATGAACAACGGAAGGTTT-3’ IAPV-R: 5’-ATCGGCTAAGGGGTTTGTTT-3’	767	(Palacios et al., 2008)
KBV	KBV-F: 5’-GATGAACGTCGACCTATTGA-3’ KBV-R: 5 -TGTGGGTTGGCTATGAGTCA-3’	415	(Stoltz et al., 1995)
BQCV	BQCV-F: 5’-CTTTATCGAGGAGGAGTTCGAGT-3’ BQCV-R: 5’-GCAATAGATAAAGTGAGCCCTCC-3’	536	(Sguazza et al., 2013)
DWV	DWV-F: 5’-TGGTCAATTACAAGCTACTTGG -3’ DWV-R: 5’-TAGTTGGACCAGTAGCACTCAT -3’	269	(Sguazza et al., 2013)
SBV	SBV- F: 5’-CGTAATTGCGGAGTGGAAAAGATT-3’ SBV- R: 5’-AGATTCCTTCGAGGGGTACCCTCATC-3’	342	(Sguazza et al., 2013)
CBPV	CBPV-F: 5’- AACCTGCCTCAACACAGGCAAC-3’ CBPV-R: 5’- ACATCTCTTCTTCGGTGTCAGC-3’	774	(Sguazza et al., 2013)
*Am*FV-112	AmFV-F:5’-CAGAGAATTCGGTTTTTGTGAGTG -3’ AmFV-R:5’-CATGGTGGCCAAGTCTTGCT-3’	551	(Gauthier et al., 2015)
VDV1	VDV-1 F:5’- GCCCTGTTCAAGAACATG-3’ VDV-1 R:5’-CTTTTCTAATTCAACTTCACC-3’	430	(Gauthier et al., 2011)

* ABPV: Acute Bee Paralysis Virus, BQCV: Black Queen Cell Virus, CBPV; Chronic Bee Paralysis Virus, DWV; Deformed Wing Virus, KBV; Kashmir Bee Virus, SBV; Sacbrood Virus, IAPV; Israeli Acute Paralysis Virus, *Am*FV-112: *Apis mellifera* Filamentous Virus, VDV1: *Varroa destructor* Virus-1

3. Results and Discussion

3.1. Determination of Varroosis, Nosemosis, and American Foulbrood

Türkiye has a rich plant diversity due to its geographical structure and climatic conditions, and beekeeping activities are carried out in many regions. Sivas province is among the provinces with the highest honey production in Turkey due to its climate and flora (Yüzbaşıoğlu, 2022). In Sivas province, the beekeeping activity lasts shorter than in other regions due to the extended winter season, and the flowering periods of the plants differ according to the regions. Although temperature conditions shorten the duration of beekeeping activities, non-sweltering summer temperatures create favorable conditions for this activity (Koç et al., 2020). Diseases encountered in beekeeping, such as viruses, bacteria, *Nosema*, and *Varroa*, affect adult honey bees and their larvae, causing low honey productivity, colony losses, and serious economic losses globally (Bordin et al., 2022).

Larval honeycomb and adult bee samples sent to the Samsun Veterinary Control Institute from Sivas province between 2020 and 2023 were examined. The research was carried out in the Sivas center and eight districts. The study investigated the presence and spread of *N. ceranae, P. larvae* spores and *V. destructor* in honey bees and suspected larvae. The results showed that *N. ceranae* spores were present in the preparations, while *V. destructor* was present in the bees, as shown in *Figure 2*. The study found that *Varroa* mite was quite common in the samples examined, with a 50% prevalence rate, whereas the presence of *Nosema* spores was observed to be less frequent, with a prevalence rate of 22.5%.

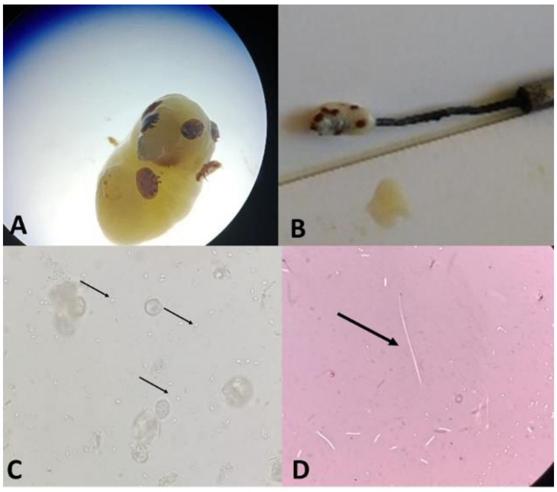

Figure 2. A-B; V. destructor on honey bee larvae, C: Nosema ceranae spores, D: Paenibacillus larvae nigrosin staining zigzag positive image

In a study conducted in Bulgaria in 2020-2021, *Varroa destructor* was investigated in honey bee samples, which were examined by light microscopy. The results revealed that 32.43% of the bees were infected with *V. destructor* (Salkova and Gurgulova, 2022). In the study by Yilmaz et al. (2018), where they examined the frequency of *V. destructor* in hives in the autumn period in the Eastern Black Sea region, the highest incidence of *V. destructor* was observed in Rize province (47.7%), while the lowest incidence was reported to be in Bayburt province (20%). Köseman et al. (2017) reported that varroosis is the most common honey bee disease in Malatya (47.8%). Karapınar et al. (2018) reported that the suspicious samples from Van province that were examined morphologically, were found to be *V. destructor*, the prevalence 89%. In our study, *V. destructor* prevalence was determined to be 50% in microscopic and morphological examination of samples from Sivas province. The discrepancies observed in studies conducted in different regions of Türkiye are attributed to the variation in climate and seasonal timings. Determining the prevalence of *Varroa* mite is crucial as it is a vector for bee viruses, acting as an ectoparasite. *V. destructor* is one of the reasons for the morphological damage it causes to adult bees and larvae, as well as the spread of disease agents in hives. In a study conducted in Bulgaria, it was observed that 25.40% of the honey bee samples were contaminated with *N. ceranae* spores. It was determined that 32.43% of the Bulgarian samples were infected with both *Varroa* mite and *Nosema* spores. Negative samples had the lowest value, with 9.74% (Salkova and Gurgulova, 2022). In a study conducted in the South Marmara region, it was reported that none of the colonies sampled were infected with *N. apis*, and *N. ceranae* was found in 64.3% of all sampled colonies (Mayack and Hakanoğlu, 2022). In a study conducted in Central Anatolia and Mediterranean regions, the rate of *N. ceranae* was reported as 46% (Avcı et al., 2022). In a survey conducted in the Muğla provinces, only the *N. ceranae* species was detected, while the prevalence of nosemosis was reported as 71.53% (Kartal et al., 2021). It is thought that the high disease intensity in Siirt, Şanlıurfa (43.8%) (Tel et al., 2021), Muğla (71.53%) (Kartal et al., 2021), and Ordu (44%) (Yaman et al., 2015) provinces may be due to climate differences and bee population density. According to Özgör et al. (2015), it was reported that temperature and humidity values directly affect *Nosema* species and density in apiaries. The spores of *N. ceranae* increased where these two factors increased, and the density of *Nosema apis* increased where these two factors decreased. The reason for the difference in disease prevalence between regions may be the differences in climatic conditions. In our study, the nosemosis infection rate was found as 22.5%. Our result was not as high as the prevalence in Muğla and Ordu provinces. The reason for that Sivas province has cold and harsh winters, and there is abundant snowfall in the winter months. In fungal infections, humidity and other conditions may also affect nosemosis intensity. Although the long winter season in Sivas province shortens the duration of beekeeping activities, the summer temperature values create suitable conditions for this activity.

In our study, *P. larvae*-positive samples were determined by cultural analysis of suspicious samples from Sivas province. The samples sent to investigate the positivity of American Foulbrood (AFB) disease agent *Paenibacillus larvae* were analyzed. Clinical observation revealed that the larvae had concave and punctured lids, and the color of the larvae changed from beige to brown. In the matchstick test, when a needle was inserted into the larval remains and removed from the cell, it was observed that the larvae elongated in threads, which is known as AFB symptoms. Microscopically, a spiralling structure typical of AFB was observed in the nigrosin staining preparation (*Figure 2*). In culture examination, small, regular, sometimes rough, and beige-colored *P. larvae* colonies were observed on MYPGP agar medium. *P. larvae* could not be detected in any of the basic comb samples received. In the cultural analysis of larval combs and adult bees, a 12.5% spread was determined (*Table 2*). It was determined that the samples with positive AFB culture came from the centre, Yıldızeli, and Kangal districts. Among the samples examined in the Northwest Pakistan region, the prevalence of AFB-positive samples was in the Kohat region, with the highest positivity rate of 39%, followed by Bannu at 37% and Karak region at 34.5% (Anjum et al., 2015). Şık et al. (2022) reported 30.7% *P. larvae* positivity in their study of suspected AFB samples from Ankara Etlik Veterinary Control Central Research Institute between 2015 and 2020. In a study conducted in the South Marmara region, AFB was prevalent in 31.3% (Mayack and Hakanoğlu, 2022). Another study conducted in the Central and Eastern Black Sea region reported a prevalence of 4.38% for AFB (Akpınar et al., 2023). In our study, it was observed that *P. larvae* positivity was less than the results in other studies (Mayack and Hakanoğlu, 2022; Şık et al., 2023; Akpınar et al., 2023).

3.2. Determination of viral agents by One-step RT-PCR method

Between 2020 and 2023, suspicious larval honeycomb and adult bee samples in Sivas province were sent to the Samsun Veterinary Control Institute to be examined for the presence of the virus. For this purpose, the larval and adult bee samples were homogenized and used for RNA isolation. The resulting RNA material was converted into cDNA to use in RT-PCR. PCR products resulting from RT-PCR were visualized on a 2% gel. The presence of PCR products of different sizes obtained for nine viruses was evaluated as positive (*Table 1*, *Figure 3*).

Tentcheva et al. (2004) reported that the virus prevalence was higher in adult bees than in larvae. Chronic Bee Paralysis Virus (CBPV) prevalence was 28% in adult bees but could not be detected in larvae. In a study conducted in Croatia in 2014, the frequency of CBPV was reported to be very low at 9.75% (Gajger et al., 2014). Other European survey studies observed that the prevalence of CBPV was relatively low. Gümüşova et al. (2010), reported a study in the Black Sea region and a prevalence of 25% of CBPV, while Çağırgan and Yazıcı (2021), conducted a study in the Aegean Region and reported a prevalence of 1.8%. The results showed that the virus with the highest prevalence was Deformed Wing Virus (DWV) (19.8%), followed by Black Queen Cell Virus (BQCV) (18%), Acute Bee Paralysis Virus (ABPV) (3.6%), and Sacbrood Virus (SBV) (2.7%), respectively. Consistent with the study conducted in the Marmara region, it was reported that CPBV could not be detected (Mayack and Hakanoğlu, 2022). It was determined that CBPV, one of the nine viruses investigated in the suspicious samples in our study, could not be detected in any sample. Similar to our study's result, it was reported that CPBV could not be detected in the study conducted in the Marmara region (Mayack and Hakanoğlu, 2022). Although the values varied in studies conducted on the prevalence of CBPV, it was observed that the results were consistent with the results in our study. In the study conducted in Amasya and Elazığ provinces, the spread of three viruses, DWV (23.81%), ABPV (12.93%), and BQCV (10.20%), was revealed (Aydın and Oksal, 2023). In Bingöl province, SBV and BQCV infection rates were reported as 7.03% and 11.70%, respectively, but ABPV infection was not detected in any of the apiaries (Güller and Kurt, 2022). Avcı et al. (2022) showed that 90% of worker bees were infected with at least one virus. BQCV (90%) had the highest prevalence, followed by DWV and ABPV prevalence of 84% and 62%, respectively. In our study, the SBV and BQCV infection rates were relatively high in our samples from Sivas province, at 55% and 60%, respectively, while the ABPV infection rate was low at 7.5%.

The presence of honey bee viruses in different climatic regions of Argentina was evaluated and compared. In the study, it was reported that Kashmir Bee Virus (KBV) and Israeli Acute Paralysis Virus (IAPV) could not be detected, and five other viruses had different prevalence: DWV (35%), ABPV (21.5%), BQCV (8.0%), CBPV (2.2%) and SBV (1.1%). Approximately 25% of sampled colonies were found to have double and triple viral associations (Molineri et al., 2017). Other studies reported the presence of KBV in France and Denmark (Tentcheva et al., 2004), but KBV could not be detected in Austria, Croatia, and Hungary (Gajger et al., 2014). According to Tozkar et al. (2015), KBV was not detected in their studies conducted in Türkiye. Similarly, Çağırgan and Yazıcı (2021) reported that neither KBV nor IAPV were detected in larvae and honey bee samples collected from the Aegean region. In the study conducted in the Marmara region, the KBV rate was reported as 2.4% (Mayack and Hakanoğlu, 2022). The result in our study was determined as KBV 2.5% and IAPV 10%. When the studies were compared in general, the prevalence of KBV and IAPV was very low or could not be detected at all.

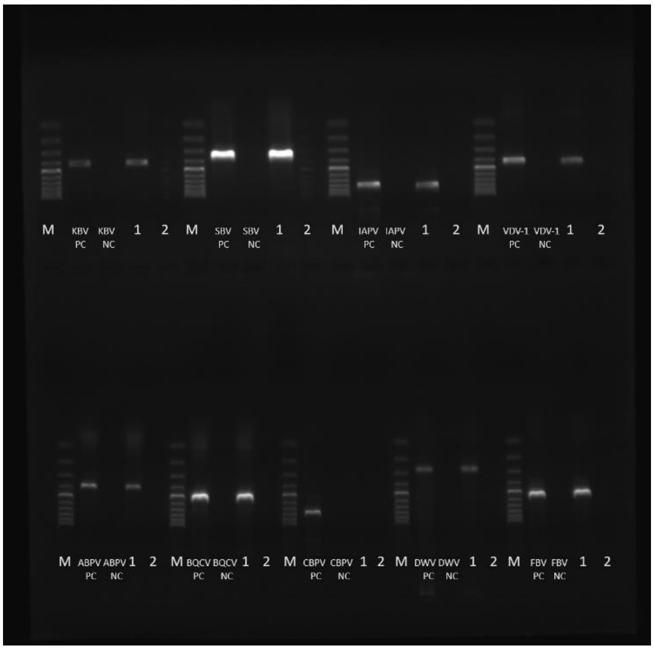

Figure 3. PCR gel images of viruses in One-step RT-PCR

PC; Positive control, NC; Negative control, M; marker, Acute Bee Paralysis Virus (ABPV), Black Queen Cell Virus (BQCV), Chronic Bee Paralyses Virus (CBPV), Deformed Wing Virus (DWV), Kashmir Bee Virus (KBV), Sacbrood Virus (SBV), Israeli Acute Paralysis Virus (IAPV), Apis mellifera Filamentous Virus (FV), Varroa destructor Virus-1 (VDV1)

The number of studies revealing the existence and spread of viral diseases of honey bees in Türkiye has increased rapidly in recent years. DWV and the closely related *Varroa destructor* virus-1 (VDV1) are the most common honeybee viruses. VDV1 was known to cause high rates of overwintering colony losses in Europe but was unknown in the USA. After developing new sequencing technology, VDV1 was identified in honeybee pupae in the USA. In 2016, VDV1 was found in 66.0% of 603 beehives in the USA; this makes VDV1 the second most common virus after DWV, found in 89.4% of colonies (Ryabov et al., 2017). DWV and VDV1 are related, but there is little information about the prevalence of VDV1. While it was known as VDV1 when first identified, it was named DWV-B, or genotype B in the following years (Paxton et al., 2022). There is a knowledge gap about this virus, considering its potential role in the colony loss rates of virus diseases. Paxton et al. (2022) reported that DWV is one of the main factors in colony collapse, and VDV1 has started to replace the DWV virus in Europe. Since VDV1 is a recombinant form of DWV, it may further increase the severity of the disease and colony collapse. In our study, the prevalence of DWV and VDV1 in Sivas province was determined to be 70% and 40%, respectively. It is noteworthy that DWV prevalence is relatively high in suspected samples, while VDV1 prevalence is close to *Varroa* prevalence (50%). Considering that *V. destructor* is accepted as an ectoparasite vector for DWV and VDV1 (Paxton et al., 2022), it is an inevitable result that the prevalence values are similar.

Table 2. Percentage of positivity in suspicious samples from Sivas province by district

Locality	**Sample**	**ABPV**	**BQCV**	**CPBV**	**DWV**	**KBV**	**SBV**	**IAPV**	**VDV1**	***Am*FV**	**Var**	**Nos**	**AFB**
Center	10	0	5	0	6	0	5	1	4	6	4	0	2
Yıldızeli	6	2	2	0	6	1	3	0	3	3	4	2	2
Zara	6	0	3	0	3	0	2	0	6	5	2	0	0
Gemerek	5	0	4	0	5	0	4	0	1	2	4	2	0
Kangal	4	0	4	0	1	0	3	1	1	2	2	3	1
İmranlı	3	0	3	0	2	0	3	1	0	2	0	1	0
Doğanşar	2	1	2	0	2	0	1	0	1	1	2	0	0
Altınyayla	1	0	0	0	1	0	0	0	0	0	1	0	0
Hafik	1	0	1	0	1	0	0	0	0	1	1	1	0
Şarkışla	1	0	0	0	1	0	1	0	0	1	0	0	0
Suşehri	1	0	0	0	0	0	0	1	0	1	0	0	0
Total	40	3	24	0	28	1	22	4	16	24	20	9	5
%	100	7,5	60	0	70	2,5	55	10	40	60	50	22,5	12.5

ABPV; Acute Bee Paralysis Virus, BQCV; Black Queen Cell Virus, CBPV; Chronic Bee Paralysis Virus, DWV; Deformed Wing Virus, KBV; Kashmir Bee Virus, SBV; Sacbrood Virus, IAPV; Israeli Acute Paralysis Virus, VDV1; Varroa destructor Virüs-1; AmFV: Apis mellifera Filamentous Virus, AFB; American Foulbrood, Nos; Nosema ceranae, Var; Varroa destructor

Apis mellifera filamentous virus (*Am*FV) is a double-stranded DNA virus that infects honey bees. The prevalence of *Am*FV in apiaries was found to vary between 10% and 80% in China (Hou et al., 2017), and that prevalence was 61% (19/31) in eight provinces of Argentina (Quintana et al., 2021). Although *Am*FV was considered a weak pathogen for honey bees, it has been proposed that it may weaken the bees to a certain degree, making them more susceptible to other pathogens (Yang et al., 2022). In a study comparing the prevalence of *Am*FV in the USA and Switzerland using PCR analysis, it was reported to be detected in 64% of Swiss colonies and 100% of US colonies (Hartmann et al., 2015). The presence and prevalence of *Am*FV were not associated with *V. destructor* in honey bee colonies, suggesting that *Varroa* is not an important factor in *Am*FV prevalence and transmission (Gauthier et al., 2015). In our study, the presence of *Am*FV was detected in all districts sampled in Sivas province (except Altınyayla), and its prevalence was determined to be 60%. *Am*FV prevalence (60%) was one of the two most common viruses after the DWV virus (70%). Similar to previous studies (Quintana et al., 2021), the prevalence of *Am*FV in Sivas province was determined to be high. In a study in Germany, the most common viruses found were BQCV (84%) and DFW-B (35%).

Honey bees in asymptomatic colonies were infected with an average of two different viruses, and simultaneous infection with four to six viruses was common (14%) (D'Alvise et al., 2019). In the multiple infection rates of honey bees in beekeeping enterprises in the Burdur region, the percentage of samples that were not infected at all was only 6.4% (Usta and Yildirim, 2022). In comparison, the share of positive samples infected with one virus was 38.7%, the rate of positive samples infected with two viruses was 29%, and the percentage of virus-infected samples with three viruses was 25.8%. As a result of our study, it was determined that the viruses were sometimes found alone and sometimes in multiple mixtures (double, triple, or quintuple). In our study, the percentage of samples with no viral infection was 7.5%, while the percentage of samples infected with a single virus was 5%. The percentages of double, triple, quadruple, and quintuple viral infections resulting in multiple viral infections were 17.5%, 30%, 22.5%, and 17.5%, respectively. These results were similar to those of other studies (D'Alvise et al., 2019; Usta and Yildirim, 2022)

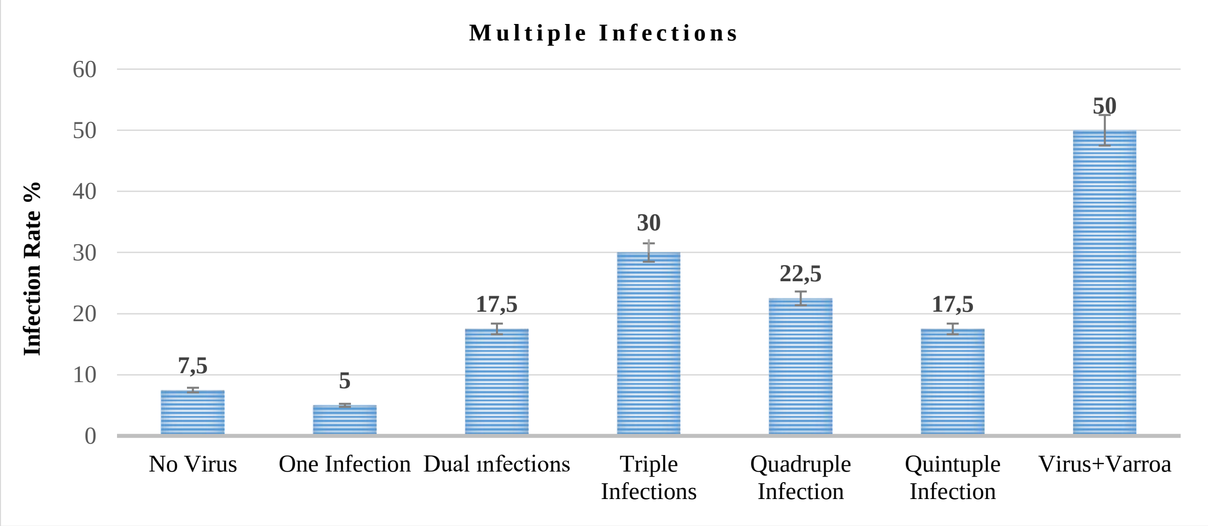

Figure 4. The multiple viral infection rates in suspicious samples from Sivas province

4. Conclusions

In conclusion, according to the study data, it has been concluded that *V. destructor* and *N. ceranae* are prevalent and dominant species in Sivas province, as in many other regions of Türkiye. Gaining insight into the dynamics of honeybee bacterial and virus infections can aid in mitigating their harmful impact on colonies. Developing a strategy to tackle *Varroa* mites and viral infections can help beekeepers prevent colony losses. Therefore, creating prevention and control measures for honey bee diseases and parasites that pose a global threat is crucial.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Karaoglu, S. A., Akpınar, R., Bozdeveci, A.; Design: Bozdeveci, A.; Data Collection or Processing: Akpınar, R., Bozdeveci, A.; Literature Search: Akpınar, R., Bozdeveci, A.; Writing, Review and Editing: Karaoglu, S. A., Akpınar, R., Bozdeveci, A.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Pratylenchus thornei Sher et Allen (Tylenchida: Pratylenchidae)'a Karşı *Myristica fragrans* Houtt (Magnoliales: Myristicaceae) Bitki Ekstraktının Nematisidal Etkinliğinin Laboratuvar Koşullarında Belirlenmesi*

Determination of Nematicidal Efficacy of *Myristica fragrans* Houtt (Magnoliales: Myristicaceae) Plant Extract against *Pratylenchus thornei* Sher et Allen (Tylenchida: Pratylenchidae) under Laboratory Conditions

Fatma Gül KAMÇILAR[1], Hayriye Didem SAĞLAM ALTINKÖY[2*]

Öz

Dünyada ve Türkiye'de temel gıda ürünlerinin başında tahıllar ve baklagiller gelmektedir. Birim alandan yüksek verim elde etmek için yoğun çalışmalar yapılmaktadır. Tarım ürünlerinde verime etki eden önemli hastalık ve zararlılar bulunmaktadır. *Pratylenchus* spp. tahıl ve baklagillerde önemli verim kayıplarına neden olan zararlılardandır. Toprak kökenli zararlılar olduğundan mücadelesi de oldukça zordur. Günümüzde kullanılan kimyasalların tarımsal üretimin sürdürülebilirliği açısından bazı olumsuzlukları ortaya çıkarması ve insan sağlığını tehdit etmesi nedeniyle alternatif mücadele yöntemleri üzerine çalışmalar yoğunlaşmıştır. Bu alternatif yöntemlerin başında bitki ekstraktlarının kullanımı yer almaktadır. Doğada bulunan birçok bitki içermiş olduğu sekonder metabolitler gibi maddeler sayesinde zararlılara karşı biyopestisit olarak kullanılmaktadır. Bu çalışmada *Pratylenchus thornei* Sher et Allen (Tylenchida: Pratylenchidae)'a karşı *Myristica fragrans* Houtt (Magnoliales: Myristicaceae) bitki ekstraktının etkinliği laboratuvar koşullarında denenmiştir. Denemede *M. fragrans* 'ın etanol ekstraktının 100, 250, 500, 1000 ve 2500 ppm dozları uygulanmış ve deneme 4 tekerrürlü ve 2 tekrarlı olarak yürütülmüştür. Denemeler 12 kuyucuklu petri kabında gerçekleştirilmiştir. 24, 48 ve 72 saat sonunda ölüm oranları belirlenmiştir. *M.fragrans* uçucu yağının analizi sonucunda ana bileşen %37.18 ile Sabinene belirlenmiştir. Bunu sırasıyla α-Pinene %29.93, 2-α-Pinene %19.00 ve dl-Limonene %3.31 oranlarında tespit edilmiştir. Deneme sonuçlarına göre 24 saat sonunda en düşük ölüm oranı % 4.93 ile 100 ppm'de belirlenmiştir. 2500 ppm'de %27.02 ve pozitif kontrol olan Abamectin etken maddeli nematisitte %85.81 olarak tespit edilmiştir. 48. saat sonunda en düşük ölüm oranı %14.14 ile 100 ppm'de belirlenmiştir. 2500 ppm'de %72.70 olan ölüm oranı Abamectin etken maddeli nematisitte %89.39 olarak tespit edilmiştir. 72. saat sonunda en düşük ölüm oranı %26.57 ile 100 ppm'de belirlenmiştir. 2500 ppm'de %75.33 olan ölüm oranı Abamectin etken maddeli nematisitte %92.50 olarak bulunmuştur. Elde edilen sonuçlara göre *M. fragrans*'ın etanol ekstraktının *P. thornei*'yi baskıladığı ve nematodun mücadelesinde kullanılma potansiyelinin olduğu belirlenmiştir.

Anahtar Kelimeler: *Pratylenchus thornei*, *Myristica fragrans*, Biyopestisit, Bitki paraziti nematod, Nematisit

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Abstract

Cereals and legumes are the main food products in the world and in Türkiye. Research is being carried out to obtain high yields per unit area. There are important diseases and pests that affect the yields of agricultural crops. *Pratylenchus* spp. are one of the pests that cause significant yield losses in cereals and legumes. Since they are soil-borne pests, their control is also quite difficult. The chemicals used today have some negative effects on the sustainability of agricultural production and human health, for this reason, studies on alternative control methods have increased. One of these alternative methods is the use of plant extracts. Many plants in nature are used as biopesticides against pests as they contain substances such as secondary metabolites. In this study, the effectiveness of *Myristica fragrans* Houtt (Magnoliales: Myristicaceae) plant extract against *Pratylenchus thornei* Sher et Allen (Tylenchida: Pratylenchidae) was evaluated under laboratory conditions. In the experiment, 100, 250, 500, 1000 and 2500 ppm doses of ethanol extract of *M. fragrans* were applied and the experiment was carried out with 4 replicates and 2 replications. The experiments were carried out in 12-well plates. Mortality rates were determined at 24, 48 and 72 hours. As a result of the analysis of *M. fragrans* essential oil, the main constituent was determined Sabinene 37.18%. This was followed by α-Pinene 29.93%, 2-α-Pinene 19.00% and dl-Limonene 3.31%, respectively. According to the results of the experiment, the lowest mortality rate at the end of 24 hours was determined at 100 ppm with 4.93%. The mortality rate was found to be 27.02% at 2500 ppm and 85.81% for the positive control nematicide Abamectin. At the end of 48th hour, the lowest mortality rate was determined at 100 ppm with 14.14%. The mortality rate was found to be 72.70% at 2500 ppm and 89.39% for the positive control nematicide Abamectin. At the end of 72 hours, the lowest mortality rate was determined at 100 ppm with 26.57%. The mortality rate was found to be 75.33 % at 2500 ppm and 92.50 % for the positive control nematicide Abamectin. According to the results, it was determined that the ethanol extract of *M. fragrans* suppressed *P. thornei* and had the potential to be used in the control of the nematode.

Keywords: *Pratylenchus thornei*, *Myristica fragrans*, Biopesticide, Plant parasitic nematode, Nematicide

1. Giriş

Dünyada her geçen gün gıda krizi artış göstermektedir. Küresel Gıda Krizi Raporuna (2023) göre 2022 yılında gıda krizi yaşayan insan sayısı son 7 yılın en yüksek rakamına ulaşmış durumda ve rapora göre 691 ila 783 milyon insanın açlıkla karşı karşıya olduğu ortaya konmuştur (Anonim, 2023a). Açlığın azaltılması için ucuz ve besin değerleri yüksek ürünlerin üretiminin artması önemlidir. İnsan beslenmesinin en temel besinlerini içermiş oldukları vitamin, mineral, karbonhidrat ve protein bakımından oldukça zengin olan tahıllar ve baklagiller oluşturmaktadır. Dünyada ve ülkemizde de en çok üretilen tarımsal ürünler arasında tahıllar ve baklagiller yer almaktadır (Anonim, 2023b). Ucuz besine ulaşım bakımından tahıl ve baklagillerin üretimi yıldan yıla önem kazansa da biyotik ve abiyotik faktörlerden dolayı verim ve kalitede düşüş meydana gelmektedir. Biyotik faktörler içinde bitki paraziti nematodlar tahıl ve baklagillerde önemli verim kayıplarının yaşanmasına neden olmaktadır. Nematodlar konukçu üzerinde yoğun popülasyona sahip olduklarında verim ve kalitede %35-40 arasında bir düşüşe sebep olmaktadır (Williamson ve Gleason, 2003). Bitki paraziti nematodların yıllık olarak verdiği zararın yaklaşık 80 milyar dolar olduğu bilinmektedir (Nicol ve ark., 2011). Bitki paraziti nematodların yaşamlarını sürdürmeleri ve üreyebilmeleri için bitkilere ihtiyaçları vardır. Geçmişten günümüze yaklaşık 40000 nematod türü belirlenmiş olup yaklaşık 4300 kadarının bitkilerde kalite ve verim kaybına neden olduğu bilinmektedir (Kepenekçi, 2012).

Bu türler arasında tahıl ve baklagillerde önemli zararlar meydana getiren Kök Lezyon nematodları olarak da bilinen *Pratylenchus* spp. yer almaktadır. Kök lezyon nematodları dünyanın neredeyse her bölgesinde bulunup, polifag zararlılar arasında yer almaktadır. Tahıllar, baklagiller, sebzeler, meyve ağaçları ve birçok süs bitkisinde önemli verim ve kalite kaybına neden olmaktadırlar. Toprakta yaşayıp, bitki köküne penetre olarak burada endoparazit olarak yaşamını devam ettiren kök lezyon nematodları besin ihtiyaçlarını karşılamaktadırlar (Kepenekçi, 2012, Göze Özdemir ve ark., 2023). Stiletleri ile açmış oldukları yaralardan bakteri, virüs, fungus gibi patojenlerin girişine de olanak sağlamalarıyla ikinci bir zarar meydana getirmektedirler.

Bitki paraziti nematodlarla mücadelede başvurulan ilk yöntem kimyasallardır. Bunun temel sebebi ise hızlı ve etkili sonuç vermesinin yanında alternatif mücadele yöntemlerinin bilinmemesidir. Kimyasallar, çevre ve insan sağlığına zarar vermekte, bilinçsiz kullanımda zararlıda direnç gelişimi oluşturmakta ve sürdürülebilirliğin önüne geçmektedir. Uzun yıllardır tarımsal verimlilik, kalite ve çiftçi gelirinin artışında önemli rol oynayan kimyasalların güvenilirliği konusunda oluşan kaygılar kimyasalların özellikle bilinçsiz kullanımı sonucu tarımda kullanılabilirliğinin tekrar değerlendirilmesine yol açmıştır. Tüketiciler kaliteli ürün isterken bunun yanında pestisit kalıntısının da olmamasını talep etmektedir. Bu talepler, ürünler üzerinde kalıntı analizlerine yönelik düzenlemelerin yapılması yolunu açmıştır.

Bu gelişmeler sonucu araştırmacılar tarafından alternatif mücadele yöntemleri geliştirilmeye ve uygulanmaya başlanmıştır. Bunların başında ise biyopestisit uygulamaları yer almaktadır. Biyopestisitlerin etki mekanizmasına bakıldığında çevre dostu olarak bitki zararlılarını kontrol ettiği ve kimyasallara göre daha az toksisiteye sahip olduğu aynı zamanda çevre ve insan sağlığına karşı kimyasallara göre daha az tehdit oluşturduğu düşünülmektedir (Srijita, 2015).

Doğada pestisit etkisi gösteren birçok bitki bulunmaktadır. Bu bitkiler genellikle yoğun olarak içerdikleri monoterpen, fenolik birleşikler, alkoloitler ve seskiterpen gibi maddeler sayesinde antibakteriyel, antiviral, antifungal, nematisidal, insektisidal ve herbisidal etki göstermektedir (Kısmalı ve Madanlar, 1988, Yaman ve Şimşek, 2022).

Myristica fragrans Houtt (Myristicaceae), genellikle Hint cevizi ya da Muskat (Nutmeg) olarak bilinmektedir. İçerdiği monoterpen hidrokarbonlar, aromatik monoterpenler ve aromatik esterler sayesinde biyopestisit özellik gösteren bitkiler grubuna dahil olmaktadır. Endonezya'nın Banda Adaları yanı sıra, Hindistan, Sri Lanka, Karayipler ve özellikle de Grenada'da yetiştiriciliği yapılmaktadır (Anonim, 2023c). Tıbbi ve aromatik bitki olarak hem baharat hem de insan sağlığı açısından kullanılmaktadır. *M. fragrans*'ın içerdiği bileşikler sayesinde antimikrobiyal, antidepresan, antioksidan özellikleri araştırılmıştır (Jaiswal ve ark., 2009). Son yıllarda yapılan çalışmalarda insektisidal (Jung ve ark., 2007; Chaubey, 2008), antifungal (Butzge ve ark., 2020) ve nematisidal (Gad ve ark., 2019) etkileri ortaya konmuştur.

Yapılan bu çalışmada *Pratylencus thornei*'ye karşı *Myristica fragrans*'ın etanol ekstraktının nematisidal etkinliği laboratuvar koşullarında denenmesi amaçlanmıştır.

2. Materyal ve Metot

2.1. Pratylenchus thornei Sher et Allen (Tylenchida: Pratylenchidae) üretim

Pratylenchus thornei'nin kitle üretimi havuç üzerinde Ahi Evran Üniversitesi Ziraat Fakültesi Bitki Koruma Bölümü Entomoloji laboratuvarında yapılmıştır. Verdejo- Lucas ve Pinochet (1992), Castillo ve ark. (1995) ve Tülek ve ark. (2009) protokollerinden yararlanılarak *Pratylenchus* kültürü havuç üzerinde oluşturulmuştur. Önce hasarsız, taze ve iri havuçlar yıkanmış ve 10 dakika boyunca alkol içerisinde bekletilmiştir. Steril kabin içerisinde alevden geçirilerek soyulan havuçlar ikinci kez alkole daldırılmış ve soyulmuştur böylece yüzey sterilizasyonu sağlanmıştır. Havuçlar 1 cm kalınlığında doğranarak steril petriler içerisine alınmıştır. Üzerlerine havuç kültüründe çoğaltılmış *P. thornei*'ler ufak parçalar halinde eklenmiştir. Bulaşmayı engellemek için petrilerin etrafı parafilm ile kapatılmış ve 21±2°C'de inkübatör içerisine yerleştirilmiştir. Yaklaşık 2-3 ay sonra nematodların üremesi istenilen yoğunluğa gelmiştir. Denemeler için havuç kültürlerinden nematodları elde etmek amacıyla Baermann funnel yöntemiyle nematodların ekstraksiyonu yapılmıştır (Baermann, 1917).

2.2. Myristica fragrans Houtt (Magnoliales: Myristicaceae) uçucu yağın eldesi

Myristica fragrans uçucu yağı mikrodalga destekli distilasyon yöntemi ile mikrodalga cihazında (Milestone-NEOS), 2450 MHz'de elde edilmiştir. Mikrodalga destekli hidrodistilasyonda optimum dalga boyu için Ragab ve ark. (2019) çalışmaları referans alınmıştır. Elde edilen uçucu yağın kimyasal bileşiminin belirlenmesi analizi için Türkiye Bilimsel ve Araştırma Kurumu Marmara Araştırma Merkezi (TÜBİTAK MAM)'ne gönderilmiş ve GS-MS (Gaz kromatografisi/ Kütle spektrometresi) analizi yapılmıştır. Sonuçlar *Tablo 1'*de vermiştir.

2.3. Myristica fragrans Houtt etanol ekstraktının elde edilmesi

Myristica fragrans meyvesi öğütücüden pürüzsüz olana dek geçirilmiştir. Ardından öğütülen *M. fragrans* 10 gram olacak şekilde tartılarak erlene alınmış ve 100 ml etanol eklenmiştir. Ardından alüminyum folyoya sarılan erlen 3 gün boyunca orbital çalkalayıcı da çalkalanmıştır. Oluşan çözelti kaba filtreden geçirilmiştir. Saf maddeyi elde etmek için Rotary Evaporatörde etanol uçurulmuştur. Saf bitki ekstraktı seyreltilerek 5 farklı dozda formülasyon hazırlanmıştır. Negatif kontrolde saf su, pozitif kontrolde ise Abamectin (Abamax 50 Sc, Rotam Global) etken maddeli nematisit kullanılmıştır.

2.4. Myristica fragrans etanol ekstraktının pratylenchus thornei karşı nematisidal etkinlik denemesi

Çalışmada *M. fragrans* etanol ektraktının 100ppm, 250ppm, 500ppm, 1000ppm ve 2500ppm dozları nematisidal etkisinin belirlenmesi amacıyla *P. thornei*'ye karşı in vitro koşullarda denenmiştir. Denemeler 12 kuyucuklu petri kaplarında gerçekleştirilmiştir. Her bir kuyucuğa mikropipet yardımıyla 20 µl saf su içerisinde (30±5) nematod ve 1 ml ekstrakt solüsyonu eklenmiştir. 24, 48 ve 72 saat sonunda ölü bireyler kaydedilmiştir ve yüzde ölüm oranları Abbott formülüne göre hesaplanmıştır (Abbott, 1925). Nematodların ölüp ölmedikleri preparat iğnesi ile dokunularak belirlenmiş, iğne dokundurulduğunda hareket etmeyen nematodlar ölü olarak kabul edilmiştir.

2.5. İstatistik analizler

Deneme sonunda elde edilen veriler SPSS Paket Programı (Versiyon 29) kullanılarak Varyans Analizi yapılmış ve Duncan Çoklu Karşılaştırma Testi ile değerlendirilmiştir. LD_{50} ve LD_{90} değerleri ise Polo Paket Programı kullanılarak hesaplanmıştır.

3. Araştırma Sonuçları ve Tartışma

3.1. Myristica fragrans Houtt GS-MS analizi sonucu

Myristica fragrans'ın öğütülmesinden sonra uçucu yağ elde edilmesi için mikrodalga destekli hidrodistilasyon yöntemi kullanılmış ve GS-MS (Gaz kromatografisi/ Kütle spektrometresi) ile analiz edilmiştir. *M. fragrans* uçucu yağında Sabinene %37.18, α-Pinene %29.93, 2-α-Pinene %19.00, dl-Limonene %3.31, α -Phellandrene %1.86, γ-Terpinene %1.43 ve α -Terpinene %1.28 oranlarında belirlenmiştir (*Tablo 1*).

Tablo 1. Myristica fragrans Houtt'ın uçucu yağ bileşenleri

Table 1. Essential oil components of Myristica fragrans Houtt

Bileşen İsmi	RT	RSI	%
α-Pinene	3.00	922	29.93
Camphene	3.46	952	0.42
2-α-Pinene	4.11	953	19.00
Sabinene	4.36	923	37.18
3-Carene	4.78	917	0.49
α -Myrcene	5.11	915	2.89
α -Terpinene	5.42	920	1.28
dl-Limonene	5.84	913	3.31
α -Phellandrene	6.05	980	1.86
Delta 3-Carene	6.75	732	0.00
γ-Terpinene	6.99	933	1.43
Benzene 1-methyl-2-(1-methylethyl)-	7.68	927	0.69
Cyclohexene 1-methyl-4-(1-methylethylidene)-	7.98	923	0.33
α-Thujone	12.35	925	0.04
1-methyl-4-(1-methylethyl) benzene	13.04	888	0.02
Terpineol,cis-α-	14.16	910	0.22
α-Copaene	14.65	744	0.01
Camphor	15.57	922	0.02
Cis-Sabinene Hydrate	17.19	893	0.13
Linalool	17.40	880	0.05
2-Cyclohexen-1-ol,1-methyl-4-(1-methylethyl),trans-	17.68	858	0.04
Exobornyl Acetate	18.05	803	0.00
1-4- Terpineol	19.09	910	0.44
1-Terpineol	20.13	800	0.02
cis-Piperitol	21.91	763	0.00
Linalyl propionate	22.64	912	0.03
1,3-Benzodioxole,5-(2-propenyl)-(CAS)	28.66	934	0.10
Benzene,1,2-dimethoxy-4-(2-propenyl)-	33.55	792	0.00
Myristcin	41.02	756	0.02
2-Acetyl-3-(2-cinnamido)ethyl-7-methoxyindole	42.25	583	0.01
3, 6-diazahomoadamantan-9-ol	43.39	674	0.03
Pyrrolizin-1,7-dione-6-carboxylic acid,methyl(ester)	49.75	694	0.02

3.2. Myristica fragrans Houtt etanol ekstraktının Pratylenchus thornei Sher et Allen'a karşı nematisidal etkinliği

Myristica fragrans bitki ekstraktının *P.thornei*'e karşı 100ppm, 250ppm, 500ppm, 1000ppm ve 2500ppm konsantrasyonları ve Abamectin etken maddeli nematisit uygulanmış ve 24 saat sonunda en düşük ölüm oranı % 4.93 ile 100 ppm'de belirlenmiştir. 2500 ppm'de %27.02 olan ölüm oranı, pozitif kontrol olan Abamectin etken maddeli nematisitte %85.81 olarak tespit edilmiştir (*Şekil 1*). Dozlar arasında farklar bulunmuş ve bu farkların istatistiki olarak önemli olduğu belirlenmiştir ($F_{(6.49)}=74.45$ $P<0.05$). Konsantrasyonlarda doz arttıkça ölüm oranının da arttığı sonucuna ulaşılmıştır.

Myristica fragrans bitki ekstraktının *P.thornei*'e karşı etkinliğinin belirlenmesinde 48. saat sonunda en düşük ölüm oranı %14.14 ile 100 ppm'de belirlenmiştir. 2500 ppm'de %72.70 olan ölüm oranı Abamectin etken maddeli nematisitte %89.39 olarak tespit edilmiştir (*Şekil 2*). Dozlar arasında farklar bulunmuş ve bu farkların istatistiki olarak önemli olduğu tespit edilmiştir ($F_{(6.49)}=145.79$ $P<0.05$). Konsantrasyonlarda doz ve zaman artışına bağlı olarak ölüm oranının da arttığı sonucuna ulaşılmıştır.

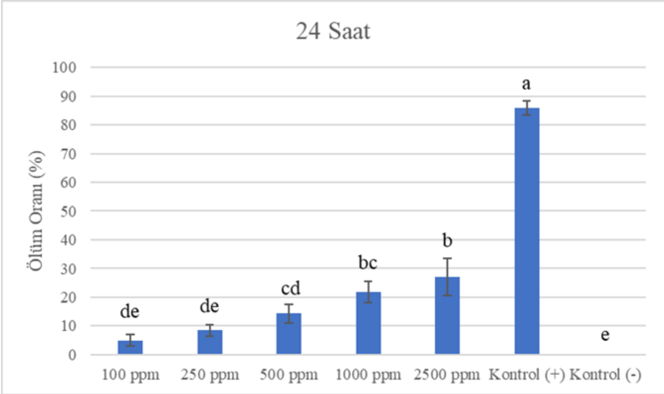

Figure 1. Nematicidal effect of Myristica fragrans Houtt plant extract against Pratylenchus thornei Sher et Allen at the end of the 24th hour.

Şekil 1. Myristica fragrans Houtt bitki ekstraktının Pratylenchus thornei Sher et Allen'a karşı 24.saat sonunda nematisidal etkisi

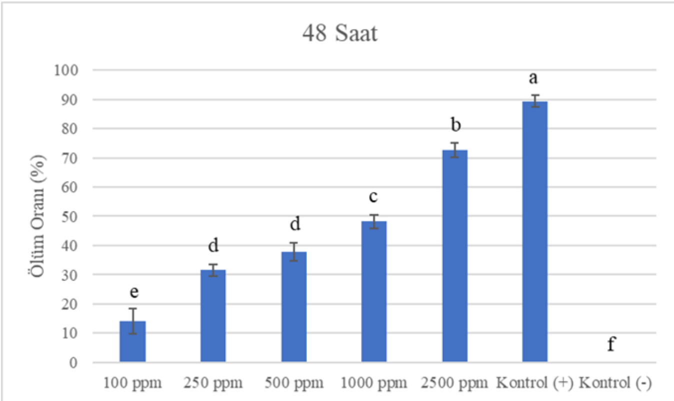

Figure 2. Nematicidal effect of Myristica fragrans Houtt plant extract against Pratylenchus thornei Sher et Allen at the end of the 48th hour.

Şekil 2. Myristica fragrans Houtt bitki ekstraktının Pratylenchus thornei Sher et Allen'a karşı 48.saat sonunda nematisidal etkisi

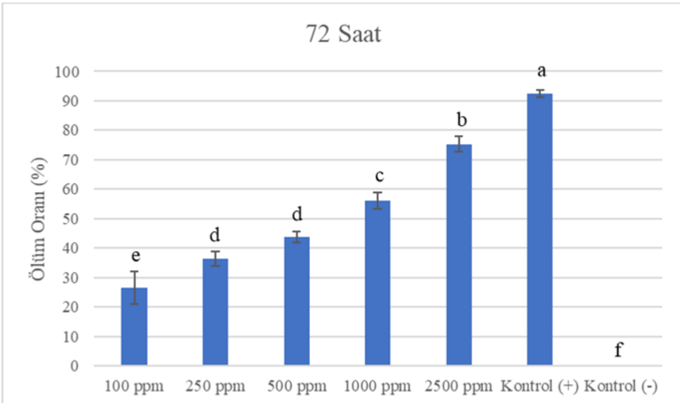

Figure 3. Nematicidal effect of Myristica fragrans Houtt plant extract against Pratylenchus thornei Sher et Allen at the end of the 72nd hour.

Şekil 3. Myristica fragrans Houtt bitki ekstraktının Pratylenchus thornei Sher et Allen'a karşı 72. saat sonunda nematisidal etkisi

Denemede 72. saat sonunda en düşük ölüm oranı %26.57 ile 100 ppm'de belirlenmiştir. 2500 ppm'de %75.33 olan ölüm oranı Abamectin etken maddeli nematisitte %92.50 olarak bulunmuştur (*Şekil 3*). Dozlar arasında farklar bulunmuş ve bu farkların istatistiki olarak önemli olduğu tespit edilmiştir ($F (6.49)=119.49$ $P<0.05$).

Myristica fragrans bitki ekstraktının *P.thornei*'e karşı nematisidal etkisinin belirlenmesi denemesi sonucunda LD_{50} ve LD_{90} değerleri hesaplanmıştır (*Tablo 2*).

Buna göre; 24. saat sonunda LD_{50} değeri 2584.18 olarak hesaplanmıştır. 48. saatte 769.75, 72 saatte ise 516.49 olarak bulunmuştur. LD_{90} değerleri ise 24. saatte 18900.00, 48. saatte 8199.32 ve 72. saatte ise 7744.02 olarak tespit edilmiştir (*Tablo 2*).

Tablo 2. Myristica fragrans Houtt bitki ekstraktının Pratylenchus thornei Sher et Allen'a karşı nematisidal etkisinin belirlenmesi denemesi sonucu elde edilen LD_{50} ve LD_{90} değerleri

Table 2. LD_{50} and LD_{90} values obtained as a result of an experiment to determine the nematicidal effect of Myristica fragrans Houtt plant extract against Pratylenchus thornei Sher et Allen

Zaman	LD_{50}	LD_{90}	Eğim	Ki -Kare	Df	Heterojenlik
24 Saat	2584.18 (1968.183667.01)	18900.00 (10944.12 -43221.26)	1.48 ±0.07	230.10	46	5.00
48 Saat	769.75 (659.60- 899.37)	8199.32 (6026.77- 12074.70)	1.24+-0.06	76.40	46	1.66
72 Saat	516.49 (424.44-621.23)	7744.02 (5379.54- 12486.7)	1.09+-0.06	86.56	46	1.88

Yapılan benzer çalışmalara bakıldığında, Esteves ve ark. (2017) cevizin içermiş olduğu naphthoquinones (juglone, 1,4-naphtoquinone ve plumbagin) maddelerini *P. thornei*'ye karşı denemişlerdir. Elde ettikleri sonuçlara göre juglone ve 1,4-naphtoquinone'nin plumbagin'e göre *P. thornei*'ye karşı daha etkili olduğunu tespit etmişlerdir. Uygulamadan sonra 72. saatte juglone için LC_{50} değeri 134.7 ppm, 1,4-naphtoquinone için LC_{50} değeri 161.2 ppm ve plumbagin için LC_{50} değeri ise 207.6 ppm bulunmuştur. Juglone ve 1,4-naphtoquinone karıştırılarak uygulandığında ise 178.8 ppm olarak belirlenmiştir. Yapılan bu çalışmada ise *M.fragrans* 'ın etanol ekstraktının *P.thornei*'ye karşı uygulanmasından 72 saat sonra LD_{50} değeri 516.49 ppm olarak belirlenmiştir. Taşkın (2020) yapmış olduğu çalışmada *P. thornei*'ye karşı Ceviz, Çiriş, Defne, Dere Otu, Hayıt, İncir, Nane, Okaliptüs, Roka, Tespih Ağacı, Zakkum ve Zencefil bitki ekstraklarını %1, %2.5 ve %5'lik konsantrasyonlarda ve 6, 12, 24 saat zaman dilimlerinde incelemiştir. Çalışmanın %1'lik konsantrasyonunda ve 6.saat sonunda en etkili ölüm sonucunu veren İncir (%30) olduğunu, 12 saat sonundaki en yüksek ölüm oranının ise Tespih Ağacı ekstraktından (%92.6) elde edildiğini bildirmiştir. 24 saat sonunda ise ölüm oranları bakımından Ceviz, Roka ve Tesbih ağacından elde edilen ekstraktlarının *P.thornei*'yi %100 baskıladığını tespit etmiştir. Altınköy Sağlam ve ark. (2020) yaptıkları çalışmada gümüş nanopartiküllü *Moringa oleifera* su ekstraktının *P.thornei*'ye karşı denemişler ve uygulamadan 48 saat sonra 168 ppm'de %90.55 ve 84 ppm'de %79.79'luk bir ölüm meydana geldiğini belirlemişlerdir. *M. oleifera*'nın nano gümüş katkılı sulu ekstraktı *P. thornei*'nin azaltılmasında etkili bulmuşlardır. Dura ve ark. (2022) ise *M. incognita* ve *P. thornei* üzerinde in vitro koşullarda doğal çam reçinesini denemişler ve çalışma sonucunda en yüksek ölüm oranını yine 72 saat sonunda %2 lik konsantrasyonda *M. incognita*'da %100, *P.thornei*'de % 96.38 olarak belirlemişlerdir. Yapılan bu çalışmada da en yüksek ölüm oranı 72. saatte tespit edilmiş ve *M. fragrans*'ın *P. thornei*'yi %75.33 oranında öldürdüğü belirlenmiştir.

Daha önce yapılan çalışmalar değerlendirildiğinde *P. thornei* ile mücadelede kullanılan bitkisel ekstraktların zamana ve doza bağlı olarak nematodu başarılı bir şekilde baskıladığı belirlenmiştir. *M. fragrans* bitkisel ekstraktının *P.thornei* üzerine etkinliğine bakıldığında diğer çalışmalara benzer şekilde doz ve zamana bağlı olarak artış gösterdiği ve en yüksek doz olan 2500 ppm'de 24.saatte %27.02, 48.saatte %72.70 ve 72 saatte ise %75.33 ile en yüksek ölüm oranları tespit edilmiştir.

4. Sonuç

Bitki paraziti nematodlar dünyada ve ülkemizde önemli verim kayıplarına neden olan bitki koruma etmenlerindendir. Bu zararlılarla mücadelede ruhsatlı ilaç sayısı sınırlıdır. Çoğunluğu *Meloidogyne* türlerine karşı ruhsatlandırılmıştır. Bu ilaçların bilinçsiz kullanımı insan ve çevre sağlığını olumsuz etkilemektedir. Bu etkileri en aza indirmek için bitkisel kökenli pestisitler üzerine çalışmaların hız kazanması ile ruhsatlandırılan bitkisel preparatlarında sayısı her geçen gün artmaktadır.

Pratylenchus türlerine karşı ruhsatlı pestisitler bulunmamaktadır. Bitkisel kökenli pestisit çalışmalarında *Moringa oleifera*, çam reçinesi, ceviz, çiriş, defne, dere otu, hayıt, incir, nane, okaliptüs, roka, tespih ağacı, zakkum ve zencefil gibi bitkilerin ekstraktları *P. thornei'* ye karşı kullanılmış ve etkili olduğu bulunmuştur. Yapılan bu çalışma sonucunda *M.fragrans* bitki ekstraktının *P.thornei*'a karşı kullanımında 72. saat sonunda %75.33'lük bir ölüm oranı tespit edilmiştir. *M.fragrans* bitki ekstraktının *P.thornei*'a karşı doğal nematisit olarak kullanılabileceği, bununla birlikte daha gerçekçi sonuçlara ulaşabilmek için bu ekstraktın farklı konsantrasyonlarda sera ve arazi koşullarında denenmesi gerektiği belirlenmiştir. Bu çalışmalar insan ve çevreye zararlı sentetik ilaçların kullanımını azaltacak ve nematodlarla yapılan mücadeleye farklı bir yöntem katacaktır. Dolayısıyla biyopestisit çalışmaları geleceğe ışık tutacaktır.

Teşekkür

Myristica fragrans Houtt'ın esansiyel yağ eldesi aşamasında yapmış olduğu yardımlar için Ahi Evran Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümünden Dr. Öğr. Üyesi Emine BİLGİNOĞLU'na teşekkür ederiz. Bu çalışma Lisansüstü seminerinden hazırlanmıştır.

Etik Kurul Onayı

Bu çalışma için etik kuruldan izin alınmasına gerek yoktur

Çıkar Çatışması Beyanı

Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz

Yazarlık Katkı Beyanı

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Tomorrow's Choices: A Comprehensive Study of Consumer Perspectives on Functional Foods*

Yarının Seçimleri: Fonksiyonel Gıdalar Üzerine Tüketici Bakış Açılarını İnceleyen Kapsamlı Bir Çalışma

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Abstract

Consumers strive for an improved quality of life and longevity on a daily basis. Owing to shifts in consumer behavior, there is a consistent rise in the proportion of well-informed and mindful consumers. Functional foods, known for their health-preserving capabilities, are gaining increased prominence within the spectrum of food products. The functional food market, both in Turkey and globally, holds promise as an unexplored sector. Within this context, food companies are keen to ascertain whether their newly developed products align with consumer expectations and how consumers engage with these offerings. The study's objective is to assess consumer attitudes towards products positioned as integral to a healthy diet, particularly those endorsed as functional foods. Moreover, the aim is to derive indicators that can enhance strategic and tactical marketing decisions based on the study's findings. The primary focus of the research centers on the purchasing behaviors of Turkish consumers. Employing an inductive research design, hypotheses were tested using data collected from 391 Turkish consumers, that reside in Istanbul, through surveys. Istanbul was chosen as it is a metropolis and a small-scale example of Turkey. Analysis methods included descriptive and inferential statistics, explanatory factor analysis (PCA), and binary regression analysis. The results revealed a heightened interest in functional foods among women, families with children, and individuals with higher incomes. Furthermore, evolving lifestyles, increased incomes, and heightened consumer awareness contribute to a surge in demand for innovative food products. The revelations derived from these findings carry profound implications that extend their influence across various domains. Primarily, state institutions actively involved in formulating and implementing public health programs stand to be significantly impacted. The newfound insights provide an invaluable resource for refining and enhancing the efficacy of existing public health initiatives. By integrating this knowledge into their strategies, these institutions can tailor interventions more precisely, addressing specific concerns and promoting the overall well-being of the populace. Moreover, the implications also reverberate within the intricate realm of the food sector, involving a diverse range of stakeholders. For businesses within this industry, understanding and adapting to these findings can prove instrumental in shaping their practices. This may encompass adjustments in production processes, sourcing of ingredients, and the development of products that align with emerging health considerations. Proactive engagement with these insights not only enhances the societal impact of these food-related enterprises but also contributes to the broader narrative of responsible and health-conscious business practices.

Keywords: Consumer attitudes, Consumer behavior, Foods with health claim, Functional foods, Strategic marketing

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Öz

Tüketiciler, günlük yaşamlarında daha iyi bir yaşam kalitesi ve uzun ömür arayışında bulunmaktadır. Bu arayış, tüketici davranışlarındaki sürekli değişikliklere paralel olarak, bilinçli ve bilgili tüketicilerin oranında artan bir eğilim göstermektedir. Sağlığı koruma yetenekleri ile bilinen fonksiyonel gıdalar, günümüzde gıda ürünleri yelpazesi içinde giderek artan bir öneme sahiptir. Türkiye'de ve küresel düzeyde, fonksiyonel gıda pazarı henüz tam anlamıyla keşfedilmemiş bir sektördür ve bu durum umut vadeden bir potansiyeli beraberinde getirmektedir. Bu bağlamda, gıda şirketleri, yeni geliştirilen ürünlerinin tüketicinin beklentileri ile uyumlu olup olmadığını anlamak ve tüketicilerin bu ürünleri nasıl benimsediğini belirlemek amacıyla çeşitli stratejiler geliştirmek istemektedir. Bu çalışmanın öncelikli amacı, özellikle sağlıklı bir diyetin ayrılmaz bir parçası olarak konumlandırılan fonksiyonel gıda ürünlerine yönelik tüketicinin tutumlarını değerlendirmektir. Ayrıca, çalışmanın bulgularına dayanarak, gıda şirketlerinin stratejik ve taktik pazarlama kararlarını daha etkili bir şekilde geliştirebilmeleri için öngörüler ve göstergeler elde etmektir. Araştırmanın ana odak noktası, Türk tüketicilerinin satın alma davranışlarına yöneliktir. İndüktif bir araştırma tasarımı kullanılarak, hipotezler İstanbul'da yaşayan 391 Türk tüketiciden toplanan anket verileri kullanılarak test edilmiştir. Türkiye'nin küçük ölçekli bir örneği olduğundan ve metropol olduğundan İstanbul ili seçilmiştir. Analiz yöntemleri arasında tanımlayıcı ve çıkarımsal istatistikler, açıklayıcı faktör analizi (PCA) ve ikili regresyon analizi bulunmaktadır. Sonuçlar, özellikle kadınlar, çocuklu aileler ve daha yüksek gelire sahip bireyler arasında fonksiyonel gıdalara karşı giderek artmakta olan bir ilgi olduğunu ortaya koymaktadır. Ayrıca, değişen yaşam tarzları, artan gelirler ve artan tüketici bilinci, yenilikçi gıda ürünlerine yönelik talepte yıl boyunca bir artışa katkıda bulunmaktadır. Bu bulguların, kamu sağlığı programları oluşturan devlet kurumları ve gıda sektöründeki paydaşlar için önemli olduğu düşünülmekte ve bu sonuçlar, stratejik ve taktik kararlarını geliştirmek isteyen bu kurumlar için değerli bir kaynak olmaktadır.

Anahtar Kelimeler: Fonksiyonel gıdalar, Sağlık beyanı olan gıdalar, Stratejik pazarlama, Tüketici davranışı, Tüketici tutumları

1. Introduction

At the beginning of the year 2020, with the impact of the Covid-19 pandemic that entered our lives, people are becoming increasingly sensitive to dietary approaches that will have a positive effect on their health and support their immune systems. In this regard, they are exploring different approaches to support their health and enhance their immune systems. Functional foods have become alternatives that consumers consider to support their health during this process (Decker, 2020). There is no universally agreed-upon definition and product group for functional foods worldwide. Generally, functional foods are described as foods that resemble traditional foods in appearance, are produced by adding substances or enhancers that positively affect the body and reduce the risk of disease (Aggett et al., 1999; Boudreau et al., 2000; Poulsen, 1999). While IFIC (International Food Information Council) defines functional foods as foods that provide health benefits beyond basic nutrition, the American Dietetic Association includes foods beneficial to health, such as vegetables, fruits, low-fat cheeses, and other snacks, to the definition of functional foods (Katan and De Roos, 2004). FUFOSE (The European Commission Concerted Action on Functional Food Science in Europe) defines functional foods as foods that have beneficial effects beyond their basic nutritional effects, reducing the risk of disease or improving general and physical condition (Siro et al., 2008). Ohama et al. (2006) (Siro et al., 2008) stated that most products known as FOSHU (Foods for Specific Health Use) in Japan since 2001 are in food form, but some may also be in the form of pills or capsules. While some scientists define products in the form of traditionally enriched foods with additives as functional foods, others also define naturally occurring foods with functional properties as functional foods. Some researchers believe that supplements in capsule form can also be considered functional foods. These different definitions contribute to the challenge of accurately determining the size of the functional food market. Nevertheless, this situation does not change the fact that the functional food market is growing in Türkiye and globally. In Türkiye, which is not yet among the top 10 in the global functional food market (Gok and Ulu, 2019), functional food sales amounted to 461.7 million dollars in 2017 (Sezgin, 2020). Global functional food sales were recorded at 161.99 billion dollars in 2020. In 2021, it is expected to reach 171.25 billion dollars with a 5.7% increase (The Business Research Company, 2021). According to a different source, functional food sales were $132 billion USD in 2005, $190 billion USD in 2010, and reached $299.32 billion USD by the end of 2017. It is projected to reach $441.56 billion USD in 2022 (Statista, 2018). Two different pieces of data expressed about the market also indicate the annual growth of the functional food market.

Consumer perspectives on functional foods may vary in different countries. Bech-Larsen and Grunert (2003) noted in their study that the approach to functional foods differs among American, European, and Danish consumers. Poulsen (1999) have found out in a study conducted with Danish consumers that the attitude towards functional foods is influenced by enriching substances and product variety. While in some countries these foods are welcomed, in some other countries the people approach to functional food with care and prefer conventional organic foods to stay healthy (Bech-Larsen and Grunert, 2003; Landstrom et al., 2009; Siegrist et al., 2015). Not only in separate countries do the approaches against functional foods differ but also, they differ according to the functional food product. Urala and Lahteenmaki (2004) stated that when choosing between traditional and functional foods, the reasons behind choosing functional food products vary according to different product categories. Also, different studies have different findings regarding choice about different functional food products (Siro et al., 2008; Jezewska-Zychowicz, 2009; Oraman, 2019). The researchers claim that functional food products are not one homogeneous group and different studies should be made in order to understand the consumer attitudes. So, in order to understand the Turkish functional food market, this study on 6 different functional food products was prepared. Research conducted on different product groups and in different countries regarding functional foods will contribute to a better understanding of this market. Research conducted in Türkiye with different functional food product groups is important for a better understanding of the functional food market in Türkiye. While some studies show that there is a difference regarding the gender in preferring functional foods (Saher et al., 2004; Ares and Gambaro, 2007; Siro et al., 2008) some have found out that there is no relationship between gender and consumption of functional foods (Ozdemir Ozkan et al., 2009; Annunziata and Vecchio, 2011). The gender and the type of functional foods the specific gender prefers may differ. Some research show that women have a more positive attitude against functional food products and that the main consumer of the functional foods are the women (Oraman, 2019; Poulsen, 1999; Bower et al., 2003; Siro et al., 2008; Dolekoglu et al., 2015), whereas the others have determined that there is no relationship between gender and preferring the functional foods

(Ozdemir Ozkan et al., 2009; Annunziata and Vecchio, 2011). Age, like gender, emerges as a variable investigated in functional food consumption studies (Dolekoglu et al., 2015). While some research suggests that age is a decisive factor in functional food preferences (Bower et al., 2003; Ares and Gambaro, 2007; Stewart-Knox et al., 2007), there are also studies that do not support these findings (Ozdemir Ozkan et al., 2009). In the older age group, it is observed that functional food products can be purchased, even if they are expensive, when it is believed that they are effective (Poulsen, 1999). The elder consumers demand the foods that lower blood pressure and cholesterol (Siro et al., 2008). Various variables influencing the usage of functional food have been examined in research studies. Factors such as income level (Dolekoglu et al., 2015; Siro et al., 2008), the presence of children in the family (Siro et al., 2008), and the existence of individuals practicing special nutrition or with illnesses (Verbeke, 2005; Annunziata and Vecchio, 2011; Siro et al., 2008) have been indicated as elements affecting the utilization of functional food whereas Ozdemir Ozkan et al. (2009) have indicated that no significant relation between attitudes against functional foods and gender, age, marital status and having children was detected. However, these studies have been conducted in different countries or on different functional food product categories. This study investigates the results of these variables in Türkiye and on six different functional food products (bread with added vitamins and minerals, yogurt containing probiotics, margarine that helps lower cholesterol, relaxing teas (e.g., relax, 7 herbs, form), breakfast cereals with added vitamins and minerals, and eggs with added selenium or omega-3) mentioned in this study.

Research conducted on different product groups and in different countries regarding functional foods will contribute to a better understanding of this market. This research aims to contribute to a better understanding of the Turkish functional food market and to define the target market for functional foods more effectively. The objective of this study is to assist in identifying which segment of potential functional food users could be functional food consumers and to support a better understanding of the target market. The effects of gender, education level, age, marital status, existence of children in the family, income level and having an individual applying a specific diet on the consumption of functional food was researched.

2. Materials and Methods

2.1. Research Methodology

The material for this study was collected from primary and secondary data sources. The data obtained through surveys conducted with Turkish consumers constitute the primary data source for the research. Additionally, printed research, articles, theses, books, applications and publications of government institutions in Turkey and worldwide, as well as project reports, form the secondary data sources for the study.

Surveys were applied to individuals residing in Istanbul. According to the 2016 population census, the population of Istanbul was determined to be 14.804.116 people (www.tuik.gov.tr). In determining the sample size, the formula recommended by Naing et al. (2006) for cases where the population size is known was utilized.

$$n = \frac{[N*t^2*(p*q)]}{[S^2*(N-1)+S^2*(p*q)]} \quad \text{(Eq. 1)}$$

N= The number of individuals in the population

p= The proportion of those who prefer functional foods

q= The proportion of those who do not prefer functional foods

s= The sampling error accepted by the researcher

t= The accepted level of significance

Based on the population of Istanbul in the year 2016, the number of individuals in the population (N) has been calculated. The proportions of those who prefer and do not prefer functional foods (p and q) are both considered to be 50%. The sampling error accepted by the researcher (s) is set at 5%. The accepted level of significance (t) (1-0.95 = 5%) corresponds to a value of 1.96.

$$n = \frac{14804116*1.96^2*(0.5*0.5)}{0.05^2*(14804116-1)+0,05^2*(0.5*0.5)} \quad \text{(Eq. 2)}$$

n=384

The sample size is 384 individuals, and the consumer surveys were applied to 391 individuals. The surveys were conducted through two different methods: online and printed.

For this study, a survey scale previously used in Sweden was adopted (Landstrom, 2008). Due to differences in the healthcare systems between Türkiye and Sweden, some questions from the survey targeted at healthcare professionals were omitted. This survey scale was developed based on scales by Roininen and Tuorila (1999) and Urala and Lahteenmaki (2007) as indicated by Landstrom (2008).

The hypotheses of the study are as follows:

H1: The consumption of functional foods varies between men and women, indicating a difference in their preferences and habits.

H2: Individuals with a family member adhering to a specific dietary regimen are more inclined to incorporate functional foods into their diet.

H3: Individuals with elevated levels of education are more likely to engage in the consumption of functional foods.

H4: Consumers above middle age are more inclined to consume functional foods.

H5: Marital status has an impact on the tendency to consume functional foods.

H6: The tried/preferred functional food product varies with age.

H7: Families with children are more likely to incorporate functional foods into their consumption habits.

H8: Individuals in a higher income bracket show a greater tendency to incorporate functional foods into their dietary choices.

The fundamental assumption of this research is that participants provide honest and sincere responses on the survey form, and they correctly understand all questions. The survey data obtained were analyzed using the SPSS 24.0 program.

The analysis includes frequency tables, which encompass frequency and percentage distributions specific to variables, as well as central tendency measures such as mean, standard deviation, and variance Islamoglu and Alniacik (2014). In this study, a frequency table was created for consumer groups regarding age, marital status, education level, and total monthly income data.

Factor Analysis is a multivariate analysis method that reduces a large number of variables to a smaller number of variables based on relationships between variables Islamoglu and Alniacik (2014). Exploratory factor analysis can be defined as a discovery study on collected data to represent a large number of variables with a smaller number of variables. Confirmatory factor analysis, on the other hand, is used to test hypotheses, extract latent variable structures from a specific sample data, and apply obtained results to the general population for generalization. In this research, exploratory factor analysis was used.

Two different scales were used in surveys conducted with each consumer. These two scales were named the functional food scale and health scale. The questions in these scales were designed in Likert scale which has a 5-point scale format. The Likert scale ranges from "1 - strongly agree" to "5 - strongly disagree."

The reliability of each scale was assessed using the Cronbach Alpha coefficient. The analysis results indicated that the scales have a high level of reliability.

Survey results were subjected to another analytical approach known as binary logistic regression analysis. The objective of logistic regression analysis is to construct a model that effectively captures the relationship between dependent and independent variables while minimizing the number of variables involved (Cokluk, 2010). According to Cokluk (2010) and Tabachnick and Fidell (1996) stated that logistic regression analysis does not require the independent variables to have a normal distribution. However, certain prerequisites must be met in logistic regression analysis to ensure the accurate interpretation of the data. In order to avoid misinterpretations during the analysis, it is essential to examine the presence of multicollinearity issues among independent variables (Cokluk, 2010). In this research, VIF values were assessed to detect multicollinearity among independent variables. In this research, VIF values were assessed to detect multicollinearity among independent variables. The findings revealed that all VIF values were below 5, indicating the absence of multicollinearity.

Subsequently, binary logistic regression analysis was conducted. Binary logistic regression analysis is a method applied when the dependent variable is binary and categorical. Logistic regression analysis requires logistic transformation due to its nonlinear nature and uses the maximum likelihood method. Logistic regression relies on probabilities, odds, and the logarithm of odds as fundamental components in its methodology. The odds are determined by dividing the probability of an event occurring by the probability of the same event not occurring (Cokluk, 2010).

$$Odds = \frac{p(y)}{1-p(y)} \quad \text{(Eq. 3)}$$

p(y): Probability of an event occuring

1-p(y) : Probability of an event not occuring

The odds ratio is defined as the ratio of two seperate odds (Ozdamar, 2013).

The logit is derived by applying the natural logarithm to the asymmetric odds ratio, transforming it into a symmetric form (Ozdamar, 2013).

The prediction equation derived from logistic regression analysis is as follows;

$$L_i = \log\frac{p(y)}{1-p(y)} = b0 + b1x1 + b2x2 + b3x3 + b4x4 + \cdots \quad \text{(Eq. 4)}$$

In the equation;

p(y): Probability of the occurrence of the condition of interest in the dependent variable

b0: Constant term

X: Independent variables

B: Beta coefficients in log-odds units

Li: Logit (Y Dependent Variable)

$$Y_i = \begin{cases} 1 & \text{Consumer has consumed the product} \\ 2 & \text{Consumer has not consumed the product} \end{cases}$$

Table 1 shows the independent variables included in binary logistic regression analysis and their coding. The minimum income level was set according to the poverty threshold belonging to the year the surveys were conducted.

Table 1. Coding of Independent Variables in Consumer Surveys

Variables	Description of Variables		Parameters (1)	(2)	(3)
X_1 (Gender)	1	Female	1	0	
	2	Male	0	0	
X_2 (Level of Education)	1	Primary-Secondary-High School	1	0	
	2	Higher Education	0	0	
X_3 (Marital Status)	0	Single	1	0	
	1	Married	0	0	
X_4 (Age)	1	<29	1	0	0
	2	30-39	0	1	0
	3	40-49	0	0	1
	4	>50	0	0	0

Table 1. Continued

X_5 (Income)	1	<1656 USD	1	0
	2	1657-3311 USD	0	1
	3	>3312 USD	0	0
X_6 (Presence of children in the household)	0	No	1	0
	1	Yes	0	0
X_7 (The presence of an individual implementing a special diet in the household)	0	No	1	0
	1	Yes	0	0
X_8 FF Scale Factor 1 (Personal reward of using FF)	0	I agree- I completely agree	1	0
	1	I do not agree - I completely disagree	0	0
X_9 FF Scale Factor 2 (Confidence in FF)	0	I agree- I completely agree	1	0
	1	I do not agree - I completely disagree	0	0
X_{10} FF Scale Factor 3 (Interest in FF)	0	I agree- I completely agree	1	0
	1	I do not agree - I completely disagree	0	0
X_{11} H Scale Factor 1(General Interest in Health)	0	I agree- I completely agree	1	0
	1	I do not agree - I completely disagree	0	0
X_{12} H Scale Factor 2 (Interest in Natural Products)	0	I agree- I completely agree	1	0
	1	I do not agree - I completely disagree	0	0
X_{13} H Scale Factor 3 (Interest in Diet Products)	0	I agree- I completely agree	1	0
	1	I do not agree – I completely disagree	0	0

3. Results and Discussion

The demographic data of the consumers attended to the survey is shown in *Table 2*.

Table 2. Demographic Data of Consumers

Variables	Frequencies	%
Gender		
F(Female)	217	55.9
M (Male)	171	44.1
Age		
<29	168	43
30-39	127	32.5
40-49	73	18.7
50-89	23	5.9
Marital Status		
Married	183	46.9
Single	207	53.1
Educational Level		
Compulsory Education	136	34.8
Higher Education	255	65.2
Monthly Total Income		
<1656 USD	234	60.3
1657-3311 USD	111	28.6
>3312 USD	43	11.1

In the application of factor analysis, both scales were examined separately using the factor analysis method. For the Functional Food Scale (FFS), reliability analysis was initially conducted. The Cronbach Alpha value was initially obtained as 0.901. In the reliability analysis, expressions that increased reliability when excluded were removed, and the analysis was conducted again, resulting in a Cronbach Alpha value of 0.911. When the factor analysis process was applied, a total of 4 factors were identified in the FFS scale. The factor loadings of expressions were examined, and expressions with loadings below 0.1 in different factors were removed, and the analysis was repeated. Separate reliability analyses were conducted for each factor group (Islamoglu and Alniacik, 2014). As a result of this process, 3 factors identified are specified in *Tables 4* and *5*. Finally, the Cronbach Alpha values for the remaining factors were found to be 0.894.

Table 3 shows the KMO (Kaiser-Meyer-Olkin) value for the consumer functional food scale. According to this result, the KMO value for the consumer surveys' functional food scale is 0.918. The KMO value indicates that the sample size is excellent for factor analysis (Cokluk et al., 2012).

Table 3. Consumer Functional Food Scale Factor Analysis KMO and Bartlett Test Table

KMO ve Bartlett Testi		
Kaiser-Meyer-Olkin Sample Measurement Value Adequacy		0.918
Bartlett Test	Chi-Square	3000.128
	Df	190
	Sig.	0.000

Table 4 shows the variances explained by the components obtained from the factor analysis initially and after applying the varimax rotation method. Initially, 52.803% of the total variance, explained by a total of 21 expressions, can be accounted for by 3 factors. If the explained variance value is between 0.40 and 0.60, it indicates convenience for factor analysis (Cokluk et al., 2012).

Table 4. Consumer Functional Food Scale Factors and Explained Variances Table

Factors	**Initial Eigenvalues**			**Squared Sum of Extracted Loadings**			**Squared Sum of Rotated Loadings**		
	Total	**Variance %**	**Cumulative %**	**Total**	**Variance %**	**Cumulative %**	**Total**	**Variance %**	**Cumulative %**
1	7.074	35.368	35.368	7.074	35.368	35.368	4.910	24.550	24.550
2	1.787	8.934	44.302	1.787	8.934	44.302	3.381	16.907	41.457
3	1.700	8.501	52.803	1.700	8.501	52.803	2.269	11.346	52.803

The results of the factor analysis applied to consumer surveys are shown in *Table 5*. Expressions marked with the letter 'R' in the leftmost column have been recoded as they are negative statements.

The process applied to the Health Scale (HS) was conducted similarly to the process applied to the Functional Food Scale. The Cronbach Alpha values obtained for all factors are higher than 0.6. The details of the identified factors are specified in *Tables 7* and *8*.

Regarding the factor loadings, significance of factor loading values can be determined taking into account the sample size. For a sample size of 120, a factor loading of 0.50; for a sample size of 200, a factor loading of 0.40; and for a sample size of 350, a factor loading of 0.30 can be considered significant (Hair et al., 2014; Akin and Asci, 2021)

The KMO and Bartlett test results for the factor analysis that was conducted for the Health Scale are shown in *Table 6*.

Table 5. Consumer Functional Food Scale Factor Analysis, Factor Loadings, Averages, Standard Deviations

	Factor 1: Personal Reward for Using Functional Foods	Factor Loading	Average	Standard Deviation
	- Products with health claims facilitate the pursuit of a healthy lifestyle.	0.793	3.0684	1.0480
	- I believe that foods with health claims enhance my overall well-being.	0.763	3.2500	1.0887
	- I view it as a positive aspect that contemporary technology allows for the creation of food products featuring health-related claims.	0.747	2.8342	1.1237
	- I experience an improved well-being when I consume foods with health claims.	0.743	3.2316	1.1320
	- The idea of maintaining my health through the consumption of foods with health claims brings me joy.	0.700	3.1421	1.1421
	- Consuming foods with health claims is entirely safe.	0.601	3.3026	1.0121
	- I believe that products with health claims undergo thorough and careful safety research.	0.574	3.2737	1.0621
	- Regular consumption of products with health claims can help me prevent diseases.	0.557	3.4500	1.1113
	- The consumption of a product with a health claim enhances my performance.	0.556	3.1579	1.0999
	- I would purchase a food product with a health claim endorsed by a doctor, dietitian, or health professional.	0.516	2.4605	1.0974
R	- Healthy individuals do not gain any advantages from using food products with health claims.	0.428	3.1105	1.2722
	Factor 1 Cronbach Alpha=0.882			
	Percentage of Variance Explained=24.550			
Factor 2: Confidence in Functional Foods				
R	- Unforeseen risks are associated with the novel features of food products with health claims.	0.784	3.2316	1.0795
R	- The health effects information on the packaging of foods with health claims is frequently overstated.	0.733	3.2711	1.1635
R	- Certain situations may arise where food products with health claims could pose risks to individuals who are otherwise healthy.	0.710	3.2421	1.1552
R	- I disagree with the constant proliferation of foods with health claims on the market shelves.	0.624	2.9395	1.1932
R	- Overindulging in food products boasting health benefits may have adverse effects on one's well-being.	0.600	3.5368	1.2096
	- Infusing products typically deemed unhealthy with purported health advantages lacks significance.	0.555	3.3342	1.2692
	Factor 2 Cronbach Alpha=0.799			
	Percentage of Variance Explained=16.907			
Factor 3: Interest in Functional Foods				
	- I am willing to allocate additional funds towards purchasing functional food.	0.707	3.8737	1.1554

Table 5. Continued

- I diligently seek information about foods that come with health claims.	0.657	3.5158	1.2013
- I enjoy consuming foods that have effects similar to drugs.	0.626	3.6500	1.2182
Factor 3 Cronbach Alpha=0.603			
Percentage of Variance Explained =11.346			

Table 6. Consumer Health Scale Factor Analysis KMO and Bartlett Test Table

KMO ve Bartlett Testi		
Kaiser-Meyer-Olkin Sample Measurement Value Adequacy		0.870
Bartlett Test	Chi-Square	2637.034
	Df	91
	Sig.	0.000

Table 7 displays the variances explained by the components obtained from the factor analysis initially and after the varimax rotation process. Three factors explain 65.428% of the total variance explained by a total of 14 statements in the Consumer Health Scale.

Table 7. Consumer Health Scale Factors and Explained Variance Table

Factors	**Initial Eigenvalues**			**Squared Sum of Extracted Loadings**			**Squared Sum of Rotated Loadings**		
	Total	**Variance Percentage**	**Cumulative Percentage**	**Total**	**Variance Percentage**	**Cumulative Percentage**	**Total**	**Variance Percentage**	**Cumulative Percentage**
1	5.351	38.224	38.224	5.351	38.224	38.224	4.090	29.215	29.215
2	2.565	18.320	56.544	2.565	18.320	56.544	2.560	18.288	47.503
3	1.244	8.883	65.428	1.244	8.883	65.428	2.510	17.925	65.428

Table 8 contains details of the factors related to the health scale. A total of 14 statements have been reduced to 3 factors, named as general health interest, interest in diet products, and interest in natural products. The table includes expressions for each factor group, factor loadings for each expression, mean values, standard deviations, and at the end of each factor group, the Cronbach Alpha values and the explained variance are provided.

Consumers were asked questions about their consumption habits related to six different functional food products which are vitamin-mineral fortified bread, probiotic fortified yogurt, margarine to help lower cholesterol, teas with relaxing properties (e.g., relax, 7-herbs, form), vitamin-mineral fortified breakfast cereals, and eggs fortified with selenium or omega-3. Additionally, an overall assessment was made about the general consumption of functional foods irrespective of product differentiation.

The *Table 9* represents Exp (B), which indicates the odds ratios. For an independent variable, the Exp (B) value, when other variables are held constant, indicates the proportional change in the expected outcome (the odds) of the dependent variable (i.e., the consumption of vitamin-mineral fortified bread) with a one unit change in the independent variable. If the Exp (B) value is greater than 1, an increase in the value of the independent variable is associated with an increase in the odds of the expected outcome. If the Exp (B) value is greater than 1, an increase in the value of the independent variable is associated with an increase in the odds of the expected outcome. If the Exp (B) value is less than 1, an increase in the value of the independent variable is associated with a decrease in the odds of the expected outcome (Islamoglu and Alniacik, 2014). If the Beta coefficient is negative, the odds ratio should be corrected as AO=1/OR (Ozdamar, 2013).

When the results of logistic regression analysis are examined, it was observed that survey results for functional yogurt, breakfast cereals, and any functional food product types provided interpretable outcomes with logistic regression application.

Table 8. Consumer Health Scale Factor Analysis, Factor Loadings, Average Values and Standard Deviations

		Factor Loading	Average	Standard Deviation
Factor 1: General Interest in Health				
	-I always eat a healthy and balanced diet	0.772	2.8203	1.0047
	-When selecting food, I ensure that my choices align with health considerations.	0.732	2.4792	1.0643
	-Ensuring the healthiness of the snacks I consume is of utmost importance to me.	0.731	2.4531	1.1115
	-Having a low-fat content in the foods I consume daily is crucial for me.	0.719	2.7292	1.1850
	-I pay close attention to the health aspects of the food I consume.	0.703	2.4479	1.1136
	- I steer clear of foods that I believe could elevate my cholesterol levels.	0.687	2.8021	1.2124
R	-I consume whatever I desire, seldom giving consideration to the health aspects of my food choices.	0.634	2.5885	1.1972
	-Ensuring that the foods I consume daily are rich in vitamins and minerals is a priority for me.	0.534	2.4609	1.0760
	Factor 1 Cronbach Alpha=0.874			
	Percentage of Variance Explained =29.215			
Factor 2: Interest in Natural Products				
	- I believe that consuming foods sweetened with artificial sweeteners can be detrimental to my health.	0.852	2.1016	1.2146
	- I avoid highly processed products because I'm unfamiliar with their ingredients.	0.790	2.3177	1.1302
	- I make an effort to consume products that are free from additives.	0.774	2.2630	1.0699
	Factor 2 Cronbach Alpha=0.823			
	Percentage of Variance Explained=18.288			
Factor 3: Interest in Diet Products				
	-I hold the belief that diet products contribute to maintaining a low cholesterol level for me.	0.906	3.1016	1.1019
	- I believe that diet products contribute positively to my overall health.	0.879	3.1354	1.1299
	- I believe that I can manage my cholesterol levels by incorporating diet products into my consumption.	0.868	3.1719	1.1524
	Factor 3 Cronbach Alpha=0.871			
	Percentage of Variance Explained=17.925			

Yogurt holds significant importance in Turkish culture and is widely consumed. According to Kizilaslan and Solak (2016), a report by Danone in 2013 indicated that Türkiye ranked second in per capita yogurt consumption. Similarly, as reported by Kizilaslan and Solak (2016), the Türkiye Nutrition and Health Survey revealed that 52.7% of the Turkish population consumed yogurt daily. Şimşek et al. (2005) expressed in their study that most of the respondents participated in their research, due to dietary habits, do not have a regular habit of drinking milk. On the other hand Turkish consumers mostly prefer yoğurt, not milk. Engindeniz et al. (2021) declared in their study that 93.36% of the household members interviewed stated that they consumed yogurt.

Analyzing yogurt consumption, it was observed that the likelihood of females consuming functional yogurt is 2.78 times higher. Additionally, in an examination of probiotic consumption, as mentioned in a study by Schultz et al. (2011), it was found that 30.6% of females consume probiotics, while only 17.2% of males do. Females generally show a higher preference for probiotic consumption. Regardless of product type, the likelihood of females consuming any functional food product is 2.54 times higher. A study conducted by Dogan et al. (2011) revealed that females consume functional foods more frequently. Research conducted in different countries also showed that females have a more positive attitude towards and a higher preference for functional foods (Bower et al., 2003; Poulsen, 1999; Siro et al., 2008). However, a study by Ozdemir Ozkan et al. (2009) suggested that there is no significant relationship between attitudes toward functional foods and variables such as gender, marital status, and having children.

In families without children, the likelihood of consuming probiotic yogurt is 1.74 times lower, and the likelihood of consuming functional breakfast cereals is 1.75 times lower. The odds ratio for functional cereals is calculated as 0.571, and for yogurt, it is 0.573. Since the Beta coefficients are negative, the odds ratios are corrected as 1/OR. Thus, the odds ratios are corrected as AO=1/0.573 and AO=1/0.571. It can be speculated that families without children may prioritize food choices that contribute to the overall health and vitamin-mineral support of their children. Hacioglu and Kurt (2012) mentioned factors such as increasing healthy intestinal bacteria, aiding in weight control, and contributing to children's growth as reasons for the preference for functional foods. Siro et al. (2008) also emphasized the significant role of the presence of children in adopting functional foods.

In families where individuals implementing a personalized nutrition program are not present, it has been observed that the likelihood of consuming probiotic yogurt is low. In his research, Verbeke (2005) noted that an individual experiencing a specific health problem within the family positively influences the consumption of functional foods. Similarly, Siro et al. (2008) stated that the presence of individuals who have experienced health problems or relatives who have experienced health problems is an important factor in the adoption of functional foods.

Consumers who perceive functional foods as a personal reward have a 2.36 times higher likelihood of consuming probiotic yogurt, a 3.10 times higher likelihood of consuming vitamin-mineral fortified breakfast cereals, and a 2.76 times higher likelihood of consuming any functional food product. Consumers with positive thoughts about functional foods, believing that these products enhance their overall health and consequently make them feel better, have a higher likelihood of consuming probiotic yogurt, functional cereals, and any functional food product.

Consumers with a monthly income below 1656 USD have a 2.58 times lower likelihood of consuming probiotic yogurt and a 3.10 times lower likelihood of consuming any functional food product. Since functional foods are generally perceived as more costly than conventional foods, it is supported by findings that consumers with lower income levels have a lower likelihood of choosing such products. Siro et al. (2008) have indicated that functional food consumers have generally a high-income level.

Single consumers have a 2.08 times higher likelihood of consuming breakfast cereals. The preference for breakfast cereals, known as convenient breakfast alternatives, aligns with the results of the research.

It has been observed that consumers showing interest in functional foods have a 1.70 times lower likelihood of consuming functional breakfast cereal products and a 2.13 times lower likelihood of consuming general functional products. Factors expressing interest in functional foods include satisfaction with paying higher prices for functional foods, making a special effort to be informed about foods with health claims, and preferring to consume foods with drug-like effects. Despite positively evaluating functional foods, consumers in this group are observed to have a low likelihood of consuming them. The analysis results emphasize that a positive attitude is not the sole factor influencing purchasing decisions. Additionally, factors such as the proven health benefit perception (Poulsen, 1999), the belief that functional food products work and influences such as price and naturalness, as highlighted by (Bower et al., 2003) also play a role.

Consumers with a high level of interest in diet products have a 1.86 times lower likelihood of consuming functional cereals. Questions indicating interest in diet products include factors such as the belief that diet products have an impact on keeping cholesterol levels low, the perception that diet products support health, and the desire to control cholesterol by consuming diet products.

Consumers below the age of 29 have a 4.65 times higher likelihood of consuming vitamin-mineral fortified breakfast cereals, while consumers in the 30-39 age range have a 3.40 times higher likelihood of consuming the same product. Consumers under the age of 39 show a higher likelihood of preferring functional cereals. Markovina et al. (2011) mentioned in their survey targeting the 14-30 age group that 75% of this age group purchases functional products.

Table 9. Odds Ratios of Consumers' Usage of Functional Products

Variable	Probiotic Added Yogurt	Vitamin-Mineral Enriched Cereals	Any Functional Food Product
Personal reward of using FF (Agree/Absolutely Agree)	2.356[a]	3.101[a]	2.765[a]
Confidence in FF (Agree/Absolutely Agree)	1.018	0.703	1.248
Interest in FF (Agree/Absolutely Agree)	0.711	0.587[b]	0.470[b]
General Interest in Health (Agree/Absolutely Agree)	1.067	0.821	1.205
Interest in Natural Products (Agree/Absolutely Agree)	1.051	0.836	1.109
Interest in Diet Products (Agree/Absolutely Agree)	1.005	0.537[b]	0.870
Gender			
Female	2.784[a]	1.315	2.544[a]
Marital Status			
Single	1.359	2.081[b]	1.616
Age			
<29	1.763	4.649[b]	1.787
30-39	1.458	3.399[b]	2.104
40-49	1.677	2.243	0.717
No children in the household	0.573 [b]	0.571[b]	0.585
Level of Education			
Compulsory Education (Primary-Secondary-High school)	0.825	0.949	1.249
Monthly Total Household Income			
<1656 USD	0.387[b]	1.092	0.322[b]
1657-3311 USD	0.675	1.235	0.804
No Individual Implementing a Special Diet in the Household	0.488[b]	1.170	0.972

a:p<0.01 b:p<0.05 c:p<0.1

4. Conclusions

Upon examining the survey results, it was observed that probiotic-fortified yogurt and general functional foods are consumed more by women among consumers. Furthermore, in families without children, the probabilities of consuming both probiotic-fortified yogurt and functional breakfast cereals were found to be lower. If it is aimed to encourage childless families to consume these products, it is recommended to provide them with more information about these product groups.

Among consumers, it was observed that the probability of consuming probiotic yogurt is lower in families where there is no individual implementing a special nutrition program at home. The presence of an individual implementing a special nutrition program at home may lead other family members to be more conscious and careful about nutrition. If there is no one implementing a special nutrition program at home, or if there is no particular interest in nutrition, individuals may be less sensitive or investigative in this regard.

Single consumers were found to have a higher likelihood of consuming breakfast cereals. For functional cereals, it is recommended to conduct studies targeting single consumers.

Consumers under the age of 39 were observed to have a higher likelihood of preferring functional cereals. As breakfast cereal products are considered a practical option, it is seen that the younger age group prefers this product more.

In comparison to traditional foods, functional foods are more costly products. In this study, consumers with a monthly income below 1656 USD were observed to have lower probabilities of consuming probiotic yogurt and any other functional food products. It can be considered a reasonable approach that consumers with lower income levels do not allocate more budget for functional foods. When the prices of functional foods become closer to the prices of traditional foods, access to functional products will be easier for this income group.

Consumers with positive thoughts about functional foods have a high probability of consuming probiotic yogurt, functional cereals, and other functional food products. In this context, to enable consumers to have more information about these products, the effects of these products on health should be conveyed more clearly and explicitly. Providing more detailed information about the effects of current and future functional foods on consumer health is expected to support consumer attitudes.

Consumers showing interest in functional foods were observed to have lower probabilities of consuming especially functional breakfast cereals and general functional products. Consumers with a higher interest in diet products were found to have lower probabilities of consuming functional cereals. The questions indicating interest in diet products involve beliefs that diet products have an impact on lowering cholesterol, the perception that diet products support health, and the desire to consume these products to keep cholesterol under control. In this context, it is considered significant that the result of functional cereal not being categorized as a diet product and not being preferred by consumers with a high interest in diet products is meaningful.

Landstrom et al. (2009) and Bech-Larsen and Grunert (2003) have stated that consumers in different countries have different approaches to functional foods. Therefore, to better understand consumers in Turkey, research on functional foods can be conducted more comprehensively by following studies conducted internationally.

Poulsen, 1999 emphasized that functional foods should be considered not as a homogeneous group but as separate products in different product categories. Ares and Gambaro (2007) also stated that different genders and age groups exhibit different approaches to products. In this regard, research on other products not examined in this study could provide more detailed insights into consumer approaches to functional food groups. This could help in better understanding the preferences of functional food consumers and diversifying activities in this market.

This research was conducted on six functional product groups. Including different product groups in future research will provide more detailed information about the functional food market. Expanding the number of respondents to the survey will enable obtaining more detailed information about the functional food market in Turkey.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Turkish Noodle (Erişte) Quality of Different Local Durum Wheat Varieties: Case Study of Lakes Region, Türkiye*

Farklı Yerel Durum Buğday Çeşitlerinin Erişte Kalitesi: Göller Bölgesi Örneği, Türkiye

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Abstract

Wheat flour noodles are a staple in the diets of many countries, and their popularity has increased in recent years. The main component of noodles is wheat flour; therefore, the qualitative attributes of noodles are predominantly dependent on the quality of wheat used in their production. This study aimed to evaluate and compare the quality of noodles made from ten different local durum wheat varieties (LDW) sourced from the Lakes Region of Türkiye. The study measured various parameters like moisture, ash, color, breaking strength, deformation, and texture profile analysis (TPA) of noodles made from LDW flours. Moreover, the optimum cooking time (OKT), cooking loss (CL), swelling volume (SV), water absorption (WA), and sensory attributes of noodles were assessed. Regarding moisture and ash content, the noodles were found to have values ranging from 6.76 to 10.51% and 2.29 to 2.77, respectively. The noodles had an average brightness of 87.24, a redness of 1.26, and a yellowness of 17.74. Ak Buğday, Ankara 98, and Gediz 75 varieties demonstrated higher levels of yellowness than the other varieties. The Kızıltan91, Çeşit1252, and Ak Buğday cultivars showed more resistance to breakage while lower levels of deformation. Significant effects ($P<0.01$) of LDW on the TPA of cooked noodles were identified. Sert Buğday and Kunduru varieties had the lowest OCT (10.29 min), while Ak Buğday and Kızıltan 91 varieties had the highest value (average 12.48 min). The CL and SV of cooked noodles varied from 7.85 (Ankara 98) to 10.39% (Sert buğday) and 110% (Burgaz) to 259.20% (Sert Buğday) respectively. The noodles with the highest SV, Sert Buğday and Gediz 75, also had higher WA. Ankara 98, with the lowest SV, had the lowest WA. The Burgaz and Kunduru cultivars were deemed unfavorable in terms of general acceptability. As a result, we can conclude that Hard Wheat and Gediz 75 durum wheat flours offer good noodle quality; thus, these varieties can be suggested for making handmade or commercial noodles.

Keywords: Wheat for pasta, Noodle texture, Cooking quality, Cooking loss

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Öz

Birçok ülkenin diyetinin önemli bir parçası olan buğday unu eriştelerinin son yıllarda popülaritesi artmıştır. Eriştenin ana bileşeni buğday unudur; bu nedenle erişte kalitesi büyük ölçüde üretiminde kullanılan buğdayın kalitesine bağlıdır. Bu çalışmanın amacı, Türkiye'nin Göller Bölgesi'nden temin edilen on farklı yerel durum buğdayı çeşidinden (YDB) üretilen eriştelerin kalitesini değerlendirmek ve karşılaştırmaktır. Çalışma, YDB unlarından yapılan eriştelerin nem, kül, renk, kopma mukavemeti, deformasyon ve tekstür profil analizi (TPA) gibi çeşitli parametrelerinin ölçülmesini içermektedir. Ayrıca, eriştelerin optimum pişirme süresi (OPS), pişirme kaybı (PK), hacim artışı (HA), su absorbsiyonu (SA) ve duyusal özellikleri değerlendirilmiştir. Eriştelerin nem ve kül değerleri sırasıyla %6.76-10.51 ve 2.29-2.77 arasında, ortalama parlaklık, kırmızılık ve sarılık değerleri ise 87.24, 1.26 ve 17.74 olarak bulunmuştur. Ak Buğday, Ankara 98 ve Gediz 75 çeşitleri diğer çeşitlere kıyasla daha yüksek sarılık değerleri göstermiştir. Kızıltan91, Çeşit1252 ve Ak Buğday çeşitleri kırılmaya karşı daha fazla direnç gösterirken deformasyon seviyeleri daha düşük olarak ölçülmüştür. YDB çeşitlerinin pişmiş eriştelerin TPA'leri üzerinde önemli etkileri ($P<0.01$) tespit edilmiştir. Sert Buğday ve Kunduru çeşitlerinin en düşük OPS (10.29 dk)'ne, Ak Buğday ve Kızıltan 91 çeşitlerinin ise en yüksek OPS (ortalama 12.48 dk)'ne sahip olduğu saptanmıştır. Pişmiş eriştelerin PK ve HA değerleri sırasıyla %7.85 (Ankara 98) ile %10.39 (Sert buğday) ve %110 (Burgaz) ile %259.20 (Sert Buğday) arasında değişmiştir. En yüksek HA'na sahip olan Sert Buğday ve Gediz 75 erişteleri aynı zamanda daha yüksek SA'na sahipken en düşük HA'na sahip Ankara 98 ise en düşük SA değeri göstermiştir. Burgaz ve Kunduru çeşitleri genel kabul edilebilirlik açısından en düşük puanları almışlardır. Sonuç olarak, Sert Buğday ve Gediz 75 durum buğdayı unları ile yapılan eriştelerin daha üstün kalite özellikleri gösterdikleri belirlenmiştir. Bu nedenle, bu çeşitler el yapımı veya ticari erişte yapımı için önerilebilir.

Anahtar Kelimeler: Makarnalık buğday, Erişte tekstürü, Pişme kalitesi, Pişme kaybı

1. Introduction

Wheat is a major cereal crop, with a global production of around 772 million tons (Anonymous, 2024a). Durum wheat (*Triticum durum or Triticum turgidum* subsp*. durum*) is the tenth most extensively cultivated cereal crop in the world, with a production of 40 million tons (Saini et al., 2023). Major durum wheat producers the European Union, Canada, Türkiye, Mexico, the United States, Algeria, Morocco, and Kazakhstan. Durum wheat production of Türkiye reached 4.3 million tons in 2023 (Anonymous, 2024b).

Different varieties of durum wheat are cultivated in Türkiye and worldwide, owing to variations in growing circumstances, soil properties, fertilization practices, environmental factors, climate, and genetic factors. The price of durum wheat is higher than that of bread wheat because it is a more valuable variety of wheat grown in specific parts of the world. In addition to its economic value, durum wheat is highly valued for its relatively high concentration of yellow pigments, low levels of lipoxygenase activity, higher protein content, and strong gluten. Durum wheat is the optimal raw material for manufacturing pasta products, including long and dried short-dried pasta, fresh and sheeted pasta, macaroni, noodles, and vermicelli. Food products other than pasta, such as couscous, flat bread (unleavened bread), bulgur, frekeh, durum wheat bread, and a puffed durum wheat ready-to-eat breakfast cereal are also made from durum wheat (Elias, 1995; Kezih et al., 2014; Hammami and Sissons, 2020; Labuschagne et al., 2023; Saini et al., 2023).

Noodles play an important role in Asian countries' daily diets. On the other hand, their global popularity has increased since they are easy to prepare, offer appealing sensory qualities, can be stored for a long time, are inexpensive, and can be cooked quickly and easily (Yazıcı et al., 2021).

Turkish noodle (erişte), which have made for years, also plays a significant role in Turkish cuisine. Noodles in Noodle Standard (TS-12950) are defined as a product that is dried, boiled, steamed, or ready for direct consumption by kneading the dough prepared after adding wheat flour, salt (such as sodium carbonate, potassium carbonate, and sodium phosphate), egg, and water, and processing it following by technique (TSE, 2003).

Flours from *Triticum aestivum* and *Triticum durum* wheat are commonly used in noodle production. Consequently, product quality depends primarily on the quality of the wheat used. The wheat should be clean and sound, with a high grain weight, uniform grain size, and hardness (Hou and Kruk, 1998; Yazıcı et al., 2021). In Türkiye, as in other parts of the world, modern varieties of *Triticum aestivum* and *Triticum durum* are generally used for food production. However, Türkiye is one of the first areas where wheat was cultivated, and it is the origin of the genes that are responsible for the local and ancient wheat varieties that have attracted a great deal of interest in recent years (Özkan and Gül, 2024).

Furthermore, in Türkiye, there is a growing number of Pioneer organizations, farmers, and newly settled communities that are cultivating local wheat cultivars (Yıldız and Özkaya, 2024). In their study, Durmaz and Aktaş (2023) concluded that local durum wheat varieties showed better characteristics in terms of plant height, thousand grain weight, peduncle length, biological yield, days to spike and protein ratio when compared to modern breeding varieties. They also identified numerous local varieties that have the potential to serve as a valuable gene source, particularly in research aimed at enhancing grain protein content and biological output.

Wheat flour significantly influences the quality attributes of noodles, including their surface appearance, texture, color, and cooking properties (Nagao, 1996). The primary factors used to evaluate the quality of noodle flour are the amount of ash, protein content and quality, color, damaged starch content, particle size and starchiness, and the rheological properties of the dough (Hou and Kruk, 1998). Noodles prepared from flours containing a significant quantity of damaged starch require a longer cooking time and experience reduced water penetration. As the quantity of solid substances released into the water during cooking rises, it of sticky noodles that have undesirable qualities for consumption (Moss et al., 1987). In noodle production, adding 1-2% salt strengthens the noodle dough and reduces the stickiness of the noodles (Bean et al., 1974).

Based on the most recent data (Anonymous, 2024c), Türkiye is the second-largest exporter of pasta in the world, following Italy. In addition to pasta, Türkiye has also started exporting noodles. Both products' exports have a significant impact on the national economy. Hence, it becomes essential to investigate the suitability of local durum wheat varieties for noodle production, as well as the technological quality of noodles made from these varieties, in order to enhance the overall quality of noodle production. Thus, the purpose of this study was to guide both domestic and international producers by examining the noodle quality of local durum wheat varieties.

The production of high-quality noodles is only possible with quality durum wheat varieties. Since the developing noodle sector needs to determine whether or not the varieties that are used in the manufacturing of pasta are suitable for the production of noodles in Türkiye, which is the leading producer of durum wheat in the world, to our knowledge, there have been no studies on the noodle quality of local durum wheat varieties cultivated in the Lakes region. Therefore, this study aimed to evaluate the suitability of durum wheat from the Göller Region, a prominent durum wheat producer in Türkiye, for noodle production by conducting noodle quality testing.

2. Materials and Methods

2.1. Materials

10 different local durum wheat samples obtained from Isparta, Burdur, and Afyonkarahisar provinces of the Lakes Region were used as material. Three varieties, namely Çeşit 1252, Gediz75, and Kızıltan91, were acquired from pasta companies, while the remaining seven varieties, including Ak Buğday, Ankara98, Burgaz, Durbel, Gökala, Kunduru, and Sert Buğday, were bought from local growers. In order to represent the whole wheat mass, about 10 kg of local wheat varieties were taken in accordance with the sampling method. These samples were then put in cotton bags and transported to the laboratory. Next, the impurities included in the wheat samples were effectively eliminated through the process of sieving and manual removal.

2.2. Tempering and milling of wheat samples

The tempering procedure involved the addition of water in accordance with the specified quantities outlined in AACC Method 26-95.01 (AACC, 2010), with the aim of reaching a moisture content of 16-17% in the wheat prior to milling. Cold tempering was carried out at room temperature for 48 hours, with stirring every 5 hours. Following the completion of the tempering procedure, the wheat samples were then ground into flour using a laboratory-grade flour milling equipment (Ekin Gıda, Ankara). After the milling process, the flours were stored in sealed packaging at ambient temperature for three weeks to allow maturation.

2.3. Noodle making method

Noodles were made by kneading 500 g of flour, 5 g of salt, and drinking water according to the amount specified on the farinograph for each type of durum wheat flour for ten minutes in a mixer (Hobart N50CE model, Hobart Corporation, USA). The dough was after that divided into 100 g equal portions, manually rolled, and allowed to rest in plastic bags at ambient temperature for 20 minutes. After resting, the dough was subjected to a preliminary thinning process with the help of a rolling pin. Subsequently, it was gradually thinned in a household noodle machine (Imperia, Italy) and kept at room temperature for 5 minutes to prevent sticking, then cut into noodle strips. The noodles were placed on perforated trays so they did not touch each other and dried at room temperature for 24 hours. The dried noodles were placed in glass jars and stored in the refrigerator at +4°C until further analysis.

2.4. Noodle analysis

The noodles' width, length, and thickness were measured using a digital caliper. Noodle samples were also analyzed for moisture (AACC Method, 44-01.01, AACC, 2010) and ash (AACC Method, 08-01.01, AACC, 2010). The colors of raw and cooked noodle samples were measured by colorimetry (Minolta CR 410, MinoltaCo Ltd., Tokyo, Japan) using Hunter L* (Lightness: Darkness L*=0 black, L*=100 white), a* (redness: +a*= red, - a*= green) and b* (yellowness: +b*=yellow, -b*=blue) color scales.

2.5. Determination of breaking strength and deformation of dried noodles

Breaking strength (N) and deformation (mm) of individual dried noodle strips were determined on a texture analyzer (TA.XT Plus, Stable Micro Systems Ltd., Godalming, Surrey, UK) using a 0.8 mm broad blade probe with a 50 kg load cell and a head speed of 1 mm s^{-1}. The breaking strength of the dried noodles was measured as the force (kg) required to break each strip of dried noodles.

2.6. Texture profile analysis (TPA) of cooked noodles

TPA of cooked noodles wasa was performed by using a texture analyzer (TA.XT Plus, Stable Micro Systems Ltd., Godalming, Surrey, UK) according to Park and Baik (2002), Khatkar, and Kaur (2018) with minor modifications. The noodle samples were cooked to their OCT, cooled with tap water for one minute, and filtered through a Buhner funnel. The water remaining on the surface of the noodle strips was gently removed with a paper towel, placed as a single strip on the table of the texture analyzer, and compressed twice using a 1.27 mm diameter sphere probe at a head speed of 2 mm s^{-1} for TPA. Hardness (g), adhesiveness (g.sec), springiness, cohesiveness, gumminess, chewiness, and resilience parameters were determined by TPA analysis.

2.7. Determination of optimum cooking time (OCT)

The OCT of the noodles was determined according to the AACC Method, 66-50.01 (AACC, 2010). According to this method, 10 g of noodle sample was added to 200 ml of distilled water boiling on the heating plate, and when it began to boil, the time with the help of a stopwatch. The samples were mixed with a glass drumstick in such a way that they were not damaged, and the loss of water during the analysis was compensated by the addition of boiling water. At 30-second intervals, a strip was taken and squeezed and crushed between 2 glass plates, and this process was continued until the white center disappeared in the middle of the noodles crushed between the glass plates. The time from the start was recorded as the OCT.

2.8. Determination of the cooking loss (CL)

25 g of dry noodles were added into 250 ml of boiling distilled water, the mouth of the beaker was covered with a watch glass, and the noodles were cooked until their OCT by stirring occasionally. At the end of the OCT, the beaker's contents were filtered through the Buhner funnel and cooked when the dripping from the funnel stopped. The noodles were placed back into the cooking vessel, washed with 90 ml of water, stirred gently, and filtered through the same funnel again. The cooking and washing water were combined, and some water was added to make the volume up to 350 ml. 50 ml of this mixture was taken into a pre-dried and tared beaker. After evaporation in a water bath, it was dried to constant weight in an oven at 98°C and weighed (Özkaya and Özkaya, 2005).

2.9. Determination of swelling volume (SV)

After the noodles were cooked, drained, and left for a few minutes, they were placed in a 250 ml measuring cylinder containing 150 ml of water, and the increase in the water level was recorded. The same method was applied to uncooked noodles. The SV was determined by dividing the water displacement of cooked noodles by the water displacement of an equal amount of uncooked noodle noodles by the water displacement of an equal amount of uncooked noodles (Özkaya and Özkaya, 2005; Khatkar and Kaur, 2018).

2.10. Determination of water absorption (WA)

25 g of dry noodles were added into 250 ml of boiling distilled water, and the beaker was covered with a watch glass. The beaker was covered with a watch glass, and the noodles were cooked until their OCT. At the end of the cooking time, the cooked and drained noodles were weighed after waiting for a few minutes and the water absorption (weight gain) was calculated in % by taking into account the uncooked weight (Özkaya and Özkaya, 2005). The WA is the difference in the weight of cooked noodles versus uncooked noodles, expressed as the percentage of weight of uncooked noodles.

2.11. Sensory analysis

The noodles cooked to the optimum cooking time and drained were evaluated by 10 panelists using a 5-point hedonic scale (1 point: I did not like it at all, 5 points: I liked it very much). In sensory analysis, the noodles were evaluated in appearance (pasty and stick together), odor, mouthfeel, taste/aroma, and overall acceptability.

2.12. Statistical analysis

The data reported are an average of three replications. The data obtained for all measured properties of the noodle samples were subjected to the Duncan multiple comparison test using analysis of variance (ANOVA) with the SPSS package program (SPSS 18.0 software for Windows).

3. Results and Discussion

3.1. Chemical properties of noodles

The moisture and ash content of noodles obtained from LDW flours are given in *Table 1*. When the mean values of moisture and ash contents were analyzed, it was determined that there were statistically significant differences between them (P<0.01).

Table 1. Moisture and ash values of noodles[1]

Durum Wheat Varieties	Moisture (%)	Ash (%)
Ak Buğday	8.16^{d}	2.41^{cd}
Ankara98	7.38^{e}	2.65^{ab}
Burgaz	9.58^{b}	2.69^{ab}
Çeşit1252	8.83^{c}	2.74^{a}
Durbel	9.53^{b}	2.64^{ab}
Gediz75	8.90^{c}	2.77^{a}
Gökala	8.45^{cd}	2.29^{d}
Kızıltan91	6.76^{f}	2.39^{cd}
Kunduru	10.51^{a}	2.52^{bc}
Sert Buğday	8.93^{c}	2.50^{bc}

[1] The differences between the values shown with the same letter in the column are insignificant according to the 0.01 confidence limit.

The moisture content of the noodles ranged from 6.76% in the Kızıltan91 to 10.51% in the Kunduru. The variations in moisture content among the noodles may be attributed to their different amounts of water absorption. Water was added to each wheat flour in the noodle production process at the rate specified in the farinograph. However, all noodles meet the moisture content requirement, as they are below the maximum moisture level of 13% established in the TS 12950 (TSE, 2003) noodle standard. The findings in this study coincide with the results of Dirim and Koç (2019), which reported the moisture content of regular Turkish noodles as 9.69±0.92%.

The Gediz 75 exhibited the greatest ash value of 2.77%, while the Gökala had the lowest ash value of 2.29%. The noodle samples were found to be non-compliant with the TS 12950 noodle standard due to their ash values exceeding the specified ash limit of 1.0% for plain noodles. This is because the grinding process was carried out in a laboratory-type mill with 4 four rollers (2 crushing and two refining rollers), and the bran-endosperm separation could not be fully realized. It is possible to produce more refined flour with a reduced ash content and noodles that meet standards if the milling is done in commercial mills. that probably, the excessive amount of salt utilized in the preparation of the noodles is another factor that contributed to the high ash content of the noodles.

Although the moisture content of the noodles lined up with the results that were reported in the literature, the ash content was observed to be greater in comparison to the relevant literature (Eyidemir, 2006; Öztürk, 2007; Demir, 2008; Aydın, 2009; Ramya et al., 2015).

3.2. Physical properties of noodles

The noodle doughs were cut by hand into regular sizes after they had been rolled out to the desired thickness. In light of this, there was no significant variation between the values of the noodles' width, length, and thickness. The noodles' mean width, length, and thickness were measured as 6.02±0.02, 120.27±0.37, and 1.55±0.04, respectively.

3.3. Colors of raw and dried noodles

Color (L*, a*, b*) values of raw and dried noodles obtained from durum wheat flours are given in *Table 2*. There was a statistically significant difference between the color values of noodles (p<0.01). The raw nodules obtained from the Ak buğday variety had a brighter color to the other types, which aligns with the wheat's name (Ak buğday=White Wheat). Conversely, the noodles produced from the Gediz 75 type had the lowest brightness level. As the noodles lost water with drying, the samples became slightly dull and yellow. Compared to the remaining noodles, the Kunduru noodles had a higher water content, resulting in a diminished intensity of the yellow color. This can probably be attributed to the high water activity of the Kunduru sample. Due to the fact that there is an inverse correlation between the amount of water activity and the Hunter b levels. Specifically, the Hunter b values declined as water activity increased (Rhim and Hong, 2011).

Table 2. Colors of raw and dried noodles[1]

Durum Wheat Varieties	Raw			Dried		
	L*	a*	b*	L*	a*	b*
Ak Buğday	92.72[a]	2.12[a]	16.25[d]	88.42[c]	2.18[a]	20.50[b]
Ankara98	91.82[c]	1.05[d]	14.11[g]	89.09[b]	2.17[a]	21.38[a]
Burgaz	90.37[e]	1.26[c]	16.74[c]	83.88[h]	0.33[g]	18.19[c]
Çeşit1252	91.13[d]	1.28[c]	14.02[g]	86.31[f]	0.84[e]	16.18[e]
Durbel	91.09[d]	1.44[b]	17.53[b]	87.28[e]	1.02[d]	17.94[c]
Gediz75	89.61[f]	1.44[b]	19.41[a]	85.54[g]	1.06[d]	20.51[b]
Gökala	92.20[b]	1.44[b]	13.74[h]	88.01[cd]	1.42[c]	15.68[e]
Kızıltan91	92.26[b]	1.42[b]	14.65[f]	89.73[a]	1.81[b]	15.50[e]
Kunduru	90.56[e]	1.29[c]	15.74[e]	87.73[de]	0.72[f]	14.45[f]
Sert Buğday	91.19[d]	1.31[c]	15.84[e]	86.39[f]	1.00[d]	17.10[d]

[1]The differences between the values shown with the same letter in the same column are insignificant according to 0.01 confidence limit.

One of the main criteria in evaluating the quality of durum wheat is the bright yellow color exhibited by pasta products, compared to their cooking characteristics and flavor (Aalami et al., 2007). Upon evaluating the impact of the tested durum wheats on the yellow color values of noodles, it was determined that the Ak Buğday, Ankara 98, and Gediz 75 varieties exhibited higher yellowness values than the others. Consequently, these varieties can be utilized in both pasta and noodle production. Besides this, it can be inferred from the high yellow color value that these kinds also have a high carotenoid content. The biological and nutritional value of grains with high levels of carotenoid pigments is enhanced by their provitamin activity, specifically vitamin A, as their antioxidant activity (Malchikov and Myasnikova, 2020).

The Ankara98 and Akbuğday noodles had a higher level of redness, as indicated by the a* value, in comparison to the other kinds. *L**, *a**, and *b** values of flours and noodles produced from these flours exhibit variation among different durum wheat cultivars, which can be attributed to the influence of environmental factors on kernel development. Similar to our results, L, a and b values of flours obtained from different Indian durum wheat varieties were reported (Kaur et al., 2015) to range from 90.92 to 92.25, 0.30 to 0.73 and 13.66 to 17.50, respectively.

3.4. Breaking strength and deformation of dried noodles

There were statistically significant differences ($p<0.01$) between the breaking stress and deformation values of the noodles (*Table 3*).

Table 3. Breaking strength and deformation of dried noodles[1]

Durum Wheat Varieties	Breaking stress ($kg\ mm^{2-1}$)	Deformation (mm)
Ak Buğday	4.98[a]	32.44[e]
Ankara98	4.37[b]	32.90[de]
Burgaz	3.78[bc]	33.06[de]
Çeşit1252	3.53[cd]	33.83[cd]
Durbel	3.06[d]	34.86[c]
Gediz75	2.35[e]	35.08[bc]
Gökala	1.53[f]	36.28[ab]
Kızıltan91	0.88[g]	36.31[ab]
Kunduru	0.78[g]	36.95[a]
Sert Buğday	0.46[g]	37.02[a]

[1] The differences between the values shown with the same letter in the same column are insignificant according to the 0.01 confidence limit.

The breaking stress values of the noodles were observed to vary between 0.46 kg mm^{2-1} (Kunduru) and 4.98 kg mm^{2-1} (Kızıltan 91). An inverse relationship was found between breaking stress and deformation. The samples displaying high breaking stress demonstrated low deformation values, whereas the samples with low breaking stress had high deformation values. Due to the fact that noodles are dried foods, they have a very long shelf life. However, this may cause breakage in the noodle during storage, transportation and sale. For this reason, it is desirable that the noodles have a firm and break-resistant texture. Hence, it can be suggested that Kızıltan91, Çeşit1252, and Ak Buğday cultivars having higher breaking resistance but lower deformation value is better appropriate for the production of noodles and pasta.

3.5. TPA of cooked noodles

Textural characteristics, such stickiness and firmness, play a crucial role in determining the quality of cooked pasta. A good pasta should maintain its firm structure, resist surface disintegration, and provide a satisfying chewy bite (Cubadda et al., 2007). TPA results of noodle samples are given in *Table 4*. The Gediz 75 noodle presented the highest hardness value, at 528.01 g. Following closely behind were Burgaz, Kızıltan91, Çeşit 1252, and Sert Buğday noodles, with hardness values of 510.85, 507.84, 507.74, and 505.64, respectively. Conversely, the Kunduru variety exhibited the least hardness, measuring 387.39 g. In contrast to the findings of our research, the firmness values of Indian durum wheat varieties were found to be lower (ranging from 2.33 to 4.31 N) in a study carried out by Kaur et al. (2015). The fact that the environment in which wheat is grown plays a significant role in determining the quality of noodles is demonstrated by this difference. The hardness of fresh cooked noodles is influenced by various elements, such as starch, damaged starch, protein, and moisture content (Tang et al., 2019). Hardness is negatively correlated with an increase in moisture content. As in the Kunduru example, the noodles showed a softer structure as the moisture content increased.

Table 4. Texture profile analysis of cooked noodles[1]

Durum Wheat Varieties	Hardness (g)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	Adhesiveness (g.s)
Ak Buğday	419.51^{d}	0.97^{ab}	0.69^{a}	295.30^{d}	287.38^{d}	0.53^{ab}	6.65^{d}
Ankara98	453.10^{c}	0.96^{ab}	0.71^{a}	317.13^{c}	305.47^{c}	0.50^{ab}	11.95^{c}
Burgaz	510.85^{b}	0.97^{ab}	0.69^{a}	335.37^{b}	327.48^{b}	0.41^{b}	8.04^{d}
Çeşit1252	507.74^{b}	0.96^{ab}	0.66^{a}	302.18^{d}	290.29^{d}	0.47^{ab}	10.83^{c}
Durbel	444.87^{c}	1.16^{a}	0.69^{a}	334.94^{b}	396.21^{a}	0.59^{a}	6.83^{b}
Gediz75	528.01^{a}	0.69^{bc}	0.69^{a}	357.36^{a}	346.46^{b}	0.49^{ab}	9.16^{d}
Gökala	452.56^{c}	0.75^{bc}	0.75^{a}	347.74^{a}	333.90^{b}	0.59^{a}	12.37^{c}
Kızıltan91	507.84^{b}	0.74^{bc}	0.74^{a}	346.22^{a}	327.75^{b}	0.59^{a}	18.94^{b}
Kunduru	350.38^{e}	0.70^{bc}	0.70^{a}	271.53^{e}	264.70^{e}	0.48^{ab}	7.86^{d}
Sert Buğday	505.64^{b}	0.66^{c}	0.66^{a}	320.67^{c}	300.17^{c}	0.39^{b}	23.79^{a}

[1]The differences between the values shown with the same letter in the same column are insignificant according to 0.01 confidence limit.

The Durbel variety displayed the lowest springiness value of 0.66, while the hard wheat variety displayed the highest springiness value of 1.16. There was no significant difference in the cohesiveness of the noodles. In the case of gumminess, Kunduru has shown the lowest value (271.53), while Gediz 75 (357.36), Gökala (347.74), and Kızıltan 91 (346.22) have shown higher values for gumminess. Chewiness varied between 396.21 and 264.70. The chewiness of the Kunduru sample was found to be the lowest. The resilience of the noodles varied only slightly. The noodle samples of the Ak Buğday variety had the lowest adhesiveness (g.s.) compared to the noodle samples of the Sert Buğday variety, which had the maximum adhesiveness. The cohesiveness, springiness, chewiness and adhesiveness results are by those reported by Kaur et al. (2015).

3.6. Cooking quality of noodles

Cooking quality is the primary characteristic consumers value greatly in durum wheat pasta and noodles. *Table 5* presents the OCT, CL, SV, and WA of noodles. Statistical differences were found between the OCT of noodles

($p<0.01$). When the OCT of the noodles obtained from durum wheat flours was analyzed, it was observed that Sert Buğday and Kunduru varieties had the lowest value (10.29 min). In comparison, Ak Buğday and Kızıltan 91 varieties had the highest values (12.49 min) and (12.47 min), respectively. These OCTs are higher than those reported (Kaur et al., 2015) for the noodles prepared from Indian durum wheat flour. The difference in the OCTs of LDW flour noodles can be attributed to genetic and environmental factors.

Table 5. OCT, CL, SW, and WA noodles[1]

Durum Wheat Varieties	OCT (Min)	CL (%)	SV (%)	WA (%)
Ak Buğday	12.49^{a}	8.12^{cd}	190.37^{bcd}	149.62^{def}
Ankara98	12.19^{b}	7.85^{d}	110.00^{e}	130.85^{g}
Burgaz	11.18^{d}	8.49^{bcd}	150.00^{d}	139.89^{fg}
Çeşit1252	11.24^{d}	8.76^{bcd}	218.50^{ab}	174.32^{b}
Durbel	11.87^{c}	8.32^{cd}	200.00^{bc}	150.65^{de}
Gediz75	11.45^{d}	9.60^{ab}	232.57^{ab}	184.02^{a}
Gökala	11.23^{d}	8.51^{bcd}	196.67^{bc}	160.70^{c}
Kızıltan91	12.47^{a}	8.57^{bcd}	170.00^{cd}	149.07^{ef}
Kunduru	10.87^{e}	9.21^{bc}	152.20^{d}	159.23^{cd}
Sert Buğday	10.29^{e}	10.39^{a}	259.20^{a}	189.01^{a}

[1]The differences between the values shown with the same letter in the same column are insignificant according to 0.01 confidence limit.

[2]: OCT: Optimum cooking time, [3]CL: Cooking loss, [4]SV: Swelling volume, [5]WA: Water absorption

The CL is widely recognized as a significant determinant of pasta quality, exerting a notable influence on consumer approval. The significant cooking loss indicated a limited cooking tolerance and excessive stickiness of noodles, which is generally undesirable in noodle production. The CL values exhibited a range of 7.85 to 10.39%. The Ankara 98 noodle had the lowest CL, whereas the Sert buğday noodle demonstrated the highest CL. The Turkish noodle standard (TS 12950, TSE, 2003) states that the quantity of substance that should be lost during cooking, also known as CL, should not exceed 10%. In light of this, all other types of noodles, except Sert Buğday noodles, are by the standard in terms of CL. It is desirable that the amount of substances that pass into the water in the noodles be low and that the noodles keep their shape without falling apart during cooking. Thus, it can be concluded that all types of noodles, except Sert Buğday, exhibit favorable qualities about this characteristic. However, lower CL 6.0 to 6.7% and 5.65 to 7.10% were reported by Abuhammad et al. (2012) and Evlice (2022), respectively, for durum wheat pasta. Meanwhile, Deng et al. (2017) reported similar CL results (ranging from 8.9 to 10.7%) for whole wheat spaghetti among the 36 durum genotypes. The observed disparity in CL can be attributed to variations in the quantity and quality of gluten in durum wheat varieties. A negative correlation exists between the firmness of the noodles and the quantity of substances released into the water during the cooking process (Petitot et al., 2010). The variations in nature, genotype, quantity, and quality of gluten proteins and the drying process could account for the disparities observed in our study.

A large volume increase in noodles while cooking is desirable. A low volume increase value means the noodles absorb little water during cooking, resulting in a complex product (Bhattacharya et al., 1999). Significant statistical differences were observed in the SV of the noodles ($p<0.01$). The SV values showed a range from 110% (Burgaz) to 259.20% (Sert Buğday). According to quality assurance laboratories of numerous noodle manufacturers, a high-quality noodle must absorb an adequate amount of water throughout the cooking process in order to achieve a minimum mass gain of 100% (Hatcher, 2010). Therefore, based on the fact that all of the studied noodles had a SV exceeding 100%, we can infer that it is feasible to manufacture high-quality noodles using all durum wheat varieties investigated in our study. Dirim and Koç (2019) found a considerably greater SV (267.50%) in comparison to our study. The variations in Turkish noodle formulas could be the cause of the discrepancies in the results. The presence of eggs in noodle production may affect the volume increase. By incorporating eggs into the noodle formulations examined in our study, it is potentially possible to produce noodles with an increased SV, mainly due to the fact that the addition of egg albumin protein enhances the cooking quality of noodles, ensuring a firm texture and reinforcing the network that retains the starch while cooking (Khouryieh et al., 2006).

Regarding the WA, the values varied between 130.85 and 189%. Simultaneously with the SV, the Sert Buğday and Gediz 75 noodles, which had the highest SV, showed more WA. Conversely, the Ankara 98, which had the lowest SV, revealed the lowest WA. WA is influenced by factors such as wheat's protein content and cooking time. Nevertheless, certain writers have reported water absorption levels comparable to or greater than the data we obtained. For instance, pasta samples prepared from 24 durum wheat genotypes (Evlice, 2022) showed values ranging from 197 to 274%, higher than ours. Differences in WA values can be attributed to variations in genotypes and disparities in the methods of noodle and pasta production and drying. WA, which refers to the percentage increase in weight during cooking, is a crucial factor for noodle manufacturers when selling noodles that are either parboiled or fresh. A noodle that can absorb a more significant amount of water during a specific cooking period while still retaining its desired textural qualities will be considered a more attractive and more profitable product (Hou et al., 1998). Based on this, we can conclude that Sert Buğday and Gediz 75 durum wheat flours, with their high WA and SV, offer good noodle quality and have significant potential for use in fresh noodles.

3.7. Sensory analysis of noodles

The findings obtained as a result of sensory evaluation of the noodle samples by the panelists are given in *Figure 1*.

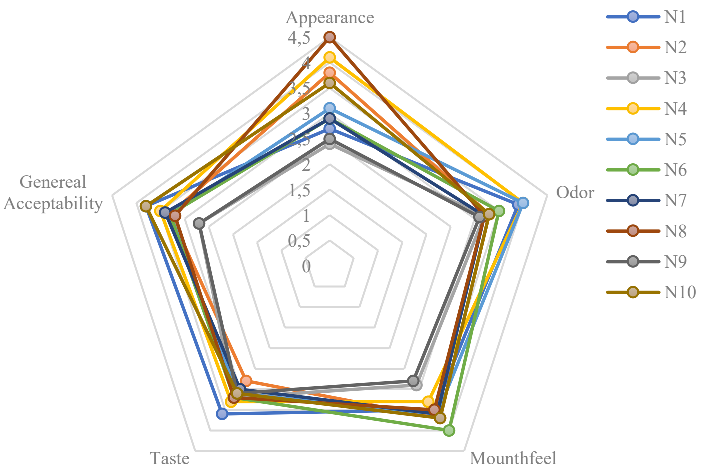

Figure 1. Sensory ratings for the noodles
N1: Ak Buğday, N2: Ankara98, N3: Burgaz, N4: Çeşit1252, N5: Durbel, N6:Gediz75, N7: Gökala, N8:Kızıltan91, N9: Kunduru, N10: Sert Buğday

Upon comparing the samples based on their appearance, it was found that the Burgaz variety had the lowest value of 2.40, followed by Kunduru with a value of 2.50. However, there was no significant statistical difference between the two. Conversely, the Kızıltan 91 variety had the greatest appearance value of 4.50. The low appearance values of the noodle samples made from the flours derived from Burgaz and Kunduru wheat varieties can be attributed to fragmentation, an undesirable outcome that occurs during the cooking process. The noodles made from Variety 1252, Durbel, and Ak Buğday flours were the most preferred in terms of odor. Durbel achieved the highest grade in mouthfeel, while Burgaz and Kunduru obtained low scores in this aspect. The kind of white wheat was the most favored in terms of taste. The Burgaz and Kunduru cultivars received low ratings in terms of overall acceptability. There was no significant disparity in the overall acceptability ratings of other variants.

According to TS 12950, noodles should have a unique taste, smell, and color before and after cooking. Additionally, they must be devoid of bitter, sour, moldy, or any foreign tastes. Furthermore, noodles should be free from visible foreign matter and odors and not be dirty or damaged (TSE, 2003). This led to the conclusion that except Kunduru and Burgaz, other tested varieties can produce noodles that meet TSE standards.

4. Conclusions

Durum wheat products have been experiencing increasing demand around the world. Noodles are one of these products. Wheat flour is the primary raw material for Turkish noodles (erişte). Therefore, it is important to study the suitability of locally grown Durum wheat varieties for noodle production to facilitate the growth of the noodle industry and enhance both domestic and international trade. Based on this, some physical, chemical, and technological qualities of local durum wheat varieties grown in the Lakes Region of Türkiye were revealed (results are not given within the scope of this study), and noodle quality was tested by making noodles.

Consequently, it was concluded that the flours derived from Sert Buğday and Gediz 75 wheat varieties exhibited favorable protein content, grain hardness, grain size, wet gluten, and gluten index values (specific results of these values were not provided in this study). Additionally, the noodles made from these flours demonstrated an excellent volume increase and water absorption values, offered good noodle quality, and had significant potential for use in Turkish noodle (erişte) production. However, further studies can be conducted to determine whether these varieties are suitable for using other durum wheat products, such as pasta.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Gül, H.; Design: Gül, H., Öztürk, A.; Data Collection or Processing: Gül, H., Öztürk, A.; Statistical Analyses: Gül, H., Öztürk, A.; Literature Search: Gül, H., Öztürk, A.; Writing, Review and Editing: Gül, H.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Trakya Bölgesi Doğal Florasından Toplanan Önemli Bazı Üçgül (*Trifolium* spp.) Türlerinin Verim Unsurları ve Kalite Özelliklerinin Belirlenmesi*

Determination Yield and Yield Components of Some Important Clover (*Trifolium* spp.) Species Collected from Thrace Region Flora

Emre İbrahim DUMAN[1], Adnan ORAK[2*]

Öz

Bu araştırmada Tekirdağ koşullarında Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü deneme ve uygulama arazisinde, 2020-2021 döneminde iki yıllık süre ile yürütülmüştür. Trakya Bölgesi Doğal Florasındaki Üçgül (*Trifolium* L.-Fabaceae) Türlerinin Taksonomisi, Dağılımı, Fenolojik, Morfolojik ve Bazı Kimyasal Özellikleri isimli TUBİTAK (119 O 950) projesi çerçevesinde yürütülen çalışmada toplanan farklı üçgül türleri materyal olarak kullanılmıştır. İlk yıl belirlenen bitki boyu, sap çapı, bitkide kömeç sayısı, bitki yeşil ot ve kuru ot verimleri değerlendirilerek belirlenen 6 farklı türe ait (*T. repens, T. nigrescens, T. constantinopolitanum, T. pratense, T. striatum ve T. lappaceum*) 32 farklı genotip materyal olarak kullanılmıştır. İkinci yıl tesadüf bloklarında faktöriyel deneme desenine göre, 3 m uzunluğundaki parsellere 75x75cm olarak her türden en az 5 bitki olacak şekilde, 8 bitki köklü olarak şaşırtılmıştır. Damla sulama sistemi ile dikim sonrası sulama yapılmıştır. Bitkilerin ihtiyaç duyduğu nisan-eylül ayları arasında 6 aylık dönemde sulamaya devam edilmiştir. Araştırmanın ilk yılında yapılan değerlendirmede en düşük ve en yüksek veriler bitki boyunda 9.00- 64.67 cm, sap çapında 0.47-2.57 mm, bitkide kömeç sayısı 6.33-67.67, bitki yeşil ot verimi 19.70-624.00 g, bitki kuru ot verimi 3.37-138.36 g olarak belirlenmiştir. Araştırmanın ikinci yılında tekerrürlü olarak şaşırtılan bitkilerin sınır değerleri; bitki boyunda 9.77-24.78 cm, sap çapında 0.50-1.82 mm, bitkide kömeç sayısında 12.40-145.17 adet, bitki yeşil ot veriminde 85.77-2006.50 g, kuru ot veriminde ise 39.90-555.56 g olarak belirlenmiştir. %50 çiçeklenme döneminde biçilen üçgül türlerine ait genotiplerde kimyasal analiz sonuçlarına göre; ham protein oranı %11.87-18.85, ham selüloz oranı %20.80-28.33, ham kül oranı %6.95-10.37, ADF %31.07-42.78, NDF %42.58-55.69 arasında değişim göstermiştir.

Anahtar Kelimeler: Ana sap uzunluğu, ADF, NDF, Ham selüloz, Kömeç sayısı, Protein oranı, *Trifolium* sp., Sap çapı

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*Bu çalışma Emre İbrahim DUMAN'ın Yüksek Lisans Tezinden özetlenmiştir.

Abstract

This research was conducted under Tekirdağ conditions in the trial and application field of Tekirdağ Namık Kemal University Faculty of Agriculture Field Crops Department for a two-year period in the 2020-2021 years. Different clover species collected were used as material in the study carried out within the framework of the TUBITAK (119 O 950) project titled Taxonomy, Distribution, Phenological, Morphological and Some Chemical Characteristics of Clover (*Trifolium* L.-Fabaceae) Species in the Natural Flora of the Thrace Region. Plant height, stem diameter, number of head per plant, fresh forage yield and hay yield per plant were evaluated in the first year for 6 different species (*T. repens, T. nigrescens, T. constantinopolitanum, T. pratense, T. striatum and T. lappaceum*). 32 different genotypes were used as material. In the second year, clover genotypes were planted according to the randomized block design with three replications to different parts of the trial area. At least five plants of each type, 8 plants with roots were transplanted on 04.08.2021 in 3 m long parcels prepared in factorial order, 75x75cm. Irrigation was done after planting with a drip irrigation system. Irrigation was continued during the 6-month period between April and September when the plants needed it. In the evaluation made in the first year of the research, the lowest and highest data were determined as 9.00-64.67 cm in plant height, 0.47-2.57 mm in stem diameter, number of flower structure per plant 6.33-67.67, fresh forage yield per plant 19.70-624.00 g, dry forage yield per plant 3.37 -138.36g. Clover genotypes were transplanted with three replications in the second year of the research, limit values of clover sp. characters were determined individually. The plant height was determined as 9.77-24.78 cm, the stem diameter was 0.50-1.82 mm, number of flower structure per plant was 12.40-145.17 units, fresh forage yield per plant was 85.77-2006.50 g, and dry forage yield per plant changed between was 39.90-555.56 g. According to the results of chemical analysis of genotypes of clover species harvested during the 50% flowering period; Crude protein ratio varied between 11.87-18.85%, crude cellulose ratio 20.80-28.33%, crude ash ratio 6.95-10.37%, ADF 31.07-42.78% and NDF was determined as 42.58-55.69%.

Keywords: ADF, NDF, Crude cellulose, Main stem length, Protein, Stem diameter, *Trifolium* sp., Number of head per plant

1. Giriş

Tarımda kullanılan yem bitkileri sınırlı sayıda olsa da yapılan inceleme ve araştırmalar birçok yem bitkisinde üstün özelliklere sahip türlerin ülkemizin farklı bölgelerinde doğal olarak bulunduğunu göstermiştir (Algan ve Bakar Büyükkartal, 1999). Hayvan beslemede kaliteli kaba yemin protein içeriğinin yüksek olması arzu edilir. Protein oranı yüksek olan baklagil yem bitkilerinde kurak dönemlerde kökün yüksek oranda olumsuz etkilendiği ve verim potansiyelinin azaldığı bilinmektedir (Beyaz, 2023). Kaba yem kaynağı olarak önemli yere sahip çayır mera alanlarında yer alan bazı yabani türler, doğası gereği hem erkenci olup hem de tohum olgunlaştırma döneminde yeşil aksamlarını koruyabilmektedirler. Mera alanlarının giderek azalması ile kaliteli kaba yem kaynağı olarak yem bitkilerinin önemi artmıştır.

Meralarda diğer türlerin gelişmesinden en az bir ay önce otlatma ve biçim zamanına gelen yabani türlerin özellikle klimaks bitki türlerini kaybetmiş bu tür meralarda kısa sürede yetiştirilmeleri zordur. Çünkü otlatma mevsimi içinde yoğun otlanan türler arasında yer almaktadır. Bu tip alanlarda öncelikle toprak özelliklerini iyileştiren, hızlı gelişen ve adaptasyon kabiliyeti yüksek tek yıllık bitkilerin yetiştirilmesi önemli fayda sağlayacaktır (Tükel ve ark., 1999). Yabani üçgül türleri hızlı gelişmeleri, adaptasyon kabiliyeti ve besin değerinin yüksek olması ile kısa süreli rotasyon meralarının tesisinde olduğu gibi mevcut meraların vejetasyonuna da önemli katkılar sağlayacak yapıya sahiptir. Üçgüller ılıman kuşağın nemli ve serin bölgelerinde doğal olarak yayılış göstermektedirler. Genellikle ince saplı ve bol yapraklı olarak bulunan üçgüller yüksek besleme değerine sahiptirler. Tek yıllık özelliğe sahip *T. constantinopolinatum, T. striatum, T. pallidum* ve *T. nigrescens* Trakya bölgesi doğal florasında yetişen yabani türler arasında bulunmaktadır. Ülkemizde tarımı yapılan *T. pratense* ve *T. repens* çok yıllık, *T. resupinatum* ve *T. alexandrinum*tek yıllık olan ve farklı özellikleri ile önem kazanan türlerdir.

Sulu koşullarda ve yağışlı bölgelerde iyi gelişen çayır üçgülü ABD, Kanada, Orta ve Batı Asya, Yeni Zelanda ve özellikle Avrupa'da yetiştirilmektedir. Genel olarak nemli ve serin iklime sahip bölgelerde güzel gelişmektedir. Trakya bölgesinin florası özellikle bitki ıslahı için gen merkezi konumundadır (Nizam ve ark., 2022). Önemli baklagil yem bitkileri arasında yer alan çayır üçgülü dik gelişmekte 59.0-61.30 cm boylanabilmektedir (Leto ve ark., 1998). Çayır üçgülü tek başına ekildiğinde 500-700 kg/da arasında kaliteli kuru ot verimi elde edilmektedir (Özyazıcı ve Manga, 1997). Tomurcuklanma döneminde yapılan biçimlerde %21-23, tam çiçeklenme döneminde yapılan biçimlerde ise %12-14 oranında ham protein içerir (Geren ve ark., 2009).

Ak üçgül (*Trifolium repens* L.), dünya genelinde geniş bir yayılış alanı gösteren, genellikle otlatma amacıyla kullanılan, besleyici değeri oldukça yüksek olan çok önemli bir baklagil yem bitkisidir. Yatık gelişmesi ve stolonlu yapıya sahip olması nedeniyle, otlatma ve çiğnenmeye karşı oldukça dayanıklı olan ak üçgül, yem bitkisi üretiminde vazgeçilemez bir yere sahiptir (Açıkgöz, 2001; Acar ve Ayan, 2012). Konu ile ilgili yapılan araştırmalarda ak üçgülün önemli düzeyde çeşitlilik gösterdiği ifade edilmiştir (Gustine ve ark., 2002; Zhang ve ark., 2010). Ak üçgül bitkisinin genetik olarak çeşitlilik göstermesi sonucu, çeşit geliştirme amaçlı ıslah çalışmalarında bu çeşitlilikten faydalanıldığı ve verim, kalite ve dayanıklılık düzeyinde başarılı sonuçlar alındığı belirtilmektedir (Zhang ve ark., 2010). Türlere bağlı olarak değişen ana sap uzunluğu çayır üçgülünde ortalama 20-50 cm, iken ak üçgülde 5-30 cm olarak saptanmıştır (Gençkan, 1983). Samsun'da yürütülen bir araştırmada ise ana sap uzunluğu çayır üçgülü ve ak üçgülde sırasıyla 70-85 ve 25-40 cm olarak belirlenmiştir (Başaran ve ark., 2006). Stolonlu ve yatık gelişme özelliğine sahip ak üçgül sürünücü tiptedir. Bitkide kömeç sayısının 10-15 adet olarak belirlendiği (Norris, 1987) ak üçgülde 2,5 mm çapa sahip olan sap (Prigge ve Gibson, 2007) 20cm'ye kadar uzamaktadır (Geren ve ark., 2009). Diğer önemli tür *Trifolium nigrescens* doğal olarak 60 cm boylanabilen dik veya yatık olarak gelişme göstermektedir. Ak üçgülün (*Trifolium repens* L.) kuru otundaki protein içeriği; tomurcuklanma dönemi için %22.4, ilk çiçeklenme döneminde %21.1, %30 çiçeklenme döneminde %18.7, %65 çiçeklenme döneminde %15.9 ve tam çiçeklenmede %14.9 olarak ölçülmüştür (Ahlgren, 1956). Samsun'da yapılan bir araştırmada ak üçgülde ham protein oranı %17.1 olarak tespit edilmiştir (Acar ve Önal Aşcı, 2006).

Yel üçgülü (*Trifolium nigrescens*) doğal olarak Avrupa'da yayılış gösterir. Gövde dik ya da yatık şekilde gelişir, 60 cm'ye kadar boylanabilir. Çiçekler pembe ila beyaz, zamanla kahverengi siyah renklidir. Sulak alanlar, tahrip edilmiş araziler ve çalılıklarda görülür. Mart-Ekim aylarında çiçeklenme görülür. 0-1600 metre arası yüksekliklerde görülebilir (Anonim, 2021). Biçilen taban meralarda, *Trifolium repens* ve *Trifolium nigrescens* gibi baklagil türlerinin yaygın olduğu belirlenmiştir (Şen, 2017).

T. striatum 50 cm boylanabilen tek yıllık, yoğun tüylü görünümde, yatık veya dik gelişen üçgül türü olarak belirlenmiştir. Üçkulak üçgülünün (*T. constantinopolinatum*) 15-35 cm boylandığı tek yıllık ve dik gelişme özelliğine sahip tür olduğu belirlenmiştir.

Tek ve çok yıllık özelliğe sahip farklı üçgül türlerinin özelliklerinin değerlendirilmesinde birbirlerinden farklı özelliklere sahip oldukları anlaşılmaktadır. Trakya bölgesi doğal florasında yabani üçgül türlerinin farklı özelliklerinin saptanması amacı ile yürütülen TÜBİTAK (119O950) projesi çerçevesinde toplanan üçgül genotiplerinin bir bölümü materyal olarak kullanılmıştır. Yüksek lisans çalışması olarak tezi olarak yürütülen bölümde beş farklı üçgül türüne ait genotiplerin ot verimi ve verim özelliklerinin belirlenmesi amaçlanmıştır.

2. Materyal ve Metot

Araştırmanın Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Tarla bitkileri Bölümü Deneme ve Uygulama Alanında 2 yıl süre yürütülmüştür. Araştırmanın yürütüldüğü deneme ve uygulama alanının önemli bazı iklim özellikleri *Tablo 1*'de, toprak özellikleri *Tablo 2*'de verilmiştir.

2.1. Araştırma yerinin iklim ve toprak özellikleri

Tablo 1. Deneme alanına ait iklim verileri

Table 1. Climatic data of the experimental area

	Ortalama Sıcaklık (°C)		Toplam Yağış (mm)		Nem (%)	
Aylar	**2020**	**Uzun Yıllar**	**2020**	**Uzun Yıllar**	**2020**	**Uzun Yıllar**
Eylül	23.1	20.7	13.7	44.1	66.9	74.1
Ekim	18.2	16.1	50.6	78.9	76.2	80.9
Kasım	11.6	11.5	1.1	60.9	84.7	82.9
Aralık	10.1	7.2	35.9	78.4	88.5	83.0
Aylar	**2021**	**Uzun Yıllar**	**2021**	**Uzun Yıllar**	**2021**	**Uzun Yıllar**
Ocak	7.8	5.2	123.5	58.6	85.7	83.3
Şubat	7.3	5.8	48.8	61.1	82.4	81.3
Mart	7.0	5.1	45.2	52.2	83.4	80.4
Nisan	10.7	12.0	49.0	41.4	82.1	78.2
Mayıs	10.5	17.1	57.6	38.4	73.2	76.7
Haziran	20.8	21.7	53.3	39.4	81.8	73.8
Temmuz	25.8	24.4	3.4	27.4	69.6	70.1
Ağustos	25.7	24.8	23.4	16.4	69.5	70.7
Eylül	20.6	20.7	5.3	44.1	69.1	74.1
Ekim	15.3	16.1	11.0	78.9	76.9	80.9
Kasım	12.6	11.5	50.2	60.9	76.8	82.9
Aralık	9.0	7.2	60.2	78.4	76.2	83.0
Aylar	**2022**	**Uzun Yıllar**	**2022**	**Uzun Yıllar**	**2022**	**Uzun Yıllar**
Ocak	5.4	5.2	23.3	58.6	74.0	83.3
Şubat	6.5	5.8	63.8	61.1	79.3	81.3
Mart	5.2	5.1	9.5	52.2	71.5	80.4
Nisan	12.7	12.0	70.6	41.4	74.3	78.2
Mayıs	16.9	17.1	15.7	38.4	75.2	76.7
Haziran	22.5	21.7	32.5	39.4	74.5	73.8
Temmuz	24.3	24.4	1.5	27.4	68.8	70.1
Ağustos	25.6	24.8	36.2	16.4	74.5	70.7
Eylül	21.5	20.7	8.1	44.1	67.9	74.1
Ortalama		**14.6**		**-**		**78.0**
Toplam		**-**		**597.2**		**-**

*(Anonim, 2020, 2021, 2022), (*1949–2022" arasını kapsamaktadır)

Araştırmanın yürütüldüğü deneme alanı toprağı, killi tınlı yapıda organik madde içeriği %1.5 dolayındadır.

Tablo 2. Deneme alanına ait toprak bazı özellikleri

Table 2. Some soil properties of the experimental area

Parametre	Birim	2018-2019	2019-2020
pH		7.55	7.08
Tuz	%	0.02	0.02
Kireç	%	0.63	0.60
Organic Madde	%	1.63	1.30
Toplam Azot (N)	%	0.11	0.07
Fosfot (P)	ppm	8.40	10.70
Potasyum (KO)	ppm	290.73	154.50
Kalsiyum (Ca)	ppm	3571.40	3653.00
Magnezyum Mg)	ppm	116.48	489.10
Demir (Fe)	ppm	7.00	22.30
Bakır (Cu)	ppm	1.60	1.83
Çinko (Zn)	ppm	0.90	1.00
Mangan (Mn)	ppm	19.58	74.37

*(Anonim, 2020,2021)

2.2 Materyal

Bu araştırmada "Trakya Bölgesi Doğal Florasındaki Üçgül Türlerinin Taksonomisi, Dağılımı, Fenolojik, Morfolojik ve Bazı Kimyasal Özellikleri" isimli 119O950 numaralı TÜBİTAK projesinin ilk yılında (2020) toplanan ve verim potansiyeli yüksek olan türler arasında yer alan 32 farklı üçgül genotipi materyal olarak seçilmiştir. Üçgül genotiplerinin türü, toplandığı yer ve koordinatları *Tablo 3*'te verilmiştir.

2.3 Metot

Araştırmanın ilk yılında (2020) nisan-temmuz döneminde 4 ay süre ile yabani üçgül türlerine ait tohumlar toplanmış, 18 Ekim 2020'de sıra arası 5 m uzunluğundaki iki sıraya 75 cm sıra üzeri, 75 cm sıra arası mesafe ile ekilmiştir. Yabani üçgül türlerinden verim ve verim özellikleri (Ana sap uzunluğu, sap çapı, bitki kömeç sayısı, bitki başına yeşil ve kuru ot verimleri) basit istatistiki analiz sonuçları dikkate alınarak belirlenen 37 farklı genotip belirlenmiştir.

Araştırmanın ikinci yılındaki çalışma (2021) tesadüf blokları deneme desenine göre 3 tekerrürlü olarak yürütülmüştür (Düzgüneş ve ark., 1987). Her parsel 3 m uzunluğunda olup, sıra arası ve üzeri 75 cm olarak, her genotipten 8 bitki olacak şekilde köklü olarak 04.08.2021 tarihinde dikim yapılmıştır. Bitki gelişimleri 15 gün süre izlenmiş, kuruyan örneklerin yerine normal gelişen bitkiler dikilerek sayıları tamamlanmıştır. 2021-2022 döneminde 1 yıl süre ile ana sap uzunluğu, sap çapı, bitkide kömeç sayısı, bitki başına yeşil ve kuru ot verimleri belirlenmiştir.

Damla sulama sisteminin kurulduğu parsellerde dikimden sonra sulama yapılmış ve bitkinin ihtiyaç duyduğu nisan-eylül ayları arasında kurak geçen altı aylık periyotta sulamaya devam edilmiştir. Sulama, zaman ayarlı sistemle 20'şer dakikalık sürelerde geceleri yapılmıştır. Elde edilen sonuçlara ait varyans analizleri MSTAT programı ile yapılmış, genotipler arasındaki farklar ile interaksiyonların önemliliği test edilmiştir. Asgari önemli fark (LSD %5) ile hat ve konu ortalamaları karşılaştırılarak gruplandırılmıştır.

3. Araştırma Sonuçları ve Tartışma

3.1. Üçgül genotiplerinin verim ve verim unsurları

119O950 numaralı TÜBİTAK projesinin ilk yılında (2020) toplanan ve verim potansiyeli yüksek olan türler arasında yer alan 32 farklı üçgül genotipine ait ana sap uzunluğu, sap çapı, bitkide kömeç sayısı, bitki yeşil ot ve bitki kuru ot verimine ilişkin veriler ve basit istatistiki sonuçları *Tablo 4*'te verilmiştir.

Tablo 4'ten de görüleceği üzere; En yüksek bitki boyu 64.67 cm ile 102/T-2 nolu üç kulak (*T. constantinopolinatum*) türünde belirlenmiştir. En kısa ana sap uzunluğu ise 140/T-2 nolu ak üçgül genotipinde 9.00 cm olarak belirlenmiştir. Varyans (204.96) ve CV değerinin (62,66) yüksek olması, genotipler arasında belirgin fark olduğunu göstermektedir (*Tablo 4*). Bulgularımız ana sap uzunluğunun çayır üçgülü, ak üçgül, yel üçgülü (*T. nigrescens* Viv.), üçkulak otu (*T. constantinopolinatum*), *T. striatum* ve koza üçgülünde (*T. lappaceum*) sırasıyla 70-85, 25-40 (Başaran ve ark., 2006) ve 0-60 (Anonim, 2021), 15-35, 50 ve 15.33-70.67 cm olduğunu bildiren araştırıcıların sonuçları ile kısmen uygun bulunmuştur. Bizim bulgularımızda çayır üçgülü ve *T. striatum*'da kısa, *T. constantinapolitanum*'da ise uzun ana sap uzunluğu ekotip ve bölgesel farklılıktan kaynaklanmıştır.

Tablo 3. Üçgül genotiplerinin türü, toplandığı yer ve koordinatları (2020)

Table 3. Type, collection location and coordinates of clover genotypes (2020)

	Genotip	Türü	Lokasyon	Yükseklik	Enlem	Boylam
1	20 H 42	*T.repens*	Kırklareli - Demirköy	560	41°46'39.37"	27°42'5.89"
2	20 H 45	*T.nigrescens* Viv.	Kırklareli - Demirköy	560	41°46'39.37"	27°42'5.89"
3	101/T-2	*T.repens*	İstanbul - Çatalca	154	41°22'1.48"	28°17'28.40"
4	101/T-4	*T.repens*	İstanbul - Çatalca	154	41°22'1.48"	28°17'28.40"
5	102/T-2	*T. constantinapolitanum*	İstanbul - Çatalca	41	41°22'51.70"	28°18'59.60"
6	11/T-1	*T. pratense*	Tekirdağ - Süleymanpaşa	330	40°49'32.59"	27°25'5.03"
7	111/T-3	*T.repens*	İstanbul - Silivri	208	41°13'36.65"	28°16'28.13"
8	113/T-2	*T. Striatum*	İstanbul - Çatalca	164	41°17'12.60"	28°28'18.26"
9	115/T-1	*T.repens*	İstanbul - Çatalca	35	41°21'18.44"	28°27'5.60"
10	128/T-1	*T.repens*	Kırklareli - Babaeski	67	41°26'38.91"	27°10'12.40"
11	13-1	*T.repens*	Tekirdağ - Şarköy	335	40°43'44.07"	27° 5'42.05"
12	138/T-4	*T.repens*	Kırklareli - Demirköy	103	41°54'50.42"	28° 0'29.59"
13	140/T-2	*T.repens*	Kırklareli - Demirköy	1	41°57'57.66"	28° 2'2.70"
14	143/T-4	*T.nigrescens* Viv.	Kırklareli - Pınarhisar	571	41°46'39.95"	27°42'3.01"
15	143/T-7	*T.repens*	Kırklareli - Pınarhisar	571	41°46'39.95"	27°42'3.01"
16	146/T-2	*T.repens*	Tekirdağ - Hayrabolu	47	41°15'17.29"	27°13'14.58"
17	148/T-1	*T.repens*	Tekirdağ - Hayrabolu	62	41°17'26.76"	27° 9'59.93"
18	148/T-6	*T.repens*	Tekirdağ - Hayrabolu	62	41°17'26.76"	27° 9'59.93"
19	149/T-1	*T.repens*	Tekirdağ - Muratlı	109	41°10'8.46"	27°20'55.58"
20	156/T-1	*T.nigrescens* Viv.	Edirne - Keşan	153	40°39'54.61"	26°27'56.61"
21	20 F 15	*T.repens*	Kırklareli - Babaeski	28	41°21'53.95"	26°53'53.36"
22	20 C 37	*T.repens*	Tekirdağ - Saray	280	41°31'5.53"	28° 1'23.22"
23	20 D 25	*T.repens*	Kırklareli - Merkez	442	41°58'44.38"	27°14'29.69"
24	20 D 78	*T.nigrescens* Viv.	Kırklareli - Merkez	487	41°54'8.19"	27° 8'18.52"
25	20 F 11	*T.nigrescens* Viv.	Kırklareli - Babaeski	28	41°21'53.95"	26°53'53.36"
26	20 G 06	*T.repens*	Kırklareli - Merkez	367	41°55'7.32"	27°32'2.85"
27	20 H 05	*T.pratense*	Kırklareli - Demirköy	3	41°53'12.10"	27°59'43.21"
28	20 H 15	*T.repens*	Kırklareli - Demirköy	2	41°49'22.92"	27°58'58.35"
29	20 H 25	*T.lappaceum*	Kırklareli - Demirköy	2	41°51'5.84"	27°58'37.15"
30	45/T-7	*T.repens*	Tekirdağ - Malkara	104	40°56'47.00"	26°59'43.09"
31	76/T-1	*T.repens*	Tekirdağ - Malkara	457	40°45'15.23"	26°57'30.40"
32	94/T-3	*T.repens*	Tekirdağ - Saray	135	41°21'55.59"	27°55'45.50"

Sap çapına ait varyans ve CV değerleri yüksek bulunmuştur. Elde edilen verilere göre; en kalın ve en ince sap çapı; sırası ile 2.57 ve 0.47 mm ile 148/T-1 ve 13.1 nolu ak üçgül (*T. repens*) genotiplerinde belirlenmiştir (*Tablo 4*). Bulgularımız, ak üçgülde sap çapının 1.4-3.79 mm (Rosso ve Pagano, 2001), yel üçgülünde (*T.nigrescens* Viv.) ortalama 2.7 mm (Williams ve ark., 2001) olduğunu bildiren kaynaklar ile uygunluk göstermektedir.

Bitkide en az kömeç sayısının (6.33 adet) *T. striatum* (113/T-2)'da en fazla kömecin ise (67.67 adet) *T. repens* (101/T-4) genotipinde olduğu belirlenmiştir. Varyans (120.84) ve CV değerinin (62.48) yüksek olması, genotipler arasında belirgin fark olduğunu göstermektedir (*Tablo 4*).

Bitki başına yeşil ot veriminin en az (19.70 g) yel üçgülü (*T. nigrescens* Viv.) 20F11 nolu genotipte, en yüksek (624.00 g) ise üçkulak otuna (*T. constantinopolinatum*) ait 102/T-2 nolu genotipte olduğu belirlenmiştir. Yeşil ot verimine ait varyans (20894.12) ve CV (107.19) değerleri yüksek bulunmuştur (*Tablo 4*). Elde edilen verilere göre; yeşil ot verimleri arasındaki farkın yüksek olması, tür farkından kaynaklamaktadır.

Tablo 4. Üçgül genotiplerinin verim ve verim unsurları ve istatistiki değerlendirilmeleri (2020)

Table 4. Yield and yield components and statistical evaluations of clover genotypes (2020)

Tür	Genotip	ASU (cm)	SÇ (mm)	BKS (adet)	BYOV (g/bitki)	BKOV (g/bitki)
T.repens	20 H 42	25.33	1.85	21.33	121.00	26.86
T.nigrescens Viv.	20 H 45	21.00	1.76	23.67	575.00	122.88
T.repens	101/T-2	15.67	1.40	29.67	165.00	39.76
T.repens	101/T-4	15.67	0.96	67.67	368.00	73.88
T. constantinapolitanum	102/T-2	64.67	1.95	19.67	624.00	138.76
T. pratense	11/T-1	15.33	1.69	12.00	97.00	24.06
T.repens	111/T-3	14.00	0.90	18.67	94.00	20.68
T. striatum	113/T-2	11.67	1.27	6.33	30.00	7.26
T.repens	115/T-1	41.33	1.44	11.33	122.65	26.47
T.repens	128/T-1	19.17	1.21	11.67	98.90	23.69
T.repens	13-1	9.33	0.47	11.67	63.80	49.01
T.repens	138/T-4	15.33	1.25	12.00	96.30	22.91
T.repens	140/T-2	9.00	1.05	26.33	104.44	27.05
T.nigrescens Viv.	143/T-4	14.00	2.15	22.66	171.94	18.53
T.repens	143/T-7	10.67	0.92	22.33	38.00	3.37
T.repens	146/T-2	47.83	2.40	13.67	128.00	26.22
T.repens	148/T-1	52.33	2.57	7.00	313.00	72.85
T.repens	148/T-6	16.00	1.38	9.33	64.72	12.16
T.repens	149/T-1	19.83	1.41	7.00	33.00	7.38
T.nigrescens Viv.	156/T-1	18.33	2.32	11.67	210.00	43.49
T.repens	20 F 15	19.00	1.14	9.67	110.90	9.67
T.repens	20 C 37	11.67	1.29	18.00	55.45	18.02
T.repens	20 D 25	46.00	1.61	18.00	59.60	13.60
T.nigrescens Viv.	20 D 78	39.67	1.09	21.00	20.00	5.86
T.nigrescens Viv.	20 F 11	34.00	1.19	17.00	19.70	5.32
T.repens	20 G 06	16.67	1.14	11.67	80.20	18.58
T.pratense	20 H 05	24.33	2.40	11.67	74.85	16.81
T.repens	20 H 15	18.00	1.08	18.33	48.84	10.95
T.lappaceum	20 H 25	32.00	1.72	17.00	57.00	11.91
T.repens	45/T-7	11.33	1.04	23.33	65.38	14.71
T.repens	76/T-1	9.33	1.18	22.33	160.71	32.15
T.repens	94/T-3	12.66	0.80	9.33	44.00	10.18
Ortalama		22.88	1.44	17.59	134.86	29.84
Minimum		9.00	0.47	6.33	19.70	3.37
Maksimum		64.67	2.57	67.67	624.00	138.36
Sx (standart sapma)		14.32	0.51	10.99	144.55	31.59
Standart hata ort.		2.23	0.091	1.94	25.55	5.59
Varyans		204.96	0.27	120.84	20894.12	998.18
CV		62.66	35.59	62.48	107.19	105.86

Bitki başına kuru ot veriminin en az 3.37 g ile ak üçgülün (*T. repens*) 143/T-7 nolu genotipinde, en yüksek verimin ise 624.00 g ile yine üçkulak otuna (*T. constantinopolinatum*) ait 102/T-2 nolu genotipte olduğu belirlenmiştir (*Tablo 4*). Otuz iki farklı üçgül genotipinde kuru ot verimine ait varyans (998.18) ile CV (105.86) değerleri yüksek bulunmuştur. Gelişme ve morfolojik özellikleri farklı türlerin kuru ot verimlerinin farklı olması doğaldır. *Tablo 4*'te görüleceği üzere bitki başına yeşil ve kuru ot veriminde sıralama yapıldığında ilk sırada tek yıllık üçkulak otu (*T. constantinopolinatum*), ikinci sırada yine tek yıllık özelliğe sahip yel üçgülü (*T. nigrescens* Viv.) ve üçüncü sırada ise ak üçgül (*T. repens*) yer almıştır. Trakya bölgesinde 2020 yılında doğal floradan toplanan ve tohum olarak ekilen türler arasında tek yıllık üçgüllerin hızlı gelişme özellikleri nedeni ile çok yıllıklardan daha yüksek ot verimine sahip olması doğaldır.

Projenin ikinci yılında (2021) tesadüf blokları deneme desenine göre 3 tekerrürlü olarak (Düzgüneş ve ark., 1987) yürütülen bölümünde üçgül genotiplerinin verim ve verim unsurları ve önemlilik grupları *Tablo 5*'te verilmiştir.

Tablo 5. Üçgül genotiplerinin verim ve verim unsurları ve önemlilik grupları (2021)

Table 5. Yield and yield components and significance groups of clover genotypes (2021)

Tür	Genotip	ASU(cm)	SÇ	BKS	BYOV	BKOV
T.repens	20 H 42	24.06ab	1.72ab	19.14p	245.62p	81.23k
T.nigrescens Viv.	20 H 45	20.48cd	1.37d	66.25hi	382.00op	130.77ı
T.repens	101/T-2	14.04i-l	1.09f	65.50i	834.33hi	257.03h
T.repens	101/T-4	12.78jk	0.93k	117.58b	1167.66c	375.43d
T. constantinapolitanum	102/T-2	13.74i-k	0.97h-k	82.87e	957.80ef	330.93ef
T. pratense	11/T-1	19.02de	1.48 cd	13.50pr	101.00rs	39.90r
T.repens	111/T-3	13.73i-m	0.93h	88.73e	1179.13c	370.76d
T. striatum	113/T-2	17.30ef	0.82j-m	10.00rs	664.00klm	177.47j
T.repens	115/T-1	11.75h-o	0.88j-m	77.00i	1091.83d	413.21c
T.repens	128/T-1	14.07qj	1.22e	71.61g	1002.66e	333.93e
T.repens	13-1	16.92fg	0.50o	53.00k	918.00fg	314.31f
T.repens	138/T-4	12.83qj	1.09f	119.43b	1201.69bc	438.80b
T.repens	140/T-2	12.15i-m	1.00f-i	51.43e-k	449.83k-o	162.46jk
T.nigrescens Viv.	143/T-4	23.03b	1.82a	17.31op	85.77rs	36.07n
T.repens	143/T-7	24.78a	1.65bc	25.42o	266.66p	104.05mn
T.repens	146/T-2	16.09fg	1.05fg	73.13l-q	687.00kl	246.54h
T.repens	148/T-1	15.26fgh	1.07fg	145.17a	2006.50a	555.56a
T.repens	148/T-6	15.15f-i	1.06fg	40.50h	341.00op	119.36lm
T.repens	149/T-1	13.40h-o	0.97h-k	48.23klm	680.05k-ı	203.88ı
T.nigrescens Viv.	156/T-1	12.48k-o	0.81 j-m	110.33c	395.50op	137.95l
T.repens	20 F 15	11.99l-o	0.78l-h	59.69j	786.74ij	256.32h
T.repens	20 C 37	10.96k-p	0.90i-k	59.50j	695.00kl	209.64ı
T.repens	20 D 25	11.62lo	0.94h-k	70.54gh	627.00lm	208.94ı
T.nigrescens Viv.	20 D 78	14.08qj	0.74 k	40.25k	492.00k	157.14k
T.nigrescens Viv.	20 F 11	13.84i-j	0.88i-k	83.75e	1021.33e	327.28ef
T.repens	20 G 06	11.77k-o	0.91i-k	47.13lm	516.50k	171.85jk
T.pratense	20 H 05	21.90bc	1.54c	12.40qrs	134.89s	39.65p
T.repens	20 H 15	11.87 k-o	0.93p	48.75klm	726.52jk	250.08h
T.lappaceum	20 H 25	11.40k-o	0.97f-j	84.00e	364.00p	124.30l
T.repens	45/T-7	9.77op	1.00f-i	45.50m	664.81kl	203.86ı
T.repens	76/T-1	11.20mno	0.93ijk	64.58l	819.00hi	221.20ı
T.repens	94/T-3	14.38 f-i	1.02fgh	107.70c	1256.81b	403.25c
LSD%5		14.95	1.11	63.12	711.33	231.35

**Aynı harfle gösterilen ortalama değerler arasında istatistiki olarak fark yoktur.*

Araştırmanın ikinci yılında tesadüf blokları deneme desenine göre 3 tekerrürlü olarak ekilen ve değerlendirilen bölümde ana sap uzunluğu bakımından genotipler arasındaki farkın istatistiki olarak önemli olması nedeni ile yapılan değerlendirmede (*Tablo 5*); ana sap uzunluğunda en fazla boylanmanın 24.70 cm ile (*T. repens*) ak üçgül genotipinde (143/T-7), en az boylanmanın ise 9.77 cm ile 45/T-7 nolu (*T. repens*) ak üçgül genotipinde olduğu belirlenmiştir. Ak üçgül (*T. repens*)'ün ana sap uzunluğuna ait bulgularımız ana sap uzunluğunun 20 cm'ye kadar uzadığını bildiren araştırıcıların (Geren ve ark., 2009) sonuçları ile uygunluk göstermektedir.

Çayır üçgülünde ana sap uzunluğuna ilişkin sonuçlarımız aynı türde yaptığı çalışmada ortalama bitki boyunun 20-50 cm olduğunu bildiren Gençkan (1983)'ın sonuçları ile uyumlu bulunmuştur.

Genotiplerin sap çapları arasındaki farklılık istatistiki olarak önemli bulunmuş, en yüksek sap çapı 1,82 mm ile 143/T-4 nolu *T.nigrescens* ssp. *nigrescens* genotipinde, en düşük sap çapının ise 0.50 mm ile 13/1 no'lu *T.repens* türüne ait genotipte olduğu belirlenmiştir. Bulgularımız, Arjantin'de doğadan topladıkları ak üçgül genotiplerinde sap çapı değerlerinin 1.4-3.79 mm olduğunu bildiren Rosso ve Pagano (2001) ile yel üçgülünde (*T.nigrescens* Viv) ortalama 2.7 mm olduğunu bildiren Williams ve ark. (2001) sonuçları ile uygunluk göstermektedir.

Genotiplerin kömeç sayıları arasındaki farklılık istatistiki olarak önemli bulunmuş, en yüksek kömeç sayısı 145,17 adet ile *T. repens* türüne ait 148/T-1 nolu genotipte, en düşük kömeç sayısı ise 10.00 adet ile *T.striatum* türüne ait 113/T-2 nolu genotipte belirlenmiştir. Bulgularımız ak üçgülde kömeç sayısının 10-15 adet arasında değiştiğini bildiren Norris (1987)'in sonuçlarından yüksek bulunmuştur. Farklılığın bölge, iklim ve genotip özelliklerinden kaynaklandığı söylenebilir.

Yeşil ot verimleri arasındaki farklılık da istatistiki olarak önemli bulunmuş, en yüksek yeşil ot verimi 2006.50 g ile *T. repens* türüne ait 148/T-1 nolu genotipte ölçülmüş olup, en düşük yeşil ot verimi ise 85.77 g ile 143/T-4 nolu *T. nigrescens* ssp. *nigrescens* genotipinde saptanmıştır.

En yüksek kuru ot verimi 555.56 g ile *T.repens* türüne ait 148/T-1 nolu genotipte, en düşük kuru ot verimi ise 36.07 g ile *T.nigrescens* Viv. genotipinde türüne ait 143/T-7 nolu genotipte belirlenmiştir.

Araştırmanın ikinci yılında elde edilen veriler doğrultusunda ana sap uzunluğu, bitkide kömeç sayısı, bitki başına yeşil ve kuru ot verimlerinde aküçgül genotipleri en yüksek değerleri alırken, sap çapında en yüksek değer tek yıllık yel üçgülünde (*T. nigrescens* Viv.) belirlenmiştir.

3.2 Kalite analizleri

Kuru ot verimi için hazırlanan bitkilerden alınan kuru ot örnekleri 1 mm' lik elekten geçecek şekilde öğütülerek analize hazırlanmıştır. Üçgül genotiplerinin ot kalitesine ilişkin sonuçları ve değerlendirmeleri *Tablo 6*'da verilmiştir.

3.2.1 Ham protein oranı

Vejetatif dönemde bulunan bitkinin ham protein içeriği olgunlaşmış ve büyümesini tamamlamış bitkilerden daha yüksektir. Bitki olgunlaştıkça yaprakların sap kısmına olan oranını azaltmakta ve olgunlaşmayla birlikte ham protein içeriği de azalmaktadır (Buxton, 1996). Farklı üçgül türlerinin %50 çiçeklenme döneminde biçilmiş üçgül genotiplerinin ham protein oranı, ortalama %17.66 olarak saptanmıştır. En düşük protein oranı %11.87 olarak yel üçgülü (*T. nigrescens* Viv.) türüne ait 143/T-4 nolu genotipte, en yüksek ise %18,85 ile ak üçgül (*T. repens*) türüne ait 20C37 nolu genotipte saptanmıştır. Elde edilen verilerin varyansının 2.52, CV değerinin ise 9.53 olması, ham protein oranı bakımından farklı türlere ait genotipler arasında önemli farklar olduğunu göstermektedir. Konuya ilişkin sonuçlarımız ak üçgülde ham protein içeriğinin %17.1 olduğunu bildiren Acar ve Önal Aşçı (2006)'nın bulguları ile benzer bulunmuştur.

3.2.2 Ham selüloz oranı

Bitkisel kaynaklı yemlerin iskeletini oluşturan bu madde grubu, geviş getirenlerin dışındaki hayvanlar için güç sindirilebilen hatta hiç sindirilemeyen, dolayısıyla sadece sindirim sistemini doldurup fiziksel tokluk oluşturarak onun normal çalışmasına katkıda bulunan lignin, selüloz ve hem selülozdan oluşmaktadır. Yabani özelliğe sahip farklı üçgül türlerine ait ot örneklerinin ham selüloz oranları arasında önemli farkların olduğu; en düşük selüloz oranı %20.80 olarak 149/T-1 nolu ak üçgül genotipinde, en yüksek ise %28.33 ile 146/T-2 nolu genotipte saptanmıştır. Elde edilen verilerin varyansının 3.06, CV değerinin ise 7.20 olması, ham selüloz oranı bakımından farklı türlere ait genotipler arasında önemli farklar olduğunu göstermektedir.

Tablo 6. Üçgül genotiplerinin kimyasal analiz sonuçlarına ilişkin değerler ve temel istatistiki analiz sonuçları (2021)

Table 6. Values and basic statistical analysis results of chemical analysis results of clover genotypes (2021)

Tür	Analizler					
	Genotip	**HP**	**HS**	**HK**	**ADF**	**NDF**
T.repens	20 H 42	16.31	24.66	10.37	33.98	48.71
T.nigrescens Viv.	20 H 45	16.09	27.07	9.63	34.42	49.34
T.repens	101/T-2	17.44	24.19	9.23	32.48	45.92
T.repens	101/T-4	17.55	23.82	8.17	31.07	43.27
T. constantinapolitanum	102/T-2	16.01	22.32	8.30	35.43	46.62
T. pratense	11/T-1	17.52	22.82	9.23	31.81	46.58
T.repens	111/T-3	17.98	24.45	7.32	35.82	45.78
T. striatum	113/T-2	14.25	23.98	7.99	38.03	48.59
T.repens	115/T-1	17.84	23.01	7.91	33.38	44.14
T.repens	128/T-1	17.67	23.47	9.00	34.9	47.34
T.repens	13-1	18.33	24.98	8.21	33.83	43.09
T.repens	138/T-4	17.31	24.86	8.12	34.6	45.48
T.repens	140/T-2	18.6	22.84	8.71	34.04	44.38
T.nigrescens Viv.	143/T-4	11.87	26.56	8.30	42.78	55.69
T.repens	143/T-7	16.86	25.32	7.94	36.04	46.91
T.repens	146/T-2	14.87	28.33	8.57	35.72	49.27
T.repens	148/T-1	17.29	23.99	8.34	34.45	46.84
T.repens	148/T-6	15.25	22.75	7.62	35.01	49.67
T.repens	149/T-1	16.08	20.80	8.45	34.76	47.87
T.nigrescens Viv.	156/T-1	16.77	24.07	8.52	36.93	46.32
T.repens	20 F 15	18.21	22.55	8.78	34.87	44.13
T.repens	20 C 37	18.85	25.05	7.67	35.24	46.99
T.repens	20 D 25	13.61	27.00	8.95	38.56	53.32
T.nigrescens Viv.	20 D 78	15.93	21.51	7.77	36.58	45.71
T.nigrescens Viv.	20 F 11	18.42	26.79	8.39	31.6	43.06
T.repens	20 G 06	16.07	23.92	8.18	36.54	48.63
T.pratense	20 H 05	15.28	26.71	8.45	38.29	53.65
T.repens	20 H 15	14.76	23.82	6.95	35.86	50.11
T.lappaceum	20 H 25	17.46	22.98	7.78	34.63	45.77
T.repens	45/T-7	18.06	22.35	7.04	31.86	42.58
T.repens	76/T-1	17.17	24.87	8.21	35.97	48.01
T.repens	94/T-3	17.26	25.33	8.28	35.23	46.43
	Ortalama	16.66	24.28	8.33	35.10	47.15
	Minimum	11.87	20.80	6.95	31.07	42.58
	Maximum	18.85	28.33	10.37	42.78	55.69
	Sx	0.280	0.31	0.13	0.41	0.54
	Varyans	2.52	3.06	0.51	5.50	9.37
	CV	9.53	7.20	8.54	6.68	6.49

3.2.3 Ham kül oranı

Ham kül oranı bitkilerin makro ve mikro besin elementi içeriklerinin bir göstergesidir. Mineral maddeler bitkiler için hayati derecede öneme sahiptir. Baklagillerin buğdaygillere kıyasla daha fazla mineral madde içeriğine sahip olduğu bilinmektedir. Doğal floradan toplanan farklı üçgül türlerine ait ot örneklerinin ham kül oranları arasında önemli farkların olduğu; en düşük ham kül oranı %6.95 olarak *T. repens* türüne ait 20 H15 nolu genotipte, en yüksek ise %10.37 ile yine ak üçgülde 20H42 nolu genotipte saptanmıştır. Elde edilen verilerin varyansının 0.51, CV değerinin ise 8.54 olması, ham kül oranı bakımından farklı türlerin birbirine yakın değerlere sahip olduğunu göstermektedir. Bulgularımız ak üçgülde ham kül oranını %13.74 olduğunu bildiren Başaran ve ark. (2006) sonuçlarından düşük bulunmuştur. Farklılığın genotip ve bölgesel farklılıktan kaynaklandığını söylenebilir.

3.2.4 ADF oranı

Bitkilerdeki ADF oranı, selüloz ve ligninin oranını göstermektedir. %50 çiçeklenme döneminde biçilen 32 farklı üçgül türünden elde edilen ot örneklerinin ADF oranı, ortalama %35.10 olarak saptanmıştır. Rohweder ve ark. (1978) bildirişlerine göre; elde edilen %35.26 ADF değerinin 1. kalite değerine sahip ot üretildiğini göstermiştir. En kaliteli otun %31.07 ADF oranına sahip 101/T-4 nolu genotipten elde edildiği belirlenmiştir. ADF oranın yükselmesi ile %42.78 oranına sahip olan 143/T-4 nolu yel üçgülü genotipinden, 3. kalitede ot elde edildiği saptanmıştır. Elde edilen verilerin varyansının 5.50, CV değerinin ise 6.68 olması, genotipler arasında farkların olduğunu göstermiştir.

3.2.5 NDF oranı

NDF bitkide hücrenin çeper maddeleri olan selüloz, hemiselüloz ve ligninden meydana gelmektedir. Baklagiller, buğdaygillere oranla daha az hücre çeperine sahiptirler, bu nedenle sindirilebilirlikleri daha yüksektir (Wilson ve Bowman, 1993). En kaliteli otun %42.58 NDF oranına sahip 45/T-7 nolu genotipten elde edildiği belirlenmiştir. NDF oranın yükselmesi ile %55.69 oranına sahip olan 143/T-4 nolu genotipten 4. kalitede ot elde edildiği saptanmıştır. Elde edilen verilerin varyansının 9.37, CV değerinin ise 6.49 olması, NDF oranı bakımından genotipler arasında farkın olduğunu göstermektedir.

3.3. Üçgül türlerine ait genotiplerin verim ve verim unsurları arasındaki ilişkiler

Ana sap uzunluğu – sap çapı; ana sap uzunluğu ve sap çapı arasında (r= 0.595**) 0.01 düzeyinde önemli ve ilişki belirlenmiştir. Sap çapının kömeç sayısı arasında (r= -0.213*) ve 0.05 düzeyinde önemli ancak olumsuz ilişki belirlenmiştir.

Ana sap uzunluğu ve bitkide kömeç sayısı arasında (r= -0.229**) 0.01 düzeyinde önemli ve olumsuz ilişki belirlenmiştir. Bitkide kömeç sayısının kuru ot verimi (r= 0.627**) ve Bitki yeşil ot verimi (r= 0.608**) arasında 0.01 düzeyinde önemli ve olumlu ilişki belirlenmiştir. (*Tablo 7*).

Ana sap uzunluğundaki artış sap çapını da artırmaktadır. Kömeç sayısının artması sap çapını azaltmıştır. Anasap uzunluğunun artması ile kömeç sayısının azaldığı belirlenmiştir. Kömeç sayısının artması yeşil ot ve kuru ot verimini artırmıştır.

Tablo 7. Üçgül türlerine ait genotiplerin verim ve verim unsurları arasındaki ilişkiler

Table 7. Relationships between yield and yield components of genotypes belonging to clover species

	Ana sap uzunluğu	Sap çapı	Bitkide kömeç sayısı	Bitki yeşil ot verimi
Ana sap uzunluğu	1			
Sap çapı	0.595**	1		
Bitkide kömeç sayısı	-0.229**	-0.213*	1	
Bitki yeşil ot verimi	0.100	-0.133	0.608**	1
Bitki kuru ot verimi	0.113	-0.155	0.627**	0.968**

4. Sonuç

Trakya bölgesi doğal florasında 77 farklı üçgül türünün bulunması geniş yayılım alanına sahip olması vejetasyon süresinin uzun olması dolayısıyla önemli baklagil yem bitkileri arasında yer almasını sağlamaktadır. Yem bitkisi olarak üretilmesi yanında çayır mera alanlarının ıslahında ve yeşil alan tesisinde geniş kullanım alanını bulunması nedeniyle Trakya bölgesi doğal florasında yer alan türlerin özelliklerinin belirlenmesi ve ıslah çalışmalarında kullanılmaları amaçlanmıştır. En iyi gelişme gösteren üçgül türlerine ait genotiplerin verim ve verim unsurlarının belirlenmesi amaçlanmıştır. 2020 yılında 119 O 950 no'lu "Trakya Bölgesi Doğal Florasındaki Üçgül (*Trifolium* L.-*Fabaceae*) Türlerinin Taksonomisi, Dağılımı, Fenolojik, Morfolojik ve Bazı Kimyasal Özellikleri" isimli Tübitak projesi kapsamında toplanan üçgül türleri arasında en iyi gelişme gösteren 5 farklı türe ait 32 genotip materyal olarak kullanılmıştır. Tarla denemelerinde incelenen özellikleri ana sap uzunluğu, sap çapı, bitkide kömeç sayısı, bitki yeşil ot verimi ve bitki kuru ot verimi gibi özellikleri belirlenmiştir. Ayrıca yeşil otlarında ham protein, ham selüloz, ham kül, ADF ve NDF gibi kalite özellikleri belirlenmiştir. Yürütülen araştırmada elde edilen sonuçlar ışığında; Trakya bölgesinde kaba yem üretimi ile mera ıslahında olduğu gibi yapay mera tesisinde de ön bitki olarak tek yıllık 102/T-2 nolu türlerden üç kulak üçgülü (*T. constantinopolinatum*) genotipi ile 20H45 nolu yel üçgülü (*T. nigrescens* Viv) ön bitki olarak yetiştirilebilecek genotipler olarak saptanmıştır. Çok yıllık tür olarak 2. yıldan itibaren hızlı gelişen yüksek ot verimine sahip 148/T-1 nolu ak üçgül (*T. repens*) genotipi bölge koşullarında tercih edilecek tür olarak saptanmıştır.

Teşekkür

119O950 nolu 1001 projesine verdikleri destekten dolayı TUBİTAK ‘a ve NKUBAP.03.YLGA.21.338 nolu projeye desteklerinden dolayı Tekirdağ Namık Kemal Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimine teşekkür ederiz.

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Bu çalışma için etik kuruldan izin alınmasına gerek yoktur.

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Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz.

Yazarlık Katkı Beyanı

Yazarlar tüm aşamalarda eşit katkı sağlamışlardır.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Some Physico-Mechanical Properties and Critical Velocity of Opium Poppy Plant (*Papaver somniferum* L.) 'Ofis 1' (Blue)

Afyon Haşhaşı Bitkisi (*Papaver somniferum* L.) 'Ofis 1'in (Mavi) Bazı Fiziko-Mekanik Özelliklerinin ve Kritik Hızın Belirlenmesi

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Abstract

Determination of some physico-mechanical properties of plant products are very important reference studies in terms of design, development and efficient use of tools and machines used in processes such as planting, harvesting, transportation, packaging, storage, product processing, etc. In this study, it was aimed to determine some physico-mechanical properties of the stalk and capsule of Ofis 1 (Blue) poppy plant, which has a significant production size in our country. According to the evaluated research findings, on the basis of average values, poppy capsule height was 37.99 mm, width was 35.82 mm, mass was 5.86 g, volume was 300.73 mm^3, horizontal projection area was 18.66 cm^2, vertical projection area was 17.91 cm^2, critical velocity was 10.22 m s^{-1}, natural angle of repose was 22.8^o, and shell ratio was 43.93%. In the study, the poppy stalk was divided into three parts: upper, middle and lower regions. During the harvest period, the wet basis moisture value of the upper region was 7.69%, the moisture value of the middle region was 7.56%, the moisture value of the lower region was 8.03%, and the average moisture value of the poppy stalk was calculated as 7.76%. The average moisture value of poppy capsule at harvest time was determined as 7.69%. The number of plants per unit area in the poppy field was 30.8 pieces m^{-2}, the number of capsules was 55.2 pieces m^{-2} and the capsule/plant ratio was 1.8. Average plant height was 119.7 cm. These values are the data that should be taken into consideration for table height and finger spacing in poppy harvesting machine designs. The majority of the plants per unit area (55.9%) are single capsule. As a result of mechanical tests, poppy stem shear force values were determined between 31.14 N-74.06 N and these values vary according to the thickness of the poppy plant stem. The average compression-crushing forces of poppy capsule were determined as 159.39 N and 110.46 N for vertical and horizontal positions, respectively. As a result of the research, Ofis 1 (Blue) poppy plant physico-mechanical properties and a resource that can be useful for the studies to be carried out in machine design studies for the cultivation and harvesting of poppy plants have been put forward.

Keywords: Opium poppy "Ofis 1" (blue), Physico-mechanical properties, Biological material

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Öz

Bitkisel ürünlerin bazı fiziko-mekanik özelliklerinin belirlenmesi; ekim, hasat, taşıma, paketleme, depolama, ürün işleme vb. süreçlerde kullanılan alet ve makinelerin tasarımı, geliştirilmesi ve verimli kullanılması açısından çok önemli referans çalışmalardır. Bu çalışmada, ülkemizde önemli düzeyde üretim büyüklüğüne sahip olan Ofis 1 (Mavi) haşhaş bitkisinin sapı ve kapsülüne ait bazı fiziko-mekanik özelliklerinin belirlenmesi amaçlanmıştır. Değerlendirilen araştırma bulgularına göre, ortalama değerler bazında, haşhaş kapsülü yüksekliği 37.99 mm, genişliği 35.82 mm, kütlesi 5.86 g, hacmi 300.73 mm^3, yatay iz düşüm alanı 18.66 cm^2, dikey iz düşüm alanı 17.91 cm^2, kritik hızı 10.22 m s^{-1}, doğal yığılma açısı 22.8°, kabuk oranı %43.93 olarak ölçülmüştür. Çalışmada haşhaş sapı üç kısma ayrılmış olup bunlar üst, orta ve alt bölgelerdir. Hasat döneminde üst bölgenin yaş baz nem değeri %7.69, orta bölgenin nem değeri %7.56, alt bölgenin nem değeri %8.03 olarak ölçülmüştür, haşhaş sapının ortalama nem değeri %7.76 olarak hesaplanmıştır. Hasat zamanındaki haşhaş kapsülü ortalama nem değeri %7.69 olarak belirlenmiştir. Haşhaş tarlasında birim alandaki bitki sayısı 30.8 adet m^{-2}, kapsül sayısı 55.2 adet m^{-2} ve kapsül/bitki oranı ise 1.8 değerindedir. Ortalama bitki boyu 119.7 cm'dir. Bu değerler haşhaş hasat makine tasarımlarındaki tabla yüksekliği ve parmak aralıkları için dikkate alınması gereken verilerdir. Birim alandaki bitkilerin büyük bir çoğunluğu (%55.9) tek kapsüllüdür. Mekanik testler sonucu haşhaş sapı kesme kuvveti değerleri 31.14 N-74.06 N arasında belirlenmiş olup bu değerler haşhaş bitkisinin sapının kalınlığına göre değişmektedir. Haşhaş kapsülü ortalama basma-kırma kuvvetleri ise dikey ve yatay pozisyonlar için sırasıyla 159.39 N ve 110.46 N olarak belirlenmiştir. Araştırma sonucunda, Ofis 1 (Mavi) haşhaş bitkisi fiziko-mekanik özellikleri ve haşhaş bitkisinin yetiştirilmesine ve hasat işlemlerine yönelik makine tasarım çalışmalarında yapılacak çalışmalara yararlı olabilecek bir kaynak ortaya konmuştur.

Anahtar Kelimeler: Ofis 1 (Mavi) haşhaş, Fiziko-mekanik özellikler, Biyolojik malzeme

1. Introduction

Determination of some physico-mechanical properties of plant products are very important reference studies in terms of design, development and efficient use of tools and machines used in processes such as planting, harvesting, transportation, packaging, storage, product processing, etc.

In Turkey, the traditionally cultivated poppy plant (*Papaver somniferum* L.) belongs to the *Papaveraceae* family. It is an annual crop. Alkaloids are obtained from the capsules of the poppy plant, and poppy oil is extracted from its seeds (Arslan et al., 2008; Seçmen et al., 2000; Erol and Yanık, 2019). Poppy has been cultivated in Anatolia since around 2000 B.C. The plant was freely produced in Turkey in 1933, following the declaration of the Republic. However, between 1971 and 1974, poppy production was banned, and starting from 1987, the Turkish Grain Board (Toprak Mahsulleri Ofisi - TMO) was tasked with overseeing poppy cultivation (Hacıyusufoğlu, 2013). Globally, poppy is grown on 87,642 hectares, with Turkey accounting for 56,511 hectares (64%). With this figure, Turkey holds the first place in global poppy production (TMO, 2019). In Turkey, varieties such as Ofis 2 (white), Ofis 1 (blue), Ofis 4 (yellow), and others are cultivated (TMO, 2021). Accordingly, the most cultivated poppy varieties in Turkey are white (69%), blue (17%), and yellow (14%) seeded varieties. Poppy seeds can be of various colors, including blue, yellow, pink, white, and brown. Poppy is better cultivated in areas with moderately warm summers and sufficient rainfall. Poppy seeds germinate at +4 °C when there is enough moisture in the soil. The poppy plant has a total temperature requirement of 2300-2700 °C and an annual precipitation requirement of 600-700 mm during its growth period (TMO, 2017). The second most produced poppy variety in Turkey is blue, developed by the Turkish Grain Board on April 19, 2016.

Figure 1 illustrates the developmental stages and vegetative parts of the blue poppy. The developmental process includes leafing, budding, flowering, capsule formation, and maturation phases. The vegetative cycle of the poppy plant lasts approximately 110-280 days. During this period after planting, activities such as hoeing/thinning, irrigation, fertilization, pest control, and harvesting are carried out (İşler, 2024). The vegetative components of the poppy plant consist of a main stem (stalk), leaves, lateral branches formed on this main stem, and poppy capsules developing on each lateral branch. There is a node point between the capsule and the stalk.

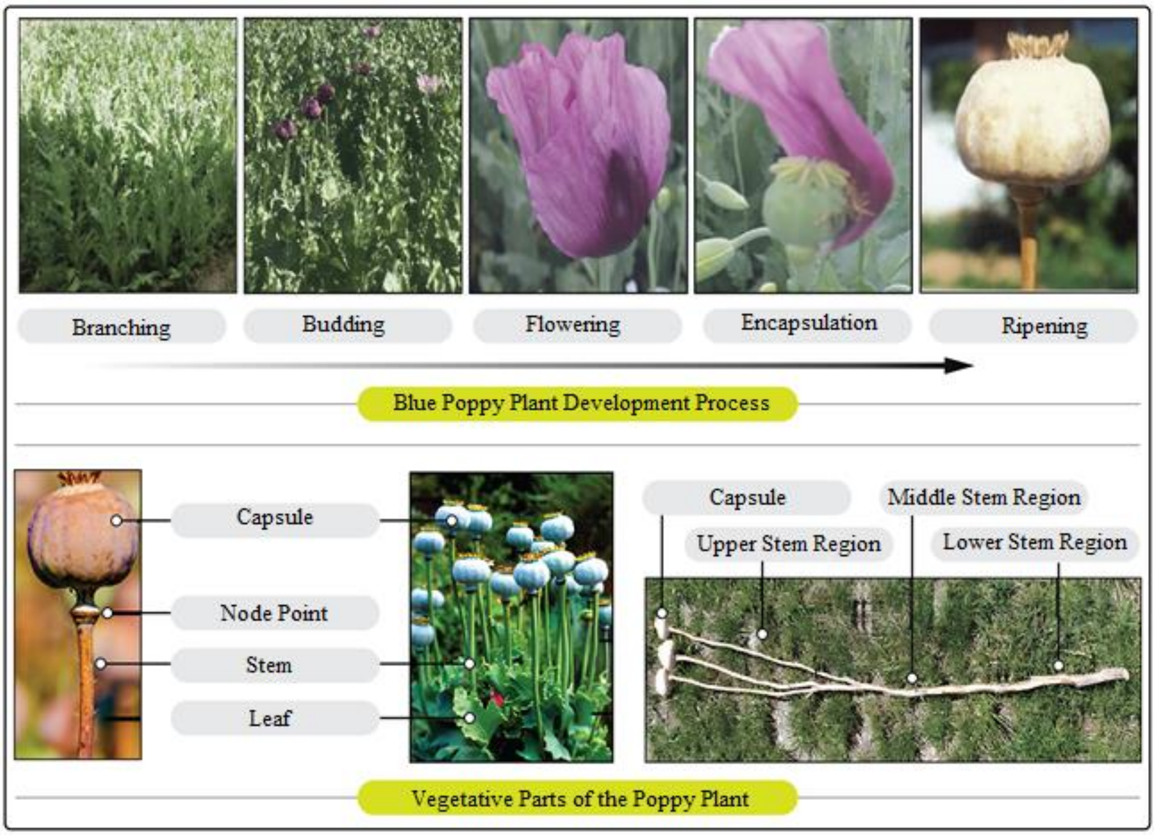

Figure 1. Developmental stages and vegetative parts of the blue poppy plant

Vegetable products are harvested once they reach a specific maturity period. For medicinal and aromatic plants, the optimal harvest period is when the moisture content is between 7-12% (Baydar, 2009). When the poppy plant reaches harvest maturity, the capsules are harvested manually by breaking the capsules at the knot point. In mechanical harvesting, it is recommended to harvest by cutting at most 10-20 cm below this knot point (Hacıyusufoğlu, 2013). This height is important for the table height of the harvester. Determination of product dimensions (width, length, mass, volume, footprint area, critical velocity, natural stacking angle, etc.) and geometric properties of agricultural products are of great importance in the design of units such as sorting, harvesting, collecting, threshing, cleaning, transferring, storing, etc., especially in harvesting machines. In addition, knowledge of these properties also contributes to the design of vehicles used for processing, drying, storage and transportation of plant products (Özarslan, 2002; Dash et al., 2008; Özlü and Güner, 2016; Polyák and Csizmazia, 2016; Taşova and Dursun, 2023). In addition, knowing the fracture resistance of plants and fruits plays an important role in harvesting machine designs (Kocabıyık et al., 2009).

The aim of this study was to determine some physico-mechanical properties of Ofis 1(blue) poppy plant, the second most produced poppy variety in Turkey. To achieve this goal, the research encompasses the determination of product dimensions, geometric characteristics, moisture content, plant and capsule numbers/ratios per unit area, stem cutting force, and capsule rupture resistance/force values.

2. Materials and Methods

In the experiments, the plant material used was Ofis 1 poppy variety, developed by TMO in 2016. All dimensional measurements and mechanical tests conducted in the study were carried out using measurement methods outlined in relevant literature.

Poppy capsule dimensions were measured using a digital caliper with a precision of 0.1 mm. Mass measurements of the capsules were conducted on a digital scale with a precision of 0.01 g. The shell ratio was calculated by dividing the mass of the capsule shell by the mass of the entire capsule. Volume measurements of the capsules were determined by immersing the capsules, taken from the stem, into a container filled with toluene, and the displaced liquid volume was calculated accordingly (Kara, 2012). The horizontal and vertical projection areas of the poppy capsules were determined using image analysis. Photographs taken with a digital camera from a fixed height were analyzed using an image processing program to calculate the area of the image (Kara, 2012). The critical velocity was determined using the aspiration method, where the air velocity at which the capsules remained stationary/suspended was defined as the critical velocity. Airflow measurements were made with an anemometer with a precision of 0.1 m s^{-2}. The tunnel using the aspiration method is 10 cm in diameter, an adjustable velocity airflow system is installed. The natural repose angle was determined by pouring poppy capsules from a fixed point onto a flat surface, and the angle formed by the lateral surface of the resulting pile with the horizontal was measured as the natural repose angle (Kara, 2012). Measurements for certain physico-mechanical properties of the poppy capsules were repeated five times. The moisture content values for both the poppy capsules and stems were determined using the oven drying method. Measurements were carried out on five samples. First, the fresh weights of the capsule and stem samples were measured as shown in Equation 1. Then, these samples were placed in a drying oven at 105 °C for 24 hours and their dry weights were measured to determine the percent moisture content on a wet basis (Mohsenin, 1986).

$$Moisture_{w.b.} = \frac{A-B}{A}.100 \qquad \textbf{(}\text{Eq. 1)}$$

Moisture w.b.: Moisture content (%)

A : Wet sample weight (g)

B : Dry sample weight (g)

In the stem cutting and capsule compression/crushing tests, moisture values in the range of 7-12% at harvest were taken into consideration (Baydar, 2009).

"Unit Area Method" was employed to determine the plant count, capsule count, plant heights, and capsule numbers on each plant. A unit area of 1 m² was selected for this purpose, and the locations of unit areas in the poppy field were randomly chosen. The experiments were conducted with five replications. In the trials, the plant and capsule numbers in each unit area were determined, plant heights were measured, and the number of capsules on each plant was identified. For the determination of poppy stem cutting force values, three regions on the plant stem were considered: namely the lower region, middle region, and upper region. Cutting trials were performed in these regions. For the determination of poppy capsule compression/breaking force values, vertical and horizontal compression/breaking measurements were conducted. TST Mares brand universal mechanical testing equipment at the Agricultural Machinery and Technologies Engineering laboratory of Akdeniz University, Faculty of Agriculture, was used for measurements. The experiments were carried out with five replications. Relevant visual examples of the measurements and mechanical tests are provided in *Figure 2*.

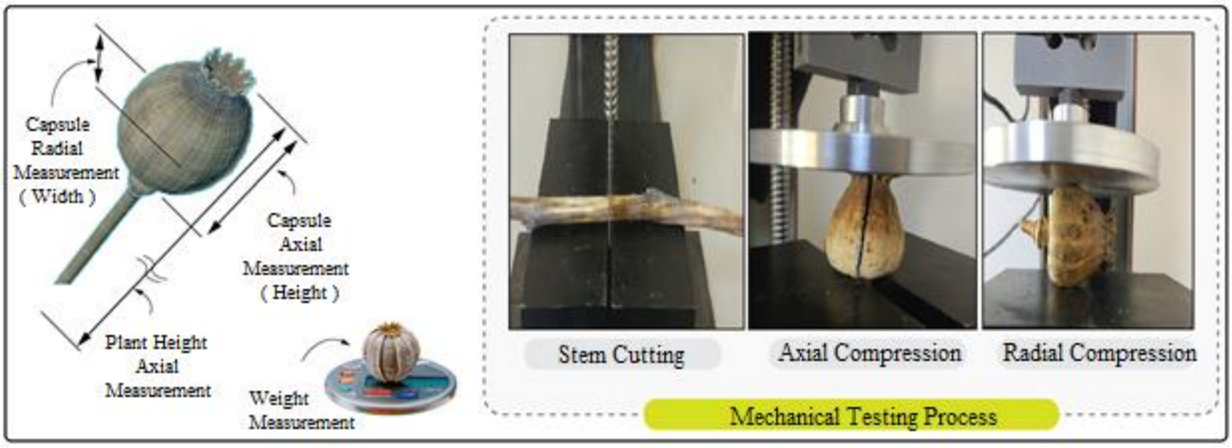

Figure 2. Sample dimensional measurement and mechanical test images

3. Results and discussion

In this study, which focuses on determining certain parameters for the design of harvesting machines, especially the units related to separation, harvesting, collection, threshing, cleaning, transfer, storage, etc., for the blue poppy plant, some physico-mechanical properties of the blue poppy capsule are presented in *Table 1*.

Table 1. Critical Velocity and some physico-mechanical properties of blue poppy capsule

Feature	Average Value ± SD
Height (mm)	37.99 ± 3.18
Width (mm)	35.82 ± 5.75
Mass (g)	5.86 ± 1.62
Volume (mm^3)	300.73 ± 139.9
Horizontal Projection Area (cm^2)	18.66 ± 4.55
Vertical Projection Area (cm^2)	17.91 ± 5.94
Critical Velocity ($m\ s^{-1}$)	10.22 ± 1.43
Natural Angle of Repose (degrees)	22.86 ± 0.81
Shell Ratio (%)	43.93 ± 2.67

According to *Table 1*; the capsule height is slightly greater than the capsule width. A similar excess is also observed in the footprint area values. This situation indicates that blue poppy capsules tend to develop more longitudinally. The mass, volume, critical velocity, and natural repose angle of the poppy capsule are determined as 2.64 g, 300.73 mm^3, 10.22 $m\ s^{-1}$, and 22.85 degrees, respectively. The shell ratio is 43.93%. This value indicates that the amount of seeds in the poppy capsule (56.07%) is higher compared to the shell. Moisture content values of plant parts and products are crucial, especially in determining the harvest time and designing the cutting, threshing, and cleaning units of harvesting machines. Moisture content values for the blue poppy stem and capsule are given in *Table 2*.

As seen in *Table 2*; the average moisture content values for the plant stem and poppy capsule are determined as 7.75% and 7.69%, respectively. The moisture content values in the upper, middle, and lower regions of the plant stem are very close to each other. Therefore, the cutting height with the machine during harvesting can be preferred from any region of the plant stem. This is a positive feature in terms of harvesting efficiency. Similar observations are present in the moisture content values for seeded and empty poppy capsule. Accordingly; it can be stated that capsule threshing, seed-shell separation, and seed cleaning can be successfully performed. The values for the number of plants, number of capsules, and capsule/plant ratio per unit area for the blue poppy plant are given in *Table 3*.

Table 2. Moisture content values of blue poppy stem and capsule

Plant Part	Feature	Average Value ± SD
Stem	Upper Stem Region Moisture Content w.b.(%)	7.69 ± 2.55
	Middle Stem Region Moisture Content w.b. (%)	7.56 ± 0.68
	Lower Stem Region Moisture Content w.b.(%)	8.03 ± 1.33
	Average (%)	7.76 ± 0.24
Capsule	Seed Capsule Shell Moisture Content w.b.(%)	6.46 ± 0.44
	Empty Capsule Shell Moisture Content w.b.(%)	8.91 ± 0.53
	Average (%)	7.69 ± 1.73

Table 3. Unit area plant count, capsule count, and capsule/plant ratio values

Repetition	Number of plants (piece m^{-2})	Number of capsule (piece m^{-2})	Capsule/Plant ratio (Decimal)
1	36	59	1.6
2	33	53	1.6
3	24	58	2.4
4	33	55	1.7
5	28	51	1.8
Average (piece)	30.8	55.2	1.8
Standard Deviation	4.3	3	0.3

As seen in *Table 3*, considering the repetitions, the total number of plants per unit area varies between 24-36 plants m^{-2}, the total number of capsules ranges from 51 to 59 capsules m^{-2}, and the capsule/plant ratio varies between 1.6-2.4. On average, these values are 30.8 plants m^{-2}, 55.2 capsules m^{-2}, and 1.8, respectively. Therefore, it can be stated that each plant has at least one or more capsules.

In practice, having only one capsule per plant is a desirable feature for both product quality and mechanization success. Uniformity in plant heights is crucial for reducing harvesting losses in machine harvesting. The number of plants per unit area according to plant height groups for the blue poppy plant is provided in *Table 4*.

Table 4. Number of plants per unit area according to plant height groups

Repetition	Plant height groups					Total number of plants
	<85 cm	86-105 cm	106-125 cm	126-145 cm	146 cm>	(count m^{-2})
1	2	6	13	12	3	36
2	0	4	12	13	4	33
3	1	3	9	10	1	24
4	2	6	11	11	3	33
5	1	4	11	10	2	28
Average (count m^{-2})	1.2	4.6	11.2	11.2	2.6	30.8
Total (count m^{-2})	6	23	56	56	13	154
Ratio (%)	3.9	14.9	36.4	36.4	8.4	100

As shown in *Table 4*, the total number of plants per unit area varies between 24 and 36. On average, this value is 30.8. Considering the repetitions, the highest number of plants per unit area based on plant height groups is equal, with 56 plants m^{-2} (36.4%) in the 106-125 cm and 126-145 cm height groups. Following these, the 86-105 cm group (23 plants m^{-2}, 14.9%), the group larger than 146 cm (13 plants m^{-2}, 8.4%), and the group smaller than

85 cm (6 plants m^{-2}, 3.9%) come in order. Taking into account the positive effect of the common moisture values in the plant stems in *Table 2*, choosing a cutting height in machine harvesting below 85 cm can significantly reduce harvesting losses. On the other hand, standardizing the heights of poppy plants through breeding efforts will contribute significantly to the efficiency of mechanization processes.

Having each poppy plant with only one capsule is crucial for both product quality and the success of mechanization processes. The number of plants per unit area according to capsule count groups for the blue poppy plant is provided in *Table 5*.

Table 5. Number of plants per unit area according to capsule count groups

Repetition	Capsule count groups				Total plant count
	1	2	3	4+	(count m^{-2})
1	23	6	4	3	36
2	21	6	4	2	33
3	7	5	7	5	24
4	20	6	5	2	33
5	15	6	4	3	28
Average (count m^{-2})	17.2	5.8	4.8	3	30.8
Total (count m^{-2})	86	29	24	15	154
Ratio (%)	55.9	18.8	15.6	9.7	100

As seen in *Table 5*, the total number of plants per unit area varies between 24 and 36. The average value is 30.8. Considering the capsule count groups based on repeated observations, the highest plant density is predominantly in the single-capsule group, determined as 86 plants m^{-2} (55.9%). Following this, there are the 2-capsule group (29 plants m^{-2}, 18.8%), the 3-capsule group (24 plants m^{-2}, 15.6%), and the 4 or more capsule group (15 plants m^{-2}, 9.7%). In other words, the majority of plants have a single capsule. This situation represents a positive feature for mechanization processes. On the other hand, conducting breeding studies to make each poppy plant single-capsuled will contribute significantly to the efficiency of both product quality and mechanization processes.

The information on stem cutting force and poppy capsule crushing force is crucial, especially for the design and improvement of mechanized harvesting units, particularly the cutting and threshing units. The values of stem cutting force and poppy capsule crushing/pressing force for the blue poppy plant are provided in *Table 6*.

Table 6. Cutting force values for blue poppy stem and capsule

Plant part	Parameter	Mean ± SD
Stem	Cutting force in the upper stem region (N)	31.14 ± 12.10
	Cutting force in the middle stem region (N)	60.01 ± 15.07
	Lower stem region cutting force (N)	74.06 ± 27.26
Capsule	Vertical pressing force (N)	159.39 ± 48.46
	Horizontal pressing force (N)	110.46 ± 15.35

As seen in *Table 6*, the cutting force values for the stem are determined as 31.14 N, 60.01 N, and 74.06 N for the upper, middle, and lower stem regions, respectively. The cutting force values increase from the upper region to the lower region, and there is significant variation in these values in each region. This situation should be taken into consideration in the design of the harvesting unit, particularly to perform cutting from the upper stem region as much as possible due to the lower cutting force, considering the lowest capsule height (refer to *Table 4*). In other words, when designing and improving the mechanized harvesting unit for poppy plants, capsule height and cutting force values should be considered.

The horizontal and vertical capsule compression/breaking force values are determined as 159.39 N and 110.46 N, respectively. The horizontal compression force value is lower compared to the vertical compression force value. These values should be utilized, especially in the design of the threshing unit, for features such as breaking capsules, separating seeds from shells, and determining operating parameters of the threshing unit.

4. Conclusions

In this study, various physico-mechanical properties of the blue poppy plant have been examined. According to the obtained results, the height of the poppy capsule is 37.99 mm, width is 35.82 mm, mass is 5.86 g, volume is 300.73 mm^3, horizontal projection area is 18.66 cm^2, vertical projection area is 17.91 cm^2, critical velocity is 10.22 m/s, natural pile angle is 22.86 degrees, and the shell ratio is 43.93%. During the harvest period, the moisture values of the upper, middle, and lower regions of the poppy stem were measured as 7.69%, 7.56%, and 8.03%, respectively. The moisture content of the empty poppy capsule is 8.91%, and the moisture content of the seeded capsule is 6.46%. The total number of plants per unit area in the poppy field ranges from 24 to 36 plants m^{-2}, the total number of capsules is between 51 and 59 capsules m^{-2}, and the capsule/plant ratio varies between 1.6 and 2.4. On average, these values are 30.8 plants m^{-2}, 55.2 capsules m^{-2}, and 1.8, respectively. According to plant height groups, the highest plant density is 56 plants m^{-2} (36.4%) in the 106-125 cm and 126-145 cm height groups. Then, the 86-105 cm group (23 plants m^{-2}, 14.9%), the group larger than 146 cm (13 plants m^{-2}, 8.4%), and the group smaller than 85 cm (6 plants m^{-2}, 3.9%) follow. The average plant height is calculated as 119.7 cm. According to capsule count groups, the highest plant density is primarily 86 plants m^{-2} (55.9%) in the 1-capsule group. Then, the 2-capsule group (29 plants m^{-2}, 18.8%), the 3-capsule group (24 plants m^{-2}, 15.6%), and the 4+ capsule group (15 plants m^{-2}, 9.7%) follow. The cutting force values for the stem are determined as 31.14 N, 60.01 N, and 74.06 N for the upper, middle, and lower stem regions, respectively. The horizontal and vertical capsule compression/breaking force values are determined as 159.39 N and 110.46 N, respectively.

In conclusion, this study reveals some physico-mechanical properties and critical velocity values of blue poppy plant. These properties will serve as a valuable resource for the design and development of harvesting machines for the mechanical harvesting of blue poppy plants.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept, Design, Data Collection or Processing, Statistical Analyses, Literature Search: Güngör, O. Writing, Review and Editing, Fiction: Akıncı, İ.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

İşletmenin Bitkisel Üretiminin Süt Koyunculuğuna Etkisi: Örnek Bir Çalışma

The Impact of The Farm's Crop Production on Its Dairy Sheep Production: A Case Study

Bekir Sıtkı AYAĞ[1], Türker SAVAŞ[2*]

Öz

Türkiye tarımsal üretiminin çok büyük bir kısmı küçük ölçekli işletmelere dayanmakta olup bunların da %38'i bitkisel ve hayvansal üretimi birlikte gerçekleştirmektedirler. Bu çalışmada ana faaliyet alanı süt koyunculuğu olan işletmelerde gerçekleştirilen diğer bitkisel üretim faaliyetlerinin koyunculuğa etkileri araştırılmıştır. Bu amaçla Çanakkale'nin Ezine ilçesinde faaliyet gösteren ve üretim sistemi bakımından birbirlerine benzeyen 60 süt koyunu işletmesi seçilmiştir. Bu işletmeler iki yıl süre ile gebelik başı (eylül), doğum dönemi (ocak) ve sütten kesim-kuzu pazarlama döneminde (nisan) ziyaret edilerek tanımlayıcı bilgileri, ekim alanları, sürü büyüklüğü değişimi ve sürüye ilişkin biyolojik parametreler gözlenmiştir. İşletmelerin %21'i topraksız iken geriye kalanların toplam arazi varlığı 327.7 ha, ortalama arazi varlığı 7 ha'dır. İşletmelerin koç altı koyun sayıları (KAKS), ve doğuran koyun oranlarında (DKO) iki yıl arasında anlamlı bir fark gözlenmemiştir (P>0.05). İşletmenin arazi büyüklüğü KBSS miktarını olumsuz etkilemektedir (P=0.0159). Sulanabilir arazi varlıkları ise DKO üzerinde olumsuz, satılan ortalama kuzu canlı ağırlığı (SOKCA), koyun başına satılan kuzu canlı ağırlığı (KBSKCA) ve koyun başına brüt gelir (KBBG) üzerinde olumlu etkide bulunmaktadır (P≤0.0397). Yem bitkileri ekim alanı büyüdükçe KAKS da büyümektedir (P≤0.05). KBSS zeytinlik varlığından olumsuz etkilenmektedir (P=0.0321). DKO tahıl ekim alanı büyüklüğünden negatif olarak (P=0.0017), SOKCA (P=0.0463) ve KBSKCA (P=0.0843) tahıl ekim alanı büyüklüğünden pozitif yönde etkilenmektedir. Türkiye'de topraksız çiftçi oranı özellikle küçükbaş hayvancılık ile iştigal eden çiftçilerde sürmektedir. İşletmeler süt koyunculuğu olarak tanımlanabilirlerse de kuzu geliri süt gelirinden daha yüksektir. Bu anlamda süt koyunculuğu üretim sistemlerinin detaylı analizi gerekmektedir. Bazı bitkisel üretim grupları kuzu üretim parametrelerini desteklemektedir. Muhtemelen sütten ziyade kuzunun getirisinin büyük olması yetiştiricilerin kuzu üretimine ağırlık vermesine neden olmaktadır.

Anahtar Kelimeler: Üretim sistemi, Küçükbaş hayvan, Toprak varlığı, Sulanabilir arazi varlığı, Bitkisel üretim

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Abstract

A large proportion of agricultural production in Turkey is based on small farms, 38% of which produce both crop and livestock products. In this study, the effects of crop production on sheep production were investigated in farms whose main activity is dairy sheep production. For this purpose, 60 dairy sheep farms with similar production systems were selected in the Ezine district of Çanakkale. These farms were visited for two years at the beginning of gestation (September), parturition period (January) and weaned lamb marketing period (April) and descriptive information, area, flock size changes and biological parameters related to the flock were observed. While 21% of the farms were landless, the total area of the remaining farms was 327.7 ha and the average area was 7 ha. There were no significant differences between the two years in the number of ewes (NE), and the proportion of lambing ewes (LE) (P>0.05). The size of the farm has a negative effect on the amount of milk sold per ewe (P=0.0159). The presence of irrigated land has a negative effect on LE, but a positive effect on average live weight of lambs sold (ALWS), live weight of lambs sold per ewe (LWSE) and gross income per ewe (P≤0.0397). The larger the forage production area, the higher the NE (P≤0.05). The quantity of milk sold per ewe is negatively influenced by the presence of olive groves (P=0.0321). While LE is negatively influenced (P=0.0017), ALWS (P=0.0463) and LWSE (P=0.0843) are positively influenced by the size of cereal area. In Turkey, the proportion of landless farmers remains high, especially among small ruminant farmers. Although the farms can be defined as dairy sheep farms, the income from lamb production is higher than that from milk production. In this sense, dairy sheep production systems need to be analyzed in detail. Some crop production groups support the parameters for lamb production. Presumably, the fact that lamb income is higher than milk income causes breeders to focus on lamb production.

Keywords: Production system, Small ruminants, Land availability, Irrigable land, Crop production

1. Giriş

Türkiye bir küçükbaş hayvan coğrafyasıdır (Ertuğrul ve ark., 1995; Kaymakçı ve ark., 2000; Kaymakçı ve ark., 2005; Ertuğrul ve ark., 2010; Cengiz ve ark., 2015; Cedden ve ark., 2020). Bu anlamda birçok farklı koyun ve keçi üretim sistemleri oluşmuştur. Üretim sistemleri farklı ırk temelli olabildiği gibi aynı ırkların yetiştirildiği ancak çayır-mera varlığı, yem bitkileri üretimi, hasat sonrası arazilerin mera olarak kullanıldığı ve sistemin uygulandığı coğrafyanın doğal kaynakları ile sosyo-ekonomik özellikler bağlamında farklılaşmaktadır. Öte yandan üretimin gerçekleştirildiği yörenin tüketim alışkanlıkları da sistemi şekillendirmektir. Koyunculukta kasaplık kuzu üretimi veya hem kasaplık kuzu üretimi hem de süt üretimi gerçekleştirilmesine bağlı olarak da üretim sistemleri değişebilmektedir.

Türkiye tarımsal üretiminin çok büyük bir kısmı halen küçük ölçekli işletmelere dayanmaktadır (Başaran, 2020). Öte yandan Kredi Kayıt Bürosu tarafından 2022 yılında gerçekleştirilen "Türkiye tarımsal görünüm saha araştırmasına" göre tarımsal işletmelerin büyük çoğunluğunda polikültürel bir üretim söz konusu olup, yalnızca hayvancılık yapan işletme oranı %1'in altında, bitkisel ve hayvansal üretimi birlikte gerçekleştiren işletmelerin oranının ise %38 olduğu rapor edilmiştir (Anonim, 2022a). Bu anlamda hayvancılığın ve bitkisel üretimin birlikte gerçekleştirilmesi durumunda birbirlerine etkileri konusu araştırmaya muhtaç bir alanı oluşturmaktadır.

2022 yılı istatistiklerine göre Türkiye koyun sütü üretiminde Çin'in arkasından 1.067.000,0 ton ile Dünya sıralamasında ikinci sırada bulunmaktadır (Anonim, 2022b). 2023 yılı verilerine göre koyun sütü üretimi Türkiye toplam süt üretiminin % 4.3'üne karşılık gelmektedir (Anonim, 2024). Ülkemizde koyun yetiştirme sistemlerinin büyük çoğunluğu düşük girdili yetiştiricilik sistemleridir (Cedden ve ark., 2020).

İster aynı işletmede gerçekleşsin isterse farklı işletmelerde, tüm tarımsal faaliyetlerin doğrudan ya da dolaylı olarak birbirlerini etkiledikleri malumdur. Bu anlamda tarımsal faaliyetin bir tarafında hayvancılık olduğunda en başta yem bitkileri üretim koşulları ve üretiminin koyunculuğa etkisi beklenir. Ancak bunun yanısıra genel anlamda bitkisel üretim koşullarının ve üretiminin hayvancılığa etkisi de olabilir. Yoğun bitkisel üretim gerçekleştirilen yörelerde özellikle meraya bağlı hayvancılık bazı kısıtlara maruz kalabilmektedir. Aynı işletmede farklı bitkisel üretim faaliyetlerinin hayvancılığı ne denli etkiledği ise başka bir sorudur. Bu anlamda ana faaliyet alanı süt koyunculuğu olan işletmelerde gerçekleştirilen bitkisel üretimin koyunculuğa genel etkilerinin araştırılması bu çalışmanın amacını oluşturmuştur.

2. Materyal ve Yöntem

2.1. Materyal

Amacı gerçekleştirmek üzere Çanakkale'nin Ezine ilçesinde faaliyet gösteren süt koyunculuğu işletmeleri içerisinden, üretim sistemi bağlamında mümkün olduğunca birbirlerine benzeyen, Tahirova ırkı hayvanlara sahip ve iş gücü aile bireylerine dayanan 60 süt koyunu işletmesi takip edilmiştir. İşletmelerde 2-2.5 aylık emiştirme dönemi sonrası yaklaşık bir ay kuzular kesif yem ağırlıklı besiye alınmakta ve 25-35 kg canlı ağırlığa ulaştıklarında kasaplık olarak pazarlanmaktadır. Yörede, kuzuların sütten kesimi sonrası koyunlar yaklaşık 4 ay sağılmaktadır. Koyunlar kış aylarında gündüz, yaz aylarında ise gece olmak üzere neredeyse yıl boyu meraya çıkarılmaktadırlar. Fizyolojik döneme göre değişen miktarlarda, ağırlıklı olarak arpa veya buğday ek yemlemesi yapılmaktadır. Gebeliğin ileri döneminde koyunlara fabrika yemi de verilmeye başlanmakta; doğum sonrasında, laktasyon sürecinde devam etmektedir. Kısıtlı mera olanaklarına sahip işletmeler ağırlıklı olarak arpa hasılı tesis etmektedirler. Zemini çoğunlukla toprak olan koyun ağılları genelde ahşap, briket ya da tuğladan kapalı barınak şeklindedir. Ancak barınağın önünde gezinti alanı bulunmaktadır.

2.2. Araştırma alanının özellikleri

Çanakkale Anadolu yarımadasının kuzeybatısında (25° 40' - 27° 30' doğu ve 39° 27' - 40° 45' kuzey) yer alır. 9.933,0 kilometrekare yüzölçümüne sahip Çanakkale Avrupa ile Asya kıtalarını birbirinden ayıran boğazın iki kıyısında konumlanmıştır. Ezine ilçesi, Çanakkale Merkez ilçenin güneybatısında yer almaktadır. İlçe merkezi ovada yer almakta; kuzey ve güneyi tepelerle çevrilidir. Çanakkale Tarım ve Orman İl Müdürlüğü 2022 bilgilendirme raporuna göre Ezine 26.894 ha işlenebilir tarım arazisine sahip olup bu arazinin %36.5'i sulanabilir tarım arazisidir. İlçenin orman ve fundalık ile kaplı arazi büyüklüğü 28.672,0 ha'dır. Ezine çayır ve mera arazi varlığı nispeten küçüktür (1.578,0 ha). Bu anlamda gerek orman ve fundalıklar gerekse hasat sonrası tarım arazileri küçükbaş hayvanlar için mera olarak kullanılmaktadır. Yine aynı bilgilendirme raporuna göre ilçenin koyun varlığı

102.167,0 baştır. Bu anlamda Çanakkale ilçeleri arasında koyun varlığı en yüksek olan ilçedir. Tarım Bilgi Sistemine göre 2023 yılı itibarıyla ilçe topraklarının 11.800,0 ha'ı zeytinliktir. Aynı yıl 305 ha sebze, 5.425,0 ha tahıl ve 1.081,0 ha yem bitkileri ekimi gerçekleşmiştir. Buna göre ilçe işlenebilir arazilerinin %44'ü zeytinlik olup %1'inde sebze, %20'sinde tahıl ve %4'ünde yem bitkileri ekimi yapılmıştır.

2.3. Yöntem

Çalışmada iki yıl süre ile yukarıda tanımlanan süt koyunculuğu işletmeleri takip edilmiştir. Çalışma başlangıcında işletmelere ilişkin tanımlayıcı bilgileri, işletme yapısı, ekim alanları ve hayvanlara ait bilgiler belirlenmiştir. Verilerin toplanmasına ilk yılın eylül ayında başlanmıştır. İşletmeler gebelik başı (eylül), doğum dönemi (ocak) ve sütten kesim-kuzu pazarlama döneminde (nisan) ziyaret edilerek sürü büyüklüğü değişimi ve koyunculuğa ilişkin parametreler takip edilmiştir.

İşletmelere ait koyunculuk parametreleri koç altı koyun sayısı (KAKS), doğuran koyun oranı (DKO), kuzu ölüm oranı (KÖO), koç altı koyun başına satılan kuzu sayısı (KBSKS), bu kuzulara ait ortalama canlı ağırlıklar (SOKCA) ve koç altı koyun başına satılan kuzu canlı ağırlığından (KBSKCA) oluşmaktadır. Ayrıca takip edilen işletmelerin süt desteklemelerine esas faturalar üzerinden koyun başına satılan süt miktarı (KBSS) belirlenmiştir. Koyun başına brüt gelirin (KBBG) hesaplanmasında 2024 yılı ortalama koyun sütü fiyatı ile ortalama kuzu birim canlı ağırlık fiyatı dikkate alınmıştır. Süt fiyatı ile kuzu fiyatını dengelemek için kuzu büyütme gideri ortalama kuzu birim canlı ağırlık fiyatından düşülmüştür.

İşletmelere ait arazi özellikleri ile bitkisel üretime ait bilgiler üretici beyanları doğrultusunda elde edilmiş ve İl Tarım ve Orman Müdürlüğü Çiftçi Kayıt Sistemi verileri ile teyit edilmiştir. İşletme ziyaretlerine eylül ayında başlanıp iki yıl sonra nisan ayında son ziyaret yapıldığı için bitkisel üretime ilişkin veriler bu iki yılın ortasına denk gelecek şekilde bir kez alınmıştır. İşletmelerde sebze olarak genellikle domates üretilmekte, tahıl olarak ise yemlik veya tohumluk mısır, arpa, buğday ve yulaf ekilmektedir. Yem bitkileri ise silajlık mısır, sorgum-sudan otu, fiğ ve yoncadan oluşmaktadır.

2.4. İstatistiksel Analizler

Takip edilen 60 işletmeye ait iki yıllık işletme koyunculuk parametrelerinin analizleri yılın sabit ve işletmenin şansa bağlı faktörler olarak yer aldığı bir model ile tekrarlı ölçümler varyans analizi yöntemiyle yapılmıştır.

Gerek işletmeye ilişkin sürü biyolojik özelliklerinin gerekse arazi varlığı ile bitkisel üretim arazi miktarlarının birbirleriyle ilişkilerini, daha iyi bir ifade ile bunların hangilerinin olası ortak faktörlerden etkilendiklerini çok boyutlu olarak özetlemek amacıyla temel bileşenler analizi gerçekleştirilmiştir.

İşletmelerin arazi ve sulanabilir arazı varlığının koyunculuk özelliklerine etkisini belirlemek amacıyla, toplam arazi varlığı ile sulanabilir arazi varlığı arasındaki ilişkinin düşük olduğu belirlendikten sonra çoklu regresyon analizi kullanılmıştır. Analizde sürüye ilişkin her bir biyolojik parametre bağımlı, toplam arazi varlığı ve sulanabilir arazi varlığı bağımsız değişken olarak yer almıştır. Yetiştiricilerin bitkisel üretim alanlarının koyunculuk üretim parametrelerine etkisini belirlemek amacıyla geriye doğru aşamalı regresyon yöntemi kullanılmıştır. Bu analizde önce bütün bağımsız değişkenler modele alınmış, sonra her adımda modele en küçük katkıyı gösteren değişken atılarak 0.10 düzeyinde anlamlı F istatistiği üretene kadar değişkenler birer birer modelden çıkarılmıştır.

İstatistiksel analizler SAS (2011) paket programında gerçekleştirilmiştir.

3. Bulgular

İşletmelerin %21'ni topraksız çiftçiler oluşturmaktadır (*Şekil 1*). Takip edilen işletmelerin %51'i sulanabilir araziye sahiptir. İşletmeler koyunculuk dışında en fazla tahıl ekimi yapmakta, en az ise yem bitkisi yetiştirmektedir (*Şekil 2*). Araştırmaya konu işletmelerin toplam işlenebilir arazi varlığı 327.7 ha olup ortalama işlenebilir arazi varlığı 7 ha'dır. İşletmelerin sahip olduğu toplam işlenebilir arazinin %46'sı sulanabilir niteliktedir. Sulanabilir arazisi olan işletmelerin içerisinde ortalama sulanabilir arazi varlığı 6.4 ha'dır. Arazi varlığı en yüksek olan işletmenin büyüklüğü 20 ha, en küçüğü ise 0.3 ha'dır.

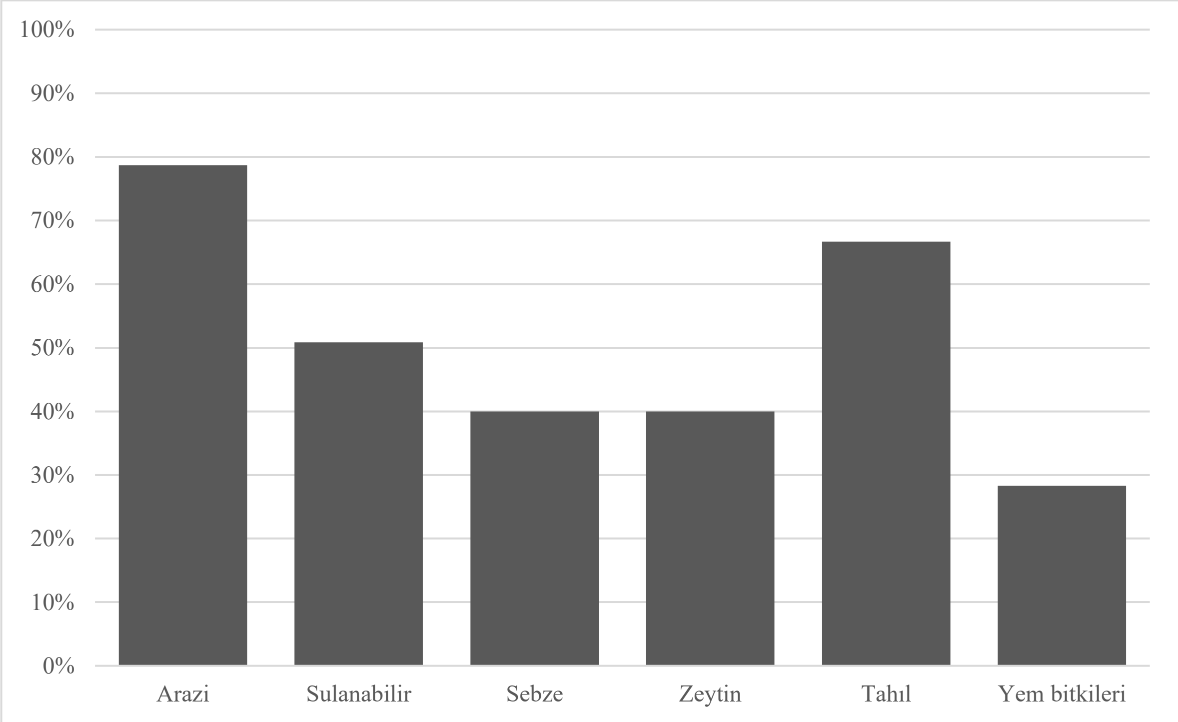

Figure 1. Proportion of farms according to cultivable land and crop production types

Şekil 1. İşlenebilir araziye ve bitkisel üretim çeşitlerine göre işletmelerin oranı

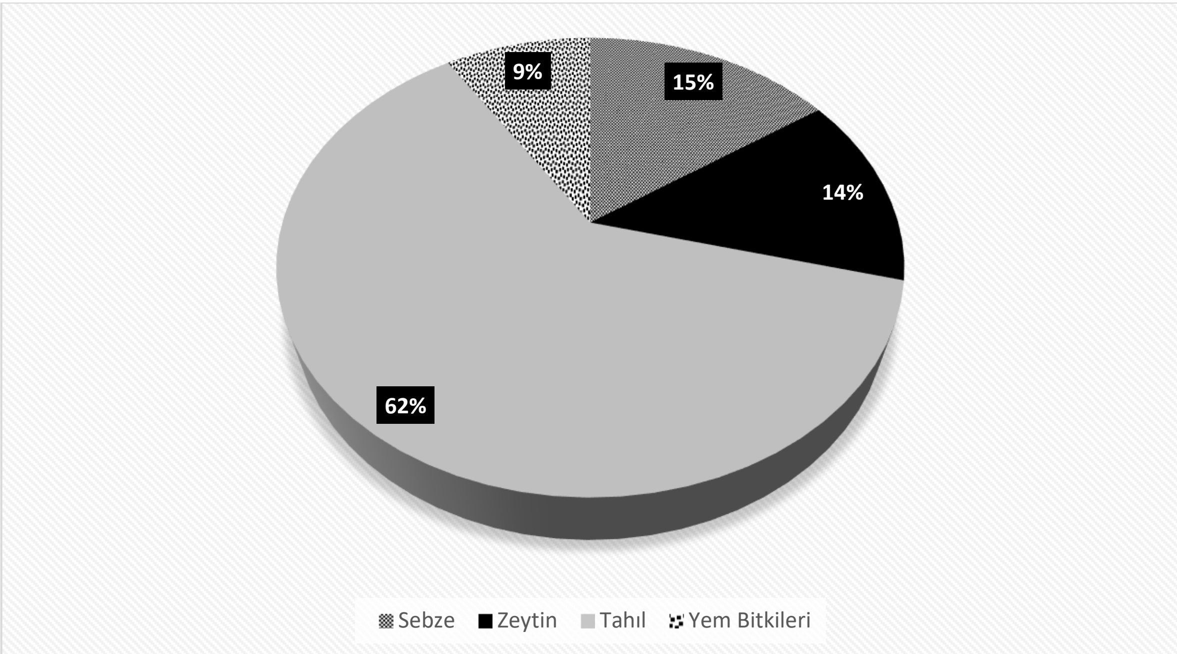

Figure 2. Proportional distribution of crop production classes in total cultivable land of farms

Şekil 2. İşletmelerin toplam işlenebilir arazi varlığı içerisinde bitkisel üretim sınıflarının oransal dağılımı

Tablo 1'de işletmelerin koyunculuk özelliklerine ilişkin iki yıla ait gözlemlerin karşılaştırılması özetlenmiştir. Buna göre koç altı koyun sayıları ve doğuran koyun oranları bakımından iki yıl arasında anlamlı bir fark gözlenmemiştir ($P \geq 0.1910$). Ancak diğer özellikler bakımından iki yıl, istatistiksel önemli derecede farklılaşmıştır ($P \leq 0.05$). Tekrarlama derecelerine göre yıllar arasında en yüksek benzerlik satılan ortalama kuzu canlı ağırlığındayken, en düşük koyun başına satılan kuzu sayısında gerçekleşmiştir.

Tablo 1. İşletmelerin koyunculuk özellikleri bakımından iki yılın karşılaştırılmasına esas en küçük kareler ortalamaları ($\bar{x}$), standart hataları (SH), istatistiksel anlamlılık değerleri (P), işletme varyans unsurları ($\sigma_İ^2$), işletme varyans unsurunun standart hataları ($SH_{\sigma_İ^2}$), kalıntı varyansları (σ_e^2), kalıntı varyanslarının standart hataları ($SH_{\sigma_e^2}$) ve tekrarlama dereceleri (r)

Table 1. Least square means ($\bar{x}$), standard errors (SH), statistical significance values (P) for the comparison of two years in terms of sheep production characteristics and farm variances ($\sigma_İ^2$), standard errors of farm variances ($SH_{\sigma_İ^2}$), residual variances (σ_e^2), standard errors of residual variances ($SH_{\sigma_e^2}$) and repeatabilities (r)

	Yıl 1	Yıl 2							
	$\bar{x}$		SH	P	$\sigma_İ^2$	$SH_{\sigma_İ^2}$	σ_e^2	$SH_{\sigma_e^2}$	r
KAKS, baş	107.1	105.9	5.21	0.8073	849.9	239.4	795.1	146.0	0.52
KBSS, l	41.5	37.2	1.96	0.0267	127.2	34.1	104.4	19.3	0.55
DKO, %	97.2	96.8	0.32	0.1910	3.1	0.8	2.0	0.4	0.61
KÖO, %	6.9	5.4	0.50	0.0156	3.7	1.8	10.04	1.9	0.27
KBSKS*, baş	1.0	1.2	0.20	<0.0001	0.7	0.4	2.7	0.5	0.21
SOKCA; kg	32.5	31.9	0.35	0.0347	4.9	1.2	2.6	0.5	0.65
KBSKCA, kg	34.1	37.4	0.97	0.0025	22.7	7.9	31.1	6.3	0.40
KBBG, TL	6890.6	7319.3	190.48	0.0349	995472	309877	1167160	215880	0.46

KAKS: Koç altı koyun sayısı; KBSS: Koç altı koyun başına satılan süt miktarı; DKO: Doğuran koyun oranı; KÖO: Kuzu ölüm oranı, KBSKS: Koç altı koyun başına satılan kuzu sayısı, SOKCA: Satılan kuzu ortalama canlı ağırlığı, KBSKCA: Koç altı koyun başına satılan kuzu canlı ağırlığı; KBBG: Koç altı koyun başına brüt gelir; *Varyans unsuru·10^{-2}.
KAKS: Number of ewes; KBSS: Amount of milk sold per ewe; DKO: Proportion of lambing ewes; KÖO: Lamb mortality rate, KBSKS: Number of lambs sold per ewe, SOKCA: Average live weight of lambs sold, KBSKCA: Live weight of lamb sold per ewe; KBBG: Gross income per ewe: *Varyans component·10^{-2}

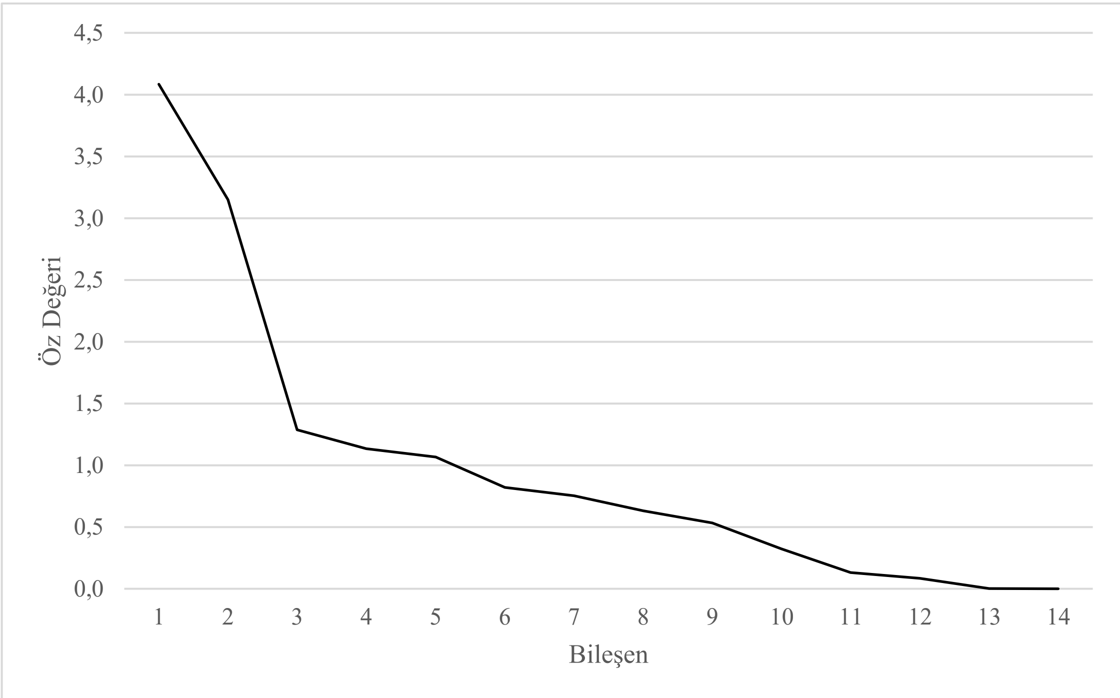

Figure 3. Progression of the eigenvalues of the components according to the principal component analysis

Şekil 3. Temel bileşenler analizi sonucuna göre bileşenlerin öz değerlerinin değişimi

Şekil 3'de temel bileşenler analizi sonucuna göre bileşenlerin öz değerleri verilmektedir. Genellikle öz değerleri 1'in üzerinde olan bileşenler toplam varyasyonun en büyük kısmını açıkladığı için diğerleri ihmal edilebilir (Kaiser, 1991). Diğer bir yaklaşımda ise öz değerlerdeki bileşenden bileşene değişimin aniden azalması öncesindeki bileşenlerin özetleme için yeterli olduğu ifade edilmektedir (Greenacre ve ark., 2022). *Şekil 3*'te görülebileceği gibi üçüncü bileşenden itibaren (dirsek noktası) öz değerlerin düşüşünde ani bir azalma olmaktadır. Ancak öz değerlerinin beşinci bileşene kadar 1 değerinin üzerinde kaldığı görülmektedir (diğer bir dirsek noktasının burası olduğu da söylenebilir). Nitekim temel bileşenler analizinde ilk üç bileşen toplam varyasyonun %61'ini açıklamaktadır. Buna karşın beşinci bileşene kadar dikkate alındığında bu değer %77'ye çıkmaktadır.

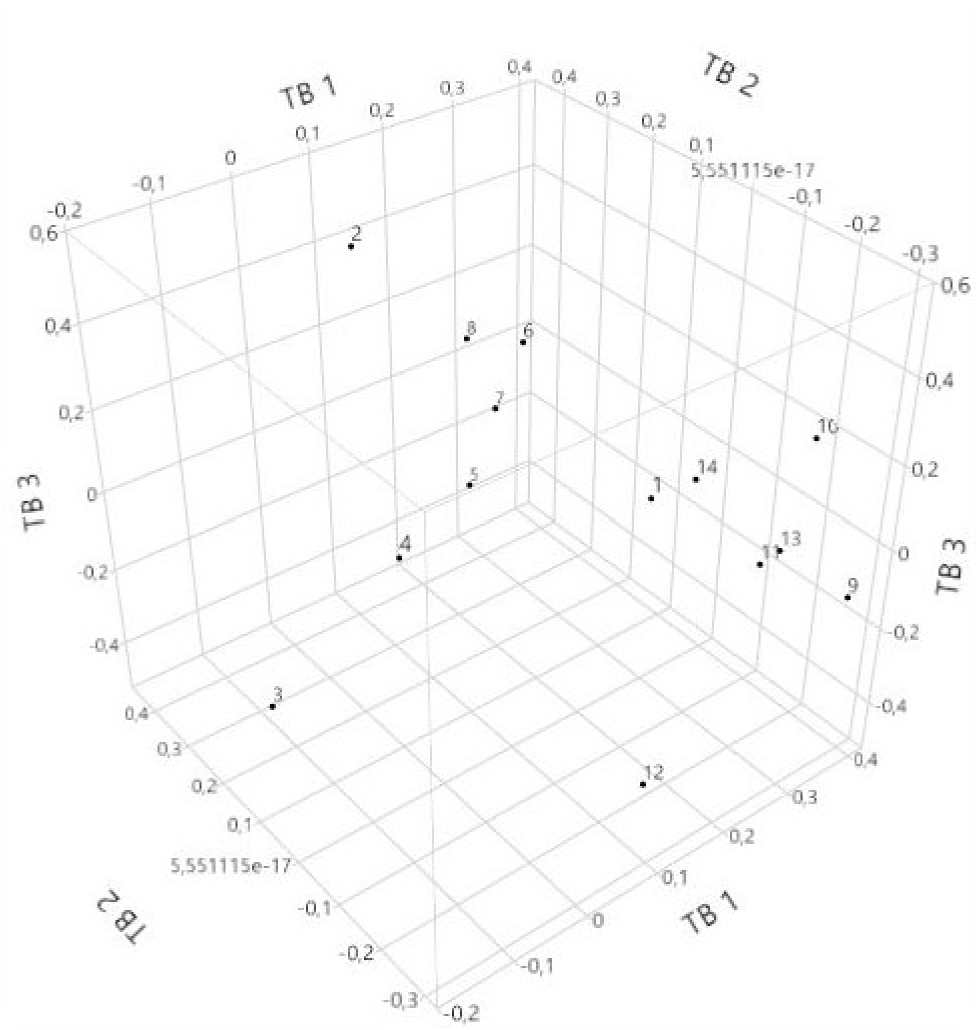

Figure 4. Intersection of the first three principal component values based on sheep production data and crop production areas

Şekil 4. İşletme koyunculuk verileri ve bitkisel üretim alanları temelinde ilk üç temel bileşen değerlerinin kesişimi

(KAKS (1): Koç altı koyun sayısı; KBSS (2): Koç altı koyun başına satılan süt miktarı; DKO (3): Doğuran koyun oranı; KÖO (4): Kuzu ölüm oranı, KBSKS (5): Koç altı koyun başına satılan kuzu sayısı, SOKCA (6): Satılan kuzu ortalama canlı ağırlığı, KBSKCA (7): Koç altı koyun başına satılan kuzu canlı ağırlığı; KBBG (8): Koç altı koyun başına brüt gelir; Toplam arazi varlığı (9); Sulanabilir arazi varlığı (10); Sebze ekim alanı (11); Zeytinlik (12); Tahıl Ekim Alanı (13); Yem Bitkileri Ekim Alanı (14))

(KAKS (1): Number of ewes; KBSS (2): Amount of milk sold per ewe; DKO (3): Proportion of lambing ewes; KÖO (4): Lamb mortality rate, KBSKS (5): Number of lambs sold per ewe, SOKCA (6): Average live weight of lambs sold, KBSKCA (7): Live weight of lamb sold per ewe; KBBG (8): Gross income per ewe; Total Land Area (9); Irrigable land area (10); Vegetable growing area (11); Olive groves (12); Cereal growing area (13); Fodder crops cultivation area (14))

Şekil 4'te çalışmada ele alınan tüm parametrelerin birbirlerine uzaklıklarını gösteren temel bileşenler analizi sonuçlarının üç temel bileşen üzerinden gösterimine ilişkin grafik verilmiştir. Bu üç bileşen varyasyonun %61'ini açıklasa da üç boyut dışında görselleştirmenin mümkün olmaması nedeniyle bu şekilde açıklanmaya çalışılacaktır. *Şekil 4*'ten görülebileceği gibi ve beklendiği şekilde koyunculuğa ilişkin parametrelerin bir tarafta, arazi ve bitkisel üretim verilerine ilişkin özellikler ise diğer yanda toplanmıştır. Özellikle kuzu üretimi ve özelliklerine ilişkin işletme parametreleri birbirlerine yakındır. Koyun başına brüt gelirde kuzu üretim parametrelerinin payının yüksek oluşu KBBG'nin de kuzu üretim parametrelerine yakın olmasını sağlamıştır. İlginç bir şekilde KÖO ve DKO bu parametrelerden oldukça uzakta yer almaktadırlar. Öte yandan KBBS'nin de koyunculuğa ilişkin üretim parametrelerinin uzağına düştüğü gözlenmiştir. KAKS koyunculuk parametreleri ile bitkisel üretim özelliklerinin arasında yer almakta; özellikle yem bitkileri üretim alanına yakındır. Zeytin alanları parametresi diğer bitkisel üretim özelliklerinden oldukça uzaktadır.

Tablo 2'de işletmelerin toplam ve sulanabilir arazi varlıklarının koyunculuğa ilişkin parametrelere etkisine ilişkin regresyon analizi bulguları verilmiştir. Buna göre işletmenin arazi varlığı yalnızca KBSS miktarını olumsuz olarak etkilemektedir (P=0.0159). Buna karşın sulanabilir arazi varlığının DKO üzerinde olumsuz, SOKCA, KBSKCA ve KBBG üzerinde olumlu etkisi bulunmaktadır (P≤0.0397).

Tablo 2. İşletmelerin arazi varlığı (da) ve sulanabilir arazi varlıklarının (da) koyunculuk özelliklerine etkisine ait regresyon denklemlerine ilişkin sabitler (β_0), regresyon katsayıları (β_i), standart hataları (SH) ve istatistiksel anlamlılık değerleri (P)

Table 2. Constants (β_0), regression coefficients (β_i), standard errors (SH) and statistical significance values (P) for the regression equations of the effect of land area (da) and irrigable land area (da) on sheep production traits

Özellik	Sabit			Arazi Varlığı			Sulanabilir Arazi			
	β_0	SH	P	β_1	SH	P	β_2	SH	P	R^2
KAKS, baş	100.77	6.427	<0.0001	0.14	0.124	0.2691	0.24	0.150	0.1197	0.1434
KBSS, l	41.58	2.217	<0.0001	-0.11	0.042	0.0159	0.06	0.052	0.2444	0.0776
DKO, %	97.33	0.362	<0.0001	-0.00	0.007	0.9492	-0.02	0.008	0.0251	0.1260
KÖO, %	6.45	0.597	<0.0001	-0.00	0.011	0.7329	0.00	0.013	0.9885	0.0029
KBSKS*, baş	107.73	2.975	<0.0001	-0.02	0.057	0.6946	0.08	0.069	0.2431	0.0221
SOKCA, kg	31.59	0.409	<0.0001	-0.00	0.008	0.7117	0.02	0.010	0.0195	0.1069
KBSKCA, kg	34.16	1.115	<0.0001	-0.01	0.022	0.5520	0.05	0.026	0.0397	0.0470
KBBG, TL	6910.77	211.341	<0.0001	-5.29	4.075	0.1981	10.84	4.932	0.0308	0.0575

KAKS: Koç altı koyun sayısı; KBSS: Koç altı koyun başına satılan süt miktarı; DKO: Doğuran koyun oranı; KÖÖ: Kuzu ölüm oranı, KBSKS: Koç altı koyun başına satılan kuzu sayısı, SOKCA: Satılan kuzu ortalama canlı ağırlığı, KBSKCA: Koç altı koyun başına satılan kuzu canlı ağırlığı; KBBG: Koç altı koyun başına brüt gelir; *Regresyon denkleminin sabiti ile katsayıları ve standart hataları "10^{-2}" ile çarpılmalıdır.
KAKS: Number of ewes; KBSS: Amount of milk sold per ewe; DKO: Proportion of lambing ewes; KÖO: Lamb mortality rate, KBSKS: Number of lambs sold per ewe, SOKCA: Average live weight of lambs sold, KBSKCA: Live weight of lamb sold per ewe; KBBG: Gross income per ewe; *The constant and the coefficients and standard errors of the regression equation should be multiplied by "10^{-2}".

Tablo 3'te geriye doğru aşamalı regresyon yöntemi ile analiz edilen bitkisel üretim arazi büyüklüklerinin işletmenin süt koyunculuğuna etkileri özetlenmiştir. Koç altı koyun sayısının bağımsız değişken olduğu denklemde, regresyon katsayılarının sıfırdan farkına ilişkin önem seviyesi P ≤0.10 olan bitki türleri grubunun yem bitkileri olduğu görülmektedir. Yem bitkileri ekim alanı büyüdükçe sürünün de büyüdüğü ifade edilebilir. KBSS bakımından ise modelde zeytinlik varlığı regresyon katsayısının istatistiksel olarak önemli olduğu görülmektedir (P=0.0321). Buna göre işletmenin zeytinlik arazisi büyüdükçe KBSS düşmektedir. DKO tahıl ekim alanı büyüklüğünden istatistiksel önemli derecede negatif olarak etkilenmektedir (P=0.0017). Öte yandan SOKCA ise tahıl ekim alanı büyüklüğünden olumlu etkilenmektedir (P=0.0463). Benzer şekilde KBSKCA tahıl ekim alanı büyüklüğünden olumlu etkilenmektedir (P=0.0843).

4. Tartışma

Çalışmaya konu işletmelerin %21'inin topraksız oldukları belirlenmiştir (*Şekil 1*). Topraksız köylü ya da çiftçi, özellikle erken Cumhuriyet tarihimizde üzerinde çokça durulan konular arasındadır (Karaömerlioğlu, 1998; Önal, 2010; Aydın, 2018). Ancak güncel topraksız çiftçi istatistiğine ulaşmak mümkün olmamıştır. Bu konuda ulaşılabilen en erken tarih olan 1981 yılında kırsalda topraksız aile oranı %27.2'dir (Oral, 2006). Günümüzde de bu oranın çok düşük olmadığı tahmin edilmektedir. Nitekim bu çalışmada süt koyunu yetiştiricilerinin %21'nin topraksız olması ve küçükbaş hayvan yetiştiriciliğine yönelik yapılan birkaç çalışmada bu oranın %3.1 ile %35.2 arasında değişmesi, en azından topraksız çiftçi konusunun küçükbaş yetiştiricisi acısından sürdüğünü göstermektedir (Paksoy ve ark., 2006; Bilginturan ve Ayhan, 2009; Kandemir ve ark., 2015). Öte yandan arazisi bulunan işletmeler içerisinde ortalama arazi varlığının düşüklüğü araştırmaya konu süt koyunu yetiştiricilerinin toprak fakiri olduklarını göstermektedir.

Tablo 3. İşletmelerin bitkisel üretim alanlarının (da) koyunculuk özelliklerine etkilerine ait regresyon denklemlerine ilişkin sabitler (β_0), regresyon katsayıları (β_i), standart hataları (SH) ve istatistiksel anlamlılık değerleri (P)

Table 3. Constants (β_0), regression coefficients (β_i), standard errors (SH) and statistical significance values (P) of regression equations for the effects of crop production area (da) on sheep production traits

Özellik	Faktör	Sabit	Zeytin	Tahıl	Yem Bitkileri	R^2
	$(\beta_0)\ \beta_i$	107.62	-	-	1.16	
KAKS	*SH*	4.802	-	-	0.384	0.1009
	P	<0.0001	-	-	0.0032	
	$(\beta_0)\ \beta_i$	39.60	-0.20	-	-	
KBSS	*SH*	1.65	0.100	-	-	0.0548
	P	<0.0001	0.0321	-	-	
	$(\beta_0)\ \beta_i$	97.57	-	-0.02	-	
DKO	*SH*	0.347	-	0.007	-	0.1134
	P	<0.0001	-	0.0017	-	
	$(\beta_0)\ \beta_i$	31.40	-	0.02	-	
SOKCA	*SH*	0.015	-	0.008	-	0.0480
	P	<0.0001	-	0.0463	-	
	$(\beta_0)\ \beta_i$	33.49	-	0.04	-	
KBSKCA	*SH*	1.084	-	0.020	-	0.0359
	P	<0.0001	-	0.0843	-	

KAKS: Koç altı koyun sayısı; KBSS: Koç altı koyun başına satılan süt miktarı; DKO: Doğuran koyun oranı; SOKCA: Satılan kuzu ortalama canlı ağırlığı KBSKCA: Koç altı koyun başına satılan kuzu canlı ağırlığı
Geriye doğru aşamalı regresyon yöntemi sonucunda tüm etkilerin modelden çıkarıldıkları parametreler ile bağımlı parametrelerin hiçbirinin regresyon denkleminde yer almaması durumunda bağımsız değişkenler (bitki grupları) tabloda yer almamaktadır.
KAKS: Number of ewes; KBSS: Amount of milk sold per ewe; DKO: Proportion of lambing ewes; SOKCA: Average live weight of lambs sold, KBSKCA: Live weight of lamb sold per ewe
Parameters for which all effects were removed from the model as a result of the backward stepwise regression method and independent variables (plant groups) that are not included in the regression equation of any of the dependent parameters are not included in the table.

2022 yılına göre Türkiye ekilebilir topraklarının %69’unda tarla bitkileri ekimi, %3’ünde sebze ekimi yapılmaktadır. Zeytinlikleri de içeren meyve, içecek ve baharat bitkileri ekim/dikim alanı ise Türkiye’nin toplam ekilebilir topraklarının %15’ine denk gelmektedir (Anonim, 2023). Çalışmaya konu işletmelerin tahıl ekim topraklarına yem bitkileri de eklendiğinde %71 ile yaklaşık Türkiye’yi temsil ettiği gözlenmektedir (*Şekil 2*). Benzer şekilde işletmelerin toplam arazi varlıklarının %14’ünü oluşturan zeytinlikler de Türkiye meyve, içecek ve baharat bitkileri ekim/dikim alanı oranına yakın bir değerdedir. Her ne kadar işletmelerin %28’i yem bitkileri ekimi yapmaktaysa da işletmelerin toplam arazi varlığının %9’unda yem bitkileri ekimi yapılmaktadır. Bu oran Türkiye için %8’dir (Acar ve ark., 2020). Çalışmaya konu işletmelerin toprak varlığının bitkisel üretim anlamındaki dağılımın Türkiye’nin geneliyle örtüşmesine karşın bu işletmelerin hepsinin süt koyunu yetiştiriciliği de yapıyor olmaları akılda tutulmalıdır.

İşletmelerin sürü büyüklükleri (KAKS) ortalamasının Çanakkale için bildirilen ortalama değerlerin biraz üzerinde olduğu gözlenmiştir (Ayağ ve ark., 2018). İller bazında yapılan çalışmalarda ortalama sürü büyüklükleri 74.2 ile 381.9 arasında değişmektedir (Kocaman ve Günal, 2006; Paksoy ve ark, 2006; Bilginturan ve Ayhan, 2009; Ceyhan ve ark., 2015; Demir ve ark., 2015; Tamer ve Sarıözkan, 2017; Özyürek ve ark., 2018; Arıtunca ve Karabacak, 2020; Oral Hanoğlu ve ark., 2021; Köseman ve ark., 2022; Bozkurt ve ark., 2023). Sürü büyüklüğü muhtemelen aile büyüklüğü, arazi varlığı, mera olanakları gibi faktörlerce belirlenmektedir.

Ayağ ve ark. (2018) 2009-2016 yılları arasında Çanakkale il genelinde çiğ süt desteklemelerine tabi olan müstahsil makbuzları üzerinden 1.152,0 işletmeye ait koyun başına satılan süt miktarını tahmin etmişlerdir. Bu değerin Kıvırcık sürülerinde 37 l, Sakız sürülerinde 47.4 l ve Tahirova sürülerinde ise 67.5 l olduğu belirlenmiştir. Bu çalışmanın öznesi süt koyunculuğu işletmeleri olmasına karşın koyun başına satılan süt miktarının nispeten düşük olmasının bir nedeni yılların etkisi olabilir. Ancak bu değerlendirmede örnek büyüklükleri arasındaki farkın da dikkate alınması gerekir. Öte yandan satılan süt miktarı üzerine özellikle süt fiyatlarının etkili olabileceği düşünülmektedir. Örneğin süt fiyatının düşük olduğu yıllarda kuzular daha geç sütten kesilerek, muhtemelen daha ziyade kuzu büyütmeye odaklanılmaktadır.

Doğuran koyun oranı ya da tersi kısır kalan koyun oranı koyunculukta önemli bir üretim parametresidir. Saha çalışmalarından elde edilen bulgularda doğuran koyun oranı (ya da kısırlık oranının tersi) %87.7 ile %97.8 arasında değişmektedir (Bilginturan ve Ayhan, 2009; Bingöl ve Aygün, 2013; Demir ve ark., 2015; Şireli, 2019; Arıtunca ve Karabacak, 2020; Demir ve Aygün, 2021; Türkmen ve Çak, 2021). Buna karşın kısır koyun oranı enstitü koşullarında Ceyhan ve ark. (2007) tarafından Kıvırcık ırkı için %20.2, Gökçeada ırkı için %32.4 ve Sakız ırkı için %25.5 olarak bildirilmiştir. Muhtemelen halk elindeki sürülerde koçlar daha uzun süre, hatta sürekli koyunların içinde bulunmaktayken enstitü koşullarında belirlenen aşım dönemi sonrasında koçlar ayrılmaktadır.

Türkiye’de yapılan çalışmalarda kuzu dönemi ölüm oranı için %3.62 ile %9.5 arasında değerler rapor edilmiştir (Bilginturan ve Ayhan, 2009; Demir ve ark., 2015; Tamer ve Sarıözkan, 2017; Şireli, 2019; Türkmen ve Çak, 2021). Bu anlamda bu araştırmada bulgulanan kuzu ölüm oranlarının makul sınırlar içerisinde olduğunu söylemek gerekir. Öte yandan birinci ve ikinci yıl için sırasıyla 32.5 kg ve 31.9 kg olan kuzu ortalama satış canlı ağırlıkları Tahirova kuzuları için bildirilen sütten kesim (90. gün) canlı ağırlıklarına yakın değerlerdir (Savaş ve ark., 2022).

Koç altı koyun başına satılan kuzu canlı ağırlığı işletmenin verimliliğine ilişkin oldukça iyi ve pratik bir göstergedir. Bu özellik kısırlık oranı, doğum tipi ve kuzu satışına dek büyümenin bir fonksiyonudur. Bu değer paraya çevrildiğinde ve buna koç altı koyun başına süt verimi eklendiğinde koç altı koyun başına brüt gelir elde edilir. Buradan yola çıkarak koç altı koyun başına maliyet hesaplanarak net gelir bulunabilir. Böylece optimum sürü büyüklüğünü de tahmin etmek mümkün olacaktır.

Özellikler bakımından çalışmanın yürütüldüğü iki yıl için orta ve orta düşük tekrarlanabilirlikler işletmelerin birbirlerinden çok farklılaşmadıklarına işaret etmektedir (*Tablo 1*). Yıllar arası işletmeler arası varyasyon ile işletme içi varyasyonun birbirine yakın olduğu görülmektedir.

Bu çalışmada temel bileşenler analizi ele alınan parametrelerin birlikte özetlenmesi amacıyla kullanılmıştır. Bilindiği gibi temel bileşen analizi değişkenler arasındaki ilişkileri kullanarak çok sayıda değişkeni bileşenler halinde özetlemektedir. Temel bileşenler analizindeki amaç gözlenen değişkenlere ait bilgileri mümkün olduğunca kaybetmeden değişken sayısını azaltmaktır. Bu çalışmada analiz sonucunda görsel olarak hangi parametrelerin birlikte hareket edebileceğine ilişkin fikir edinmek amaçlanmıştır. Öncelikle bileşenlerin öz değerlerinin değişimi ele alınarak, parametrelerin birlikte ele alınmasından kaç “özellikte” özetlenebileceği üzerinde fikir edinilmiştir (*Şekil 3*). Şekilden toplam varyasyonun büyük kısmının 5 bileşen ile açıklanabildiği görülmektedir. Ancak 5 boyutlu olarak görselleştirmek mümkün olmadığı için parametreler arası ilişkiler, varyasyonun % 61’ini açıklayan üç temel bileşen ile üç boyutlu olarak görselleştirilmiştir (*Şekil 4*). Söz konusu grafikte sulanabilir arazi varlığının yem bitkileri ekimini teşvik ettiği, onun da sürü büyüklüğüne etkili olduğu sonucu çıkarılabilir. Öte yandan kuzu üretimine ilişkin parametrelerin birbirlerine yakınlığı dikkati çekmektedir. Koyun başına gelirin büyük kısmının da kuzu parametrelerinin etkisi altında olduğu açıkça görülmektedir.

İşletmelerin toplam ve sulanabilir arazi büyüklüklerinin koyunculuk faaliyetine doğrusal etkilerine bakıldığında satılan süt miktarının toplam arazi büyüklüğünden olumsuz etkilendiği gözlenmektedir (*Tablo 2*). Muhtemelen bunun sebebi arazi varlığının büyümesinin iş yoğunluğunu artırıyor olması; aile işgücüne dayalı bu işletmelerde bitkisel üretim faaliyetleri ile sağım döneminin kesişmesi neticesinde satılan sütün azalmasıdır. Özellikle süt fiyatlarının nispeten düşük olduğu yıllarda bu durumun daha da belirginleşeceği düşünülebilir (Ayağ ve ark., 2018). Diğer koyunculuk parametreleri üzerine toplam arazi büyüklüğünün doğrusal bir etkisi görülmemektedir. Ancak sulanabilir arazi büyüklüğü doğuran koyun oranını olumsuz etkilemesine karşın, satılan kuzu ortalama canlı ağırlığını, koyun başına satılan kuzu canlı ağırlığını ve koyun başına brüt geliri olumlu etkilemektedir. DKO’nun sulanabilir arazi büyüklüğünden olumsuz etkilenmesinin altında olasılıkla yatan neden sulama gerektiren sebze üretim dönemi (ağırlıkla domates üretimi) ile aşım döneminin çakışması, ancak yoğun sebze üretim faaliyeti nedeniyle koyunculuğa “ilginin” azalmasıdır. Öte yandan kuzu büyütme dönemi nispeten bitkisel üretim faaliyetlerinin daha az olduğu bir dönemdir. Ayrıca sulanabilir arazi varlığı nedeniyle kaliteli kaba yem üretme olanağının bulunması ve bu üretimin kuzu büyütmeyi desteklemesi kuzu parametrelerinin sulanabilir arazi büyüklüğünden olumlu etkilenmelerini açıklayabilir.

Bitki gruplarının koyunculuk parametrelerine doğrusal etkisine bakıldığında yem bitkileri ekim alanı büyüklüğü sürü büyüklüğünü (KAKS) desteklemektedir (*Tablo 3*). Beklendiği gibi yem bitkileri üretme olanağı olan veya yem bitkileri üreten işletmeler daha fazla sayıda koyuna bakabilmektedirler. Öte yandan zeytinlik büyüklüğü satılan süt miktarını olumsuz etkiliyor gözükmektedir. Zeytinliklerde ilkbahar ve erken yaz döneminde bakım işleri nispeten yoğundur (Özcan, 2020). Bu dönem sağım dönemine denk gelmektedir. Dolayısıyla yukarıda belirtildiği gibi aile işgücünün dağılması ve sağımın sekteye uğraması; hatta süt fiyatlarının nispeten düşük olduğu bazı yıllarda tamamen bırakılması söz konusu olabilir. Geriye doğru aşamalı regresyon yöntemi ile oluşturulan ve bağımlı değişkenlerin koyunculuk parametreleri, bağımsız değişkenlerin ise bitki grupları arazi ekim büyüklükleri analizi sonucuna göre DKO’nun tahıl ekim alanı büyüklüğünden olumsuz etkilendiği gözlenmektedir. Bu noktada Tablo 1’deki bulgulara atfen sebze üretiminin de DKO miktarını olumsuz etkilemesi beklenebilir. Ancak iki farklı analiz sonucu farklı noktaları işaret etmektedir. Muhtemelen sulanabilir arazi varlığı, tamamen olmasa da sebze ekimini daha fazla yansıtmaktadır. Aynı zamanda suya bağlı diğer bitkilerin (yem bitkileri gibi) üretimini de içermektedir. Hatta sulanabilir arazi olmasına karşın kuru koşullarda yetiştirilen bitkiler de bu alanın içerisinde olabilir. Ancak gerçekten de tahıl üretim alanı büyüklüğünün DKO’ya doğrusal olumsuz etkisini açıklamak zordur. Buna karşın tahıl üretim alanı büyüklüğü SOKCA (P=0.0463) ve KBSKCA’yı (P=0.0843) desteklemektedir. Muhtemelen üretilen tahıllar koyun ve kuzu beslemede yoğun olarak kullanılmaktadır (Ayağ ve Savaş, 2011). Buna bağlı olarak enerji yoğun tahıllar kuzu canlı ağırlıklarını artırmaktadır. Ancak regresyon modellerinin determinasyon katsayılarının düşüklüğü (R^2=0.0359-0.1134) yorumlara dikkatle yaklaşılmasını gerektirmektedir.

Süt koyunculuğunun ve hatta tüm hayvancılık faaliyetlerinin, genel hayvancılık bilgisi dahilinde söz konusu faaliyetleri gerçekleştiren işletmelerin arazilerinde hayvancılığı destekleyecek üretim yapmaları beklenir. Diğer bir deyişle işletmelerin arazi varlıklarının tüm hayvancılık parametrelerini olumlu etkilemeleri gerektiği düşünülebilir. Ancak araştırmaya konu işletmelerde bu durumun gerçekleşmediği gözlenmektedir. Bunun muhtemel nedenleri arasında koyunculukta beslemenin tamamen meraya bağlanması yönündeki alışkanlıkların olduğu söylenebilir. Öte yandan bazı bitkisel ürünlerin, koyunculuğu destekleyecek bitkisel üretimden daha yüksek getirisinin olması da muhtemeldir. Yıllar bakımından farklılaşsa da domates üretiminin böyle bir yönünün olduğu tahmin edilmektedir.

5. Sonuç

Bu çalışmada önemli bir yan bilgi olarak Türkiye’de topraksız çiftçiliğin halen azımsanmayacak boyutta olabileceği ortaya konmuştur. Özellikle küçükbaş hayvancılık ile iştigal eden çiftçilerde bu durumun daha belirgin olabileceği tahmin edilmektedir. Öte yandan yine koyunculuk ile uğraşanların toprak fakiri oldukları da söylenebilir. Buna bağlı olarak topraksızlık ya da toprak fakirliği köylüleri muhtemelen küçükbaş hayvan yetiştiriciliğine yönlendirmektedir.

Araştırmaya konu işletmeler her ne kadar süt koyunculuğu faaliyeti içerisinde bulunsalar da kuzu gelirinin süt gelirinden daha yüksek olduğu ortaya çıkmaktadır. Bu anlamda Türkiye’nin koyun sütü gereksinimi ve süt koyunculuğu üretim sistemlerinin detaylı analizine ihtiyaç bulunmaktadır.

Her ne kadar koyunculuk parametrelerini olumsuz etkileyen bitkisel üretim faaliyetlerinin, bunlarla koyunculuk faaliyetlerinin çakışması neticesinde iş yoğunluğuna bağlanabileceği tartışılsa da bu durumun net olarak söylenebileceği konusunda emin olunamamaktadır. Ancak bu araştırmada özellikle ele alınan kuzu üretim parametrelerinin bazı bitkisel üretim gruplarından olumlu etkilenmesi bu üretim gruplarının nispeten yüksek getirisi olan kuzu üretimini desteklediğini göstermektedir. Nitekim muhtemelen sütten ziyade kuzunun getirisinin büyük olması yetiştirici konsantrasyonunun da kuzuya yönelmesine neden olmaktadır.

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Bu çalışma için etik kuruldan izin alınmasına gerek yoktur.

Çıkar Çatışması Beyanı

Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz

Yazarlık Katkı Beyanı

Literatür Tarama ve Planlama: Savaş, T., Ayağ, B.S.; Veri Toplama: Ayağ, B.S.; İstatistiksel Analiz: Savaş, T.; Bulguların Değerlendirmesi: Savaş, T., Ayağ, B.S.; Makalenin Kaleme Alınması: Savaş, T., Ayağ, B.S.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Development of New Models Using Empirical Modeling of Global Solar Radiation and Its Application in Usak City, Turkey

Global Güneş Radyasyonun Ampirik Modellenmesi için Yeni Modellerin Geliştirilmesi ve Uşak İlinde Uygulanması

Rabia ERSAN[1*], Recep KÜLCÜ[2]

Abstract

With this study, 12 empirical models in the literature, 2 new models developed within the scope of this study, SARAH and CMSAF satellite-based models, COSMO and ERA5 re-analysis solar radiation data sets in the PVGIS database were compared in order to detect the monthly average global solar radiation coming to the horizontal plane of Usak province. New models developed within the scope of the study; it uses the region's temperature, cloudiness coefficient and sunset hour angle. In comparison of the datas within the scope of the study; coefficient of determination (R^2), mean percent error (MPE), deviation error (MBE), root mean square error (RMSE), absolute relative error (ARE) parameters were used. As a result of the evaluations, the method that most successfully predicts the global solar radiation values of Usak province was tried to be determined. According to the monthly evaluation of the models; It was determined that 14 models and satellite-based systems have absolute relative error values below 5% in March-April-May-June, September-October and December. The most accurate estimates were realized for May in 16 of 18 different estimation methods used in the study. The coefficient of determination of empirical models and PVGIS data sets was above 0.97. When the success of the models was evaluated according to the RMSE values, It was determined that the logarithmic based Model 14 (0.90058 RMSE, 0.98327 R^2, -1.079894 MPE, -0.05033 MBE, 0.185628 t) which was obtained by using the sunset hour angle and the max-min temperature difference developed within the scope of this study, made the most accurate estimations. COSMO data from spatial data (1.053134 RMSE, 0.979036 R^2, -1.196348 MPE, -0.25105 MBE, 0.8141 t) made successful estimations, but the accuracy of the COSMO data was lower than the data estimated by Model 14. It was concluded that used the models and satellite-based systems were generally successful. As a result, In the studies to be carried out for the global solar radiation forecast of Usak province. It has been concluded that Model 14 developed within the scope of the study can be used in precise calculations and COSMO data from PVGIS datas can be used in more superficial or pre-feasibility studies.

Keywords: Solar energy, Global solar radiation, Modelling, PVGIS, Usak (Turkey).

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Öz

Bu çalışma ile Uşak iline yatay düzleme gelen aylık ortalama global güneş radyasyonunun tespit edilebilmesi için literatürde yer alan 12 amprik model, bu çalışma kapsamında geliştirilen 2 yeni model ve PVGIS veri tabanında yer alan SARAH ve CMSAF uydu tabanlı ile COSMO ve ERA5 yeniden analiz veri setleri karşılaştırılmıştır. Çalışma kapsamında geliştirilen yeni modeller; bölgenin sıcaklık, bulutluluk oranı ve saat açısını kullanmaktadır. Çalışma kapsamındaki verilerin karşılaştırılmasında; determinasyon katsayısı (R^2), ortalama yüzde hata (MPE), sapma hatası (MBE), ortalama karekök hatası (RMSE) ve yüzde hata (IeI) parametreleri kullanılmıştır. Değerlendirmeler sonucunda Uşak ilinin global güneş radyasyonu değerlerini en başarılı tahmin eden yöntem belirlenmeye çalışılmıştır. Modellerin aylık değerlendirmesine göre; Mart-Nisan-Mayıs-Haziran, Eylül-Ekim ve Aralık aylarında 14 modelin ve uydu tabanlı sistemlerin mutlak bağıl hata değerlerinin %5'in altında olduğu belirlenmiştir. Mayıs ayı için çalışmada kullanılan 18 farklı tahmin yönteminden 16'sında en doğru tahminler gerçekleşmiştir. Ampirik modellerin ve PVGIS veri setlerinin belirleme katsayısı 0,97'nin üzerindedir. Modellerin başarısı RMSE değerlerine göre değerlendirildiğinde bu çalışma kapsamında geliştirilen; saat açısı ve maks- min sıcaklık farkını kullanan logaritmik tabanlı Model 14'ün (0.90058 RMSE, 0.98327 R^2, -1.079894 MPE, -0.05033 MBE ve 0.185628 t) en doğru tahminleri yaptığı belirlenmiştir. Konumsal verilerden COSMO yeniden analiz verisi (1.053134 RMSE, 0.979036 R^2, -1.196348 MPE, -0.25105 MBE ve 0.8141 t) başarılı tahminler gerçekleştirmiş fakat COSMO verilerinin doğruluk seviyesi Model 14 tarafından tahmin edilen verilerden daha düşük gerçekleşmiştir. Çalışma ile kullanılan modellerin ve uydu tabanlı sistemlerin genel olarak başarılı olduğu sonucuna varılmıştır. Sonuç olarak Uşak ilinin global güneş radyasyonu tahmini için gerçekleştirilecek hassas hesaplamalarda çalışma kapsamında geliştirilen Model 14'ün kullanılabileceği, daha yüzeysel ya da ön fizibilite çalışmalarında PVGIS içerisinde yer alan COSMO yeniden analiz verisinin kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Güneş enerjisi, Küresel güneş radyasyonu, Modelleme, PVGIS, Uşak (Turkey).

1. Introduction

The need for energy was constantly increasing due to industrialization, agricultural production and developments in urban life in the World. Fossil energy resources were used a large extent to meet the rapidly increasing energy need since the industrial revolution. However, there had been a rapid transition from fossil energy sources, which were the main source of GHGs (Greenhouse gases) that cause global climate change, to renewable resources in recent years. Solar energy was the source with the highest potential among renewable energy sources. Solar energy was a source of heat and light for our World and the living creatures on it, as well as in shaping climates. Turkey due to the geographical feature has a high solar energy potential (Artkın, 2018). The average annual sunshine duration of Turkey was calculated as 2640 hours (daily total of 7.2 hours), average total solar radiation was 1311 kWh m^{-2} $year^{-1}$ (daily total of 3.6 kWh m^{-2}), solar energy potential was 380 billion kWh $year^{-1}$ (Anonymous, 2020a).

Önler and Kayişoğlu (2023), were determined Monthly, seasonal, and annual optimum tilt angles using meteorological insolation data from many years in the provinces of Tekirdag and Konya in the study they conducted. At optimum tilt angles, monthly, seasonal, and annual total radiation on the tilted surface were 1516.7 kWh m^{-2} $year^{-1}$, 1504.1 kWh m^{-2} $year^{-1}$ and 1448.1 kWh m^{-2} $year^{-1}$ in Tekirdag, respectively. In Konya, these values were 1851.4 kWh m^{-2} $year^{-1}$, 1833.51 kWh m^{-2} $year^{-1}$ and kWh m^{-2} $year^{-1}$, respectively. In both provinces, it was observed that there was no significant difference in the total radiation values coming to the tilted surface in monthly and seasonal optimum tilt angles (1%). At the annual optimum tilt angle, a decrease of approximately 5% was observed in the total amount of radiation coming to the tilted surface compared to the monthly optimum tilt angle.

As can be seen from literature studies, due to the differences in the angle of incidence of global solar radiation on the horizontal surface, the solar energy falling on the horizontal surface varies spatially, and therefore the ideal model must be determined for each location. There are many models used in global solar radiation prediction. However, these prediction models vary according to the climate and geographic characteristics of the region involved. When the prediction model determined for a region is used in a different region, the prediction model may not work. In order to gain absolute and stable results from these models, the studies should be either custom-made or teste (Külcü and Ersan, 2021).

Solar radiation observations were useful data sources used to measure the average incident radiation. In the lack of solar radiation observations, it was possible to estimate the solar radiation using data obtained from nearby locations with similar climates or empirical models using parameters such as sunshine duration, cloudiness, environmental temperature and etc. (Duffie and Beckman, 1980; Kallioğlu et al., 2015). Since the repair, maintenance and investment costs of solar radiation measuring devices are very high, they cannot be placed at every measurement point. For this reason, empirical models or satellite-based forecasting systems are usually used in solar radiation calculations (Işık and İnallı, 2011; Gül and Çelik, 2017).

Psiloglue et al. (2020), examined the performance of the estimated solar radiation components obtained via the Meteorological Radiation Model, satellite-based data sets (CAMS, PVGIS-CMSAF-SARAH) and reanalysis (PVGIS-ERA5) against ground measurements taken with the Sunshine-Pyranometer at Methoni Station, Greece. Then, they compared the estimation results obtained. The MRM uses astronomical values (solar constant, seasonally adjusted Sun-earth distance, solar altitude and azimuth, inclination) and widely available meteorological parameters (air temperature, relative humidity, surface pressure and sunshine fraction) as inputs. The results showed that MRM simulates the global (RMSE~12%) and direct horizontal (RMSE~16-21%) irradiations in higher accuracy compared to CAMS (RMSE ~19-28%, respectively), while CAMS represented better the diffuse radiation (RMSE 46% for MRM and RMSE 38% for CAMS). The PVGIS data sets revealed high uncertainties in the simulation of the instantaneous solar irradiances; their performance was lower compared to MRM and CAMS, although a direct comparison cannot be applied. CMSAF showed better estimates, while the reanalysis ERA5 resulted in similar statistics with the satellite-based SARAH.

Supit and Van Kappel (1998) aimed to use daily global radiation estimates as input for the European Union Plant Growth Monitoring System. For this purpose, they developed an estimation model from the maximum-minimum temperature and average daily cloudiness datas obtained from meteorological sources. The developed model had been tested in various regions of Europe from Finland to Italy. Comparison of measured and estimated global irradiance values in the tested regions was made, and an average of 2.48 RMSE and -0.25 MJ m^{-2} day MBE values were found.

Almorox et al. (2013) in the daily global solar radiation estimation study from the temperature data of Canada de Luque, Cordoba, Argentina region; they made estimations of solar radiation with Hargreaves-Samani, Allen, Samani, Bristow-Campbell, Almorox and linear regression models. The results showed that, all the analyzed models were robust and accurate (R^2 and RMSE values between 0.87 to 0.89 and 2.05 to 2.14, respectively), so global radiation can be estimated properly with easily available meteorological variables when only temperature data are available. While Hargreaves-Samani, Allen, and Bristow-Campbell models can be used with typical values to estimate solar radiation, Samani and Almorox models have been suggested to be used after their coefficients are calibrated for the region in which they will be used by concluding that only Model 3 has a significant improvement (0.887 R^2) for its local applicability.

Kulcu et al. (2017) made estimation a monthly average daily global solar radiation using 6 empirical models in Mersin province, Turkey. Model 6 in Equation 1 where -hour angle and cloudiness coefficient were used and found as the most successful estimation model for Mersin province with 0.8576 RMSE, -0.3251 MBE, -4.7622 MPE values, respectively.

$$\frac{H}{H_0} = \left[\frac{1.333962\left(\frac{S}{S_0}\right)}{0.044188 w_s}\right] + 0.002578\ w_s \qquad \text{(Eq. 1)}$$

In this study; the data of Usak (Turkey) meteorology station, the solar energy estimation models developed by other researchers and developed in this study, the solar radiation data obtained using forecasts with the SARAH and CMSAF satellite-based and the re-analysis data sets of COSMO and ERA5 in PVGIS were compared. The ideal global solar radiation estimation model has been determined for the city of Usak, Turkey.

2. Materials and Methods

Solar energy calculations on the horizontal surface within the scope of the study; 35S 653505 -36S 241430 longitude, 4228190-4311902 (UTM grid system) and 907 m elevation was carried out for the provincial borders of Usak province (*Figure 1*). Usak Province is located in the Central Western Anatolia part of the Aegean region, Afyonkarahisar in the east, Manisa in the west, Kutahya in the north and Denizli in the south. The area of the province is 534.063 hectares and it has 6 districts. The region generally consists of mountainous and rugged lands. It looks like wavy plateaus split by a dense network of valleys. In places, mountains rise above the plateau plains. Murat Mountain, the most important of these mountains and also the highest point of Innerwest Anatolia, has an altitude of 2309 meters. 57.5% of the provincial lands consist of plateaus, 37% of mountains and 5.5% of plains. Murat, Bulkaz and Ahır Mountains form the natural borders of the province in the north, northeast and east. The west of the provincial lands opens to the Aegean Region with the Gediz valley. The provincial lands look like wavy plateaus split by many valleys. These plateaus descend from northeast to southwest and take a slightly wavy appearance in some parts. The province of Usak is geographically located between the Aegean and the Central Anatolia region. As a natural result of this location, transition climate characters prevail in Usak province (Anonymous, 2020b). In *Table 1*, the average climate data of Usak for many years (1939-2020) were presented. The average monthly total precipitation amount was 557.6 mm, the average temperature was 12.5 °C, the average lowest temperature was 6.8 °C, and the average maximum temperature was 18.5 °C (Anonymous, 2020c). The annual radiation amount is in the range of 1550-1650 kWh m^{-2} year. On province basis, the average incoming solar radiation in Turkey 1350 kWh m^{-2} years. Considering this situation, Usak province is one of the suitable conditions to invest in solar energy (Anonymous, 2020a).

Table 1. Climate data of Usak for long years (1939-2020) (Anonymous, 2020c)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average temperature (°C)	2.3	3.3	6.2	10.9	15.6	19.9	23.4	23.4	19.1	13.7	8.3	4.2	12.5
Average High Temperature (°C)	6.8	8.3	11.8	16.8	21.8	26.5	30.3	30.5	26.3	20.3	14.1	8.8	18.5
Average Lowest Temperature (°C)	-1.3	-0.6	1.4	5.2	9.2	12.6	15.5	15.6	11.9	7.9	3.8	0.7	6.8
Average Sunshine duration (hour)	3.9	4.6	5.5	6.8	8.8	10.9	11.8	11.3	9.7	7.3	5.3	3.8	7.5
Average Rainy Days	12.2	10.7	10.8	11.0	10.1	6.0	3.1	2.4	3.4	7.1	8.5	12.7	98.0
Average Monthly Total Rainfall (mm)	73.4	66.7	58.0	50.9	48.0	27.2	16.5	12.6	18.6	42.2	58.9	84.6	557.6

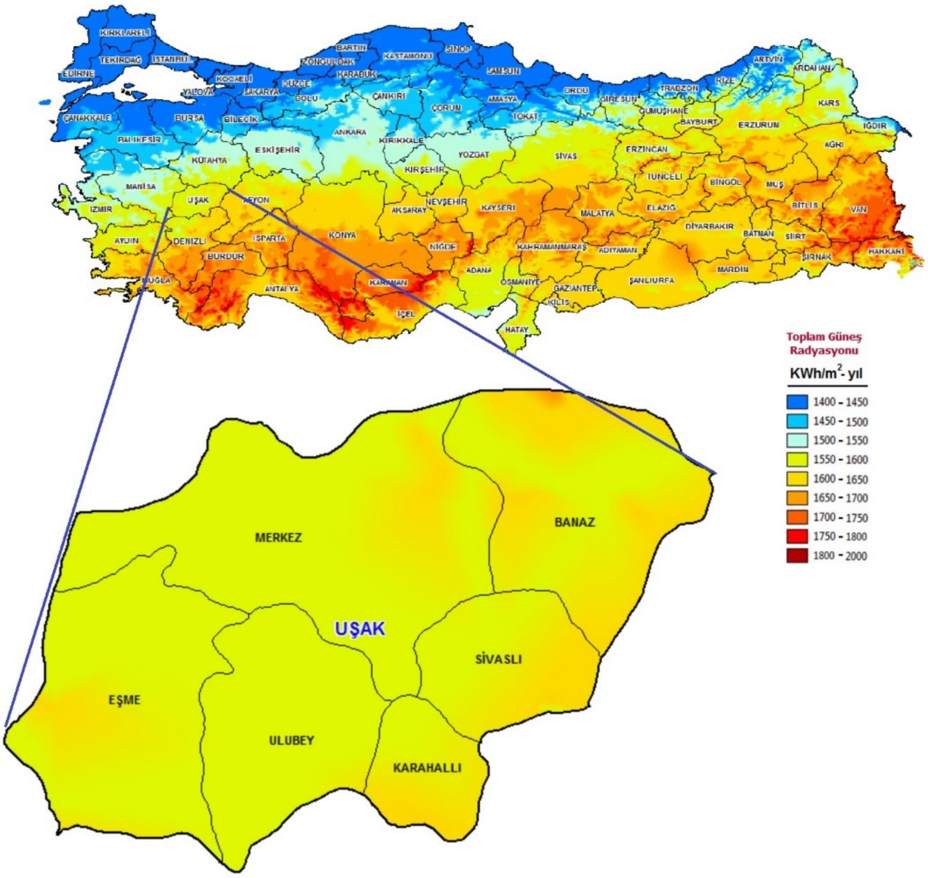


Figure 1. Solar energy potential and location map of Usak province (Anonymous, 2021a)

2.1. Calculation of the amount of solar radiation coming out of the atmosphere in Usak province

The amount of extra-terrestrial radiation coming on a horizontal surface in a day was calculated using Equation 2 (Duffie and Beckman, 1980);

$$H_O = \frac{24x3600xG_{SC}}{\pi}\left[1+0.033\left(Cos\frac{360n}{365}\right)\right] * \left[Cos\varphi\ Cos\delta\ sinw_s + \frac{\pi}{180}w_s Sin\varphi Sin\delta\right] \quad \text{(Eq.2)}$$

The declination angle refers to the angle between the plane around which the earth rotates around the sun at noon (when the sun is on the local meridian) and the equatorial axis. This angle takes maximum value on June 21st and minimum value on December 21st, and it becomes zero on the 21st of March and 21st of September. The declination angle was calculated using Equation 3. *Table 2* was used to find the value of n (Cooper, 1969; Duffie and Beckman, 1980).

$$\delta = 23.45\ Sin\left(360\frac{n+284}{365}\right) \quad \text{(Eq.3)}$$

Sunset hour angle (w_s) expresses the angle between the latitude where the sunlight (at the time the sunset) and the latitude calculated using equation numbered 4 (Duffie and Beckman, 1980);

$$w_s = arccos[-tan(\varphi)tan(\delta)] \quad \text{(Eq.4)}$$

S used in the models indicates the sunshine duration of that day on the date and coordinate calculated, and S_0 indicates the total day length in the same day and in the same place. While the S value was determined according to meteorological measurements, the S0 value was calculated using the equation numbered 5 (Duffie and Beckman, 1980);

$$S_0 = \frac{2}{15}\cos^{-1}[-\tan(\varphi)\tan(\delta)] \quad \text{(Eq.5)}$$

Table 2. Recommended Average Days for Months and Values of n by Months (Klein, 1977; Duffie and Beckman, 1980)

Month	*n* for *i*th day of month	For Average Day of Month		
		Date	*n*	*δ*
January	*i*	17	17	-20.9
February	31 + *i*	16	47	-13.0
March	59 + *i*	16	75	-2.4
April	90 + *i*	15	105	9.4
May	120 + *i*	15	135	18.8
June	151 + *i*	11	162	23.1
July	181 + *i*	17	198	21.2
August	212 + *i*	16	228	13.5
September	243 + *i*	15	258	2.2
October	273 + *i*	15	288	-9.6
November	304+ *i*	14	318	-18.9
December	334 + *i*	10	344	-23.0

Do not use for $|\varphi| > 66.5^o$.

2.2.Empirical estimation models used in the study

In the modeling of solar radiation reaching Usak, Equation 6-17 in the literature and Equation 18-19 developed within the scope of this study were used.

Model 1 [Angstrom-Prescott model]; In order to obtain maximum benefit from solar energy and to determine its efficiency, it is extremely important to simultaneously obtain solar radiation and sunshine duration at the same point. To show this relationship, first Kimball (1919) and then Angstrom (1924) developed equations. Later, Prescott (1940) has developed the Angstrom equation by dimensionlessing it with extraterrestrial solar radiation and insolation time. And the model in Equation 6 has been called Angstrom-Prescott since 1940 (Güçlü, 2019). The Angstrom-Prescott model is one of the most widely used estimation methods for calculating monthly average daily irradiance.

$$\frac{H}{H_0} = c_1 + c_2\left(\frac{S}{S_0}\right) \quad \text{(Eq.6)}$$

Model 2 (Elagib and Mansell, 2000);

$$\frac{H}{H_0} = c_1 + c_2\left(\frac{S}{S_0}\right)^{c_3} \quad \text{(Eq.7)}$$

Model 3 (El-Metwally, 2005);

$$\frac{H}{H_0} = c_1^{(1/S)} \quad \text{(Eq.8)}$$

Model 4 (Külcü, 2015);

$$\frac{H}{H_0} = \left[\frac{c_1\left(\frac{S}{S_0}\right)}{c_2\, w_s}\right] + c_3 w_s \quad \text{(Eq.9)}$$

Model 5 (Bahel et al., 1987);

$$\frac{H}{H_0} = c_1 + c_2\left(\frac{S}{S_0}\right) + c_3\left(\frac{S}{S_0}\right)^2 + c_4\left(\frac{S}{S_0}\right)^3 \quad \text{(Eq.10)}$$

Model 6 (Ampratwum and Dorvlo, 1999);

$$\frac{H}{H_0} = c_1 + c_2\left(\frac{S}{S_0}\right) + c_3 log\left(\frac{S}{S_0}\right) \quad \text{(Eq.11)}$$

Model 7 (Almorox and Hontoria, 2004);

$$\frac{H}{H_0} = c_1 + c_2 exp\left(\frac{S}{S_0}\right) \quad \text{(Eq.12)}$$

Model 8 (Dogniaux and Lemoine, 1983); Unlike other models, latitude degree was used in this model.

$$\frac{H}{H_0} = c_1 + \left[c_2\left(\frac{S}{S_0}\right) + c_3\right]\varphi + c_3\left(\frac{S}{S_0}\right) \quad \text{(Eq.13)}$$

Model 9 (Külcü, 2019); In this model, unlike other models, solar radiation was estimated by using the logarithmic relationship of the cloudiness coefficient with the hour angle.

$$\frac{H}{H_0} = c_1 + c_2 log\left(\frac{S}{S_0}\Big/ w_s\right) + c_3\left(\frac{S}{S_0}\right) \quad \text{(Eq.14)}$$

Model 10 (Hargreaves et al., 1985); Unlike previous models, maximum and minimum temperature differences was used in Model 10.

$$\frac{H}{H_0} = c_1 * (\Delta T)^{0.5} + c_2 \quad \text{(Eq.15)}$$

Model 11 (Chen Model (Coppolino, 1994));

$$\frac{H}{H_0} = c_1 * ln(\Delta T) + c_2 \quad \text{(Eq.16)}$$

Model 12 (Bristow and Campbell, 1984);

$$\frac{H}{H_0} = c_1 * [1 - \exp\{-c_2 * (\Delta T)^{c_3}\}] \quad \text{(Eq.17)}$$

Model 13; In this study, it was a new model developed using the linear logarithmic method. There were various solar radiation estimation models based on S/S_o ratio, including linear, second order, third order and logarithmic. In this model, the cloudiness coefficient was fixed with the c_2 coefficient and its logarithm was taken. Also, the maximum-minimum temperature changes were fixed with the c_3 coefficient and the last coefficient was summed up with the c_4 coefficient and a linear relationship is established with the radiation coming from the extraterrestrial. And thus, the global monthly average daily solar radiation amount was estimated from here;

$$H/H_0 = c_1 * log[(c_2 * S/S_0) + (c_3 * \Delta T)] + c_4 \quad \text{(Eq.18)}$$

Model 14; An second liner logarithmic model developed within the scope of this study. In this model, the effects of temperature changes and temporal dependence had been demonstrated in calculation of the global monthly average daily solar radiation by using the hour angle instead of the cloudiness coefficient;

$$H/H_0 = c_1 * log[(c_2 * w_s) + (c_3 * \Delta T)] + c_4 \quad \text{(Eq.19)}$$

2.3. PVGIS-based data sets used within the scope of the study

With Remote Sensing (RS) technologies, it is fast and easy to collect data belonging to a large part of our World. RS technologies are also using among the basic data sources of renewable energy sources as they are in many fields today. Data provided by RS technologies or meteorological measurements are collected in GIS-based software. And thanks to the calculation modules included in this software, the solar radiation estimation of the desired location can be made hourly, daily, monthly and yearly. Photovoltaic Geographical Information System (PVGIS) is one of the web-based versions of these software. It was created by the European Commission and offered for open access in a web browser. Energy production data was calculated using different satellite bases and parameters with PVGIS positional solar radiation and photovoltaic systems. These variables offer different success in different positions (Anonymous 2021b).

In the study, monthly solar radiation data obtained by using SARAH and CMSAF satellite-based (COSMO and ERA5) data sets in kWh m^{-2} unit of Usak province were obtained from the PVGIS web portal (*Table 3*). These data were converted to MJ m^{-2} and monthly average daily solar radiation values were obtained proportioning the days of each month.

Table 3. Properties of solar radiation databases in PVGIS (Anonymous, 2021b)

Database	Type	Start Year	End Year	Spatial Resolution
PVGIS-SARAH	Satellite	2005	2016	0.05° x 0.05° (~ 5 km)
PVGIS-CMSAF	Satellite	2007	2016	0.025° x 0.025° (~ 2.5 km)
PVGIS-ERA5	Re-analysis	2005	2016	0.25° x 0.25° (~ 25 km)
PVGIS-COSMO	Re-analysis	2005	2015	0.055° x 0.055° (~ 5 km)

2.4. Statistical parameters used to test the estimation success of the models

The estimation capabilities of the models examined within the scope of the study were compared. Monthly average data were compared using parameters MPE (mean percentage error) in Equation 20, MBE (mean bias error) in Equation 21, RMSE (root mean square error) in Equation 22, R^2 (determination coefficient) in Equation 23. And, monthly data were compared using the (ARE) (absolute relative error) parameter in Equation 24.

The R^2 is an indicator of the inter-variable dependence, and its close to one indicates that there is a strong bond between the variables. The RMSE is an indicator of the deviation between the measured and calculated values and provides information about the short-term performance of the model under study. The closer the RMSE value is to zero, the better the performance of the model is evaluated. MBE provides information about the long-term performance of the model under study. The closer the MBE value is to zero, the higher the performance of the model. If this value is positive, it indicates that an estimate has been made above the calculated value, if it is negative, it indicates that an estimation has been made below the calculated value. The MPE is the indicator of the percentage value of the deviation between the measured and calculated values, and the closer the value to zero, the higher the performance of the model (Tırmıkçı, 2018). The ratio of the absolute error to the measured value gives the relative error. Relative error is a type of error that shows proportionally how close to the real value is. In most studies, relative error means more than absolute error (Anonymous, 2021c). Relative errors between -10% and +10% are acceptable value ranges (Skeiker, 2006). An useful measure of goodness is absolute relative error (Dyer and Dyer, 2007). Absolute relative error is calculated by proportioning the absolute error to the measured value and taking the percentage (Navarro, 1992; Green and Tashman, 2009). Absolute relative error getting too close to zero means that the estimate is very close to the target value (Anacan et al., 2018; Marfo and Okyere, 2019).

$$MPE = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{H_{ip}-H_{io}}{H_{io}}\right)x100 \quad \text{(Eq.20)}$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(H_{ip}-H_{io}\right) \quad \text{(Eq.21)}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(H_{ip}-H_{io}\right)^2} \quad \text{(Eq.22)}$$

$$R^2 = \frac{\sum_{i=1}^{N}(H_{ip}-H_{ipa})(H_{io}-H_{ioa})}{\sqrt{[\sum_{i=1}^{N}(H_{ip}-H_{ipa})^2][\sum_{i=1}^{N}(H_{io}-H_{ioa})^2]}} \quad \text{(Eq.23)}$$

$$ARE = \left(I\frac{H_{ip}-H_{io}}{H_{io}}I\right)x100 \quad \text{(Eq.24)}$$

3. Results and Discussion

3.1. Global Solar Radiation Data of Usak Province

According to the radiation values measured in Usak, the lowest global solar radiation reaches the ground surface in December (6.83 MJ m^{-2} day^{-1}) and the highest radiation in July (26.83 MJ m^{-2} day^{-1}). Global solar radiation values of Usak province according to meteorological data varies between 6.83-7.67 MJ m^{-2} day^{-1} in December-January, 8.14-8.98 MJ m^{-2} day^{-1} in November-February, 12.88-13.05 MJ m^{-2} day^{-1} in October-March, 18.14-18.29 MJ m^{-2} day^{-1} in September-April, 20.87-22.81 MJ m^{-2} day^{-1} in August-May and 25.53-26.83 MJ m^{-2} day^{-1} in June-July. It was seen that the estimation models and PVGIS-based data sets used within the scope of this study generally reveal estimates close to the measured data.

3.2. Global Solar Radiation Estimate Models and PVGIS Based Datasets

The global solar radiation values estimated by the models used within the scope of this study, the global radiation values based on PVGIS and the changes of the global radiation values measured from the Usak Meteorology Station were given in *Table 4* using the color scale. According to the color scale, Model 3, 4, ERA5 and SARAH made quite different estimates from the measured data. Deviations of other models and data sets were at lower levels. In *Table 5*, the comparison of each of the models with the measured monthly average daily solar irradiance data was given as graphic template and interpreted.

Table 4. Measured and estimated radiation information table of Usak province

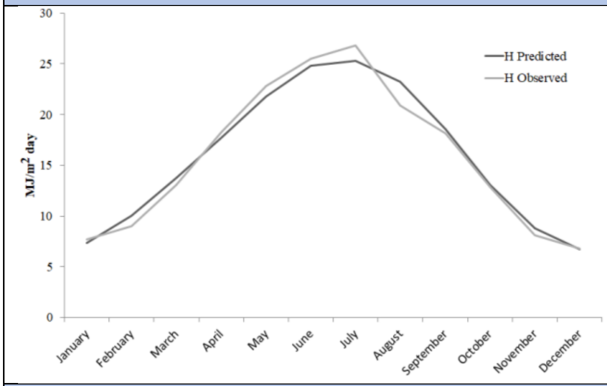
H (MJ m^{-2} day^{-1})	17 January	16 February	16 March	15 April	15 May	11 June	17 July	16 August	15 September	15 October	14 November	10 December
Measured												
Model 1												
Model 2												
Model 3												
Model 4												
Model 5												
Model 6												
Model 7												
Model 8												
Model 9												
Model 10												
Model 11												
Model 12												
Model 13												
Model 14												
COSMO												
ERA5												
SARAH												
CMSAF												
Color Scale	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26	26-27	27-28
	28-29											

In Model 1, it was observed that the estimates were higher than the measured values between February-March, early August, mid-September, and late October-November. And the opposite situation was observed in the period from mid-April to the end of July, and the estimates were below the measured values. The estimates were realized as expected in the period from end of March to mid-April, end of July, mid-September-end of October and in December. Estimates close to Model 1 were obtained from Model 2. This is because the Equation structures of the two models are similar to each other. During the period from the end of April to mid-May, and the period from mid-September to mid-October, the estimates obtained with Model 3 approached the measured values and made high estimates in this period. It was observed that the estimations were higher than the measured values in the summer months, and the estimations were realized below the measured values in the winter and spring months. The fact that this model is based on the sunshine duration has been effective in estimating high irradiance values in the summer months and low irradiance values in the winter months.

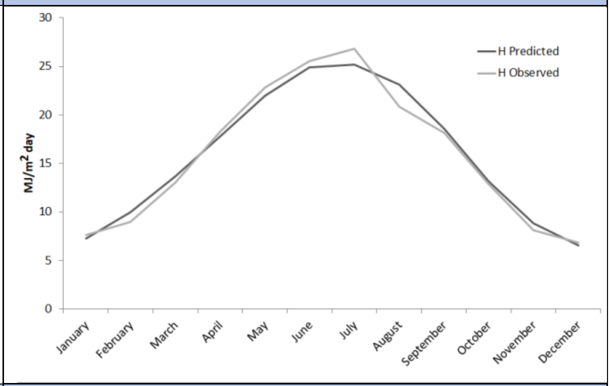
The estimates obtained by Model 4 were high for the first 6 months of the year, while the last 6 months made low estimates. It gave results close to the values measured in January, June and August. Estimates close to Models 1 and 2 were obtained from Model 5. Model 6 was a model based on the logarithm of the cloudiness coefficient developed by Ampratwum and Dorvlo (1999). This model made estimates close to the measured values in January, the period from the end of March to May, in July, the period from mid-September to November and in December. It was observed that the estimates moved away from the measured values in the June-August period. Model 7 made estimates close to the measured values in January, from late March to mid-April, in late July, from mid-September to October, and in December. The most distant estimates were observed in February and August. Model 8 made estimates close to the values measured in January, end of March, mid-April, end of July, mid-October and December. The most distant estimates were in February and August. Model 9 had quite accurately estimated values for January, end of March, mid-April, end of July, the period from mid-September to the end of October and in December. It made the most distant estimations in February and August. Model 9 made estimates very close to Model 8.

Table 5. Comparison graphs of monthly average daily solar radiation data estimated and measured by models

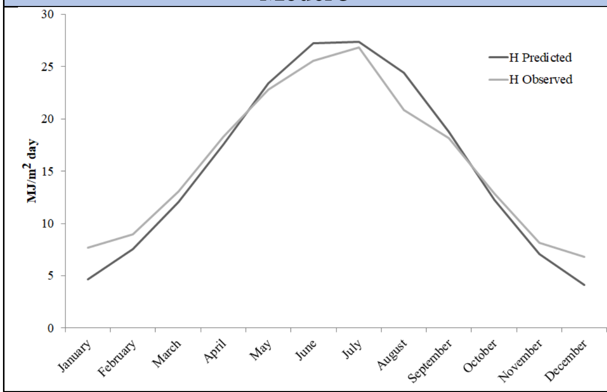
Model 1



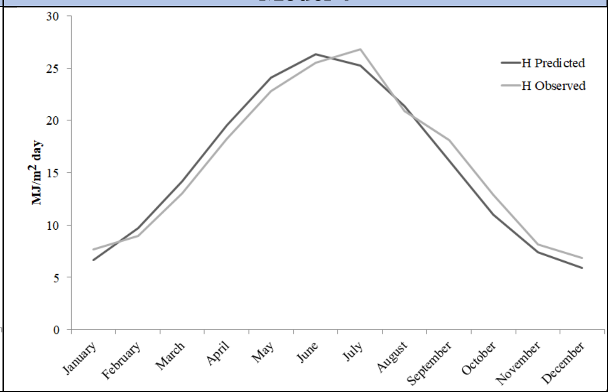
Model 2



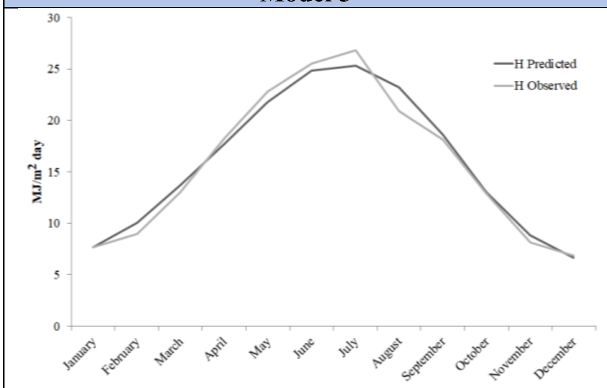
Model 3



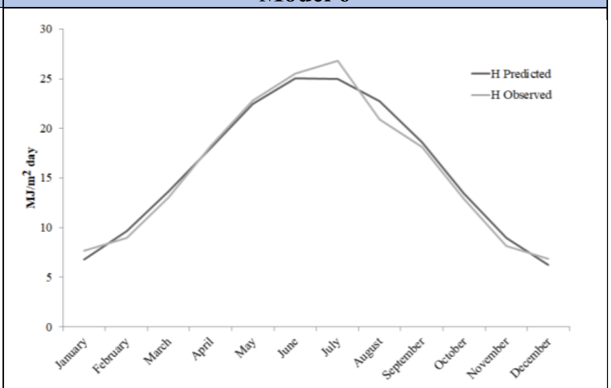
Model 4



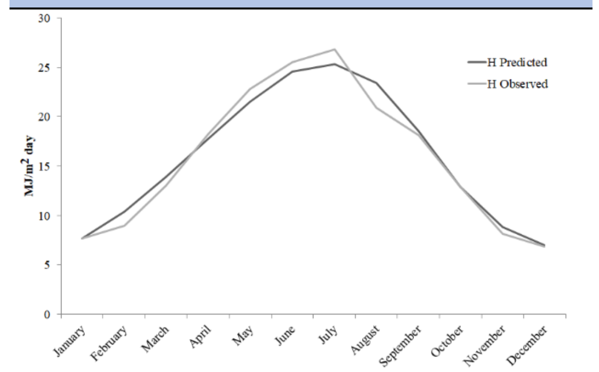
Model 5



Model 6



Model 7



Model 8

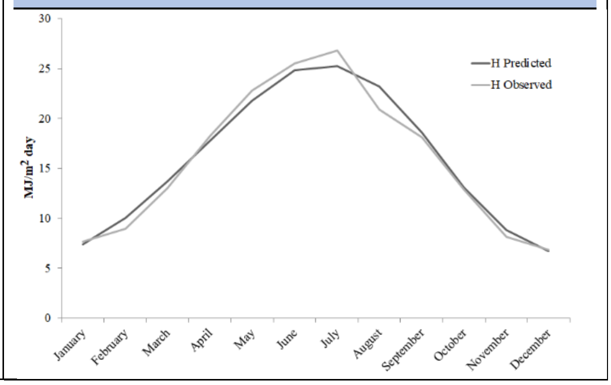
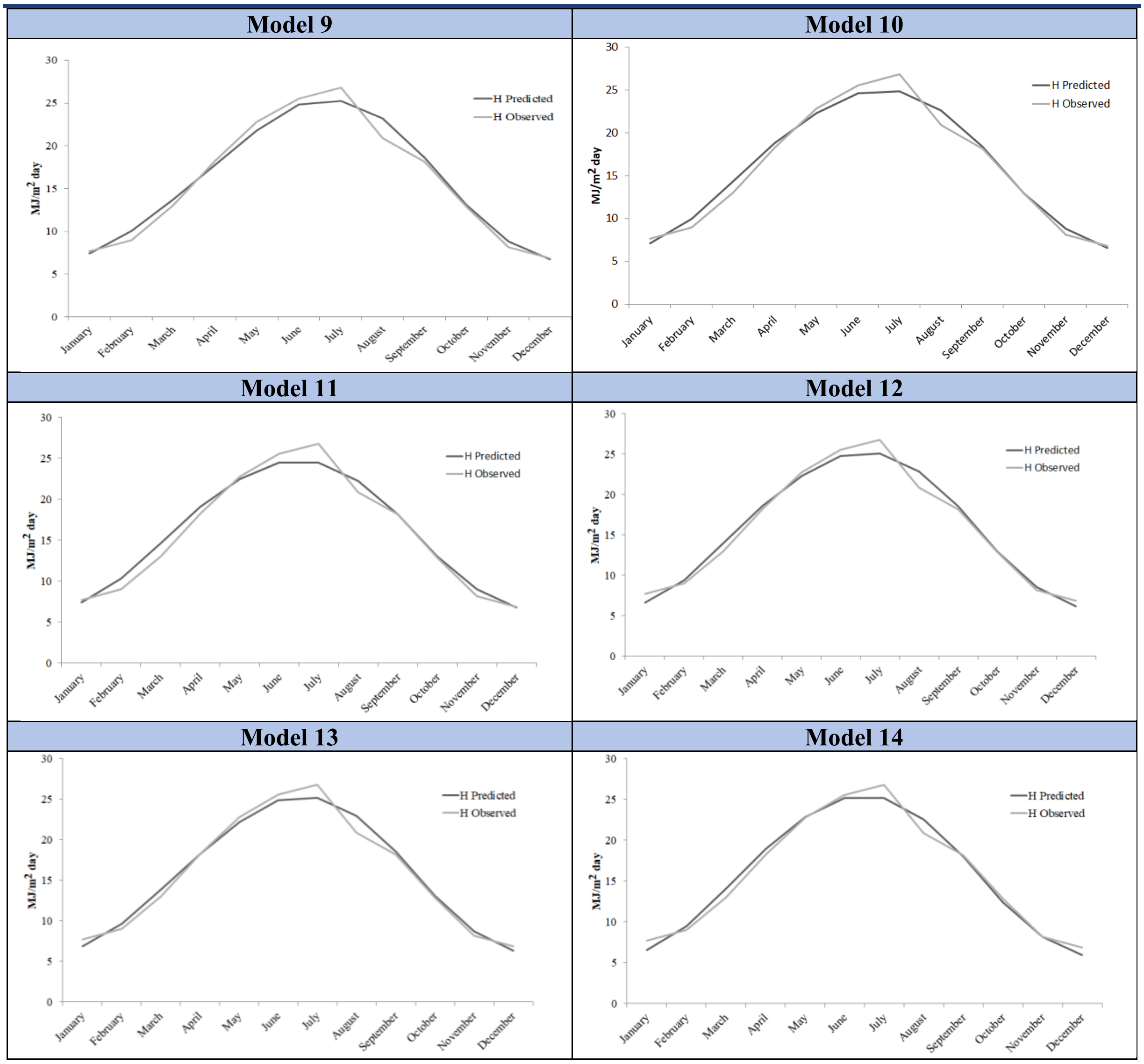


Table 5. (contiuned) Comparison graphs of monthly average daily solar radiation data estimated and measured by models



While Model 10 makes estimates close to the values measured in January, the period from mid-April to mid-May, late July, mid-October and December, the most distant estimates were realized in February and March. Model 11 made estimates close to the values measured during the period in January, the period end of April until mid-May, in early August, the period from first week of September to the last week of October and in December. The estimates from January to April were observed above the measured values and below the measured values between May and July. The furthest estimate came in July. Model 12 had produced estimates close to the values measured in the period February, from to mid-April to mid-May, in early August and from mid-September to December. The estimates were above the measured values between February-April and August-September, and below the values between May-July. The furthest estimate came in July. Model 13 obtained estimates close to the measured values in early February, in April, in early August and from mid-September to December. The estimates were above the measured values between February-April and August-September, and below the values between May-July. The furthest estimate came in July. Model 14 made estimates close to the values measured in early February, April, early August and from mid-September to December. The estimates were above the measured values between February-April and August-September, and below the values between May-July. The furthest estimate came in July. Especially in the late spring-beginning of summer and autumn period, estimates close to the measurements were obtained.

In recent years, solar radiation estimations can be made by comparing and evaluating land measurements with satellite and re-analysis datas as well as empirical models (Ineichen, 2014; Urraca et al., 2017, 2018; Feng et al., 2019). *Figure 2* shows the data obtained by using SARAH and CMSAF satellite-based and COSMO and ERA5 re-analysis global solar radiation estimate data sets for Usak province.

When the global solar radiation values obtained with the COSMO re-analysis data were examined, it was seen that estimates were made close to the monthly average daily radiation data measured in January, April, July, September and November. Estimates were obtained above the measured values between January-April and August-September, and below the measured values between April-August and September-November. The furthest estimate came in July. When the data obtained with the ERA 5 re-analysis data are examined, it was seen that estimates were obtained above the monthly average daily radiation data measured in all months of the year. The closest estimates were made in January, May-July, September-October and December. When the radiation graph obtained with SARAH satellite data was examined, it was seen that estimates were obtained above the monthly average daily radiation data measured in all months of the year. The closest estimates were made in January, May, September-October and December. The most distant estimates were observed in the months of July-August. When the radiation graph obtained with CMSAF satellite data was examined, it had been observed that estimates above the monthly average daily radiation data measured in all months of the year, and it had been observed that estimates close to the radiation data obtained from SARAH satellite data.

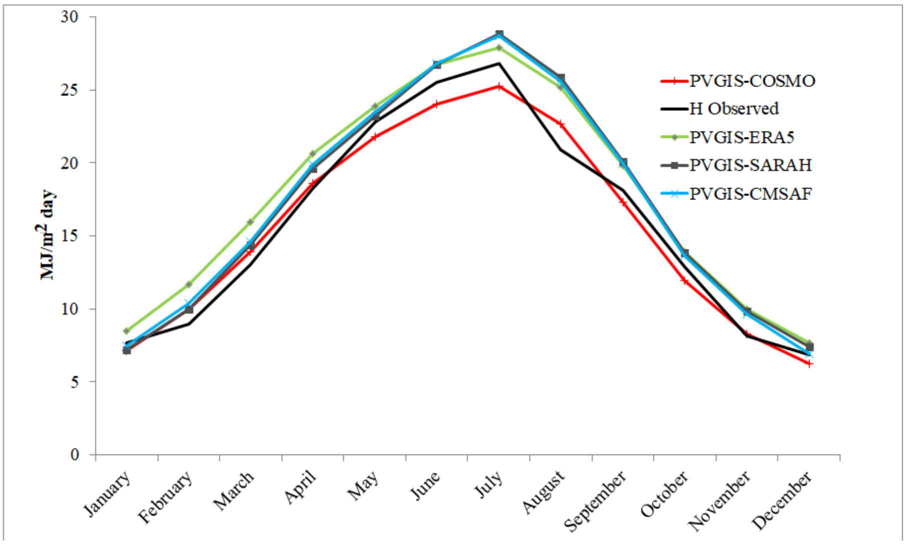


Figure. 2. Comparison graphs of the daily radiation data measured, the radiation data obtained by re-analysis and the satellites in the PVGIS database

When the estimated values obtained by the satellite data and re-analysis with the radiation measurements coming to the horizontal surface were evaluated together; It had been observed that the radiation estimates obtained with satellite-based data were higher than the measured values. As a matter of fact, Frank et al. (2018) reported that re-analysis data overestimated the radiation incident on the global horizontal surface in cloudy conditions. In a similar study, Psiloglue et al. (2020) reported that while satellite data and ground measurement radiation data obtained in cloudless weather conditions were in harmony with each other, they showed high uncertainty in cloudy or partially cloudy weather conditions.

The monthly success of the models and satellite-based estimation data used within the scope of the study were interpreted according to the IeI values in *Table 6*. In January, absolute relative errors were obtained below 1% from Model 5 and Model 7, 3% from CMSAF satellite data, and 3-4% from Model 11, Model 9, Model 1 and Model 8. An absolute relative error of 5% was obtained from Model 12 in February. The absolute relative error of other estimation models did not follow this level in February and was realized in the range of 5.6-29.8%. In March, an absolute relative error in the range of 4-5% was obtained from Model 6, Model 5 and Model 2. In April, absolute relative errors were obtained in the range 0.3% from Model 13, 1-2% from Model 6, COSMO re-analysis satellite data and Model 12, 2-3% from Model 2, Model 7, Model 9, Model 1, Model 8 and Model 10, 3-4% from Model 5 and Model 14, 4-5% from Model 3 and Model 11. It was observed that 14 out of 18 estimation sets used in April had an absolute relative error below 5% and in the other 4 estimation sets between 5-12.7%. While an absolute relative error of less than 5% was obtained from 16 of the 18 estimation data sets used in May, an absolute relative error of 5.7% was obtained from Models 7 and Model 4. When the forecasts obtained with the estimation models used in the study and satellite-based data sets are evaluated, the most successful estimations during the year were obtained in May. In June, while the estimates obtained from CMSAF satellite data, COSMO re-analysis data and Model 3 equation, respectively, 5.1%, 6.0% and 6.7% absolute relative errors were obtained, below 5% absolute relative errors were obtained from other estimation sets. In July, it was obtained an absolute relative error below 5% from Model 3 and ERA5 re-analysis estimation set, and was obtained below 8.7% from other estimation sets. In August, an absolute relative error below 5% was obtained from the Model 4 estimation model, and an absolute relative error between 5-23.8% was obtained in other estimation sets. In September, the absolute relative error was obtained in the range of less than 1% from Model 11 and Model 14, 1-2% from Model 10 and Model 7, 2-3% from Model 12, Model 6, Model 13, Model 9, Model 1, Model 8, Model 2 and Model 5, 3.5% from Model 3. Also, from the satellite data sets, an absolute relative error of 4.7% was obtained from the COSMO re-analysis data. In October, an absolute relative error below 1% from Model 7, Model 12 and Model 10, between 1-2% from Model 11, Model5, Model 8, Model 1, Model 9, Model 13 and Model 2, 3.6% from Model 14, 4.2% from Model 6 was obtained. The absolute relative error of other data sets was between 5.1-14.4%. In November, an absolute relative error was obtained 0.8% from the Model 14, %1.4 from the COSMO re-analysis data, %5.3-22.2 from the other estimation sets. In December, Model 11 with a value of 0.2%, CMSAF satellite data, Model 9, Model 1 and Model 8 between 1-2%, Model 5 and Model 7 2-3%, Model 2 and Model 10 3-4% with an absolute relative error made successful estimations close to the measured value. In this month, estimates far from the measured value were obtained with a value of 39.9% from the Model 3 estimation model. The absolute relative error in the range of 7.7-13.9% was obtained from other estimation models and data sets.

According to the monthly evaluation error analysis results of estimate models and PVGIS satellite data sets, the most successful estimations were obtained in April-June, September-October and December (below 5%). An error of less than 39.9% was obtained from all estimation models and satellite-based datasets. With these values, very reasonable estimates that were close to reality had been obtained.

The monthly average of the absolute relative errors of the monthly average daily global solar radiation data of the COSMO, ERA5, SARAH and CMSAF data sets in *Table 6* were 6.1%, 13.4%, 10.0% and 9.3%, respectively. The RMSE values of these data sets were 1.053134, 2.077154, 1.893419 and 1.840986, respectively (*Table 7*). When the PVGIS data sets were compared within themselves, values close to the real values were obtained with the order of COSMO> CMSAF> SARAH> ERA5, as can be seen from the RMSE and absolute relative error values.

Models 13 and 14 were the models developed within the scope of this study. It had been seen that these two models were among the top 4 most successful models. As a result of evaluating the estimation success of the models, it took place Model 14 ranks first with 0.90058 RMSE and 0.98327 R^2 value, Model 6 second with 0.92664 RMSE, 0.98226 R^2 value, Model 13 third with 0.93959 RMSE, 0.98166 R^2 value, Model 12 fourth with 0.952089 RMSE, 0.980939 R^2 value in the first four of the 18 models used.

Within the scope of the study, when the satellite-based data sets and models used to estimation the global solar radiation of Usak were evaluated together, it was seen that the most successful estimations were made by Model 14 developed within the scope of this study (0.90058 RMSE, 0.98327 R^2). This model was followed by Model 6 (0.92664 RMSE, 0.981226 R^2) developed by Ampratwum and Dorvlo (1999) and Model 13 (0.939589 RMSE, 0.98166 R^2) developed within the scope of this study, respectively. The estimation success of satellite-based data sets was lower than the models.

Table 6. The success ranking of the models according to the percentege absolute relative error (ARE%) values

January		February		March		April		May		June		July		August		September		October		November		December	
Model 5	0.0	Model 12	5.0	Model 6	4.5	Model 13	0.3	Model 14	0.2	Model 14	1.3	Model 3	2.0	Model 4	2.4	Model 11	0.2	Model 7	0.0	Model 14	0.8	Model 11	0.2
Model 7	0.2	Model 14	5.6	Model 5	4.8	Model 6	1.3	Model 6	1.5	Model 6	1.8	ERA5	4.1	Model 11	6.6	Model 14	0.9	Model 12	0.2	COSMO	1.4	CMSAF	1.1
CMSAF	3.0	Model 6	7.5	Model 2	5.0	COSMO	1.6	Model 11	1.5	Model 2	2.6	Model 7	5.7	Model 14	8.0	Model 10	1.2	Model 10	0.4	Model 12	5.3	Model 9	1.6
Model 11	3.5	Model 13	7.5	Model 8	5.2	Model 12	2.0	SARAH	1.7	Model 13	2.6	Model 5	5.7	Model 10	8.3	Model 7	2.0	Model 11	1.1	Model 13	7.4	Model 1	1.6
Model 9	3.8	Model 4	8.1	Model 1	5.2	Model 2	2.5	Model 12	2.1	Model 8	2.8	Model 8	5.8	COSMO	8.6	Model 12	2.3	Model 5	1.4	Model 10	7.9	Model 8	1.7
Model 1	3.8	Model 2	11.0	Model 9	5.2	Model 7	2.7	Model 10	2.1	Model 5	2.8	Model 1	5.8	Model 6	8.9	Model 6	2.3	Model 8	1.5	Model 5	8.1	Model 5	2.1
Model 8	3.8	Model 10	11.0	Model 13	6.0	Model 9	2.8	Model 3	2.7	Model 9	2.8	Model 9	5.8	Model 12	9.6	Model 13	2.4	Model 1	1.5	Model 7	8.3	Model 7	2.4
Model 2	5.5	COSMO	11.2	COSMO	6.6	Model 1	2.8	Model 13	2.7	Model 1	2.8	Model 4	5.9	Model 13	10.1	Model 9	2.4	Model 9	1.5	Model 8	8.4	Model 2	3.3
SARAH	5.7	SARAH	11.5	Model 7	6.7	Model 8	2.8	CMSAF	2.9	Model 12	2.9	COSMO	6.0	Model 2	10.7	Model 1	2.4	Model 13	1.6	Model 1	8.4	Model 10	3.6
Model 10	6.8	Model 5	11.6	Model 12	7.4	Model 10	2.9	Model 2	3.7	Model 4	3.0	Model 2	6.0	Model 9	11.2	Model 8	2.5	Model 2	2.1	Model 9	8.4	Model 13	7.7
COSMO	6.9	Model 8	12.1	Model 3	7.7	Model 5	3.1	Model 9	4.4	Model 10	3.7	Model 13	6.2	Model 1	11.2	Model 2	2.5	Model 14	3.6	Model 2	8.8	SARAH	8.0
Model 13	10.5	Model 1	12.1	Model 14	8.1	Model 14	3.7	Model 1	4.4	Model 7	3.9	Model 14	6.2	Model 8	11.2	Model 5	2.5	Model 6	4.2	Model 4	9.5	COSMO	8.3
ERA5	10.6	Model 9	12.1	Model 4	8.5	Model 3	4.2	Model 8	4.4	Model 11	4.2	Model 12	6.3	Model 5	11.3	Model 3	3.5	Model 3	5.1	Model 11	10.4	Model 6	9.0
Model 6	11.0	Model 11	14.6	Model 10	10.0	Model 11	4.3	Model 5	4.5	ERA5	4.6	Model 6	6.9	Model 7	12.1	COSMO	4.7	CMSAF	5.6	Model 6	10.4	Model 12	10.2
Model 4	13.3	Model 7	15.4	SARAH	10.4	Model 4	6.9	COSMO	4.6	SARAH	4.8	CMSAF	7.1	Model 3	16.8	ERA5	9.1	COSMO	7.2	Model 3	13.4	ERA5	12.6
Model 12	13.6	CMSAF	15.5	CMSAF	11.8	SARAH	7.3	ERA5	4.7	CMSAF	5.1	Model 10	7.4	ERA5	20.7	CMSAF	9.9	SARAH	7.3	CMSAF	18.3	Model 14	12.6
Model 14	14.7	Model 3	15.9	Model 11	12.4	CMSAF	8.8	Model 7	5.7	COSMO	6.0	SARAH	7.5	CMSAF	22.5	SARAH	10.5	ERA5	7.9	PSARAH	20.8	Model 4	13.9
Model 3	39.1	ERA5	29.8	ERA5	22.3	ERA5	12.7	Model 4	5.7	Model 3	6.7	Model 11	8.7	SARAH	23.8	Model 4	11.1	Model 4	14.4	ERA5	22.2	Model 3	39.9

Green: 0-1, Pink: 1-2, Yellow: 2-3, Blue: 3-4, Orange: 4-5, White: >5

Table 7. Statistical analysis results of the models

Coefficients	c_1	c_2	c_3	c_4	MPE	MBE	RMSE	t	R^2
Model 1	0.31126	0.38816			1.62779	0.10137	1.00516	0.33620	0.98024
Model 2	0.00000	0.68273	0.43034		1.36944	0.08958	0.97292	0.30667	0.98124
Model 3	0.01045				-7.79935	-0.59046	1.77903	1.16693	0.98415
Model 4	0.96995	0.97005	0.00567		-2.78882	-0.20903	1.23947	0.56747	0.97273
Model 5	0.30655	0.39462	0.00000	0.35823	1.78399	0.10943	1.00122	0.36470	0.98066
Model 6	1.18460	0.55350	1.31525		0.52424	0.04773	0.92664	0.17107	0.98226
Model 7	0.39025	0.03689			2.42743	0.14110	1.11295	0.42390	0.97692
Model 8	0.23093	0.00670	0.00207	0.12927	1.62517	0.10122	1.00516	0.33571	0.98023
Model 9	0.31127	0.00000	0.38815		1.62798	0.10139	1.00516	0.33627	0.98024
Model 10	0.15871	0			1.6279829	0.101392	1.005157	0.369948	0.981095
Model 11	0.223418	0			2.6266197	0.174522	1.09458	0.535662	0.97947
Model 12	0.91289	0.276647	0.27664727		-0.265234	0.002701	0.952089	0.009408	0.980939
Model 13	0.646266	3.124511	0.175862928	0.161353	0.422136	0.040554	0.939589	0.143285	0.98166
Model 14	0.89387	0.015035	0.196824754	0.031273	-1.079894	-0.05033	0.90058	0.185628	0.983274
COSMO					-1.196348	-0.25105	1.053134	0.8141	0.979036
ERA5					13.438342	1.809879	2.077154	5.889214	0.978999
SARAH					8.9986237	1.415286	1.893419	3.731965	0.976245
CMSAF					8.793807	1.411759	1.840986	3.962675	0.980089

4. Conclusions

In this study, the success of empirical models and satellite-based data sets in global solar radiation estimations of Usak province were compared. In addition, 2 different models were developed and tested within the scope of this study.

According to the monthly evaluation of the models, it had absolute relative error values below 5% in March-April-May-June, September-October and December, and accurate estimates were obtained in these months. Especially in the late spring-early summer and autumn period, estimates close to the measurements were obtained. Absolute relative error below 5% was seen in May in 16 of the 18 models used. The closest estimates were made in May. The determination coefficients of empirical models and satellite-based data sets were calculated over 0.97. This result shows that the models and satellite-based data sets used are generally successful. When the success of the models within themselves was evaluated according to the RMSE values, the most successful estimations were obtained from the Model 14 data (0.90058 RMSE, 0.98327 R^2, -1.079894 MPE, -0.05033 MBE ve 0.185628 t), which was developed logarithmically based on the clock angle and the maximum temperature difference, using 4 constant coefficients (c_1, c_2, c_3 and c_4) from the empirical models. From the spatial data, the most successful estimates were obtained from the COSMO re-analysis data (1.053134 RMSE, 0.979036 R^2, -1.196348 MPE, -0.25105 MBE ve 0.8141 t). Results from satellite-based datasets (PVGIS) were not as successful as estimations made by empirical models. However, the advantage of these data was that they present ready data for wide geographies, although they were not highly sensitive. These data can be used to see the spatial radiation values of the areas to be studied or were of a nature to shed light on more superficial studies.

As a result, it had been observed that empirical models can be preferred in detailed sensitive studies for global solar radiation estimation in Usak, and satellite-based data sets (PVGIS) can be used in more superficial or pre-feasibility studies. It was concluded that Model 14 from the models and COSMO re-analysis data among satellite-based data sets (PVGIS) can be used in global solar radiation estimation studies in Usak.

Nomenclature

ARE	Absolute Relative Error	c_n	*n*th coefficient
CAMS	Copernicus Atmosphere Monitoring Service	G_{sc}	Solar constant 1367 W m^{-2}
		h	hour
CMSAF	Satellite Application Facility on Climate Monitoring	H	Average daily solar radiation on a horizontal surface (J m^{-2} day^{-1})
COSMO	Concertium for Small-Scale Modelling	H_0	Monthly average daily extraterrestrial radiation on a horizontal surface
DHI	Diffuse radiation on a horizontal surface	H_{io}	Measured H value
		H_{ip}	Estimated H value
DirHor	Direct horizontal	*i*	ith day of month
ERA5	ECMWF Reanalysis v5	kWh	Kilowatt hour
GHGs	Greenhouse gases	MJ	Mega joule
GHI	Global radiation on a horizontal surface	n	The number of the day of the year starting from the first of January
GIS	Geographical Information System	R^2	Determinasyon katsayısı
		S	Sunshine length (h)
MBE	Mean Bias Error	S_0	Day length (h)
MPE	Mean Percentage Error	t	t statistik
MRM	Meteorological Radiation Model	w_s	Hour angle
		π	Pi
PVGIS	PhotoVoltaic Geographical Information System	ΔT	The difference of temperature between maximum and minimum
RMSE	Root Mean Square Error	φ	Latitude
RS	Remote Sensing	δ	The Solar declination angle
SARAH	Surface Solar Radiation Data Set-Heliosat		
UTM	Universal Transversal Mercator		

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Ersan, R. Külcü, R.; Design: Ersan, R. Külcü, R.; Data Collection or Processing: Ersan, R.; Statistical Analyses: Ersan, R.; Literature Search: Ersan, R.; Writing, Review and Editing: Ersan, R. Külcü, R.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Important Weed Species, Densities and Frequencies in Hazelnut (*Corylus avellana* L.) Orchards in Düzce Province*

Düzce İli Fındık (*Corylus avellana* L.) Bahçelerinde Görülen Önemli Yabancı Ot Türleri, Yoğunlukları ve Rastlanma Sıklıklarının Belirlenmesi

Adnan KARA[1*], Hakan ERMEÇ[2], Sezer DIBLAN[3]

Abstract

Hazelnut (*Corylus avellana* L.) cultivation has strategic value for Türkiye, which is a leader in global hazelnut production. This study aims to determine the important weed species, densities, and frequencies in hazelnut orchards in Düzce province. The presence of weeds is a significant challenge in hazelnut cultivation as they compete with the crop for nutrients, water, and sunlight, while also serving as hosts for pests and pathogens. Effective weed management is critical to maintaining yield and quality. Field research was conducted in 50 hazelnut orchards in 8 districts of Düzce and weed densities and frequencies were calculated using the Odum & Barrett method. In the survey studies conducted in Düzce hazelnut orchards, it was determined that 103 weed taxa belonging to 31 families and the ones with the species with the densest populations included *Potentilla reptans* (creeping cinquefoil) (35.46 plants m^{-2}), *Poa pratensis* (meadow grass) (12.15 plants m^{-2}), and *Bromus hordeaceus* subsp. *hordeaceus* (soft brome) (11.97 plants m^{-2}). The most frequent species were calculated to be *Potentilla reptans* (creeping cinquefoil) (81.80%), *Oenanthe silaifolia* (narrow-leaved water-dropwort) (78.34%) and *Lapsana communis* (nipplewort) (60.72%). Among the families identified, the *Poaceae* family has the highest number of species (19), followed by *Fabaceae* (14) and *Asteraceae* (13). Studies have detected those motorized scythes and herbicides, whose increased use may cause environmental effects and increase pest problems, are widely used in weed control. Identifying weed species and understanding their density and frequency will contribute to the adoption of more precise and environmentally friendly control methods and thus to increasing productivity and sustainability in hazelnut cultivation. Based on these findings, by applying targeted weed control measures, yield losses can be significantly reduced, beneficial organisms can be protected and the overall productivity and economic sustainability of hazelnut agriculture in Düzce Province can be contributed.

Keywords: Weed, Hazelnut, Survey, Density, Frequency, Düzce

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Öz

Fındık (*Corylus avellana* L.) yetiştiriciliği, küresel üretimde lider konumda olan Türkiye için stratejik değer taşımaktadır. Bu çalışmanın amacı Düzce ili fındık bahçelerinde bulunan önemli yabancı ot türlerini, yoğunluklarını ve sıklıklarını belirlemektir. Yabancı otların varlığı; besin maddesi, su ve güneş ışığı için ürünle rekabet ederken, aynı zamanda zararlılar ve patojenler için de konukçu görevi gördükleri için fındık yetiştiriciliğinde önemli bir zorluktur. Etkili yabancı ot yönetimi, verim ve kaliteyi korumak için kritik öneme sahiptir. Düzce'de 8 ilçede 50 fındık bahçesinde Odum & Barrett yöntemine göre sürvey çalışması yapılarak yabancı ot yoğunlukları ve sıklıkları hesaplanmıştır. Düzce fındık bahçelerinde yapılan çalışmalarda 31 familyaya ait 103 yabancı ot türü ve en yoğun popülasyona sahip olanlarının *Potentilla reptans* (reşatınotu) (35.46 bitki m^{-2}), *Poa pratensis* (çayır salkımotu) (12.15 bitki m^{-2}) ve *Bromus hordeaceus* subsp. *hordeaceus* (başakotu) (11.97 bitki m^{-2}) olduğu belirlenmiştir. En sık görülen türler arasında *Potentilla reptans* (reşatınotu) (%81,80), *Oenanthe silaifolia* (attohumu) (%78.34) ve *Lapsana communis* (şebrek) (%60.72) yer almaktadır. Tespit edilen familyalar arasında *Poaceae* familyası en fazla tür sayısına (19) sahip olup onu *Fabaceae* (14) ve *Asteraceae* (13) takip etmektedir. Teşhis edilen türler arasında en çok temsil edilen familyalar *Poaceae, Fabaceae* ve *Asteraceae* olmuştur. Yapılan çalışmalarda yabancı ot kontrolünde motorlu tırpanların, çevresel etkilere ve haşere sorunlarının artışına sebep olabilecek herbisitlerin yaygın olarak kullanıldığı belirlenmiştir. Yabancı ot türlerinin, yoğunluklarının ve rastlanma sıklıklarının belirlenmesi; daha kesin ve çevre dostu kontrol yöntemleri benimsenmesine ve böylece fındık yetiştiriciliğinde üretkenlik ve sürdürülebilirliğin arttırılmasına katkıda bulunacaktır. Bu bulgulara dayanarak hedefe yönelik yabancı ot kontrol önlemlerinin uygulanması ile verim kayıplarını önemli ölçüde azaltılabilir, faydalı organizmalar korunabilir ve Düzce ilindeki fındık tarımının genel verimliliğine ve ekonomik sürdürülebilirliğine katkıda bulunulabilir.

Anahtar Kelimeler: Yabancı ot, Fındık, Sürvey, Yoğunluk, Rastlanma sıklığı, Düzce

1. Introduction

Hazelnuts, whose homeland is the Black Sea coast, are cultivating primarily in Türkiye, in Europe in Spain, Italy, France, and Russia; in Asia in Georgia, Azerbaijan, Iran, and China; and in America in the USA and Chile. Also, efforts are intending to expand hazelnut production in many countries worldwide (Anonymous, 2019a). Hazelnut cultivation is one of the main livelihoods of the Black Sea Region countryside in Türkiye. Thusly, most of the hazelnut production in the world is carried out in Türkiye (Yenisu, 2017). For this reason, hazelnut cultivation has significant strategic value for our country.

In the agricultural production of hazelnuts, which has a valuable place in terms of nutrition and consumption in the world and our country, the importance of fighting against diseases, pests, and weeds, which are among the factors that reduce productivity, is increasing today (Eker and Kolören, 2023; Yonat and Kolören, 2023). It has been known for years that the effects of weeds on crop plants cause a significant decrease in yield and quality. Weeds compete with cultivated plants for nutrients, water, and sunlight, and also host pests and pathogens, causing an increase in diseases and pests (Mennan et al., 2006; Öğüt Yavuz and Boz, 2007). Weeds can also make harvesting operations more costly because they make it difficult to harvest the grown crops. Hazelnut producers generally carry out weed control in the orchards before harvest time and one of these methods is to use plant protection products. However, inappropriate total herbicide applications can harm both the environment and the hazelnut plant. In recent years, it has also been thought that the increasing use of herbicides in hazelnut orchards has increased the hazelnut skunk population and thus the resulting crop damage (Köse et al., 2014). In our country, survey studies on weeds are not sufficient in hazelnut production areas, which have a strategic importance in economic and agricultural terms. In order to find the right solutions to the weed problem in hazelnut cultivation, identifying the species and determining their distribution and density is of primary importance (Mennan et al., 1999).

Mennan et al. (1999) identified 210 weed species belonging to 54 different families as a result of 108 survey studies carried out between 1997 and 1999 in order to detect the weed species that are problematic in the hazelnut orchards of the Black Sea Region. These identified weed species, 32 were monocotyledonous and 178 were dicotyledonous. The important weed species in the region, according to their frequency, are; *Pteridium aquilium*, *Rubus dicolor*, *Bellis perennis*, *Poa annua*, *Convolvulus arvensis*, *Mercurialis annua*, *Poa trivialis*, *Avena fatua* and *Urtica urens*.

Aslan et al. (2001) determined 253 weed species belonging to 37 different families as a result of the study carried out between 1997 and 1999 in order to determine the weed species that are problematic in the pistachio orchards of the Southeastern Anatolia Region. These determined weed species, 124 were annual and 129 were perennial. The number of endemic species is 18 and the endemism rate is 7.1%. The main families in the study area in terms of the number of species they contain are; *Leguminosae* (*Fabaceae*) 22.1% (56 species), *Cruciferae* (*Brassicaceae*) 11.1% (28 species), *Gramineae* (*Poaceae*) 6.7% (17 species), *Compositae* (*Asteraceae-Cichoraceae*) 5.9% (15 species) and *Ranunculaceae* 5.5% (14 species).

Yazlık et al. (2019) detected 68 weed species (herbaceous/shrub) from 29 families in the study conducted to understand the weed species found in fruit nursery production areas in Düzce and the effects of these species. The most detected species were in the *Poaceae* families with 11 species and the Asteraceae families with 10 species, followed by the *Brassicaceae* (6 species) and *Fabaceae* (5 species) families. While the majority of the species are annual (34 species) and perennial (22 species) in terms of lifespan, one species has a biennial lifespan, and 11 species have a common lifespan. In terms of life form, 67 species are herbaceous and only one species (*Rubus* sp.) is shrub. The environmental and socioeconomic impacts caused by the identified species were evaluated as positive and negative impacts, and the most impact type was determined in 44 taxa included in the scope of environmental and socioeconomic impact.

This study aims to determine the weed species that share the plant nutrients in the soil and have a role as vectors for many diseases and pests in the cultivation of hazelnuts, an agricultural product of strategic importance for Türkiye, in Düzce province, their density and frequency. The goal of this study is to facilitate the selection of the control method in hazelnut orchards and to encourage the application of the most appropriate friendly weed control methods for the environment that will prevent yield losses. In addition, by becoming aware of the beneficial weeds growing in the hazelnut gardens in the province, it is envisaged that such species will be utilized and contribute to the country's economy.

2. Materials and Methods

2.1. Research Area

The territory of Düzce Province is surrounded by Sakarya from the west, Bolu from the south and southeast, and Zonguldak from the northeast. It has a 35 km long coastline on the Black Sea in the north (*Figure 1*). The area covered by the provincial territory is 259,300 hectares. Located on the same latitude as Kocaeli and Sakarya provinces, the westernmost and eastern ends of Düzce are between 30° 49' and 31° 51' east longitudes and are approximately 88 km long. The southernmost and northernmost points of the province are located between 40° 37' and 41° 06' northern latitudes, and the distance between the North and South extreme points is approximately 52 km. Along with the central district, it has 8 districts: Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı, Yığılca (Anonymous, 2011).

Figure 1. Map of districts where weed surveys are carried out in hazelnut orchards in Düzce province (Saygılı, 2020)

55% (38.903 ha) of Düzce city center, 33% (3.992 ha) of Gümüşova, 62% (16.741 ha) of Gölyaka, 35% (806 ha) of Çilimli, 33% (778 ha) of Cumayeri, 42% (17.266 ha) of Akçakoca, 65% (32.666 ha) of Yığılca and %64 (11.350 ha) of Kaynaşlı are forest areas, a total of 51% (122.502 ha) of Düzce province is forest area. Approximately 86% of Düzce, 2.200 km², is mountainous and rugged and the mountains are separated by deep valleys in many places (Anonymous, 2022c). According to long-term average meteorological data in Düzce Province, the month with the most rainfall is December, and the month with the least rainfall is July. The total annual rainfall is 829.8 mm per m² (Anonymous, 2022d).

The cultivated agricultural land of Düzce province is 74.854 hectares and approximately 30.000 hectares of the agricultural area in question is irrigable. 12.092 hectares of agricultural land are irrigated in the province. Only 35% of the real area of Düzce province can be used as agricultural land. 122.034 hectares of the land, that is, approximately 47%, is forest area. Düzce has 7,932 hectares of pasture and meadow area, and the remaining 37.919 hectares of its land assets are non-agricultural land. A very small part of the actual area of Düzce province is Class I agricultural land. The total of first, second and third class land, defined as absolute agricultural land, reaches only 15% of the land asset (Anonymous, 2019b).

There are first class alluvial soils in most of the Düzce plain. These soils lie on young sediments carried by streams and are generally layered. The transition between topsoil and subsoil is unclear. Alluvial soils are 75% suitable for agriculture and suitable for various products. Additionally, colivial and non-calcareous brown forest soils are found around Düzce. Collivial soils consist of materials accumulated in places where the slope decreases.

Non-limestone brown soils are rich in organic matter, acidic character and occur under deciduous forests. These soils are suitable for agriculture and are especially ideal for the production of beets, potatoes, vegetables, and fruits (Anonymous, 2022a).

Düzce province is located in the A3 square according to the vegetal square system of P.H. Davis (1965). This area is under the influence of the Euro-Siberian flora area and the Mediterranean (Mediterranean) flora area, which are generally distributed in the northwestern Black Sea region. Still, it is also under the slight influence of the Iranian-Turanian flora area. Düzce is located in the transition zone between Emcine (Central Western Black Sea) and Xsero-Euxine (Arid Western Black Sea) in terms of flora. While the effect of the sub-region (Sub-Euxine) of the European-Siberian flora area is seen in the Samandere Valley and the surrounding Abant Mountains (1600 m) in the southeast, the Mediterranean flora area effect is seen locally in the Uğursuyu Creek valley located in the front northern part. The Iranian-Turanian flora area effect is seen in the south of the area, in the transition zones to the Xero-Euxine flora area with xeriform character, in the high parts of Sinekli and Sakarca plateaus, and in the subalpine vegetation areas of the Abant Mountains at 1500-1600 m. Due to its geographical location and geomorphological structure, Düzce has a rich flora and vegetation diversity, that includes stream, remnant maquis, forest, sub-alpine and rock vegetation types, and the spread of rare plant habitats (Aksoy et al., 2016).

2.2. Field Studies

Table 1. Hazelnut orchard areas, number of trees, yield and production amounts and the number of orchards to be surveyed in Düzce city center and districts (Anonymous, 2024)

District	Production Area (Decare)	Number of Trees (Number)	Yield (kg Tree^{-1})	Production (Ton)	Number of Gardens to be Surveyed (Number)
Akçakoca	218.670	10.832.000	3	29.064	17
Cumayeri	54.000	2.675.000	2	5.825	4
Çilimli	35.250	1.762.000	4	6.631	3
Gölkaya	42.290	2.111.750	2	5.207	4
Gümüşova	34.760	1.735.500	3	4.635	3
Kaynaşlı	23.150	1.157.500	3	4.008	2
Yığılca	94.500	4.725.000	3	14.688	7
City Center	129.030	6.451.250	2	15.630	10
Total	631.650	31.450.000	3	85.688	50

The research was carried out in lands in the Survey region, Düzce province, City Center, Akçakoca, Yığılca, Cumayeri, Gölyaka, Çilimli, Gümüşova and Kaynaşlı districts. In this research, it was planned to conduct surveys in hazelnut orchards for a total of 50 orchards according to tree counts of every district. In determining the number of gardens to be surveyed, it was planned to carry out surveys in a total of 50 gardens, considering the difficulty of transportation, the time spent during the survey, the time and labor to be spent during the census. The distribution of these 50 gardens by districts was proportioned and distributed as in *Table 1*, considering the shares of each district in the total hazelnut garden area of the province. Various road routes were determined and in the selection of the points for sampling, the width of the hazelnut production area as well as their distance from each other in different directions to represent the district were taken into consideration.

In order to avoid edge effects in hazelnut gardens, approximately 10 m should be entered, and in the counts, a 1/4 m² square frame was thrown according to the size of the garden, as seen in *Figure 2*; Weed species found in the area within the frame and their densities per m² were determined for that counting point. The number of samples was determined according to the size of the hazelnut orchards, and the frame was thrown 4 times up for 1-5 decares, 6 times for between 5-10 decares, and at least 8 times for hazelnut orchards larger than 10 decares. When counting weed species, broad-leaved weeds were counted as the whole plant, and in narrow-leaved ones, each tiller (spike) was counted as a plant and recorded in the survey forms in this way. The frame was randomly thrown by moving in the direction of the diagonals of the entered garden. Plants entering the frame and those touching the outside of the frame were separated and counted according to weed species (Kara and Ata, 2021).

Figure 2. Weed species detection and counting in hazelnut orchards where survey studies were carried out

A sufficient number of plant samples from each weed species detected during the survey were collected and dried by pressing between newspaper papers in accordance with the technique to make them suitable for diagnosis (*Figure 2*). Then, samples were glued to standard-size cardboards (*Figure 3*) and turned into herbarium materials. Weed identification studies were carried out by Prof. Dr. Necmi AKSOY and Dr. Serdar ARSLAN in the Düzce University Faculty of Forestry (DUOF) Herbarium laboratory (*Figure 3*) and plant samples were recorded in the Düzce University Faculty of Forestry (DUOF) Herbarium inventory (Anonymous, 2022b).

Figure 3. Pressing and drying of plant samples in accordance with the technique & identification and registration of weed samples in the DUOF Herbarium

2.3. Evaluation of Population Measurements

After determining the weed species and their numbers, the frequency (F) of each species used in the evaluation of the population was determined. In determining the frequency, all weeds in the environment were recorded, regardless of whether they were included in the frame or not. Each Frequency (F, %) was calculated by using the number of survey points where each species is found (N) and the total number of sampled survey points (M). Frequencies were calculated according to Odum and Barrett (1971) and the following Equation (1) was used.

$$F = \left(\frac{N}{M}\right) \times 100 \qquad \text{(Eq. 1)}$$

Density (plant m^{-2}) was calculated by counting the individuals according to the genus and species of the weeds in the frame, multiplying the number of plants belonging to the species in each frame by four, taking the arithmetic averages according to the number of frames thrown, and densities of the weeds at that counting point were calculated. In these determined areas, the density and frequency of weeds according to the number of frames were calculated using Odum and Barrett (1971) and Uygur (1991). Using Bora and Karaca (1970), the density of weed species at the district level was determined on a weighted average basis. The density of weeds at the district level was calculated by multiplying the weed density (plant m^{-2}) determined for each census point by the area of that garden and dividing the sum of these multiplication results by the total hazelnut garden area surveyed in that district. The average of the species at the provincial level was calculated by taking the average of the districts (Uygur et al., 1984).

3. Results and Discussion

3.1. Results

The densities and frequency of the weed species detected in the hazelnut orchards of Düzce province according to the areas where the research was conducted are given in *Table 2*. As a result of the research, 103 weed species belonging to 31 families were identified. *Potentilla reptans* (35.46 plants m^{-2}), *Poa pratensis* (12.15 plants m^{-2}), *Bromus hordeaceus* subsp. *hordeaceus* (11.97 plants m^{-2}), *Cynosurus cristatus* (10.52 plants m^{-2}), *Bromus sterilis* (8.97 plants m^{-2}), *Hordeum bulbosum* (8.43 plants m^{-2}), *Trifolium pratense* var. *pratense* (6.17 plants m^{-2}), *Holcus lanatus* (5.87 plants m^{-2}), *Alopecurus myosuroides* subsp. *myosuroides* (5.84 plants m^{-2}), *Trifolium campestre* (5.75 plants m^{-2}) species were determined as the 10 densest species throughout the province. The densest species are given in *Table 3*.

Considering the frequency; *Potentilla reptans* (81.80%), *Oenanthe silaifolia* (78.34%), *Lapsana communis* (60.72%), *Convolvulus arvensis* (51.37%), *Rubus tereticaulis* (43.87%), *Geranium pyrenaicum* (38.2%), *Trifolium campestre* (37.1%), *Trifolium pratense* var. *pratense* (32.13%), *Conyza canadensis* (31.81%), *Urtica dioica* subsp. *dioica* (31%, 72) took the first places. The most frequent species are given in *Table 4*.

The distribution of the weeds detected according to families as a result of the surveys carried out in the hazelnut orchards of Düzce province between April and July 2021 is shown in *Figure 4*. Among the families identified, *Poaceae* ranks first with 19 species, *Fabaceae* ranks second with 14 species, and *Asteraceae* ranks third with 13 species. These are followed by *Lamiaceae* with 7 species, Rosaceae with 7 species, *Boraginaceae*, *Caprifoliaceae*, *Geraniaceae*, *Plantaginaceae*, *Rubiaceae* with 3 species each, and *Caryophyllaceae*, *Convolvulaceae*, *Euphorbiaceae*, *Polygonaceae*, *Primulaceae* with 2 species each. Only one species from each of the 15 families could be identified respectively.

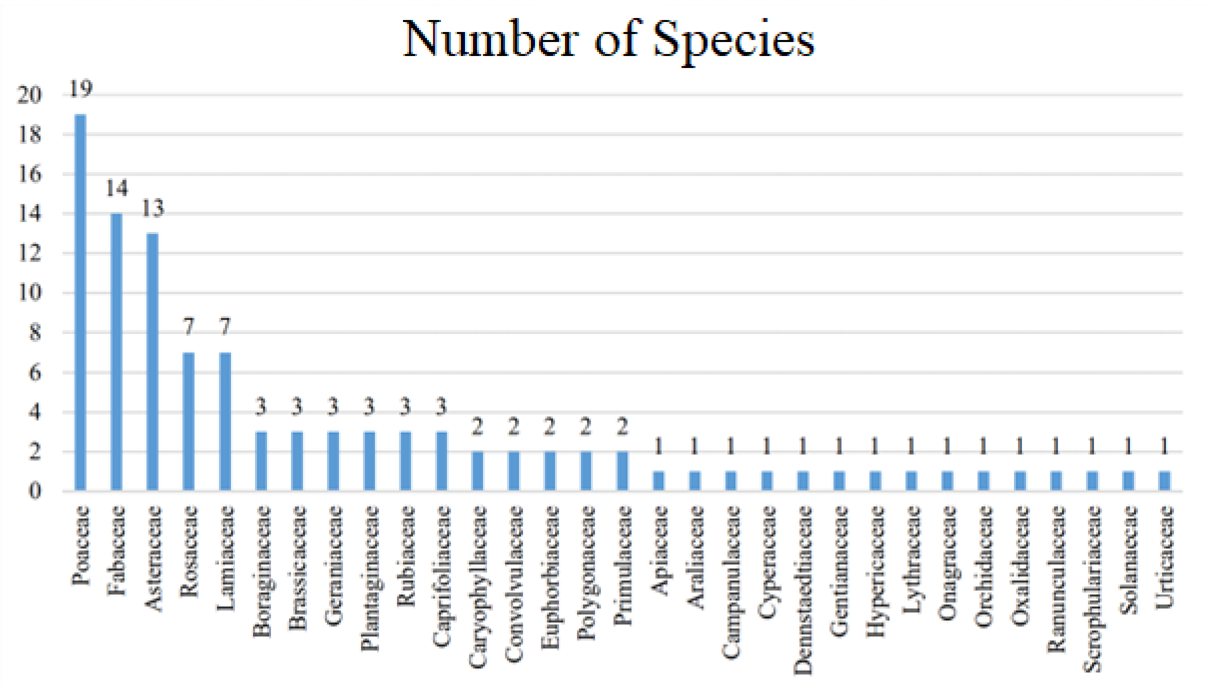

Figure 4. Distribution chart of weed species detected in hazelnut orchards in Düzce province according to families

Table 2. Weed species detected in hazelnut orchards in Düzce province, densities (plant m^{-2}) and frequencies (%)

Weed Species	**Akçakoca**		**Cumayeri**		**Çilimli**		**Gölyaka**		**Gümüşova**		**Kaynaşlı**		**Yığılca**		**Center**		**Düzce**	
	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.
Agrimonia eupatoria L.	0.00	0.00	0.00	0.00	33.33	2.15	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.50	10.00	0.43	7.20	0.39
Ajuga reptans L.	5.88	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.09
Alopecurus myosuroides subsp. *myosuroides* Huds	5.88	2.80	50.00	2.17	33.33	26.31	0.00	0.00	100.0	15.44	0.00	0.00	0.00	0.00	0.00	0.00	23.65	5.84
Anacomptis pyramidalis L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.06	0.00	0.00	1.79	0.01
Anagallis arvensis L. var. *arvensis*	29.41	2.36	50.00	0.41	33.33	0.26	0.00	0.00	66.67	1.56	0.00	0.00	42.86	1.04	30.00	0.77	31.53	0.80
Anthemis cotula L.	17.65	0.83	50.00	2.17	33.33	1.35	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.08	0.00	0.00	14.41	0.55
Asperula involucrata Wahlenb.	5.88	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.39
Avena barbata Pott ex Link	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	14.93	0.00	0.00	0.00	0.00	0.00	0.00	4.17	1.87
Avena fatua L.	5.88	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.35
Bellis perennis L.	5.88	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.02
Bituminaria bituminosa (L.) C.H.Stirt.	0.00	0.00	25.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.30	0.00	0.00	4.91	0.18
Brachypodium pinnatum (L.) P.Beauv.	0.00	0.00	25.00	13.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	1.68
Briza maxima L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	5.80	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.73
Bromus hordeaceus subsp. *hordeaceus* L.	5.88	0.19	0.00	0.00	0.00	0.00	25.00	95.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.59	6.36	11.97
Bromus japonicus Thunb	5.88	3.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	7.20	20.00	7.32	5.02	2.27
Bromus sterilis L.	11.76	9.75	50.00	4.25	0.00	0.00	0.00	0.00	100.0	47.41	0.00	0.00	0.00	0.00	20.00	10.36	22.72	8.97
Calepina irregularis (Asso) Thell.	5.88	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.03
Calystegia silvatica (Kit.) Griseb.	11.76	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	1.20	10.00	0.43	4.51	0.22
Campanula glomerata subsp. *hispida* (Witasek) Hayek	0.00	0.00	0.00	0.00	33.33	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.09
Centaurium erythraea subsp. *erythraea* Rafn.	5.88	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.54	1.99	0.09
Cichorium intybus L.	11.76	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.08	0.00	0.00	3.26	0.04
Clinopodium vulgare L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	5.60	0.00	0.00	1.79	0.70
Convolvulus arvensis L.	41.18	1.92	25.00	0.13	66.67	9.95	50.00	4.83	66.67	7.00	50.0	3.65	71.43	2.88	40.00	1.05	51.37	3.93
Conyza canadensis (L.) Cronquist	41.18	1.50	75.00	17.70	33.33	1.04	25.00	0.89	0.00	0.00	50.0	6.22	0.00	0.00	30.00	1.13	31.81	3.56
Crepis setosa Haller f.	5.88	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.08	1.99	0.02

1 ***Table 2 (Continued). Weed species detected in hazelnut orchards in Düzce province, densities (plant m^{-2}) and frequencies (%)***

Weed Species	Akçakoca		Cumayeri		Çilimli		Gölyaka		Gümüşova		Kaynaşlı		Yığılca		Center		Düzce	
	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.
Crepis vesicaria L.	5.88	0.06	25.00	3.51	0.00	0.00	25.00	0.17	66.67	3.10	0.00	0.00	0.00	0.00	10.00	0.25	16.57	0.89
Cynosurus cristatus L.	0.00	0.00	0.00	0.00	33.33	80.23	0.00	0.00	66.67	3.90	0.00	0.00	0.00	0.00	0.00	0.00	12.5	10.52
Cynosurus echinatus L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.72	30.00	6.03	5.54	0.84
Cyperus esculentus L.	11.76	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.04
Dactylis glomerata subsp. *glomerata* L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	1.61	1.25	0.20
Dianthus armeria L.	0.00	0.00	25.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	0.09
Dipsacus laciniatus L.	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	0.07
Echium vulgare L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.20	10.00	0.04	3.04	0.03
Epilobium tetragonum subsp. *tetragonum* L.	0.00	0.00	0.00	0.00	33.33	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.19
Euphorbia stricta L.	29.41	2.85	25.00	1.84	0.00	0.00	25.00	2.83	33.33	2.20	50.00	1.44	0.00	0.00	20.00	0.49	22.84	1.46
Filipendula vulgaris Moench	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	14.51	0.00	0.00	0.00	0.00	0.00	0.00	4.17	1.81
Fragaria vesca L.	11.76	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.86	2.72	0.25
Galega officinalis L.	5.88	0.33	50.00	3.85	0.00	0.00	0.00	0.00	33.33	2.07	0.00	0.00	14.29	0.38	10.00	0.21	14.19	0.86
Galium verum L.	0.00	0.00	25.00	22.84	33.33	2.05	0.00	0.00	33.33	10.54	0.00	0.00	0.00	0.00	0.00	0.00	11.46	4.43
Geranium asphodeloides Burm.f. subsp. *asphodeloides*	23.53	2.07	0.00	0.00	0.00	0.00	25.00	0.67	33.33	4.15	0.00	0.00	14.29	0.25	20.00	0.60	14.52	0.97
Geranium macrostylum Boiss.	0.00	0.00	25.00	0.88	0.00	0.00	25.00	4.00	33.33	12.29	0.00	0.00	0.00	0.00	0.00	0.00	10.42	2.15
Geranium pyrenaicum Burm.f.	11.76	0.40	25.00	0.28	33.33	3.46	25.00	3.27	33.33	0.73	50.00	8.34	57.14	6.00	70.00	14.20	38.20	4.59
Geum urbanum L.	23.53	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.94	0.13
Glechoma hederacea L.	23.53	2.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	6.76	4.19	1.21
Hedera helix L.	11.76	2.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57	7.16	0.00	0.00	5.04	1.26
Holcus lanatus L.	17.65	2.71	75.00	25.26	0.00	0.00	0.00	0.00	33.33	1.24	0.00	0.00	0.00	0.00	60.00	17.73	23.25	5.87
Hordeum bulbosum L.	5.88	6.43	0.00	0.00	0.00	0.00	25.00	52.33	0.00	0.00	50.00	4.17	0.00	0.00	30.00	4.48	13.86	8.43
Hordeum murinum subsp. *leporinum* (Link) Arcang.	5.88	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.68	3.24	0.16
Hypericum androsaemum L.	5.88	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.01
Hypochaeris radicata L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.73	2.50	0.09
Knautia arvensis (L.) Coult.	0.00	0.00	25.00	0.42	0.00	0.00	0.00	0.00	33.33	7.46	0.00	0.00	14.29	0.06	0.00	0.00	9.08	0.99

1 ***Table 2 (Continued). Weed species detected in hazelnut orchards in Düzce province, densities (plant m^{-2}) and frequencies (%)***

Weed Species	Akçakoca		Cumayeri		Çilimli		Gölyaka		Gümüşova		Kaynaşlı		Yığılca		Center		Düzce	
	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.
Knautia degenii Borbás ex Formanek	0.00	0.00	0.00	0.00	66.67	1.77	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	2.31	13.96	0.51
Lapsana communis L.	52.94	1.85	50.00	0.55	33.33	0.77	100.0	3.31	66.67	2.12	100.0	2.00	42.86	1.06	40.00	1.29	60.72	1.62
Lapsana communis subsp. *intermedia*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	1.40	1.25	0.17
Lathyrus nissolia L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	2.63	50.00	0.52	0.00	0.00	0.00	0.00	10.42	0.39
Lathyrus sativus L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.56	1.25	0.07
Lolium perenne L.	0.00	0.00	50.00	4.94	0.00	0.00	25.00	6.30	33.33	12.00	50.00	5.21	0.00	0.00	80.00	16.99	29.79	5.68
Lotus corniculatus var. *corniculatus* L.	0.00	0.00	50.00	0.82	33.33	0.54	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.08	10.00	0.89	13.45	0.29
Lysimachia nummularia L.	0.00	0.00	0.00	0.00	0.00	0.00	25.00	2.44	33.33	1.02	0.00	0.00	0.00	0.00	0.00	0.00	7.29	0.43
Lythrum cf. *hyssopifolia* L.	5.88	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.01
Medicago arabica (L.) Huds.	17.65	1.05	0.00	0.00	0.00	0.00	25.00	4.33	66.67	3.37	0.00	0.00	0.00	0.00	20.00	0.69	16.16	1.18
Melissa officinalis L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.43	16.03	0.00	0.00	8.93	2.00
Mentha sp.	11.76	1.31	0.00	0.00	0.00	0.00	75.00	9.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.85	1.32
Mercurialis annua L.	5.88	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.02
Moenchia mantica (L.) Bartl.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	2.49	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.31
Myosotis alpestris subsp. *alpestris*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	2.63	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.33
Oenanthe silaifolia M.Bieb.	52.94	3.13	50.00	2.14	66.67	3.35	100.0	6.36	100.0	10.37	100.0	8.27	57.14	2.52	100.0	5.14	78.34	5.16
Oxalis corniculata L.	35.29	4.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.14	4.65	0.00	0.00	11.55	1.09
Plantago lanceolata L.	0.00	0.00	0.00	0.00	0.00	0.00	25.00	2.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	0.29
Plantago major subsp. *major* L.	23.53	0.85	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.44	0.00	0.00	14.29	0.75	0.00	0.00	8.89	0.25
Poa pratensis L.	11.76	2.02	0.00	0.00	33.33	11.04	0.00	0.00	33.33	68.05	50.00	4.31	28.57	5.28	40.00	6.49	24.63	12.15
Poa trivialis L.	0.00	0.00	50.00	3.77	0.00	0.00	50.00	19.36	33.33	0.73	0.00	0.00	0.00	0.00	40.00	6.09	21.67	3.74
Potentilla reptans L.	52.94	21.25	50.00	5.72	100.0	38.31	100.0	70.62	100.0	34.20	100.0	42.89	71.43	18.76	80.00	51.89	81.80	35.46
Prunella vulgaris L.	29.41	2.70	50.00	7.37	33.33	11.31	0.00	0.00	0.00	0.00	50.00	8.62	42.86	0.92	30.00	3.46	29.45	4.30
Pteridium aquilinum (L.) Kuhn	17.65	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	1.91	28.57	0.28	10.00	0.13	13.28	0.37
Pulicaria dysenterica (L.) Bernh.	5.88	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.11
Ranunculus constantinopolitanus	5.88	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57	0.40	20.00	0.90	6.81	0.18

1 ***Table 2 (Continued). Weed species detected in hazelnut orchards in Düzce province, densities (plant m^{-2}) and frequencies (%)***

Weed Species	Akçakoca		Cumayeri		Çilimli		Gölyaka		Gümüşova		Kaynaşlı		Yığılca		Center		Düzce	
	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.	Freq.	Dens.
Raphanus raphanistrum L.	17.65	0.34	0.00	0.00	0.00	0.00	25.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.33	0.10
Rorippa sylvestris (L.) Besser	5.88	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.06
Rubus tereticaulis P.J.Müll.	41.18	1.38	0.00	0.00	0.00	0.00	75.00	4.63	33.33	1.32	100.0	4.52	71.43	2.25	30.00	1.31	43.87	1.93
Rumex crispus L.	17.65	0.47	0.00	0.00	0.00	0.00	0.00	0.00	33.33	3.07	0.00	0.00	0.00	0.00	0.00	0.00	6.37	0.44
Rumex obtusifolius L.	11.76	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.06
Salvia forskahlei L.	11.76	0.21	25.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	50.00	9.10	0.00	0.00	0.00	0.00	10.85	1.20
Sanguisorba minor L.	5.88	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.20	30.00	0.47	6.27	0.10
Scrophularia scopolii var. *scopolii.*	41.18	5.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57	2.05	0.00	0.00	8.72	0.97
Securigera varia (L.) Lassen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.20	0.00	0.00	1.79	0.03
Setaria glauca (L.) P.Beauv.	5.88	0.21	0.00	0.00	33.33	16.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.90	2.08
Sherardia arvensis L.	0.00	0.00	75.00	1.64	0.00	0.00	0.00	0.00	66.67	10.41	0.00	0.00	14.29	0.24	50.00	3.60	25.74	1.99
Solanum nigrum L.	5.88	1.73	0.00	0.00	33.33	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.90	0.25
Sonchus asper subsp. *glaucescens* (Jord.) Ball	11.76	0.21	25.00	0.13	66.67	3.10	0.00	0.00	0.00	0.00	0.00	0.00	42.86	1.38	10.00	1.63	19.54	0.81
Sophora jaubertii Spach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.30	0.00	0.00	1.79	0.04
Sorghum bicolor (L.) Moench	0.00	0.00	0.00	0.00	33.33	30.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.17	3.78
Taraxacum macrolepium Schischk.	5.88	0.78	0.00	0.00	0.00	0.00	25.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.86	5.11	0.23
Trachystemon orientalis (L.) G.Don	23.53	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57	1.22	10.00	0.56	7.76	0.35
Trifolium campestre Schreb.	5.88	0.32	50.00	2.67	33.33	7.54	0.00	0.00	33.33	10.37	100.0	15.45	14.29	0.70	60.00	8.99	37.10	5.75
Trifolium hybridum var. *hybridum* L.	0.00	0.00	25.00	0.59	0.00	0.00	25.00	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25	0.37
Trifolium pratense var. *pratense* L.	11.76	1.00	25.00	1.55	66.67	4.79	75.00	25.02	0.00	0.00	50.00	15.12	28.57	1.90	0.00	0.00	32.13	6.17
Trifolium repens L.	35.29	8.49	25.00	5.86	0.00	0.00	25.00	0.70	33.33	7.90	0.00	0.00	57.14	9.47	50.00	5.04	28.22	4.68
Urtica dioica subsp. *dioica* L.	23.53	2.23	0.00	0.00	33.33	1.73	75.00	4.38	33.33	4.68	50.00	2.39	28.57	3.30	10.00	2.07	31.72	2.60
Veronica filiformis Sm.	5.88	0.32	0.00	0.00	0.00	0.00	25.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.86	0.10
Vicia sativa subsp. *nigra* var. *nigra* (L.) Ehrh.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	3.95	0.00	0.00	0.00	0.00	10.00	0.18	5.42	0.52
Vicia sativa subsp. *nigra* var. *segetalis* (Thuill.)	5.88	0.05	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.44	0.00	0.00	14.29	0.08	10.00	0.32	7.94	0.11
Xanthium orientale subsp. italicum (Moretti) Greuter	5.88	0.20	25.00	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.86	0.24

Table 3. Weed species with the highest density in hazelnut orchards in Düzce province

Weed Species	Akçakoca Dens.	Cumayeri Dens.	Çilimli Dens.	Gölyaka Dens.	Gümüşova Dens.	Kaynaşlı Dens.	Yığılca Dens.	Center Dens.	Düzce Dens.
Potentilla reptans L.	21.25	5.72	38.31	70.62	34.20	42.89	18.76	51.89	35.46
Poa pratensis L.	2.02	0.00	11.04	0.00	68.05	4.31	5.28	6.49	12.15
Bromus hordeaceus subsp. *hordeaceus* L.	0.19	0.00	0.00	95.00	0.00	0.00	0.00	0.59	11.97
Cynosurus cristatus L.	0.00	0.00	80.23	0.00	3.90	0.00	0.00	0.00	10.52
Bromus sterilis L.	9.75	4.25	0.00	0.00	47.41	0.00	0.00	10.36	8.97
Hordeum bulbosum L.	6.43	0.00	0.00	52.33	0.00	4.17	0.00	4.48	8.43
Trifolium pratense var. *pratense* L.	1.00	1.55	4.79	25.02	0.00	15.12	1.90	0.00	6.17
Holcus lanatus L.	2.71	25.26	0.00	0.00	1.24	0.00	0.00	17.73	5.87
Alopecurus myosuroides subsp. *myosuroides* Huds	2.80	2.17	26.31	0.00	15.44	0.00	0.00	0.00	5.84
Trifolium campestre Schreb.	0.32	2.67	7.54	0.00	10.37	15.45	0.70	8.99	5.75

Table 4. Weed species with the highest frequency in hazelnut orchards in Düzce province

Weed Species	Akçakoca Freq.	Cumayeri Freq.	Çilimli Freq.	Gölyaka Freq.	Gümüşova Freq.	Kaynaşlı Freq.	Yığılca Freq.	Center Freq.	Düzce Freq.
Potentilla reptans L.	52.94	50.00	100.0	100.0	100.0	100.0	71.43	80.00	81.80
Oenanthe silaifolia M.Bieb.	52.94	50.00	66.67	100.0	100.0	100.0	57.14	100.0	78.34
Lapsana communis L.	52.94	50.00	33.33	100.0	66.67	100.0	42.86	40.00	60.72
Convolvulus arvensis L.	41.18	25.00	66.67	50.00	66.67	50.00	71.43	40.00	51.37
Rubus tereticaulis P.J.Müll.	41.18	0.00	0.00	75.00	33.33	100.0	71.43	30.00	43.87
Geranium pyrenaicum Burm.f.	11.76	25.00	33.33	25.00	33.33	50.00	57.14	70.00	38.20
Trifolium campestre Schreb.	5.88	50.00	33.33	0.00	33.33	100.0	14.29	60.00	37.10
Trifolium pratense var. *pratense* L.	11.76	25.00	66.67	75.00	0.00	50.00	28.57	0.00	32.13
Conyza canadensis (L.) Cronquist	41.18	75.00	33.33	25.00	0.00	50.00	0.00	30.00	31.81
Urtica dioica subsp. *dioica* L.	23.53	0.00	33.33	75.00	33.33	50.00	28.57	10.00	31.72

3.2. Discussion

In this study, it was observed that weed control was generally carried out in the hazelnut orchards where surveys were carried out. Although herbicide is mostly applied in the control, it has been observed that the use of motorized scythes is also common. It is known that weeding is at high density due to the rainfall regime of the Black Sea Region. High weed density in hazelnut orchards, especially during fertilization periods, can cause yield losses in the product by sharing nutrients in the soil, but can also be a host for diseases and pests. To prevent this, knowing the weed species, their density, and frequency may be advantageous to the producer or technical staff in deciding on the periods and methods of control. By selecting the appropriate herbicide according to weed density and type and determining the control method that will protect nature, beneficial organisms can also continue their activities. The identified species are new records detected in the hazelnut orchards of Düzce province.

Öğüt Yavuz and Boz (2007) aimed to determine the weed species found in the nurseries of Aydın province in summer and winter, their frequency, number per m² and coverage areas. According to the research they conducted between 2004 and 2005, a total of 20 species belonging to 13 families, 7 of which are monocotyledonous and 13 of which are dicotyledonous, were identified among the weeds detected in the summer period. Among these species, Purslane (*Portulaca oleraceae*) ranks first with a frequency of 87.80%. A total of 47 weed species belonging to 20 families, 12 of which are monocotyledonous and 35 of which are dicotyledonous, were detected during the winter period. Among these species, Chickweed (*Stellaria media*) ranks first with 79.80%.

Ahkemoğlu and Uygur (2018) studied six different orange gardens in Adana Province in 2015 and 2016; and concluded that weeds, which interact with various factors in the agroecosystem, can host plant disease agents and harmful arthropods and nematodes, serve as the main host and alternative host, or can be a wintering place for these organisms. Based on the idea that "one of the examples of this relationship is the interaction between weeds and mealybugs", the study planned to investigate the weed species in the gardens and the mealybug species on them. In total, 78 weed species belonging to 24 plant families were identified. Citrus mealybug, *Planococcus citri* (Risso), which is the most important mealybug species for citrus gardens, common mallow (*Malva sylvestris* L.), toadflax (*Linaria* sp.), black nightshade (*Solanum nigrum* L.), red-root amaranth (*Amaranthus retroflexus* L.), crimson clover (*Trifolium incarnatum* L.), purslane (*Portulaca oleraceae* L.). Other species identified are *Chorizococcus rostellum* (Lobdell), *Peliococcus turanicus* (Kiritshenko), *Phenacoccus solani* (Ferris), and *Phenacoccus solenopsis* (Tinsley).

Sokat and Çatıkkaş (2019) investigated the weed species, their density and frequency in the almond production areas of Manisa and Muğla Province in 2017. As a result of this research, a total of 62 different weed species belonging to 27 families were identified. Of the mentioned species, 1 is a parasite (*Viscum album*), 13 are narrow-leaved, and 40 are broad-leaved weed species. In Muğla province, among broadleaf weeds, it was determined that the highest weed density and frequency were in the species *Oxalis pes-caprae* (18.57 plants m^{-2}; 60%), *Raphanus raphanistrum* (16.03 plants m^{-2}; 56%), *Convolvulus arvensis* (5.36 plants m^{-2}; 20%) and among grassweeds *Sorghum halepense* (8.72 plants m^{-2}; 38%), *Cyperus rotundus* (6.46 plants m^{-2}; 36%).In Manisa province, the most dense and frequent broadleaf weed species were *Ranunculus arvensis* (18.57 plants m^{-2}; 45%), *Crepis* spp. (16.12 plants m^{-2}; 55%), *Matricaria chamomilla* (15.19 plants m^{-2}; 65%), *Senecio vernalis* (9.48 plants m^{-2}; 32%) and among narrow-leaf weeds *Cynodon dactylon* (20.89 plants m^{-2}; 35%), *Poa annua* (20.5 plants m^{-2}; 31%), *Bromus tectorum* (18.57 plants m^{-2}; 28%).

4. Conclusions

In conclusion, in order to minimize the decrease in productivity caused by weeds in hazelnut cultivation and production; Knowing which weeds we will be fighting against and at what density they occur is important to choose a more appropriate, economical, and effective control method to protect against diseases and damage. Thus, with correct and conscious weed control, it will be possible to contribute to production, nature, and economy by preventing yield losses caused by weeds in hazelnuts. The effect of powdery mildew disease (*Erysiphe betae*) on yield, which has been a significant problem in hazelnut production in recent years, and its relationship with weeds as hosts may be a new research topic in this sense.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest.

Authorship Contribution Statement

Concept: Kara, A.; Design: Kara, A., Ermeç, H.; Data Collection or Processing: Kara, A., Ermeç, H.; Statistical Analyses: Kara, A., Ermeç, H., Dıblan, S.; Literature Search: Ermeç, H., Dıblan, S.; Writing, Review and Editing: Ermeç, H., Dıblan, S.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Analyze of The Effects of Possible Climate Change Scenarios for Biomass and Grain Yields of Sunflower and Winter Wheat with AquaCrop Model in The Thrace Region of Türkiye

Trakya Bölgesi'nde Olası İklim Değişikliği Senaryolarının Ayçiçeği ve Kışlık Buğdayın Biyokütle ve Tane Verimine Etkilerinin AquaCrop Modeli ile Analizi

Fatih BAKANOĞULLARI

Abstract

Prediction of crop yield and biomass in agricultural production is crucial for both food safety and national economic projections. This study aimed to determine the relationship between the effects of climate change and biomass and grain yield of two crops (winter wheat and sunflower) at two locations, Kirklareli (KRK), Edirne-Orhaniye (EOR), with different soil textures, in the Thrace region. The scenarios (n=S1, S2,…,S65) of sensitivity analysis established by considering the expected trend of climate change were evaluated in terms of biomass and grain yield for sunflower and winter wheat crops with the AquaCrop model. The model predicted the highest losses of grain yield and biomass, when the air temperature was increased by 5 °C and the precipitation was decreased by 50% during the growing seasons of both crops (in the scenario S42). In the scenarios where only temperature was increased, grain and biomass yield values of sunflower was decreased, while those of winter wheat was increased. The combined effects of increased global solar radiation and decreased temperature had a negative effect on wheat production at EOR. For both sunflower and wheat, the most negative impacts on yield and biomass production were observed with the combined scenarios of various temperature increases and precipitation decreases during each growing season at each location. According to the simulation results of the defined single and combined scenarios in both spatial areas, while the grain and biomass yields of the summer planted sunflower plant were negative linear relations every scenario, non-linear relations were determined in the yields of the winter-wheat plant. Finally, with the defined sensitivity scenarios, the correlation coefficients between biomass and grain yield of sunflower and winter wheat under similar climate but different soil types in two locations were found to be R^2= 0.88 and 0.87 for KRK and R^2 = 0.56, and 0.79, for EOR, respectively.

Keywords: Agrometeorology, Winter wheat, Sunflower, Sensitivity analysis, AquaCrop

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Öz

Tarımsal üretimde ürün verimi ve biyokütlenin tahmini hem gıda güvenliği hem de ulusal ekonomik projeksiyonlar açısından büyük önem taşımaktadır. Bu çalışmada, Trakya bölgesinde, Kırklareli (KRK), Edirne-Orhaniye (EOR) de, farklı toprak bünyesine sahip iki lokasyonda iklim değişikliğinin etkileri ile iki ürünün (kışlık buğday ve ayçiçeği) biyokütle ve tane verimi arasındaki ilişkinin belirlenmesi amaçlamıştır. İklim değişikliğinin beklenen eğilimi dikkate alınarak oluşturulan hassaslık analizi senaryoları (n=S1, S2,…,S65) AquaCrop modeli ile ayçiçeği ve kışlık buğday bitkisi için biyokütle ve tane verimi açısından değerlendirilmiştir. Model, her iki ürünün yetiştirme sezonu boyunca hava sıcaklığının 5 °C arttığı ve yağışların %50 azaldığı senaryoda (S42) dane ve biyokütle veriminde en yüksek kayıpları tahmin etmiştir. Sadece sıcaklığın artırıldığı senaryolarda ayçiçeğinin dane ve biyokütle verim değerleri düşerken, kışlık buğdayın dane ve biyokütle verim değerleri arttı. Artan global güneş radyasyonu ve azalan sıcaklığın birleşik etkileri, EOR istasyonunda buğday dane üretimi üzerinde negatif bir etki yarattı. Hem ayçiçeği hem de buğday için, dane ve biyokütle üretimi üzerindeki en olumsuz etkiler, her iki gelişme sezonu boyunca, iki lokasyonda da çeşitli sıcaklık artışları ve yağış düşüşlerinin bir araya getirildiği senaryolarla gözlemlendi. Oluşturulan hassaslık analiz senaryolarının tekli ve birleşik senaryoların her iki mekânsal alanda simülasyon sonuçlarına göre, yazlık ekilen ayçiçeği bitkisinin tane ve biyokütle verimleri her senaryoda negatif doğrusal ilişkiler gösterirken, kışlık buğday bitkisinin dane verimlerinde doğrusal olmayan ilişkiler belirlenmiştir. Son olarak, tanımlanan duyarlılık senaryoları ile benzer iklim ancak farklı toprak tiplerine sahip iki lokasyondaki ayçiçeği ve kışlık buğdayın biyokütle ve tane verimi arasındaki korelasyon katsayıları sırasıyla KRK için R^2= 0.88 ve 0.87 ve EOR için R^2 = 0.56 ve 0.79 olarak bulunmuştur.

Anahtar Kelimeler: Agrometeoroloji, Kışlık buğday, Ayçiçeği, Hassasiyet analizi, AquaCrop

1. Introduction

Agricultural production is greatly influenced by the climate. Changes in greenhouse gas concentrations, global solar radiation, and air temperature patterns may have significant consequences for potential and rainfed yields. Except in the coldest regions where the temperature is currently below the optimum range, rising temperatures can affect crop production negatively by shortening the growing season and reducing the time for biomass accumulation (Supit et al., 2012).

Prediction of crop yield and biomass in agricultural production is crucial for both food safety and national economic politics. The effects of climate change on future yield rates of widely grown and potential crop types in different regions of the world have been a long-standing concern.

Effects of climate changes on future yield rates of currently grown and possible crop types in the different regions of the globe have long been at stake and many crop growth simulation models have been used to predict crop responses to possible climate changes for years. Among those, the AquaCrop model developed by the Food and Agriculture Organization of the United Nations (FAO) has become widespread in recent years (Raes et al., 2018). Researchers from different countries have used agrometeorological models to evaluate irrigation schedules and agricultural practices to better understand the possible impacts of agricultural drought on crop growth and yield (Andarzian et al., 2011; Mkhabela and Bullock, 2012; Nazeer and Ali, 2012; Vanuytrecth et al., 2014; Voloudakis et al., 2015; Kale, 2016; Zeleke and Nendel, 2020). The AquaCrop model has been used to estimate the grain yield and biomass of various plant species under rainfed conditions or different irrigation regimes (Iqbal et al., 2014; Paredes et al., 2015; Toumi et al., 2016; Bello and Walker, 2017; Jin et al., 2018; Nyathi et al., 2018; Pirmoradian and Davatgar, 2019). Especially, by the sensitivity analysis and calibration procedures, scientifically reasonable results were achieved by the AquaCrop model on major plant species grown under diverse agro-meteorological conditions (Trombette et al., 2016; Xing et al., 2017; Xiuliang et al., 2018). Argentel-Martinez et al. (2021) aimed to evaluate the existing correlation among vegetative and reproductive variables in wheat in a climate change scenario based on temperature increase, under field conditions, in the crystalline wheat cultivar CIRNO C2008, and recommend variables as precise indicators of heat stress tolerance.

Eitzinger et al. (2013) compared the performance of the AquaCrop model for winter wheat and maize yields. These authors reported that the greatest decrease in yield, by about 28% and 90%, respectively, was observed with the scenario of changes of +4°C in both minimum and maximum daily temperatures and zero precipitation. They also analyzed the sensitivity of crop models to extreme weather events for winter wheat and maize in Austria.

Some researchers have been used different crop growth simulation models to predict crop responses to possible long term climate changes in the Thrace Region. Şaylan et al. (2017) analyzed growing season (2010-2011) of the selected winter wheat in the KRK location used for two crop growth models, namely DSSAT and WOFOST that were calibrated for winter wheat and yield changes were estimated with the RegCm4 model and 1975-2010 and 2013-2040 projections. Çaldağ et al. (2017) monitored and analyzed two consecutive winter wheat growing seasons (2009-2010 and 2010-2011) in the selected field with the RegCM4 regional climate model for the data of the wheat plant in two growing seasons in the KRK location. Input databases of the CERES-Wheat and WOFOST models were provided regularly. Also, the sensitivity of the winter wheat grain and biomass yields changes has been determined for future projections using with same scenarios. Konukcu et al. (2020) investigated the effect of climate change on wheat yield in the short (2020-2030), medium (2046-2055) and long (2076-2085) term periods in the Thrace Region using AquaCrop and WOFOST models. RegCM3 Regional Climate Model, reference and A2 scenario outputs were used to predict climate change. Wheat yields obtained from farmer fields in Çorlu Pınarbaşı sub-basin in 2016-2017 growing period were compared with the model prediction in order to do the calibration and yields were focused to forecasted in the future periods. (Yeşilköy and Şaylan, 2020) investigated actual crop yield and Crop Water Footprint of winter wheat grown under rainfed conditions by using AquaCrop model for two growing seasons. RCP 4.5 and 8.5 scenario results produced by HadGEM2-ES model were used as input data to estimate the crop yield and water footprint of the future (2020-2099) by AquaCrop. The AquaCrop was performed according to RCP 4.5 and 8.5 scenarios with and AquaCrop was not performed because necessary input data such as meteorological, soil and crop phenological data for the model were insufficient. Öztürk (2024) compared the performance of the winter wheat genotype about abiotic conditions and reported that the importance of genotype and environmental effects on yield and quality.

Fuso et al. (2023) stated global circulation models (GCMs) provide climate projections on a coarse grid resolution, generally not suitable to represent climatic variability at a local scale.

Relevant literature shows that there are several models used to predict climate changes in the long term future periods and give different results in spite of using the same scenarios which extensively focused on cereal crops in the semiarid climates and Regional Climate Models, like as RCP 4.5, 8.5 and A2 scenario outputs were used to predict climate change. To fulfil this knowledge gap, this research has a focus not only on cereal crop but also on oil crop plant, sunflower, widely cultivated in the region. Additionally, Scenarios regarding possible climatic fluctuations in the future were compared with the changes in grain and biomass yields in the years when the experiments were carried out.

The northwest part of Turkey (Thrace region) plays an important role in rainfed sunflower and winter wheat cultivation and production, accounting for 65% and 15% of the total crop production of the country, respectively. However, the atmospheric conditions are becoming unpredictable in the region, which is expected to have both positive or negative impacts on regional agriculture under the recent fluctuations of climate variables. The aspect of crop productivity for the major cultivars is a concern that needs to be assessed by explanatory modelling approaches. The objectives of this study were to analyze the sensitivity of yield and biomass of winter wheat and sunflower under rainfed conditions to different the changes in meteorological variables for two different soil type and location using the AquaCrop model. The results obtained from this study can offer valuable insights for adaptation to the risks of the effects of climatic fluctuations and biomass and grain yield of sensitivity of climate change. Climate change is affecting agricultural production and pattern in the Thrace part of Turkey

The paper is structured as follows. In the “Material and methods” section, the study area, the agricultural practices, the meteorological data and plant materials, the model description, the statistical analysis and the climate scenarios methodology are presented. Results are in the “Results and discussion” section. Conclusion is the “Conclusion” section, respectively.

2.Material and Methods

2.1. Study area, agricultural practices, meteorological data and plant materials

This experimental study was conducted in the fields of Atatürk Soil Water and Agricultural Meteorology Research Institute to compare the AquaCrop model-based predictions with the measured values of biomass and grain yields of sunflower and wheat between the years 2014 and 2018 under rainfed conditions. The field studies were carried out at two sites: Kirklareli (KRK) (41°42′ N, 27°12′ E) and Edirne-Orhaniye (EOR) (41°43′ N, 26°26′ E), in the northeast and the southwest of the Thrace region of Turkey (*Figure 1*).

The total sizes of fields at KRK and EOR were 3.6 and 3.0 ha, respectively. The widely grown domestic cultivars of sunflower (Tunca) and winter wheat (Gelibolu) were planted under local conventional farming practices in the region. Sunflower was planted for three growing seasons (2014, 2015, and 2017) and winter wheat for two growing seasons (2015–2016 and 2017–2018) at both locations.

The sunflower hybrid genotype Tunca and the Gelibolu cultivar of winter wheat were sown at a depth of 4–5 cm. The furrows were 30 cm apart with a plant spacing of 70 cm for sunflower, and 5 cm apart with a plant spacing of 10 cm for winter wheat, respectively. The experimental fields were monitored for pests and weeds, and pesticides were applied when needed. Seed bed and seed sowing operations were carried out by following a wheat-sunflower rotation system under traditional rainfed agriculture. Chemical fertilization for sunflower was carried out with 100 kg ha^{-1} di-ammonium phosphate (46-18-0) fertilizer as the base fertilizer and 100 kg ha^{-1} urea (46-0-0) in hoeing and additionally, 1500 ml ha^{-1} imazamox was used as an herbicide. For wheat fertilization, 150 kg ha^{-1} di-ammonium phosphate was applied as the base fertilizer and 150 kg ha^{-1} urea in tillering period and 100 kg ha^{-1} urea in the growing period along with 10 gr ha^{-1} of clorsulfuron and 1250 gr ha^{-1} of the mixture of prothioconazole + spiroxamine as a crown and 1250 gr ha^{-1} of the mixture of epoxiconazole and fenpropimorph as herbicides. Biomass analysis was conducted by taking three different samples from in the field every 15 days for each crop.

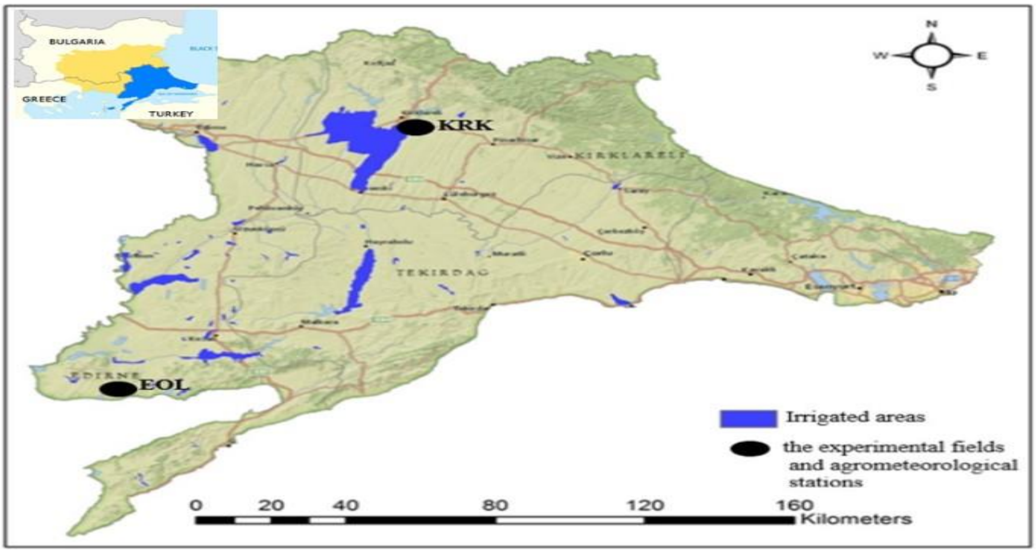

Figure 1. Site location map in the Thrace region. the experimental fields at the Kirklareli (KRK) and Edirne-Orhaniye (EOR) sites

Full-automated meteorological stations were installed at the research fields in each site including a datalogger (CR1000 Campbell Sci, Inc., Logan, UT, USA) which regularly recorded air temperature and relative humidity (Rotronic and Vaisala), wind speed and direction (NRG) and soil water content (CS616, Campbell Sci.) gauged at the depths of 0-30, 30-60, 60-90 cm by moisture sensors and a pyranometer (CMP6, Kipp and Zonen). Complete systems are capable to measure data in 30 sec. time interval, taking 10, 30, 60 min and 24-hour records, as well (*Figure 2*).

The ETo (Reference Evapotranspiration) calculator (FAO, 2009) estimated the daily reference evapotranspiration (ETo) during growing periods of plants. Mean values of monthly rainfall, mean monthly maximum and minimum air temperature for five-year periods (2014-2018) were regularly measured and recorded.

Figure 2. Meteorological stations in the KRK site (on the left) and the EOR site (on the right)

Additionally, all necessary data for the model were measured, collected, and observed during the measuring period such as phenological stages, soil properties, biomass, yield, and agricultural management (fertilization, irrigation, etc.). Before cultivation, soil samples were taken from each field at depths of 0-30, 30-60, and 60-90 cm. The physical and chemical properties of the soil in the experiment fields are given in *Table 1*.

Table 1. Properties of the soils measured at the experimental fields

Location	KRK site			EOR site		
Soil Parameters	Soil Depth (cm)					
	0-30	30-60	60-90	0-30	30-60	60-90
Saturation (%)	44	59	57	61	56	50
Sand (%)	66.67	54.17	56.25	22.92	27.08	27.08
Silt (%)	20.83	27.08	27.08	25.00	22.92	20.83
Clay (%)	12.50	18.75	16.67	52.08	50.00	52.09
Soil texture	Sandy loam	Sandy loam	Sandy loam	Clay	Clay	Clay
FC (%)	16.20	16.85	22.82	29.36	23.65	23.93
WP (%)	6.73	10.32	10.12	20.69	17.35	18.08

KRK: Kirklareli, EOR: Edirne-Orhaniye, FC: field capacity, WP: wilting point.

2.2. Model description

In this study, AquaCrop model v6.0 (Raes et al., 2018) was used to model biomass and grain yield of sunflower and winter wheat. This model was developed to help agronomists, consultants, irrigation engineers, and farm managers to increase crop water productivity under rainfed and irrigated conditions (Raes et al., 2009). Under water limiting conditions, AquaCrop can simulate water requirements, water use efficiency and crop productivity. Apart from being easy to operate when compared to other models, it also requires a limited set of input parameters for predictions. AquaCrop uses the first (Doorenbos and Kassam, 1979) equation for the biomass calculation and, finally, the crop yield, proportional to the biomass according to a "harvestable part". The software simulates Biomass (B) and Yield (Y) of crops, focusing on water stress conditions (Steduto et al., 2009). In the current study, Aqua Crop model v 6.0 was used to model biomass and grain yield of sunflower and winter wheat. The CO_2 (carbon dioxide in the air) data that the AquaCrop model needs is the mean annual atmospheric CO_2 concentration. The 'MaunaLoa.CO_2' file contains the observed yearly atmospheric [CO_2] concentration for the period 1902 till today. Annual atmospheric [CO_2] concentration data for the experiment periods (between 2014 and 2018) were taken from the relevant file.

2.3. Statistical analysis

Model was calibrated and evaluated by using the default conservative parameters which were given the model for winter wheat and sunflower, along with local management-dependent parameters (measured) and phenological stages for the local cultivars during the growing seasons between 2014-2018, as listed in *Table 2.*

Calibration of the model for sunflower and winter wheat was carried out by comparing the simulated and measured biomass (BM) and grain yield (GY) of sunflower and wheat in the growing seasons of 2014, 2015, and 2017 and 2015–2016, and 2017–2018, respectively. The comparison criteria were the root mean square error (RMSE), mean absolute error (MAE), relative error (RE), as follows:

The agreement between the observed (Oi) and predicted (Pi) values were evaluated by the following statistical performance indicators: 1) RMSE, 2) MAE, and 3) RE [Eq. (1), (2) and (3), respectively].

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_i - P_i)^2} \qquad \text{(Eq. 1)}$$

$$MAE = \frac{\sum_{i=1}^{N}|P_i - O_i|}{N} \qquad \text{(Eq. 2)}$$

$$RE = \frac{|P_i - O_i|}{O_i} \times 100 \qquad \text{(Eq. 3)}$$

Table 2. Measured values of certain local parameters used in the AquaCrop model to simulate sunflower and winter wheat growth and yield

Description, Location/Plant	Measured values			
	KRK Sunflower	**EOR Sunflower**	**KRK Winter wheat**	**EOR Winter wheat**
Number of plants per hectare	50000	50000	4500000	4500000
Maximum canopy cover (CCx) in fraction soil cover	0.9	0.9	0.9	0.9
GDDays: from sowing to emergence	67	200	127	138
VGDDays: from sowing to start senescence	1303	1560	1636	1873
GDDays: from sowing to maturity (length of crop cycle)	1730	2148	2397	2910
Base temperature (°C) below which crop development does not progress	6.7	6.7	0.0	0.0
Upper temperature (°C) above which crop development no longer increases with an increase in temperature	30.0	30.0	26.0	26.0
Calendar Days: from sowing to emergence	9	14	11	11
Calendar Days: from sowing to maximum rooting depth	90	80	223	181
Calendar Days: from sowing to start senescence	105	97	206	192
Calendar Days: from sowing to maturity (length of crop cycle)	135	129	248	243

KRK: Kırklareli, EOR: Edirne-Orhaniye.

Table 3. Single and combined climate scenarios (S) used in the sensitivity analysis

Scenario	T +1	T +2	T +3 (˚C)	T +4	T +5	T -1	P -10	P -20	P -30	P -40 (%)	P-50	Rg +2	Rg +4
T +1˚C	S1						S14	S20	S26	S32	S38	S44	S55
T +2˚C		S2					S15	S21	S27	S33	S39	S45	S56
T +3˚C			S3				S16	S22	S28	S34	S40	S46	S57
T +4˚C				S4			S17	S23	S29	S35	S41	S47	S58
T +5˚C					S5		S18	S24	S30	S36	S42	S48	S59
T -1˚C						S6	S19	S25	S31	S37	S43	S49	S60
P -10%							S7					S50	S61
P -20%								S8				S51	S62
P -30%									S9			S52	S63
P -40%										S10		S53	S64
P -50%											S11	S54	S65
Rg +2%												S12	
Rg +4%													S13

S1, S2, S3, ……, S64 and S65: number of scenarios,
T+1 ˚C, T+2 ˚C, T+3 ˚C, T+4 ˚C, and T+5 ˚C indicate 1, 2, 3, 4 and 5 ˚C increases in the air temperature, respectively.
T-1 ˚C indicates 1 ˚C decrease in air temperature.
P -10%, P -20%, P -30%, P -40% and P -50% signify 10, 20, 30, 40 and 50 percent reductions in the precipitation, respectively.
Rg +2% and Rg +4% signify 2 and 4 percent increases in the global solar radiation, respectively.

2.4. Sensitivity scenarios methodology

Considering the boundary conditions of most of the General Circulation Models (GCM) and approaches from two different scenarios (RCP 4.5 and 8.5), average temperatures would show an increasing trend, whereas no such common result can be deduced for precipitation (Yeşilköy and Şaylan, 2020). Therefore, in the current study, instead of using global or regional climate scenarios, sixty-five (65) climate sensitivity analysis scenarios created by considering the expected trend of climate change were evaluated for the effects of single and combined variations of meteorological factors on plant grain and biomass yields. These sensitivity scenarios which are in *Table 3* were used to determine the changes in the biomass and yield of wheat and sunflower under rainfed conditions.

3. Results and Discussion

3.1. Model runs and evaluation

The calibrated Aquacrop model was used for the scenario of sensitivity analysis as shown in *Table 3* and simulated grain yield and biomass for each crop and location as shown in *Table 4*.

According to the mean data for three years for sunflower and two years for winter wheat, the average sunflower and winter wheat yields grown under rainfed conditions were 2.20 t ha^{-1} and 4.77 t ha^{-1}, respectively. In addition, the average grain yields during the same growing periods in Thrace were 2.38 (8.2% more) for sunflower and 3.75 (21.4% less) t/ha for winter wheat. Simulations for the sunflower crop indicated that the average RMSE, MAE and RE values were 0.06; 0.06 and 2.8%, respectively. The performance indicators for winter wheat were 0.1, 0.1, and 2.1%. According to these performance criteria, the model predicted the observed values very well Iqbal et al. (2014) tested the ability of the AquaCrop model (v 3.1) to simulate winter wheat grain yield and biomass, and reported RMSE values of 0.58 and 0.87 t ha^{-1}, respectively. Kale (2016) tested the AquaCrop model (v 5.0) for winter wheat under fully irrigation and rainfed conditions in the semi-arid Central Anatolian region, comparing model predictions with actual results and reported RMSE values of 1.17 and 0.32 t ha^{-1}, respectively, for biomass and crop yield. These data suggest very good agreement between observed and simulated values, despite the slight overestimation by the model. Mkhabela and Bullock (2012) evaluated spring wheat yield and found RMSE and MAE values of 0.74 and 0.61 t ha^{-1}, respectively. Similarly, estimated winter wheat grain yield by Konukcu et al. (2020) MAE values between 0.15 and 0.31 t ha-1 and the average relative errors (RE) between 1.87% and 6.18% at the pinarbası watershed, by Yeşilköy and Şaylan (2020) RE in the cities of Edirne and Kirklareli were 2.4%, -1.6%, respectively.

Table 4. Statistics of the measured and simulated grain yield and biomass with the Aquacrop for sunflower and wheat at the KRK and EOR experimental sites

Location	Plant	Parameter	Observed ($t\ ha^{-1}$)	Simulated ($t\ ha^{-1}$)	RMSE ($t\ ha^{-1}$)	MAE ($t\ ha^{-1}$)	RE (%)
KRK	Sunflower	GY	2.24	2.28	0.002	0.04	1.87
		BM	14.57	15.34	0.59	0.77	5.28
EOR		GY	2.15	2.23	0.01	0.1	4.05
		BM	15.40	11.09	18.58	-4.31	-28.0
Average		GY	2.20	2.26	0.06	0.06	2.80
		BM	14.99	15.34	3.10	2.54	16.6
KRK	Winter Wheat	GY	4.67	4.59	0.006	-0.1	-1.63
		BM	17.62	16.27	1.69	-1.3	-7.39
EOR		GY	4.86	4.74	0.014	-0.1	-2.43
		BM	22.59	20.42	4.75	-2.18	-9.65
Average		GY	4.77	4.67	0.10	0.10	2.10
		BM	20.11	18.35	1.81	1.76	8.60

KRK: Kirklareli, EOR: Edirne-Orhaniye, BM: Biomass, GY: Grain yield, RMSE: root mean square error, MAE: mean absolute error, RE: relative error.

3.2. Sensitivity analysis of climate-changing on grain and biomass yields of plants

In the current study, instead of using global or regional climate scenarios, sixty-five (65) climate sensitivity analysis scenarios created by considering the expected trend of climate change were evaluated for the effects of single and combined variations of meteorological factors (air temperature, precipitation and solar radiation) on selected cultivars to future climatic conditions depends firstly on logical validation according to the corresponding variations in meteorological factors. In this context, expected changes and impacts of these factors are given in *Table 3*, where the examination was done individually or in combination.

Figure 3 and *4* show sunflower grain yield (KRKsfg), sunflower biomass (KRKsfb), winter wheat grain yield (KRKwwg) and winter wheat biomass (KRKwwb) at the KRK site, along with sunflower grain yield (EORsfg), sunflower biomass (EORsfb), winter wheat grain yield (EORwwg), and winter wheat biomass (EORwwb) at EOR site. Additionally, the response (sensitivity) of the model for every combination of parameters in 65 different scenarios are detailed in *Table 3*.

Figure 3-A shows the changes in sunflower grain yields compared to the reference values for the sensitivity scenarios at each site. Based on percent changes in sunflower grain yields, the highest yield loss was estimated for the scenario S42 (T+5°C, P -50%) with decreases of 61% and 59% at the KRK and EOR sites, respectively. The highest yield increase was observed for the scenario S6 (T -1°C) with increases of 6.8 and 7.2% at the KRK and EOR sites, respectively.

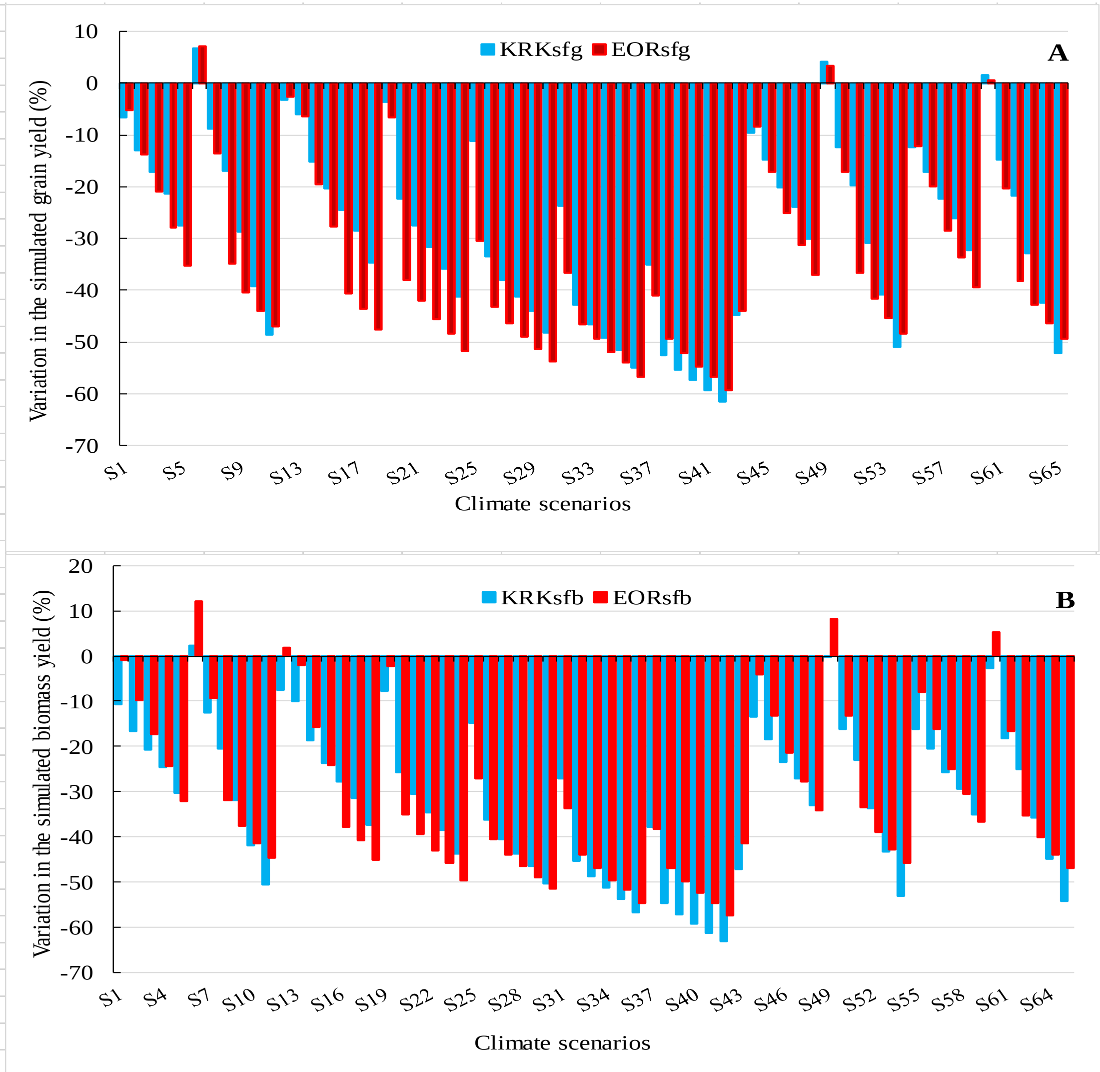

Figure 3. Relative deviations of simulated sunflower grain (sfg) yields (A) and sunflower biomass (sfb) yields (B) associated with selected climate scenarios at the Kirklareli (KRK) and Edirne-Orhaniye (EOR) sites

Single and combined scenarios of temperature increases (S1-S5) and precipitation decreases (S7-S10) were associated with decreases in yield. The scenarios of S12 and S13, which represented increases in global solar radiation, had a minor negative impact on the grain yield of sunflower in both sites. However, such increases were also observed in the S6 scenario (T -1°C) as well as in the scenarios of S49 and S60 (Rg +2% and Rg +4%, respectively).

Figure 3-B shows the changes in sunflower biomass yields by the climate change scenarios at both locations. The highest yield loss occurred with the scenario S42 (T +5°C, P -50%) showing decreases of -63.2% and -57.5% at the KRK and EOR sites, respectively. The highest yield increase was simulated for the scenario S6 (T -1°C) with increases of 2.3% and 12.2% at the KRK and EOR sites, respectively. Scenarios representing only temperature increases and precipitation decreases (S1-S5) and their combinations with other parameters (S7-S10) (*Table 3*) were all associated with a decrease in biomass yield. As expected, decreases in precipitation caused losses in the grain yield as well as in the biomass. Scenario S12 (Rg +2%) caused a minor increase of around 1.9% in biomass at the EOR site, but this was not the case with the scenario S13 (Rg +4%), which brought about a 2% decrease in the biomass at the same site. In the scenarios S49 and S60 [(T -1°C, Rg+2%) and (T -1°C, Rg +4%)], slight decreases in biomass of -0.2 and -2.8, respectively, were observed at the KRK site. On the contrary, increases in biomass of 8.3% and 5.3%, respectively, were observed at the EOR site.

Figure 4-A shows the grain yield variations of winter wheat due to climate change by considering only temperature rise (S1-S5). Here, an increase in grain yield was noted at both sites. The scenario S5 particularly led to the highest increases (15.9% and 19.3% for the KRK and EOR sites, respectively) in the grain yields. Similarly, scenarios S14-S18, in which precipitation was decreased and temperature was increased gradually, the grain yield was increased. For example, an increase of 6.8% for scenario S16 at the KRK site and 15.3% for scenario S18 at the EOR site were observed. Additionally, scenarios S44-S48 (temperature increases with both Rg +2%) and S55-59 (gradual temperature increases with both Rg +4%) resulted in increases in yield by up to 15.2% and 18.5% at both sites.

In the scenario S6, a decrease in temperature by as little as a 1°C caused 7.1% and 6.2% decrease in grain yield at the KRK and EOR sites, respectively. Likewise, decreases in precipitation had a significant negative effect on the grain yield of winter wheat, represented by 40.4% and 15.2% losses in the scenario S11 at the KRK and EOR sites, respectively. Evaluation of the possible effects of global solar radiation scenarios (S12 and S13) showed that both Rg +2% and Rg +4% had positive impacts on grain yield. In addition, their combinations with extreme increases in air temperature and decrease in precipitation (scenarios S38-S43) showed the most dramatic decrease in the grain yield of wheat.

Figure 4-B shows the biomass sensitivities of winter wheat grown at both sites. As observed with grain yield, the biomass values also tended to be affected positively by temperature increments. Moreover, there was a positive effect of extending the optimum growing period due to increased mean temperatures. Thus, the scenario S5, which simulated such conditions, was associated with the highest biomass increments of 10.5% and 22.0% at the KRK and EOR sites, respectively. A 1°C drop in temperature (scenario S6) decreased the biomass yield by 2.9% and 6.8% at KRK and EOR, respectively. Similarly, all scenarios representing decreases in precipitation resulted in a reduction in the biomass, as expected. In particular, the scenario S43 (T -1 °C and P -50%) resulted in biomass losses of 53.8% and 18.4% at the KRK and EOR sites, respectively.

Contrary to the results of the winter wheat model used in this study, in both models used in Çaldağ et al. (2017), losses in both grain and biomass yields were determined due to temperature increases for the selected year at the KRK station. Decreases in biomass and grain yields were determined when rainfall decreased, and increases in yields were determined when solar radiation values increased, and these results are similar to the results of my study. Eitzinger et al. (2013) stated that the grain yield and biomass of winter wheat showed an increase with increasing temperatures. Our data revealed that it is of pivotal importance to determine which meteorological parameters are more sensitive to the yield during the development period of the modelled plant. Calculations for the sensitivity analysis helped us to understand how plants primarily reacted to climate change. In this connection, temperature, precipitation, and global solar radiation come to the fore as the most important variables affecting plant phenological stages and yield.

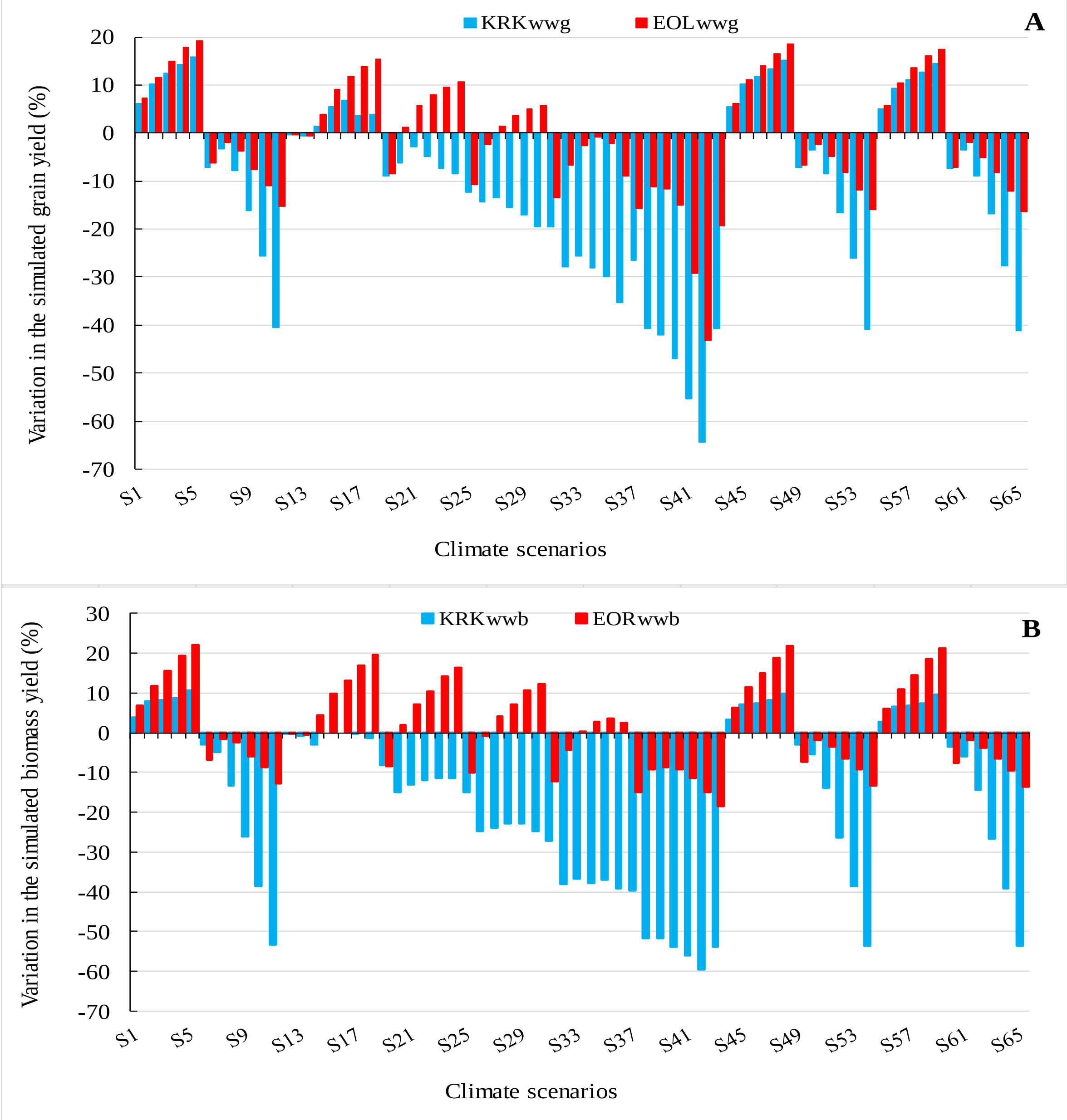

Figure 4. Relative deviations of simulated winter wheat grain (wwg) yields (A) and winter wheat biomass (wwb) yields (B) associated with selected climate scenarios at the Kirklareli (KRK) and Edirne-Orhaniye (EOR) sites.

As mentioned earlier, a series of sensitivity analyses was performed on the grain and biomass yields of two plants at the KRR and EOR sites under different climate conditions and soil structure. Since the KRK and EOR sites had very similar mean values of climatic factors, the changes in the grain yields were not different. However, temporal changes in the meteorological factors during the developmental stages of plants showed differences. The yield at the EOR field was higher than that at the KRK site. The reason for this may be a difference in the soil structure as well as the hydraulic properties of the soil, along with the time frame of meteorological factors during the development period in the EOR. As emphasized by Eitzinger et al. (2013), the yield of winter wheat is highly sensitive to differences in soil properties.

The variability of the model results in summer (sunflower) and winter (wheat) planted plants, in soils with different water retention capacities, in response to possible future scenarios of changes in two spatial areas was evaluated. The correlation results are shown between the defined single and combined scenarios of temperature, precipitation and global solar radiation and biomass and grain yield of two crops (winter wheat and sunflower) at spatial areas (KRK and EOR) in *Figure 5* and *Figure 6*.

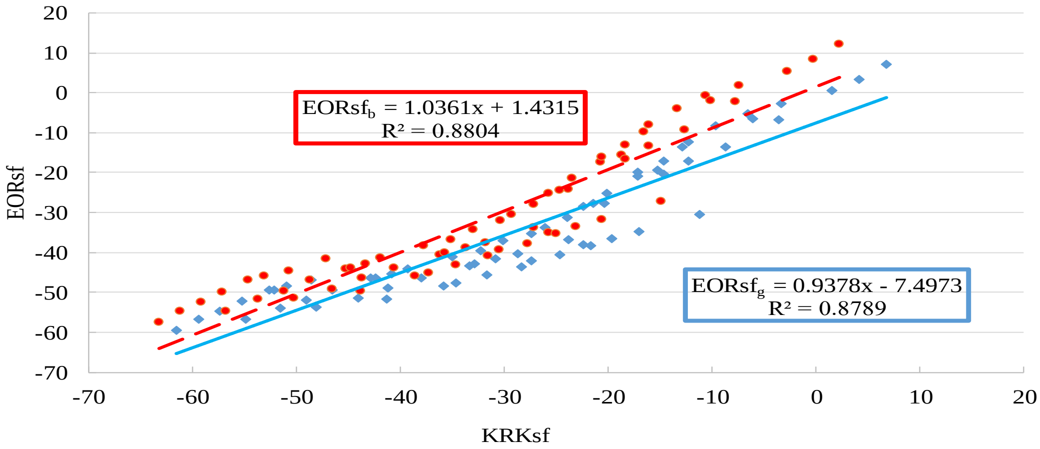

Figure 5. Correlation between biomass and grain yields of sunflower at the Kirklareli (KRK) and Edirne-Orhaniye (EOR) sites

Under the defined sixty-five (65) scenarios results, statistically significant relationships were found between sunflower biomass and grain yield for the KRK (r^2 = 0.88) and EOR (r^2 = 0.87) sites (*Figure 5*). However, weaker relationships were identified between the winter wheat biomass and grain yield at the KRK (r^2 = 0.56) and EOR (r^2 = 0.79) sites (*Figure 6*). According to the simulation results of the defined single and combined scenarios in both spatial areas, while the grain and biomass yields of the summer-sunflower plant were negative linear relations every scenario, non-linear relations were determined in the yields of the winter-wheat plant.

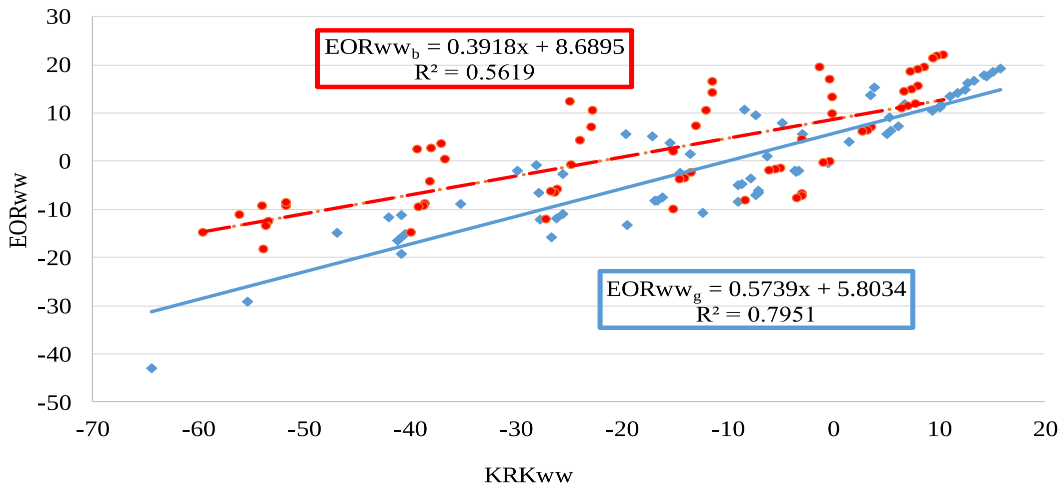

Figure 6. Correlation between biomass and grain yields of winter wheat at the Kirklareli (KRK) and Edirne-Orhaniye (EOR) sites.

4. Conclusion

This study has been analyzed the results of sensitivity analysis for the grain and biomass yields of the winter wheat and summer-sunflower in both locations using the AquaCrop model. With the highest yield loss and the highest yield gains for the sunflower grain and biomass yields were determined in the same scenarios (in the scenario S42 (T +5°C, P -50%) and S6 (T -1°C)) at both locations. The highest grain and biomass yield decreases were determined at -61.6, -63.2, -59.4, and -57.5% in the scenario S42 where precipitation decreased by 50% and temperature increased by 5°C in the KRK and the EOR sites, respectively. Loss of sunflower grain and biomass yields and increase in grain and biomass yields at the EOR site gave more positive results than the KRK site. The highest yield losses and the highest yield gains of winter wheat were determined in the same scenarios of S42 and S5 at both locations, with one exception that the biomass yield loss took place in the scenario S43 in EOR site. Although, the highest decreases in the grain and biomass yields were -64.4, -43.1, and -59.54%, for KRKwwg, KRKwwb and EORwwg in the scenario S42 where precipitation decreased by 50% and temperature increased by 5°C. The highest decrease in the biomass yield was -18.4% for EORwwb in the scenario S43 where there were decreases in both precipitation (P -50%) and temperature (T -1°C).

The winter wheat showed different rates of responds to climatic changes. Unlike the sunflower most of the scenarios had positive impacts on the grain and biomass yields of winter wheat in the two experimental sites.

According to climate scenarios analysis, increases in both temperature and global radiation along with decreases in precipitation had a negative impact on grain yield and biomass of sunflowers. This, however, was not the case for the winter wheat, suggesting that the grain yield and biomass of sunflowers could be more sensitive to heat and precipitation stress under defined climatic cases at the selected locations. Although an increase in average temperatures was associated with increases in wheat yield and biomass, the combined effects of increased global solar radiation and decreased temperatures had negative effects on wheat production at the EOR site. For both sunflower and wheat, the combined scenarios of temperature increase to varying extents and decreases in precipitation during each growing season at each location had the most detrimental effect on yield and biomass production. These results may provide important information to decision makers, especially in order to focus on winter-planted oil crops such as Canola oil plant instead of summer-grown oil crops in the region.

Instead of using global or regional climate scenarios, local agrometeorological measurement on the plant by considering the expected trend of climate change should have evaluated for the effects of single and combined variations of meteorological factors on plant grain and biomass yields. The results obtained from this study can offer valuable insights for adaptation to the risks of the effects of climatic fluctuations biomass and grain yield for two plant that can result precise indicators of the context of climate change. Moreover, the results of crop growth models couldn’t give same prediction in the same locations, so they should be supported by field studies to get better evaluations.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

The author declares that they have no conflict of interest.

Authorship Contribution Statement

Concept; Design; Data Collection or Processing; Statistical Analyses; Literature Search; Writing, Review and Editing: Bakanoğulları, F.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Epibrassinolide Uygulamasının Soyanın Verim Performansına Etkileri*

The Effects of Epibrassinolide Application on the Yield Performance of Soybean

Aykut ŞENER[1*], Muharrem KAYA[2], Sedat KICIR[3]

Öz

Bu araştırma, farklı dozlarda epibrassinolide (EBR) uygulamalarının soyanın verim ve bazı verim ögeleri üzerine etkilerini belirlemek amacıyla kurulmuştur. Tarla denemeleri Isparta ilinde yer alan Isparta Uygulamalı Bilimler Üniversitesi (ISUBÜ), Ziraat Fakültesi Eğitim, Araştırma ve Uygulama Çiftliği arazisinde 2022-2023 yıllarında iki yıl süre ile yürütülmüştür. Çalışmada, PG Victoria soya çeşidi tohum materyali olarak kullanılmıştır. Yapraklardan hormon uygulaması için ise Biosynth Carbosynth firmasına ait epibrassinolide ($C_{28}H_{48}O_6$) bitki büyüme düzenleyicisi kullanılmıştır. Deneme tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Çiçeklenme öncesi dönemde bitkilere saf su ve EBR'nin 3 dozu (0.5, 1.0 ve 1.5 µM EBR) yapraktan pülverize edilerek uygulanmıştır. Araştırmada; soyanın %50 çiçeklenme gün sayısı, bitki boyu, ilk bakla yüksekliği, bitkide bakla sayısı, bitkide tane sayısı, bitkide tane ağırlığı, hasat indeksi, yüz tane ağırlığı, tane verimi ve yağ oranı özellikleri incelenmiştir. Farklı dozlarda EBR uygulanan soyanın; çiçeklenme süresi 56.0-59.7 gün, bitki boyu 67.13-102.43 cm, ilk bakla yüksekliği 10.23-14.03 cm, bitkide bakla sayısı 16.80-80.30, bitkide tane sayısı 42.73-193.53, bitkide tane ağırlığı 4.85-22.79 g, hasat indeksi %24.66-31.28, yüz tane ağırlığı 11.00-13.00 g, tane verimi 270.16-566.67 kg da^{-1} ve yağ oranı % 20.56-21.49 arasında değişim göstermiştir. Sonuçlar incelendiğinde; yıllar arasındaki iklimsel farklılıklardan kaynaklı geniş varyasyonlar olduğu belirlenmiştir. Çalışma sonucunda 0.5 µM EBR uygulamasının çiçeklenme süresini kısalttığı, bitki boyunu, bitkide bakla sayısını, bitkide tane sayısını, bitkide tane ağırlığını ve tane verimini arttırdığı belirlenmiştir. Bu dozun üzerindeki uygulamaların ise verim ögelerini olumsuz yönde etkilediği saptanmıştır. EBR'nin soyanın yüz tane ağırlığı üzerine etkisi yıllara göre değişim göstermiştir. Yağ oranı ise 0.1 µM EBR dozunda arttığı tespit edilmiştir.

Anahtar Kelimeler: Soya, Epibrassinolide, Hormon uygulama, Tohum verimi, *Glycine max* L.

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*Bu çalışmanın 1. yıl verileri Sedat KICIR'ın Yüksek Lisans tezinden özetlenmiştir.

Abstract

This research was conducted to determine the effects of different doses of epibrassinolide (EBR) applications on the yield and some yield components of soybeans. Field experiments were carried out for two years (2022-2023) at the Isparta University of Applied Sciences (ISUBÜ), Faculty of Agriculture, Research and Application Farm, located in Isparta province, Turkey. In the study, seeds of the PG Victoria soybean variety were used as the material. For the hormone application from leaves, epibrassinolide ($C_{28}H_{48}O_6$), a plant growth regulator from the Biosynth Carbosynth company, was used. The experiment was established with three replications according to a randomized complete block design. Before flowering, plants were subjected to foliar application of distilled water (control) and three doses of EBR (0.5, 1.0, and 1.5 µM EBR). In the study, 50% flowering time, plant height, first pod height, number of pods per plant, number of grains per plant, grain weight per plant, harvest index, hundred-grain weight, grain yield, and oil content characteristics of soybeans were examined. In soybeans treated with different doses of EBR, flowering period ranging from 56.0 to 59.7 days, plant height from 67.13 to 102.43 cm, first pod height from 10.23 to 14.03 cm, pods per plant from 16.80 to 80.30, grain number per plant from 42.73 to 193.53, grain weight per plant from 4.85 to 22.79 g, harvest index from %24.66 to %31.28, hundred grain weight from 11.00 to 13.00 g, grain yield from 270.16 to 566.67 kg da^{-1}, and oil content from %20.56 to %21.49. When the results were examined, it was determined that there were wide variations in yield characteristics due to climatic differences appeared between experimental years. The results of the study indicated that the application of 0.5 µM EBR shortened the flowering period and increased plant height, pod number per plant, grain number per plant, grain weight per plant, and grain yield. However, applications above this dose were found to adversely affect yield components. The effect of EBR on the hundred-grain weight of soybeans varied over the years. The oil content, on the other hand, was found to increase at a dose of 0.1 µM EBR.

Keywords: Soybean, Epibrassinolide, Hormone treatment, Seed yield, *Glycine max* L.

1. Giriş

Soya (*Glycine max.* (L) Merr.) baklagiller familyasına dahil, Uzakdoğu orijinli, önemli bir yağ ve protein bitkisidir. Soya tohumları %26 karbonhidrat, %36-40 protein, %18-24 yağ ve %18 mineral maddeler içermektedir. İçerdiği besinler nedeniyle yüzyılın mucize bitkisi olarak anılmaktadır (Arıoğlu, 2007). Soya geçmişten günümüze kadar ağırlıklı olarak yağ elde etmek için kullanılmış, ancak ileri teknoloji uygulamalarının gelişmesiyle yüksek ve kaliteli protein içeriğine bağlı olarak protein kaynağı olarak da kullanılmaya başlanmıştır. Bu nedenle soya artık protein bitkisi olarak tanımlanmaktadır. Çok değerli bir proteine sahip olan soyanın kullanılma alanları artmıştır. Nitekim, soya tohumlarından; kuru soya fasulyesi, soya unu, soya yağı, soya küspesi, soya sütü, soya ezmesi ve soya eti üretilebilmektedir. Soyanın taze yeşil fasulyeleri haşlanarak, çiğ veya konserve olarak yenilebilmekte, bunun yanında yeşil aksamları ve taneleri hayvan yemi olarak kullanılmaktadır.

Türkiye'de sulu tarım yapılan bölgelerde soya üretimi ana ürün (Marmara, Trakya, Karadeniz ve Akdeniz Bölgeleri) ya da II. Ürün (Güneydoğu Anadolu, Ege ve Akdeniz Bölgeleri) tarımı şeklinde yapılmaktadır. Soya üretiminin %91'i Adana, Hatay, Mersin, Osmaniye ve Kahramanmaraş'ı içeren Akdeniz bölgesinde, %8'i Karadeniz Bölgesi'nde Samsun ve Ordu civarında, %1'i ise Ege Bölgesinde yapılmaktadır (TÜİK, 2010). 2022 yılında 380.090 da'lık bir alanda 155.000 ton soya üretilmiştir (TÜİK, 2023). 2019-2020 döneminde Türkiye'de soyada kendine yeterlilik derecesi %4.7 iken, 2020-2021 yıllarında bu oran %5.4'e yükselmiştir. Aynı yıllarda Türkiye'nin soyada kişi başı tüketim miktarı 0.2 kg olmuştur (TÜİK, 2022). Türkiye'nin yağlı tohumlu bitkilerde kendine yeterlilik derecesi ortalamasının %49 olduğu ve kalan yarısının ithalat ile karşılanabileceği bildirilmiştir (Kadakoğlu ve ark., 2023). 2021-2022 sezonunda 2.95 milyon ton soya ithalatı gerçekleşmiştir (TÜİK, 2022). Buna bağlı olarak, Türkiye soya üretiminin arttırılması gerekmektedir. Bu amaçla üretimi daha çok 2. ürün tarımı şeklinde Akdeniz Bölgesi'nde yoğunlaşmış olan soya ekim alanlarının iç bölgelere de kaydırılması gerekmektedir. Bu bölgelerde soya tarımının yaygınlaşması için bölge ekolojisine uygun çeşit kullanmanın yanında farklı agronomik uygulamalar yapılarak soyadan yüksek verim alabilmek mümkündür.

Soyada en önemli verim bileşenleri; bakla başına tane sayısı, bitkideki bakla sayısı, tek bitki tane verimi ve bin tohum ağırlığıdır (Schuster, 1985). Yağlı tohumlu bitkilerde bitki başına tane sayısı genotip, çevre ve yetiştirme koşullarına oldukça bağlıdır. Soya üzerinde yapılan bir çalışmada, döllenme döneminde strese bağlı verim düşüşünün başlıca sebebi olarak bitki başına düşen dal sayısı olduğu vurgulanmıştır (Dağtekin ve Bilgili, 2020). Özellikle çiçeklenme ve bakla olum döneminde yaşanan kuraklığın (su kısıtı) çiçeklenme oranını düşürdüğü, bitkide bakla sayısının azalmasına neden olduğu belirtilmiştir (He ve ark., 2017). Bitkinin gelişme aşamasında soyadaki çiçeklerin bir kısmının, (çiçeklerin %70-85'ine kadar artabilir) aniden dökülerek önemli verim kayıplarına neden olduğu bildirilmiştir. Bitkide çiçek, bakla ve tane dökümü, verimi sınırlayıcı ana faktörlerden biri olarak tanımlanmıştır (Ruan ve ark., 2012). Henüz bitkilerin çiçek dökme fizyolojisi tam olarak anlaşılmış değildir. Çiçek dökmenin çevresel stresle artmakta olduğu, ancak normal koşullarda da olabileceği belirtilmektedir. Bazı tarımsal uygulamaların çiçek silkme miktarını azaltabileceği ve verimin artırılmasında etkili olacağı vurgulanmıştır (Dağtekin ve Bilgili, 2020). Bu nedenle soyada verimin arttırılabilmesi için ekolojik koşullardaki değişimlerin yanı sıra yetiştirme tekniğine (tarımsal girdiler ve bakım işlemleri) dikkat edilmesi gerekmektedir. Son yıllarda bitkilerin farklı gelişme dönemlerinde farklı bitki organlarına fitohormon uygulamaları konusunda çalışmalar yoğunluk kazanmaya başlamıştır. Yakın zamana kadar, beş hormon grubunun (gibberellinler, oksin, sitokininler, absisik asit ve etilen) bitki büyümesini ve gelişimini düzenlediği düşünülmekteydi. Ancak son yıllarda yapılan araştırmalar, bitki hormonlarının altıncı grubu olarak brassinosteroidlerin (BR) bitki yetiştirmede değerlendirilmesine yol açmıştır (Ceritoğlu ve Erman, 2020).

Yeni bir bitkisel hormon sınıfı olan brassinosteroidler, bitkilerde yaygın olarak bulunan spesifik bir bitki steroidleri grubudur. Çok düşük konsantrasyonlarda bile BR, bitkilerde hücre bölünmesi, uzama ve genişleme, fotomorfogenez, üreme organı gelişimi, yaprak yaşlanması, toplam biyokütle, polen tüpü gelişimi, apikal hakimiyetin sürdürülmesi ile artan çiçeklenme ve verim dahil olmak üzere birçok önemli fonksiyonlara sahiptir. Bitki büyüme ve gelişmesindeki rolünün çevresel strese uyum durumunda da etkili olduğu kanıtlanmıştır. Brassinosteroidler hücresel düzeyde; uzama ve bölünmeyi destekler, hormonal dengeyi korur, protein ve nükleik asit sentezini aktive eder, enzimatik aktiviteyi arttırır ve H^+ pompa aktivitesini, membran kompozisyonunu ve doygunluğu düzenlerler. Yağ asidi kompozisyonuna etki etmekte, fotosentetik kapasiteyi arttırmakta ve ürünlerin hareketinde etkili olmaktadır. Tüm bitki düzeyinde, büyümeyi teşvik etmekte, döllenmeyi artırmakta, vejetatif gelişme süresini kısaltmakta, meyve kalitesini ve boyutunu artırmakta, besin içeriğine etki etmekte, uygun olmayan çevresel faktörlere, strese ve hastalığa karşı direnci ve ürünlerin verimliliğini artırmaktadır (Surgun ve ark., 2012). Brassinosteroidler, bitki metabolizmasını ve büyümesini düzenleyen diğer bitki hormonları ile sinerjik olarak hareket etmektedir. Örneğin; BR'ler oksinler, sitokininler, gibberellinler, absisik asit (ABA), etilen (ET), salisilik asit (SA) ve jasmonik asit (JA) ile etkileşime girerek bitki büyümesine ve metabolizmasına katkıda bulunmaktadır. BR'lerden biri olan 24-Epibrassinolide'in bitkilerde sıcaklık ve tuzluluk toleransını arttırdığı düşünülmektedir (Divi ve ark., 2010).

Brassinosteroidler vejetatif gelişim aşamasında (Vardhini ve Rao, 1998), çiçeklenme aşamasında (Vardhini, 2012; 2013), tane dolum aşamasında (Vardhini, 2012), tozlaşma aşamasında (Liu ve ark., 2007), ekim öncesi tohumlara (Zhang ve ark., 2007) ve kök bölgesine (Shang ve ark., 2006; Song ve ark., 2006) uygulanabilmektedirler (Altaş, 2016). Soya üzerinde yapılan bir çalışmada, bitki yapraklarına brassinosteroid uygulanması yaprak şeker ve prolin düzeylerini artırırken, artan POD (peroksidaz) ve SOD (süperoksit dismutaz) aktivitesi yaprak MDA (malondialdehit) düzeylerini düşürerek verimi artırmıştır. Çalışmalar, brassinosteroidlerin bitkilerde sadece kuraklık ve tuzluluk gibi abiyotik streslere karşı değil, aynı zamanda pestisitler, sıcaklık değişiklikleri ve ağır metaller gibi diğer stres faktörlerine karşı da koruyucu bir rol oynadığını göstermektedir (Vardhini ve Anjum, 2015). Ayrıca EBR'nin soya tohum verimini doğrudan etkileyen verim faktörlerinde iyileştirmelere yol açtığı vurgulanmıştır (Zurek ve Clouse, 1994; Terakado ve ark., 2005; Pereria ve ark., 2019; Yin ve ark., 2019; Soliman ve ark., 2020; Jiang ve ark., 2020; Cheng ve ark., 2021).

Bu çalışmada, Isparta ekolojik koşullarında yetiştirilen soyanın çiçeklenme öncesi döneminde uygulanan farklı dozlardaki brassinosteroid'in verim ve verim bileşenlerine etkisinin belirlenmesi amaçlanmıştır.

2. Materyal ve Metot

Bu araştırmada, tarla denemeleri Isparta ilinde yer alan Isparta Uygulamalı Bilimler Üniversitesi (ISUBÜ), Ziraat Fakültesi Eğitim, Araştırma ve Uygulama Çiftliği arazisinde 2022-2023 yıllarında yürütülmüştür. Isparta ili, Göller yöresi olarak adlandırılan bölgede yer almakta olup, yöre Akdeniz ve karasal iklimler arası geçit kuşağı iklim özelliğindedir. Denemenin yürütüldüğü lokasyon 37.50 kuzey 30.32 doğu koordinatlarındadır. Arazinin deniz seviyesinden yüksekliği 1008 metredir. Araştırmada bitki materyali olarak PG Victoria soya çeşidi kullanılmıştır. PG Victoria; II. ürün ekilişlerinde de verim potansiyeli yüksek, olum grubu 3.2 olan bir soya çeşididir. Yapraklardan hormon uygulamasında ise bitki büyüme düzenleyicisi olarak Biosynth Carbosynth firmasından temin edilen ve saf halde bulunan epibrassinolide ($C_{28}H_{48}O_6$) kullanılmıştır. Araştırmada epibrassinolide'in 3 farklı dozu bitkilere yapraktan uygulama şeklinde çiçeklenmeden önceki dönemde (çıkışlardan itibaren bitkiler 4-5 haftalık periyotta) yapılmıştır.

Ekim işlemi 1. yıl 13 Mayıs 2022 ve 2. yıl ise 17 Mayıs 2023 tarihlerinde elle yapılmıştır. Ekimin hemen öncesinde denemenin kurulacağı parsellere dekara 17 kg hesabıyla 12-12-17 kompoze gübresiyle temel gübreleme yapılmıştır. Tarla denemeleri, 2x4 m (toplam 8 m^2) ebatlarındaki parsellere, 50 cm sıra arası ve her parsel 4 sıra olacak şekilde kurulmuştur. Denemede parsel arası 1 m ve blok arası 2 m olacak şekilde ayarlanmıştır. Tüm parsellerde tarla çıkışları tamamlandıktan sonra bitki sıralarında çapa ile seyreltme yapılarak, sıra üzeri mesafeler 3 cm olarak ayarlanmıştır. Denemede; her blokta kontrol (hiçbir uygulama yapılmamış) ve saf su (sadece saf su pülverize edilmiş) uygulamaları dahil edildiğinde brassinosterodin 3 dozu (0.5, 1.0 ve 1.5 µM EBR) ile birlikte 5 uygulama parseli ve bunların üç tekerrüründen oluşan toplamda 15 parsel yer almıştır. Çalışmada EBR çözeltilerini hazırlamak için; 0.025 g epibrassinolide tartılmış, üzerine çözünmesini sağlamak için 25 ml %70'lik etil alkol eklenerek iyice karıştırılmış, çözünen epibrassinolid üzerine distile su eklenerek 200 ml'ye tamamlanmıştır. Hazırlanan stok epibrassinolid çözeltisinden 3 farklı doz (0.5, 1 ve 1.5 µM) hazırlamak için sırasıyla 1.92 ml, 3.85 ml ve 5.77 ml alınarak 1'er litreye tamamlanmıştır (Kıcır, 2023). Hazırlanan bu çözeltiler parsellere 30 l da^{-1} hesabıyla şarjlı-motorlu sırt pülverizatörü ile pülverize edilerek uygulanmıştır. Deneme 3 tekerrürden oluşacak şekilde tesadüf blokları deneme desenine göre kurulmuştur. Ekimden hemen sonra "pendimethalin" etken maddeli çıkış öncesi herbisit 300 ml/da dozunda parsellere uygulanmıştır. Ekimden sonra çıkışı sağlamak için yağmurlama sulama yöntemiyle parseller sulanmıştır. Diğer sulamalar yetiştirme periyodu boyunca iklim şartlarına bağlı olarak 8 kere (her sulama 3 saat süreyle yapılmıştır) damla sulama yöntemiyle gerçekleştirilmiştir. Denemede %50 çiçeklenme gün sayısı, ekim tarihinden itibaren parsellerdeki bitkilerin % 50'sinin çiçeklendiği tarihe kadar geçen süre gün olarak belirlenmiştir. Çalışmada ele alınan diğer morfolojik/agronomik özelliklerin (ilk bakla yüksekliği, bitkide bakla sayısı, bitkide tane sayısı, bitkide tane ağırlığı, hasat indeksi, yüz tane ağırlığı, tane verimi ve yağ oranı) belirlenmesi Kıcır (2023)'te belirtilen yöntemlere göre yapılmıştır.

2.1. Deneme yerinin iklim ve toprak özellikleri

Denemenin yürütüldüğü arazinin toprak özellikleri killi-tınlı, pH 7.66, kireç (%28.7) ve potasyum (772.2 mg kg^{-1}) bakımından zengin, organik madde (%1.54) ve fosfor (23.5 mg kg^{-1}) bakımından fakirdir. Tarla denemelerinin kurulduğu lokasyona ait iklim verileri ise *Tablo 1*'de gösterilmiştir.

Tablo 1. Denemenin yürütüldüğü yıllar ile uzun dönem iklim verileri

Table 1. The years during which the experiment was conducted and the long-term climatic data

İklim Faktörleri	Yıllar	Mart	Nisan	Mayıs	Haziran	Temmuz	Ağustos	Eylül	Ekim	Ort./Top
Ortalama Sıcaklık (^oC)	2022	3.2	14.6	17.3	21.5	25.3	25.3	21.2	15.9	18.0
	2023	9.1	10.8	15.5	20.1	25.8	27.3	21.7	16.7	18.4
	1929-2022	6.0	10.8	15.5	19.9	23.4	23.3	18.9	13.4	16.4
Yağış (mm)	2022	78.3	17.4	12.9	46.1	0.8	18.4	16.3	9.4	199.6
	2023	73.8	69.9	111.0	47.3	8.0	3.1	29.1	9.7	351,9
	1929-2022	58.9	51.2	55.9	35.6	15.6	14.2	18.4	37.8	287.6

Meteoroloji İstasyonu iklim verileri

3. Bulgular ve Tartışma

Araştırmada incelenen özelliklerde varyans analizleri yapılmıştır. Buna göre ilk bakla yüksekliği, bitkide bakla sayısı, bitkide tane sayısı, bitkide tane ağırlığı, hasat indeksi, yüz tane ağırlığı, tane verimi ve yağ oranı özelliklerinde yıl × uygulama interaksiyonu P≤0.01 düzeyinde; %50 çiçeklenme gün sayısı özelliğinde ise yıl × uygulama interaksiyonu P≤0.05 düzeyinde istatistiki olarak önemli bulunmuştur (*Tablo 2, 3* ve *4*).

Tablo 2. Farklı dozlarda EBR uygulanan soyada %50 çiçeklenme gün sayısı, bitki boyu, ilk bakla yüksekliği ve bitkide bakla sayısına ait ortalamalar

Table 2. Averages for soybean subjected to different doses of EBR in terms of 50% flowering time, plant height, first pod height, and number of pods per plant

	%50 çiçeklenme gün sayısı (gün)			Bitki boyu (cm)			İlk bakla yüksekliği (cm)			Bitkide bakla sayısı (adet)		
Uygulama	1.yıl	2.yıl	Ort.	1.yıl	2.yıl	Ort.	1.yıl	2.yıl	Ort.	1.yıl	2.yıl	Ort.
Kontrol	59.7 a	56.0 b	57.8	97.27 b	70.13 ab	83.70 B	11.03 b	13.90 a	12.47 A	54.53 c	20.00 b	37.27 D
Saf su	58.7 ab	56.7 b	57.7	96.63 b	67.67 c	82.15 B	10.23 b	14.03 a	12.13 AB	70.40 b	16.80 c	43.60 B
0.5 µM	57.7 ab	56.0 b	56.8	102.43 a	71.17 a	86.80 A	10.43 b	12.43 b	11.43 B	80.30 a	32.73 a	56.52 A
1.0 µM	58.3 ab	58.3 ab	58.3	88.27 c	67.13 c	77.70 C	12.63 a	12.17 b	12.40 A	50.47 d	31.80 a	41.13 C
1.5 µM	56.7 b	59.7 a	58.2	85.37 d	68.27 bc	76.82 C	12.17 a	10.83 c	11.50 B	48.80 d	33.67 a	41.23 BC
Ort.	58.20	57.33	-	93.99 A	68.87 B	-	11.30 B	12.67 A	-	60.90 A	27.00 B	-
CV(a)	%2.7			%1.83			%6.7			%2.58		
CV(b)	%2.46			%1.73			%3.94			%2.9		
F Değeri	Yıl (A): 2.315 ns			Yıl (A): 2130.846 **			Yıl (A): 21.919 *			Yıl (A): 6728.396 **		
	Uygulama (B): 1.012 ns			Uygulama (B): 52.680 **			Uygulama (B): 6.491 **			Uygulama (B): 201.543 **		
	A×B: 4.716 *			A×B: 25.856 **			A×B: 32.302 **			A×B: 267.964 **		

*ns = Önemsiz. *: Önemli (P≤0.05). **: Önemli (P≤0.01)*
**: Aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark istatistiksel olarak önemsizdir.*

Yıllara göre değişmekle birlikte %50 çiçeklenme gün sayısında uygulamalar arasında farklılıklar önemli bulunmuştur. Denemenin birinci yılında en geç çiçeklenme kontrol parsellerinde belirlenmiş, saf su ve EBR dozları çiçeklenme süresinin azalmasına neden olmakla birlikte, safsu, 0.5 µM ve 1.0 µM EBR dozu uygulamalarından elde edilen ortalamalar kontrol parsellerine benzer olup, aynı grupta yer almıştır. En erken çiçeklenme gün sayısı ise 1.5 µM EBR uygulamasında gözlenmiş olup, çiçeklenme süresi kontrol grubuna göre istatistiki yönden önemli düzeyde kısalmıştır. İkinci yılında ise birinci yılın tersine1.5 µM EBR çiçeklenme süresini uzatmıştır. Safsu, 0.5 µM ve 1.0 µM EBR uygulamaları kontrol parselleri ile benzer sonuçlar vermiş olup, istatistiki yönden aynı grupta yer almışlardır. İki yılın ortalaması bakımından en erken çiçeklenme gün sayısı 0.5 µM EBR uygulamasında, en geç çiçeklenmeler ise 1.0 µM ve 1.5 µM EBR uygulamalarında belirlenmiştir (*Tablo 2*). Yıllara göre EBR uygulamaları arasında farklılıklar saptanmıştır. Bunun nedeni olarak deneme yılları arasındaki iklimsel değişimler olduğu söylenebilir. Ayrıca EBR bitkilerin çiçek gibi kısımlarında da sentezlenebilmektedir (Ankudo, 2004). Brassinosteroidin sinyal transdüksiyonu ve biyosentezi arasında bir bağlantı bulunmakta olup, bu bağlantının çiçeklenmenin başlamasını kontrol ettiği bildirilmiştir. (Clouse, 2008). İklimsel farklılığın yanında EBR uygulaması çiçeklenmeyi etkilemiştir. Soyada çiçeklenme gün sayıları; kullanılan çeşitlere, iklim ve çevre şartlarına, genotip × çevre interaksiyonuna ve yetiştirme tekniği paketine göre değişebilmektedir (Uncu ve Arıoğlu, 2005; Erbil, 2020). Soya ile yürütülen diğer çalışmalarda çiçeklenme gün sayıları Samsun'da 44.3-52.8 gün (Erdoğmuş, 2007), Tokat'da 61-76 gün (Sarıoğlan, 2019), Diyarbakır'da 32-56 gün (Barış ve ark., 2020) ve Şanlıurfa'da 37.7-42.7 gün (Erbil, 2020) arasında değişen değerler almıştır.

Bitki boyu, soyada verime doğrudan etki eden önemli karakterlerden birisi olup, çeşitlerin genetik yapısına, yetiştirilen çevreye, genotip × çevre interaksiyonu ve yetiştiricilikte kullanılan girdiler ve uygulamalardan etkilenmektedir (Ertaş, 2017; Altınyüzük ve Öztürk, 2023). Soyaya farklı dozlarda EBR uygulanan bu çalışmada, bitki boyu ortalamaları 76.82-86.80 cm arasında değişim göstermiştir (*Tablo 2*). Her iki deneme yılında da kontrol ve safsu uygulamalarına göre 0.5 µM EBR uygulaması bitki boyunu önemli düzeyde arttırmış olup, en yüksek değerler elde edilmiştir. İkinci yıl 0.5 µM EBR dozunda daha yüksek ortalamalar belirlenmekle birlikte kontrol parselleri ile aynı istatistik grupta yer almışlardır. 0.5 µM dozundan daha yüksek EBR dozlarında ise bitki boyu kısalmış ve en düşük bitki boyu ortalamaları 1.5 µM EBR uygulamasında ölçülmüştür. Brassinosteroidler hücre büyümesini ve bölünmesini teşvik etmektedir (Surgun ve ark., 2012). Bu büyümeyi teşvik edici etkiler hücre uzaması ve bölünmesinin hızlanması ile gerçekleşmektedir. Fasulye üzerine yapılan bir araştırmada, kesilen boğum araları belirli sürelerde farklı dozlarda brassinosteroid içine batırılmış ve uygulamaların düşük dozlarda büyümeyi teşvik ettiği belirlenmiştir (Strnad ve Kohout, 2003; Šíša, ve ark., 2007). EBR'in düşük dozu (0.5 µM) kontrol ve safsu uygulamasına göre soyada bitki boyunun uzamasını teşvik etmiştir. Daha yüksek dozlarda ise bitki boyu yönünden EBR olumsuz yönde etkili olmuştur.

Soyada ilk bakla yüksekliği bakımından EBR uygulamaları arasındaki farklılıklar istatistiki yönden önemli ($P \leq 0.01$) bulunmuştur. İlk bakla yüksekliği ortalamaları iki yıllık değerlere göre 11.43-12.47 cm arasında değerler almıştır. Birinci deneme yılında 1.0 ve 1.5 µM EBR dozları (sırasıyla 12.63 ve 12.17 cm) soyada ilk bakla yüksekliğinin önemli düzeyde artmasına neden olmuş, bu iki uygulama üst ve aynı grupta yer almıştır. Kontrol, safsu ve 0.5 µM EBR uygulamalarında ise daha düşük değerler elde edilmiş ve bu uygulamalardan elde edilen ortalamalar istatistiki olarak aynı grupta değerlendirilmişlerdir. 2023 yılında ise en yüksek ortalamalar kontrol ve safsu uygulanan parsellerden elde edilmiştir. İkinci yılda EBR uygulamaları ilk bakla yüksekliğinin önemli düzeyde azalmasına neden olmuştur. İki yıllık ortalamalara göre en yüksek değerler kontrol, safsu ve 1 µM EBR uygulamalarından elde edilmiştir (*Tablo 2*) Elde edilen verilere göre ilk bakla yüksekliği bakımından EBR uygulamalarının etkilerinin yıllara göre değişkenlik gösterdiği söylenebilir. Yapılan çalışmalarda soyada ilk bakla yüksekliğinin 1.8-40.3 cm arasında değiştiği bildirilmiştir (Acar, 2015; Karabulut, 2018; Yıldırım ve İlker, 2018; Ertaş, 2017; Barış ve ark., 2020; Yiğit ve ark., 2021). İlk bakla yüksekliği makineli hasat için önemli bir özelliktir. Bitkilerin genetik özelliklerine bağlı olarak ilk bakla yüksekliği değişim göstermektedir. Genotipik özelliklere ek olarak ekim sıklığı, ekim zamanı, fotoperiyod ve toplam sıcaklık gibi ekolojik etkenler de ilk bakla yüksekliğini etkilemektedir (Altınyüzük ve Öztürk, 2023). Denemenin birinci ve ikinci yılında ilk bakla yükseklikleri farklılıklar göstermiştir. Birinci yıl ilk bakla yüksekliği ortalaması 12.67 cm, ikinci yıl ise 11.30 cm olarak belirlenmiştir. Sonuçlara göre ilk bakla yüksekliği üzerine iklim şartlarının etkisinin önemli olduğu değerlendirilmiştir. Yapılan çalışmalarda da soya genotiplerinin ilk bakla yüksekliğinin yıllara ve lokasyona göre değiştiği bildirilmektedir (Tuğay ve Atikyılmaz, 2009; Kulan ve ark., 2017).

Bitkide bakla sayısı yıllar ve uygulamalara göre geniş bir varyasyon göstermiştir. Birinci deneme yılı ortalaması 60.90 adet iken, ikinci yıl ortalaması 27.00 adet olarak hesaplanmıştır. İkinci yıl bakla sayısının düşük olmasının nedeni, çiçeklenme dönemine kadar günlük hava sıcaklığı değerlerinin uzun yıllar ortalamasına yakın seyretmesi ancak parsellerin çiçeklenme zamanında ise uzun yıllar bölge ortalamasına göre çok yüksek günlük sıcaklık derecelerinin görülmesine bağlı olarak meyve bağlayan çiçek sayısının azalması olduğu söylenebilir. Birinci yıl kontrol parsellerine göre safsu ve 0.5 µM EBR uygulamasında bakla sayıları önemli düzeyde artmış, istatistiki bakımdan en yüksek ortalama 80.30 adet ile 0.5 µM EBR dozunda belirlenmiştir. Ancak 0.5 µM EBR dozundan sonraki artan EBR dozları bakla sayısını olumsuz etkilemiştir. İkinci yılda ise EBR uygulaması yapılan parsellerde bakla sayısı kontrol ve safsu uygulamasından önemli oranda yüksek bulunmuş, ancak EBR dozlarının etkileri benzer olmuş, üç EBR dozu uygulaması da aynı grupta yer almıştır. Brassinosteroidlerin bitki gelişimindeki başlıca etkileri arasında hücre bölünmesi ve genişlemesi, hücresel farklılaşma, lateral kök gelişimi, polen tüpü gelişimi, çiçeklenme ve stres toleransının arttırılması yer almaktadır (Rao ve ark., 2002; Savaldi-Goldstein ve Chory, 2006; Clouse ve Sasse, 1998; Sasse, 2003; Amzalling ve Vaisman, 2006; Ashraf ve ark., 2010). Yapılan çalışmalarda çiçek dökmenin çevresel strese bağlı olarak arttığı, fakat normal koşullarda da olabileceği bildirilmiştir. Uygulamaların çiçek silkme miktarının azaltılmasında etkili olacağı vurgulanmıştır (Dağtekin ve Bilgili, 2020). Bu çalışmada da kontrol uygulamasına göre, EBR uygulamaları ile bitkide bakla sayısının arttığı belirlenmiş olup, EBR uygulamalarının çiçek dökümünü azaltması sonucunda bakla tutumunun arttığı söylenebilir.

Tablo 3. Farklı dozlarda EBR uygulanan soyada bitkide tane sayısı, bitkide tane ağırlığı ve hasat indeksine ait ortalamalar

Table 3. Averages for soybean subjected to different doses of EBR in terms of grain number per plant, grain weight per plant, and harvest index

	Bitkide tane sayısı (adet)			**Bitkide tane ağırlığı (g)**			**Hasat indeksi (%)**		
Uygulama	**1.yıl**	**2.yıl**	**Ort.**	**1.yıl**	**2.yıl**	**Ort.**	**1.yıl**	**2.yıl**	**Ort.**
Kontrol	150.87 c	53.67 c	102.27 D	17.79 c	6.25 c	12.02 B	26.86 ab	24.95 c	25.90 C
Saf su	170.13 b	42.73 d	106.43 CD	20.10 b	4.85 d	12.47 B	25.62 bc	24.68 c	25.15 C
0.5 µM	193.53 a	88.97 a	141.25 A	22.79 a	10.64 a	16.71 A	27.64 a	30.83 a	29.24 A
1.0 µM	144.93 c	73.80 b	109.37 C	15.50 d	8.40 b	11.95 B	25.42 bc	27.47 b	26.44 BC
1.5 µM	144.60 c	88.00 a	116.30 B	15.47 d	10.56 a	13.02 B	24.66 c	31.28 a	27.97 AB
Ort.	160.81 A	69.43 B	-	18.33 A	8.14 B	-	26.04 B	27.84 A	-
CV(a)	%4.61			%3.91			%0.68		
CV(b)	%3.11			%4.74			%3.83		
F Değeri	Yıl (A): 2226.194 **			Yıl (A): 2910.687 **			Yıl (A): 733.372 **		
	Uygulama (B): 112.407 **			Uygulama (B): 60.396 **			Uygulama (B): 15.268 **		
	A×B: 91.668 **			A×B: 65.566 **			A×B: 16.323 **		

*ns = Önemsiz. *: Önemli (P≤0.05). **: Önemli (P≤0.01)*
**: Aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark istatistiksel olarak önemsizdir.*

Soyada bitkide tane sayısı birinci yıl ortalaması 160.81 adet olarak belirlenmiştir. İkinci yılda ise bakla sayısındaki azalmalara bağlı olarak tane sayısı da azalmıştır. Soyada bitkide tane sayısı doğrudan verim ile ilişkili bir özelliktir. Çeşit, iklim ve çevre şartları ve yetiştirme koşullarına bağlı olarak değişebilmektedir. Bitkide tane sayılarında yıllar arasındaki farklılığın sebebi deneme yılları arasındaki iklimsel farklılıklar olduğu söylenebilir. Bakla sayısına benzer şekilde, birinci yıl safsu ve 0.5 µM EBR uygulamasında kontrole göre tane sayıları da artmıştır. En yüksek ortalama 0.5 µM EBR dozunda saptanmış ve en üst grupta yer almıştır. EBR'nin yüksek dozlarında (1.0 ve 1.5 µM) ise tane sayısı olumsuz etkilenmiş ve azalmıştır. İkinci yılda da en yüksek tane sayısı değeri 0.5 µM EBR dozunda saptanmış olmakla birlikte, 0.5 µM ve 1.5 µM EBR dozları aynı istatistik grupta değerlendirilmiştir. Bu iki uygulamada da tane sayısı kontrole göre yüksek bulunmuştur. İki yıllık ortalama verilere göre; soyada en yüksek bitkide tane sayısı (141.25 adet) 0.5 µM EBR uygulamasında elde edilmiş olup, artan dozlarda bitkide tane sayısında önemli düşüşler belirlenmiştir. İklim koşullarına göre değişmekle birlikte, EBR'nin en düşük dozu tane sayısını olumlu yönde etkilemiştir. Bitki başına bakla sayısını arttıran uygulamalar bitki başına tane sayısını da etkilemektedir (Barış ve ark., 2020). Soyada yapraktan EBR uygulamasının bitkide tane sayısını önemli oranda arttırdığı bildirilmektedir (Muminova ve ark., 2022).

Bitkide tane ağırlığı soyada verime etkisi yüksek olan özellikler arasında sayılmaktadır. Farklı dozlarda EBR uygulanan soyada bitkide tane ağırlığı ortalamaları birinci yıl 15.47-22.79 g, ikinci yıl 4.85-10.64 g arasında değişim göstermiştir. Soyada genotip × çevre interaksiyonunun önemli olmasından dolayı çeşitlerin ve yetiştirilen ekolojik koşulların bitkide tane ağırlığına etkisi yüksektir (Acar, 2015). Birinci yıl 0.5 µM EBR dozunda, ikinci yılda ise 0.5 ve 1.5 µM EBR dozlarında en yüksek bitkide tane ağırlığı değerleri elde edilmiştir. İkinci yıl saf su uygulamasında bitki tane ağırlığı ortalaması, bitkide bakla ve tane sayılarında olduğu gibi kontrole göre azalma eğiliminde olmuştur. Elde sonuçlar, bitkide tane ağırlığı bakımından saf su ve EBR dozları etkisinin vejetasyon dönemindeki iklim koşullarından çok etkilendiğini göstermektedir. Yılların ortalaması olarak değerlendirildiğinde her iki deneme yılında da 0.5 µM EBR uygulaması bitkide tane ağırlığına olumlu etkide bulunmuştur. Artan dozlar (0.5 µM üzeri) bitkide tane ağırlığını negatif etkilemiştir. Brassinosteroidler tüm bitki düzeyinde büyümeyi teşvik etmekte, döllenmeyi artırmakta, uygun olmayan çevresel faktörlere, strese ve hastalığa karşı direnci ve ürünlerin verimliliğini artırmaktadır (Surgun ve ark., 2012). Ayrıca EBR'nin bitki tohum verimini önemli oranda arttırdığı bildirilmiştir (Muminova ve ark., 2022).

Farklı dozlarda EBR uygulanan soyada hasat indeksi ortalamaları iki yıllık verilere göre %25.15-29.24 arasında değişim göstermiştir. En yüksek değerler 0.5 ve 1.5 µM EBR dozlarında (sırasıyla %29.24 ve %27.97) belirlenmiştir. Birinci yıl 0.5 µM EBR dozunda en yüksek ortalama elde edilmiş, ancak bu değer kontrol parselleri ortalamasına benzer bulunmuştur. İkinci yıl ise en yüksek değerler sırasıyla 1.5 ve 0.5 µM dozlarında belirlenmiş, diğer uygulamalarda hasat indeksi önemli düzeyde azalış göstermiştir. Bitki verimi ve bitki boyu gibi tane verimini ve biyolojik verimi etkilen faktörler çevre şartlarından etkilendiği için hasat indeksi de etkilenmektedir (Acar, 2015; Altınyüzük ve Öztürk, 2023). Yapılan çalışmalarda, soyada hasat indeksi değerlerinin %23.74-93.3 arasında değiştiği belirtilmiştir (Ertaş, 2017; Karabulut, 2018).

Tablo 4. Farklı dozlarda EBR uygulanan soyada yüz tane ağırlığı, tane verimi ve yağ oranına ait ortalamalar

Table 4. Averages for soybean subjected to different doses of EBR in terms of hundred-grain weight, grain yield, and oil content

	Yüz tane ağırlığı (g)			**Tane verimi (kg da^{-1})**			**Yağ oranı (%)**		
Uygulama	**1.yıl**	**2.yıl**	**Ort.**	**1.yıl**	**2.yıl**	**Ort.**	**1.yıl**	**2.yıl**	**Ort.**
Kontrol	13.00 a	11.62 ab	12.31 A	439.93 c	285.70 ab	362.82 C	20.56 c	21.03 ab	20.80 C
Saf su	11.00 c	11.24 b	11.12 B	525.47 b	291.75 ab	408.61 B	21.06 b	21.06 ab	21.06 B
0.5 µM	12.33 b	12.04 a	12.19 A	566.67 a	301.17 a	433.92 A	20.71 c	20.95 b	20.83 C
1.0 µM	11.33 c	11.21 b	11.27 B	378.33 d	270.16 b	324.25 D	21.49 a	21.27 a	21.38 A
1.5 µM	12.00 b	12.20 a	12.10 A	387.33 d	297.68 a	342.51 CD	20.99 b	20.56 c	20.78 C
Ort.	11.93	11.66	-	459.55 A	289.29 B	-	20.96	20.98	-
CV(a)	%1.69			%5.73			%0.79		
CV(b)	%2.69			%3.86			%0.62		
F Değeri	Yıl (A): 14.101 ns			Yıl (A): 471.755 **			Yıl (A): 0.038 ns		
	Uygulama (B): 18.437 **			Uygulama (B): 60.243 **			Uygulama (B): 23.175 **		
	A×B: 6.442 **			A×B: 42.611 **			A×B: 11.662 **		

*ns = Önemsiz. *: Önemli (P≤0.05). **: Önemli (P≤0.01)*
**: Aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark istatistiksel olarak önemsizdir.*

Yüz tane ağırlığı ortalamaları incelendiğinde; birinci yıl en yüksek değer (13 g) kontrol parsellerinde belirlenmiştir. Hem saf su uygulaması hem de EBR dozları tane iriliğinin önemli düzeyde azalmasına neden olmuştur. İkinci yılda ise en yüksek değerler 1.5 µM, 0.5 µM EBR dozları ve kontrol parsellerinde (sırasıyla 12.20, 12.04 ve 11.62 g) saptanmış, üç uygulamada istatistik olarak aynı grupta yer almıştır. Denemede iki yıllık ortalamalar incelendiğinde; en yüksek tane iriliği değerleri kontrol parselleri ile 0.5 ve 1.5 µM EBR dozu uygulanan parsellerden elde edilmiştir (*Tablo 4*). Birinci yıl kontrol parsellerinde en yüksek yüz tane ağırlığı değerlerinin elde edilmesinin nedeninin, bu uygulamada bitkide bakla ve tane sayısının az olmasına bağlı olarak tanelerin daha çok beslenmesi ve iri tohum elde edilmesi olduğu söylenebilir. Yüz tane ağırlığı genetik yapının yanında, ekolojik şartlara ve agroteknik işlemlere göre değişmektedir. Yüksek sıcaklıkta, kötü bakım koşullarında ve erken hasatta yüz tane ağırlığı düşebilmektedir (Acar, 2015; Altınyüzük ve Öztürk, 2023). Denememizde yüz tane ağırlığının yıllara ve uygulamalara göre farklılık göstermesinin nedeni olarak soyanın değişen çevresel koşullar altında farklı uygulamalara farklı tepkiler vermesi olduğu söylenebilir. Ayrıca EBR'lerin tüm bitki düzeyinde; döllenmeyi, meyve kalitesi ve meyve boyutunu artırıcı fizyolojik etkileri vardır (Yokota, 1997). Soya ile yapılan çalışmalarda yüz tane ağırlıklarının 8.6-22.9 g arasında değiştiği bildirilmiştir (Ertaş, 2017; Karabulut, 2018; Yıldırım ve İlker, 2018; Barış ve ark., 2020; Özüstün, 2022; Altınyüzük ve Öztürk, 2023; Yılmaz, 2024).

Tane verimi değerleri incelendiğinde; yıllara göre değişmekle birlikte, EBR uygulamaları arasında önemli varyasyonlar gözlenmiştir. Birinci yıl hem safsu hem de 0.5 µM EBR dozu uygulaması kontrole göre tane verimini önemli düzeyde arttırmıştır. En yüksek tane verimi 0.5 µM EBR dozunda (566.67 kg da^{-1}) saptanmıştır. 0.05 µM EBR dozundan sonraki artan EBR dozları verimin önemli düzeyde azalmasına neden olmuştur. İkinci yılda da en yüksek tane verimi 301.17 kg da^{-1} ile 0.5 µM EBR dozunda olmakla birlikte, denemede ele alınan uygulamaların kontrol parselleri ile arasındaki fark anlamlı bulunmamış, ortalamalar aynı grupta yer almıştır. Denemede iki yılın ortalamasına göre, en yüksek tane verimi değerleri 0.5 µM EBR uygulamasında belirlenmiş olup, 0.5 µM üzerindeki uygulamalar verimi olumsuz etkilemiştir. Brassinosteroidler büyümeyi teşvik etmekte, döllenmeyi artırmakta, vejetatif gelişme süresini kısaltmakta ve tane verimini artırmaktadır (Surgun ve ark., 2012). Bu çalışmada da uygulamalar arasından, 0.5 µM EBR dozunun soyada tane verimini teşvik ettiği söylenebilir.

Farklı dozlarda EBR uygulanan soyada yağ oranı değerleri yıl × uygulama interaksiyonuna göre önemli varyasyonlar göstermiştir. Hem birinci (%21.49) ve ikinci yılda (%21.27), hem de iki yıllık ortalama (%21.38) verilere göre soyada en yüksek yağ oranları 1.0 µM EBR dozu uygulanan parsellerden elde edilmiştir. İlk yıl 1.0 µM EBR dozundan elde edilen yağ oranı değeri önemli düzeyde yüksek bulunmuştur. Kontrol ve diğer tüm uygulamalarda genellikle yağ oranları azalış göstermiştir. Denemenin ikinci yılında en yüksek yağ oranı elde edilen 1.0 µM EBR dozu ile kontrol ve safsu uygulanan parseller arasındaki farklılıklar anlamlı olmamıştır. Elde edilen sonuçlara göre soyada tane yağ oranı üzerine 1.0 µM EBR dozunun olumlu etkiler gösterdiği söylenebilir. Brassinosteroidler uzama ve bölünmeyi destekler, hormonal dengeyi korur, protein ve nükleik asit sentezini aktive eder, enzimatik aktiviteyi arttırır, yağ asidi kompozisyonuna etki eder ve fotosentetik kapasiteyi arttırır (Surgun ve ark., 2012). Yapılan çalışmalarda da soyada tane yağ oranı değerlerinin %17.9-24.73 arasında olduğu bildirilmiştir (Altınyüzük, 2017; Turhan, 2019; Vurarak, 2024).

4. Sonuç

Farklı dozlarda EBR uygulanan soyada 0.5 µM EBR uygulaması çiçeklenme süresini kısaltmış, bitki boyunu, bitkide bakla sayısını, bitkide tane sayısını, bitkide tane ağırlığını, hasat indeksini ve tane verimini artırmış olup, yağ oranını ise 1.0 µM EBR uygulaması artırmıştır. İncelenen özelliklerde; %50 çiçeklenme gün sayısı 56.0-59.7 gün, bitki boyu 67.13-102.43 cm, ilk bakla yüksekliği 10.23-14.03 cm, bitkide bakla sayısı 16.80-80.30, bitkide tane sayısı 42.73-193.53, bitkide tane ağırlığı 4.85-22.79 g, hasat indeksi %24.66-31.28, yüz tane ağırlığı 11.00-13.00 g, tane verimi 270.16-566.67 kg da^{-1} ve yağ oranı %20.56-21.49 arasında değişim göstermiştir. Yapraktan EBR uygulaması ile soyanın verim ve verime doğrudan etkili özellikleri üzerinde yıllara göre değişmekle birlikte farklı etkilerinin olduğu belirlenmiştir. Genel olarak değerlendirildiğinde 0.5 µM EBR uygulamasının soyada verim ögeleri üzerine olumlu etkileri olduğu sonucuna varılmıştır. Bundan (0.5 µM) daha yüksek dozlardaki EBR uygulamalar, tane verimi ve verime doğrudan etkili özellikler üzerine olumsuz etkilerde bulunmuştur.

Etik Kurul Onayı

Bu çalışma için etik kuruldan izin alınmasına gerek yoktur.

Çıkar Çatışması Beyanı

Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz.

Yazarlık Katkı Beyanı

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Mevsimlik Gezici Tarım İşçisi Hanelerin Karşılaştığı Yoksunlukları Anlamak: Ankara İli Bala İlçesi Örneği*

Understanding the Deprivations Faced by Seasonal Migrant Agricultural Worker Households: The Case of Bala District in Ankara Province

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Öz

Tarımsal üretimin, en önemli bileşenlerinden olan mevsimlik gezici tarım işçileri, üretime yaptıkları katkı ile yerelde ve ulusalda ekonomiyi desteklerken, gıda güvencesi açısından gıda tedarikinin istikrarını sağlamada kilit rol oynamaktadırlar. Ancak, mevsimlik gezici tarım işçileri, sağladıkları önemli katkıya rağmen, tarımsal üretime katkıda bulunmak üzere geçici olarak gittikleri, ancak uzun süre geçirdikleri yerlerde, yaşam koşullarına ilişkin ihtiyaçlarının yeterince karşılanmamasından dolayı yoksunluklar yaşamaktadırlar. Bu yoksunluklar, yalnızca tek boyutta değil çoklu boyutlarda yaşadıkları yoksunluklardır. Bu çalışmada, mevsimlik gezici tarım işçisi hanelerinin yaşadığı çok boyutlu yoksunluklar incelenmektedir. Yoksunluk kavramı, toplumun mevcut olan koşullarına göre göreli olarak yetersiz olan maddi ve sosyal koşullar olarak ele alınmaktadır. Analizde, barınma, temizlik koşulları ile sağlık, beslenme durumları ile enerjiye erişim, bilgi ve teknolojiye erişim boyutlarına yer verilmiştir. Çalışmada, mevsimlik gezici tarım işçilerinin, çalışmak için geldikleri yerde uzun süre deneyimledikleri söz konusu boyutlardaki yoksunlukları ele alınmaktadır. Ankara ili Bala ilçesinde, mevsimlik gezici tarım işçiliği yapan ve kartopu örneklemesi ile belirlenen 80 hane ile yüz yüze görüşüldüğü 2022-2023 yıllarında yürütülen araştırmada, hanelerden öncelikle demografik bilgiler ve çalışma durumları ile ilgili veriler alınmıştır. Devamında, ele alınan boyutlarda hanelerin çalışmak için geldikleri ilçede, sahip oldukları olanaklar ile iyi olma halleriyle ilgili bilgiler alınmıştır. Bulgular, yaşam koşullarını ve mevsimlik gezici tarım işçilerinin genel refahını iyileştirmeye yönelik potansiyel müdahalelere dair girdiler sunmaktadır. Bu bulgular, iklim koşullarına aşırı hassas ve yetersiz barınma alanları, ihtiyaç duyulan sanitasyon olanaklarından yoksun yaşam koşulları, tekrarlayan fiziksel rahatsızlıklar, beslenme yetersizlikleri, bilgi ve teknolojiye sınırlı erişim gibi yaşam kalitelerini etkileyen yoksunluklardır. Mevsimlik gezici tarım işçilerinin, özellikle barınma koşullarını iyileştirmeye yönelik merkezi ve yerel yönetimlerce çeşitli önlemler alınmaktadır. Ancak, yasal düzenlemelerin yanında, mevsimlik gezici tarım işçilerinin yoksunluklarını gideren kapsamlı politikalar ile işçilerin maddi manevi çalışma haklarının korunduğu, insana yaraşır yaşam koşullarına sahip çalışma ortamları oluşturulmalıdır. Böylelikle, mevsimlik gezici tarım işçilerinin refahının sürdürülebilirliğinin sağlanması ile eşitlikçi ve sürdürülebilir bir tarım sektörü sağlanabilir.

Anahtar Kelimeler: Tarımda istihdam, Mevsimlik tarım işçisi, Yoksunluk

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Abstract

Seasonal migrant agricultural workers, who are one of the most important components of agricultural production, support the local and national economy with their contribution to production, while playing a key role in ensuring the stability of food supply in terms of food security. However, despite the significant contribution they make, seasonal migrant agricultural workers experience deprivation due to the fact that their living conditions are not sufficiently met in the places where they temporarily go to contribute to agricultural production but spend long periods of time. These deprivations are not deprivations experienced in a single dimension but in multiple dimensions. This study examines the multi-dimensional deprivations experienced by seasonal migrant agricultural worker households. The concept of deprivation is considered as material and social conditions that are relatively inadequate compared to the existing conditions of the society. The analysis includes the dimensions of shelter, sanitation and health, nutritional status, access to energy, and access to information and technology. The study examines the deprivations experienced by seasonal migrant agricultural workers in the relevant dimensions for a long period in the locations where they come to work. In this study, information was collected through face-to-face interviews conducted in 2022-2023 with 80 households selected by snowball sampling from seasonal migrant agricultural worker households in Bala district of Ankara province. Firstly, their demographic information and data on their employment status were collected. Subsequently, information was gathered regarding the facilities available to households and their well-being in the districts they came to for work, based on the dimensions addressed. The findings provide inputs regarding potential interventions to improve the living conditions and general well-being of seasonal migrant agricultural workers. These findings are the deprivations that affect the quality of life, such as inadequate shelters that are extremely sensitive to climatic conditions, living conditions that lack the required sanitation facilities, recurring physical illnesses, nutritional deficiencies and limited access to information and technology. Measures are being taken by local and central management to improve especially the housing conditions of seasonal migrant agricultural workers. However, in addition to legal regulations, comprehensive policies that eliminate the deprivations of seasonal migrant agricultural workers should be established and working environments where workers’ material and moral rights to work are protected and where they have decent living conditions should be created. Thus, an equitable and sustainable agricultural sector can be achieved by ensuring the sustainability of the welfare of seasonal migrant agricultural workers.

Keywords: Agricultural employment, Seasonal agricultural worker, Deprivation

1. Giriş

Araştırmalara göre, her yıl Türkiye'de yaklaşık yarım milyon insanın emek yoğun tarımsal üretim için mevsimlik göç yollarında olduğu tahmin edilmektedir (Zırh ve ark., 2020). Tarımda işgücü talebini karşılayan, beceri ve dayanıklılık gerektiren zorlu tarım işlerini üstlenen ve bu denli geniş çaplı bir göçün parçası olan gezici tarım işçilerinin, tarım sektöründeki rolü çok önemlidir.

Tarımsal üretimin herhangi bir aşamasında, işin yapıldığı yöre dışından gelerek, ücret karşılığında sözleşmeyle veya sözleşme olmaksızın çalışan gerçek kişilere mevsimlik (gezici) tarım işçisi denir (Görücü ve ark., 2010). Diğer bir tanımla, mevsimlik (gezici) tarım işçileri, tarım işlerinin yoğunlaştığı zamanlarda, ürün desenine ve işçi talebine göre, bir bölgeden (yaşadıkları yerlerden) başka tarımsal alanlara doğru, çoğunlukla aileleriyle birlikte yer değiştiren işgücü grubudur (Uyan Semerci ve ark., 2014).

Literatürde, Türkiye'nin çeşitli bölgelerinde gezici mevsimlik tarım işçilerinin sosyal, ekonomik ve barınma sorunlarının analizi yapılarak, bu işçilerin çalıştıkları yerlerde karşılaştıkları yaşamsal sorunlar ortaya konulmuştur (Özbekmezci ve ark., 2004; Yıldırak ve ark., 2003; Kantar Davran ve ark., 2009; Karaman ve ark., 2011; Şimşek, 2012).

Yıldırak ve ark. (2003) çeşitli illerde farklı tarım işlerinde çalışan mevsimlik gezici ve/veya geçici çalışan kadınları odak alarak yaptıkları araştırmalarında, bu kadınların konumunu ve karşılaştıkları sorunları incelemek amacıyla gezici/geçici kadın işçilerin aile durumu, sosyal güvenlik durumu, ücret yapısı, yaşam koşulları ve sosyal çevresini analiz etmiştir. Özbekmezci ve ark. (2004), Çukurova Aşağı Seyhan Ovasında, yöre içinde sürekli ikamet eden ve yöre dışından gelen mevsimlik tarım işçisi ailelerini kapsadıkları araştırmalarında, mevsimlik tarım işçilerinin sosyal, ekonomik ve barınma sorunlarını analiz ederek, yaşamsal sorunları ortaya koymuştur. Kantar Davran ve ark. (2009), Adana ilinde gerçekleştirdikleri araştırmalarında, mevsimlik tarım işçilerinin çalışma ve yaşam koşullarını incelemiş, makro düzeyde çözüm önerileri sunmuştur. Karaman ve ark. (2011) çalışmalarında, Giresun ve çevresine fındık toplama için Doğu ve Güneydoğu Anadolu'dan gelen mevsimlik ya da gezici tarım işçilerinin taşıma, konaklama, sağlık, beslenme ve eğitim gibi sorunlarını ele almıştır. Şimşek (2012), Şanlıurfa ve Adıyaman illerinde yapılan araştırmada, mevsimlik tarım işçisi ailelerin sağlık durumlarını, sağlık hizmetlerine erişim olanaklarıyla birlikte incelemiştir.

Mevsimlik gezici tarım işçilerinin ekonomik, sosyal, sağlık durumları ile yaşam koşullarının incelendiği söz konusu çalışmalar, gezici mevsimlik tarım işçilerinin çeşitli boyutlarda yaşadıkları zorlukları vurgulamaktadır. Bu sorunların ele alınması, mevsimlik gezici tarım işçilerinin refahının sağlanması doğrultusunda, işçilerin içinde bulundukları durumun ortaya konulması yönünde önem arz etmektedir.

Mevsimlik gezici tarım işçilerin refahının sağlanamaması, pek çok açıdan tarım sektörünün sürdürülebilirliğini tehdit edecektir. Öncelikle, yaşam ve çalışma koşullar iyileştirilemeyen mevsimlik tarım işçileri, daha istikrarlı ve daha yüksek ücretli sektörlere geçerek tarım sektörünü terk edecektir. Gerekli olan besin ihtiyaçlarının temini olan gıda güvencesinin sağlanması hususunda riskler oluşacak, yeterli gıda temini konusunda zorluklar ortaya çıkacaktır. Aynı zamanda, tarım arazilerinin tarım dışı amaçlar için kullanılması riskine ve devamında da üretimde uzun vadeli düşüşe yol açacaktır. Sonuç olarak, tarımsal Gayri Safi Yurtiçi Hasıla (GSYİH) olumsuz etkilenecektir (Sarıoğlu ve ark., 2024). Diğer yandan, ortaya çıkan sonuçlar yalnızca ekonomik olmayacak, kırsaldaki işgücünün diğer sektörlere vasıfsız işgücü olarak katılmasına, böylelikle sosyo-ekonomik refahın bozulmasına sebep olacaktır (Karakayacı ve ark., 2022).

Yoksunluk, bireyler ve haneler tarafından deneyimlenen, toplumda tecrübe edilen ya da mevcut olan koşullara göre göreli olarak yetersiz olan maddi ve sosyal koşullardır (Townsend, 1987). Yoksunluk kavramı, belirli bir şeye sahip olamama, yoksun olma, hane halkının ya da bireyin asgari yaşam düzeyini sürdürebilmesi için gerekli, yalnızca en temel ihtiyaçlarını bile karşılayamaması durumu olarak tanımlanabilmektedir. Bireylerin ya da grupların içinde bulundukları durumlar veya koşullar sebebiyle yaşadıkları yoksunluklar, ekonomik olabileceği gibi, siyasi ve sosyal de olabilmektedir. Başka bir ifadeyle, yoksunluk, birey, hane ya da grupların, genel toplum veya ülke seviyesine göre gözlenebilir ve kanıtlanabilir dezavantajlı durumda olmalarıdır (Townsend, ve ark., 1988). Yoksunluk, yalnızca mali kaynakların olmayışından değil, çeşitli kaynakların olmayışından kaynaklanırken, yoksulluk ise mali kaynakların olmayışından kaynaklanmaktadır. Bu bağlamda, yoksunlukların incelenmesi, çok boyutlu bir yaklaşım gerektirmektedir.

Mevsimlik gezici tarım işçilerinin, göç ettikleri ve uzun süreli kaldıkları yerlerdeki yaşam koşullarının incelenmesi, tarımsal üretimin en önemli parçası olan bu tarım işçilerinin katkılarının büyüklüğü açısından önem taşımaktadır.

Bu sebeple, mevsimlik gezici tarım işçiliği ile ilgili, çeşitli açılardan değerlendirmelerin yapıldığı literatürdeki incelemelerin yanında, bu işçilerin eş zamanlı olarak maruz kaldıkları birden fazla boyuttaki yoksunluklara ilişkin, bütüncül bir inceleme ihtiyacı bulunmaktadır. Bu araştırmada, mevsimlik gezici tarım işçilerinin demografik yapılarının incelenerek, tarımda çalışmak üzere geldikleri yerde, barınma, temizlik koşulları, sağlık, beslenme, enerjiye erişim ile bilgi ve teknolojiye erişim boyutlarındaki yoksunluklarının belirlenmesi amaçlanmıştır.

2. Materyal ve Yöntem

2.1. Materyal

Bu çalışmanın ana materyalini Ankara ili Bala İlçesine gelen mevsimlik gezici tarım işçilerinden anket soru formlarının doldurulması ve gözlem yoluyla elde edilen veriler oluşturmaktadır. Bunun yanı sıra, konu ile ilgili daha önce yapılan çalışmalar, TÜİK (Türkiye İstatistik Kurumu) verileri, raporlar, tezler ise ikincil materyali oluşturmuştur.

2.2. Yöntem

Saha çalışmanın örneklemi için bir olasılıksız örnekleme yöntemi olan kartopu örnekleme yöntemi kullanılmıştır. Bu çalışmada, kartopu örnekleme yönteminin kullanılmasının sebebi halen Ankara iline giriş yapan ve uzun süre kalan gezici tarım işçilerinin sayısı ve yerleriyle ilgili resmi kaydın olmayışıdır. Kartopu örneklemesinde, bir temas noktasıyla başlayıp, onun tavsiyesiyle ikinci bir temas noktasına geçilip öngördüğümüz anket sayısına erişene kadar anket sürdürülür (Erdoğan, 2021).

Görüşmelerin planlandığı dönem olan Ağustos-Eylül aylarında, tarımsal faaliyette bulunmak üzere Bala ilçesinde bulunan mevsimlik gezici tarım işçilerinin yerleşkelerine ulaşmak için, Bala İlçe Tarım ve Orman Müdürlüğü ilk iletişim noktası olmak üzere, ilk yerleşim yerine ulaşılmıştır. İlgili yerin muhtarı ve mevsimlik tarım işçisi aracılarından alınan bilgilerle, bir sonraki ulaşılacak yerleşkeler belirlenmiştir. Bu çalışmada, en az bir çocuğu olan haneler kapsama alınmıştır. Araştırma kapsamına girdiği belirlenen, Ankara ili Bala ilçesinde mevsimlik gezici tarım işçiliği yapan 80 haneye ulaşılmış, her haneden, mevsimlik tarım işçiliği yapmak üzere Bala ilçesine gelmiş hanehalkı fertleri ile ilgili bilgi verebilecek yetişkin bir hanehalkı ferdinden bilgi alınmıştır. Çalışmada kullanılan hanehalkı tanımı, aralarında akrabalık bağı bulunsun veya bulunmasın, aynı konutta ya da aynı konutun bir bölümünde yaşayan gelir ve giderlerini ayırmayan, hanehalkı hizmet ve yönetimine katılan bir veya birkaç bireyin oluşturduğu topluluktur (TÜİK, 2016). Hane temelinde alınan ve listelenen yanıtlar; ele alınan, barınma, temizlik koşulları, sağlık, beslenme, enerjiye erişim ile bilgi ve teknolojiye erişim boyutları itibarıyla, gezici tarım işçilerin durumunu ve yaşadıkları yoksunlukları ortaya koymak amacıyla analiz edilmiştir.

Diğer yandan, hanehalkı fertlerine ilişkin alınan demografik ve öğrenim durum bilgileri, hanelerin ve fertlerin profilini ortaya koymak üzere analize tabi tutulmuştur. Fertlerin demografik özellikleri incelenirken, araştırma kapsamındaki hanehalkı fertlerinin toplam yaş bağımlılık oranı da değerlendirilmiştir. Toplam yaş bağımlılık oranı nüfusun yaş yapısının bir ölçüsüdür. Bu oran, günlük yaşamları için başkalarının desteğine "bağımlı" olması muhtemel bireylerin (gençler ve yaşlıların) sayısı ile bu desteği sağlayabilen bireylerin sayısı arasında ilişki kurar (Anonim, 2024).

3. Araştırma Bulguları

3.1. Hanehalkı yapısı

Araştırma kapsamında, görüşülen hanelerin Bala ilçesine gelmiş hanehalkı fertleri listelenmiş ve demografik bilgileri alınmıştır. Bu bilgilere göre, araştırma kapsamındaki hanelerin ortalama büyüklüğü (hanehalkı fert sayısı) 6.4'tür. Ortalama hanehalkı büyüklüğü Türkiye için 2023 yılında 3.1 olup, iller düzeyinde de en yüksek ortalama hanehalkı büyüklüğünün olduğu iller sırasıyla Şırnak (4.9), Şanlıurfa (4.7) ve Batman (4.6) olmuştur (TÜİK, 2024a). Buna göre, mevsimlik gezici tarım işçisi olarak gelen hanehalklarının ortalama büyüklüğü, Türkiye genelinden ve de Güneydoğu Bölgesi illerinden de yüksektir. Araştırma kapsamındaki hanelerin %60'ı 5-9 hanehalkı ferdi büyüklük grubundadır.

Hanehalkının sosyo-ekonomik durumu ve hanede yaşayan tüm fertlerin kişisel özellikleri hakkında, en doğru bilgiye sahip, hanenin yönetiminden ve geçiminden sorumlu yetişkin hanehalkı üyesine, hanehalkı sorumlusu denmektedir. Diğer bir deyişle; hanehalkının yönetiminde söz sahibi olan, hanehalkının hukuki, sosyal ve ekonomik planlama ve karar sürecinde en etkin rol oynayan, genellikle 18 ve daha yukarı yaştaki hanehalkı ferdi, hanehalkı sorumlusu olarak değerlendirilmektedir (TÜİK, 2024b). Hanehalkı sorumlularına bakıldığında da hanehalkı sorumlularının %82.5'inin erkek olduğu gözlenmiştir (*Tablo 1*).

Tablo 1. Araştırma kapsamındaki hanelerin yapısı

Table 1. Structure of households surveyed

Özellik	Nitelik	Sayı	%
Hanehalkı büyüklüğü (fert sayısı)	<5	22	27.5
	5-9	48	60.0
	>=10	10	12.5
Hanehalkı sorumlusunun cinsiyeti	Erkek	66	82.5
	Kadın	14	17.5
Toplam		80	100.0

Araştırma kapsamındaki toplam 514 hanehalkı ferdinin %52.7'sini kadınlar oluşturmaktadır. En kalabalık yaş grubu olan 12-17 yaş grubundaki fertler toplamın %31.1'ini oluşturmaktadır (*Şekil 1*).

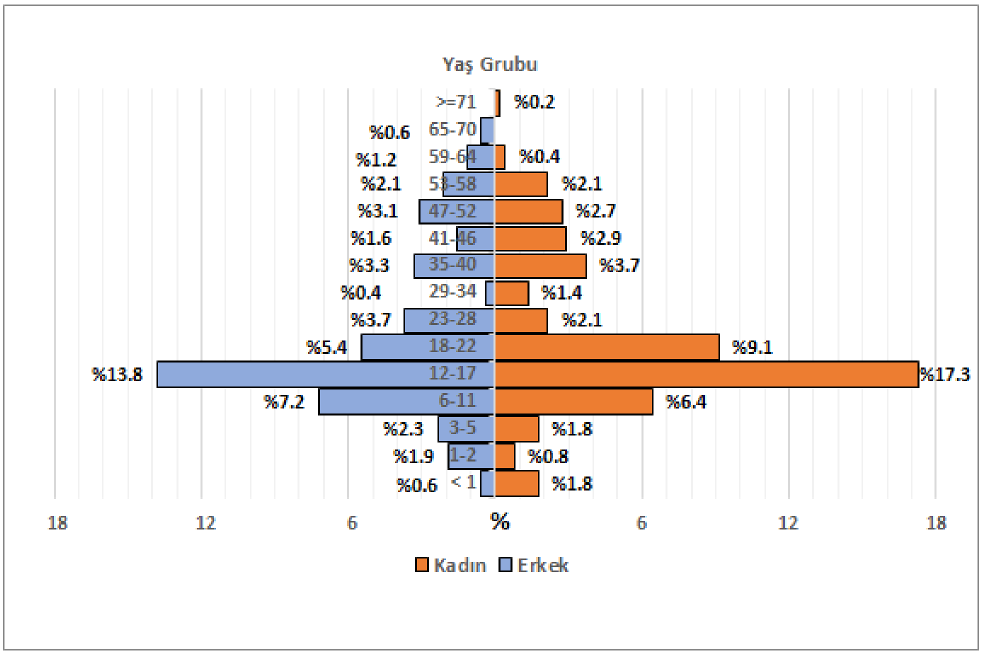

Figure 1. Distribution of household members surveyed by age group and sex (%)

Şekil 1. Araştırma kapsamındaki hanehalkı fertlerinin yaş grubu ve cinsiyete göre dağılımı (%)

Hanehalkı fertlerinin ortanca yaşı 17 iken erkek fertlerin 18, kadın fertlerin ise 19'tur. Diğer yandan, 2023 yılı itibarıyla Türkiye'de ortanca yaş 34'e, erkeklerde 33.2'ye ve kadınlarda ise 34.7'ye yükselmiştir (TÜİK, 2024a). Buna göre, nüfusun geneline bakıldığında, Türkiye nüfusunun çok genç kısmı mevsimlik gezici tarım işçisi olarak alanda bulunmaktadır.

Araştırma kapsamındaki, fertlerin %62.1'i çalışma çağındaki nüfus olarak tanımlanan 15-64 yaş grubundadır (*Tablo 2*). Bunun yanında, çalışma çağındaki birey başına düşen çocuk ve yaşlı birey sayısını ifade eden toplam yaş bağımlılık oranı ise %61.1'dir. Diğer bir deyişle, araştırma kapsamındaki hanehalkı fertlerinin 15-64 yaş grubunda bulunan çalışma çağındaki her yüz bireyine karşılık 61 çocuk ya da yaşlı bulunmaktadır.

Tablo 2. Hanehalkı fertlerinin demografik yapısı

Table 2. Demographic structure of household members

Özellik	Nitelik	Sayı	%
Cinsiyet	Erkek	243	47.3
	Kadın	271	52.7
Yaş grubu	<15	191	37.1
	15-64	319	62.1
	>=65	4	0.8
Toplam		514	100.0

Toplam bağımlılık oranı, Türkiye için 2023 yılında %46.3 ve iller arasında en yüksek oran olarak da Şanlıurfa için %72.5'tir (TÜİK, 2024a). Buna göre, araştırma kapsamındaki hanelerde, iş gücüne katılımı beklenmeyen ve aynı zamanda haneye giren gelirden yararlananların oranı olan %61.1, Türkiye geneline göre oldukça yüksektir. Yüksek bağımlılık oranı, ekonomik olarak aktif nüfusun, çoğunlukla ekonomik olarak bağımlı olan çocukların ve yaşlıların ihtiyaç duyduğu sosyal hizmetleri destekleme ve sağlama konusunda, daha büyük bir yükle karşı karşıya olduğunu göstermektedir (UN, 2007).

3.2. Hanehalkı fertlerinin eğitim durumu

Hanehalkı fertlerinin geneline bakıldığında, %10.7'sinin okul çağında olmadığı ve % 0.4'ünün de özel gereksinimli çocuklar için oluşturulmuş özel eğitim programlarından yararlandığı öğrenilmiştir. 15 yaş ve üzeri hanehalkı fertlerine bakıldığında, %53.9'unun kadın olduğu görülmektedir.

Toplam fertlerin %62.8'ini oluşturan 15 yaş ve üzeri 323 hanehalkı ferdinin öğrenim düzeyine bakıldığında, %19.8'i okur-yazar değildir. %12.4'ü-nün de okur-yazar olmasına rağmen diploması yoktur ve %5.3'ü de ilkokula başlamış ancak terk etmiştir. 15 yaş ve üzerindeki bu fertlerin %62.5'i ise en az ilkokul mezunudur. Türkiye rakamlarına bakıldığında, 2023 yılında 15 yaş ve üzeri nüfusta okur-yazar olmayanların oranı %2.6 olarak hesaplanmaktadır. Bu oran, 15 yaş ve üzeri erkekler için %0.7 iken kadınlar için %4.4'tür (TÜİK, 2024c). Türkiye geneliyle kıyaslandığında, araştırma kapsamındaki 15 yaş ve üzeri bireylerin okur yazarlık oranı ciddi bir oranda Türkiye genelinden düşüktür.

Özellikle, okur-yazar olmayan 15 yaş ve üzeri hanehalkı fertlerinin %87.5'inin kadın olması dikkat çekerken, okur yazar olup da diploması olmayan fertlerin %32.5'i, ilkokulu terk etmişlerin %41.2'si ve ortaokulu terk etmişlerin %62'si kadındır (*Şekil 2*).

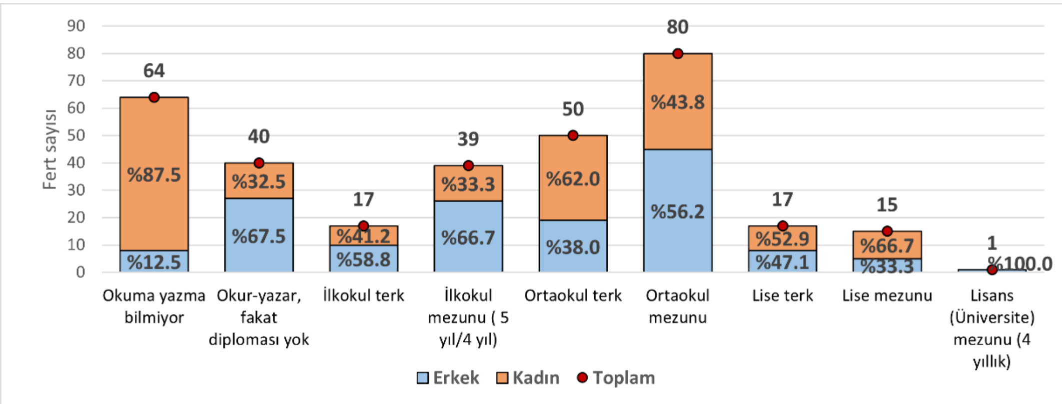

Figure 2. Distribution of surveyed household members aged 15 and over by education level and sex

Şekil 2. Araştırma kapsamındaki 15 yaş ve üzeri hanehalkı fertlerinin öğrenim düzeyi ve cinsiyete göre dağılımı

Türkiye'de 2023 yılında okur-yazar olmayan 15 yaş ve üzeri bireylerin %87.1'i kadındır (TÜİK, 2024c). Türkiye ve araştırma kapsamındaki bireyler için, okur-yazar olmayan toplam birey sayısı içindeki kadın oranları karşılaştırıldığında, Türkiye oranı ile araştırma kapsamında elde edilen oranın paralellik gösterdiği görülmektedir.

Diğer bir deyişle, okur-yazar olmayanların ağırlıklı kısmını kadınlar oluşturmaktadır.

3.3. Hanehalkı fertlerinin çalışma ve gelir durumu

Hanelerin %20'si yılda 5 ay ve daha kısa az süre mevsimlik gezici tarım işçiliği yaptığını belirtirken, %63.8'i 6 ila 7 ay, %15'i de 8 ila 10 ay, %1.2'si de tüm yıl mevsimlik tarım işçiliği yaptığını belirtmiştir. Nisan-Kasım ayları en fazla mevsimlik tarım işçiliğinin yapıldığı aylar olmuştur (*Şekil 3*).

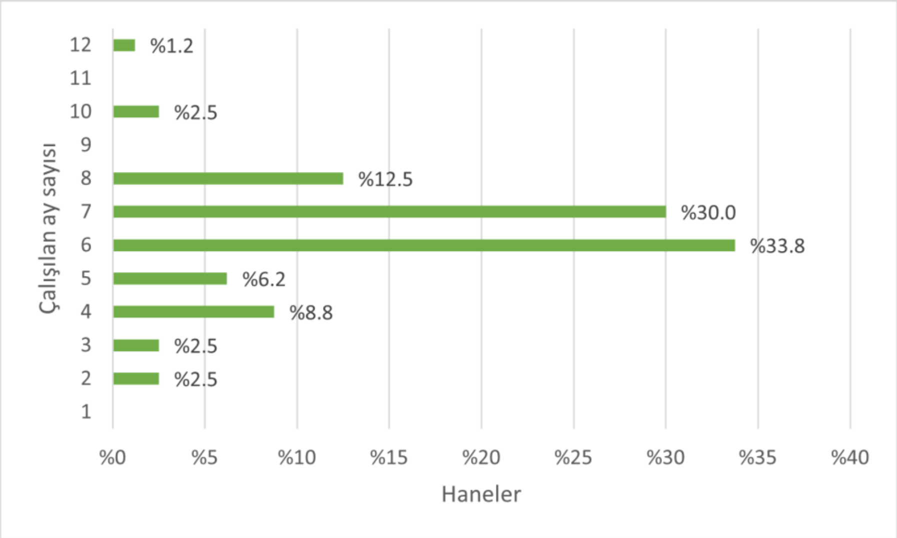

Figure 3. Distribution of households in the survey by number of months worked in a year

Şekil 3. Araştırma kapsamındaki hanelerin yıl içinde çalıştığı ay sayısına göre dağılımı

Görüşülen hanelerin, Bala ilçesinde, görüşme tarihi itibarıyla, yaptıkları işler kuru soğan, fasulye, domates, salatalık, biber, armut, elma, kavun toplama işleri ile file ve boru toplama işleridir. En fazla yapılan iş, hanelerin %51'inde kuru soğan hasadı işidir.

Ödeme şekli olarak, soğan hasadı dışında, diğer işlere günlük yevmiye verilirken, soğan hasadı için kabala denen çuval başı ödeme yöntemi kullanılmaktadır. Kabala yöntemi ile ödemesi yapılan soğan hasadı, bu ödeme şekli sebebiyle, yaz döneminde hava kararana kadar devam etmektedir. Bu ödeme şekli, ücret yönünden baskı yarattığından, işçilerin yıpratıcı şekilde, günlük olarak daha fazla çalışmasına sebep olmaktadır.

Araştırma için hanelerin ziyaret edildiği dönem, ülkede genel tüketici fiyatlarının artmaya devam ettiği dönemlerdendir. Daha önce, belirli bir yevmiye miktarı üzerinden çalışmaya başlamış gezici tarım işçilerinin, değişen ekonomik koşullar sebebiyle, tarım aracıları vasıtasıyla, işverenle tekrar ücret pazarlığı yaptıkları öğrenilmiştir. Bu şekilde, artan masraflarını karşılamak üzere, işverenlerden ücretlerinin yükseltilmesini talep etmişlerdir.

Masraflarını düşük tutmaya çalışan hanelerin, toplu erzak alımı yaptıkları, kendi ekmeklerini kendi ürettikleri gözlenmiştir. Yine masraflarını düşük tutmak üzere, ekmek pişirmek, yemek pişirmek, su ısıtmak için odun ateşi kullandıkları görülmüştür.

Gelir sağlamak için, zorlu çalışma ve yaşam koşullarına maruz kalan mevsimlik gezici tarım işçilerinin, bu güç koşullara ek olarak, harcanan emeğe karşılık sağladıkları gelir arasında yeterince denge sağlanamadığı görülmektedir. Birçoğu için, tüm yıl geçimlerini sağlamalarının tek yolu mevsimlik tarım işçiliğidir ve bu bireylerin tarımsal üretimde olmalarının sebebi, kendilerinin dile getirdiği şekilde, 'mecbur' olmalarıdır. Çalışma ortamında hakların ve kabul edilebilir geçim düzeyinin sağlanması, aynı zamanda çalışan ve aile bireyleri için sosyal koruma ile işverenle sosyal diyaloğun varlığı, insan onuruna yaraşır çalışma ortamını ifade eder (ILO, 1999). Bu tür çalışma ortamı, adil ücretin, işyeri güvenliğinin sağlandığı çalışma ortamlarıdır. İnsan Hakları Evrensel Beyannamesi'nde de ifade edildiği gibi 'Çalışan herkesin, kendisi ve ailesi için insan onuruna yaraşır bir yaşam sağlayacak düzeyde, adil ve elverişli ücretlendirilmeye hakkı vardır'. İnsana yakışır iş kavramının temel amacı; dünya genelinde kadın erkek tüm bireylere, özgürlük, eşitlik, güvenlik ve saygınlık koşullarında, insan onuruna uygun istihdam olanağının sağlanmasıdır. Ancak bu amaç, salt iş yaratmayı değil, bu işlerin kabul edilebilir işler olmasını sağlayan kapsamlı bir bakış açısına sahip olmalıdır (Işığıçok, 2005). Bu bağlamda, mevsimlik gezici tarım işçilerinin, insan onuruna yaraşır çalışma koşullarından yoksun olmalarının yanı sıra, çalışmaları süresince sigortalarının olmayışı da ayrı bir yoksunluğu gün yüzüne çıkarmaktadır.

3.4. Hanelerin barınma koşulları

Hanelerin %88'i çadırlarda barınmaktadır (*Tablo 3*). Bu çadırlar, demir ve tahta direkli çadır türleri olmak üzere değişkenlik gösteren ortalama 3x5 metre büyüklüğündeki plastik çadırlardır. Çadırlar, bölmesiz, tek kullanım alanına sahip barınma alanları şeklindedir. Bazı haneler, mutfak ve kiler olarak kullanılan ayrı bir çadıra sahiptir. Araştırma kapsamındaki coğrafi alanda bulunan tek konteyner yerleşkesinde, tek bir bütün konteyner olup, ayrı ayrı ailelere tahsis edilmiş 2-3 bireylik odalar bulunmaktadır.

Tablo 3. Hanelerin barınma durumları

Table 3. Housing conditions of households

Barınma türü	Barınan hane sayısı	Barınan ortalama birey sayısı	Barınan ortalama yetişkin sayısı
Çadır	70	6.9	3.2
Konteyner	10	3.0	1.7
Toplam	80	6.4	3.0

Kalınan yerleşim yerlerinde, soğuğa karşı alınan önlemlere ilişkin olarak hanelerin %28.1'i havanın soğuk olmadığını işaret ederken, %31.7'si yorgan ya da battaniye ile ısındığını, %19.5'i kalın giysi giyerek önlem aldığını belirtmiştir. Yanıtların %14.6'sı ise odun sobası ile ya da dışarıda yakılan ateş ile ısınıldığını belirtmiştir. Mevsimlik tarım işçiliği için gelinen Ankara ilinde, mevsimlik işçilerin genel olarak Mayıs-Ekim ayı arasında çalıştığı düşünüldüğünde, mevsimlik işçi olarak gelen haneler, kış aylarına göre daha az olsa da, soğuk havayla karşılaşma riskiyle karşı karşıyadır.

Bunun yanında, en önemli sorunlardan bir tanesi son yıllarda artmış bulunan, fırtına ve kısa süreli aşırı yağış yüzünden barınma yerlerinde yaşanmakta olan sorunlardır. Bunlar, çadırların şiddetli rüzgar etkisi ile yerinden ayrılarak uçması, aşırı yağış ile toprak zeminli çadır içlerine su basması şeklindedir. Çadır yaşamını zorlaştıran bu sert iklim koşulları ve sel basmasından dolayı hanelerin erzakları kullanılmayacak duruma gelmekte, yaşam alanlarında maddi kayıplar yaşanmaktadır. Rüzgâr, fırtına ve su baskınlarına karşı, kum torbası, hendek kazılması vb. önlemler alınmış olsa da, yapılan görüşmelerde, maddi kayıpların yanında, çadır alanlarında yaşanan aşırı rüzgar, fırtına ve yağmurun, hem yetişkinlerde ve hem de çocuklarda kaygıyı artırdığı, özellikle çocuklarda güvensizlik ile ciddi korku oluşturduğu öğrenilmiştir.

Sabit barınma olanakları ile kıyaslandığında, birey sayısına göre barınma alanının yetersizliği, bireye özel alan oluşturmadaki olanaksızlık göze çarpmaktadır. Türkiye'de ortalama hane büyüklüğü 6 ve üzeri olan hanelerin %48.3'ü 4 odalı evlerde otururken (TÜİK, 2022), araştırma kapsamında ortalama hane büyüklüğü 6.4 olan hanelerden çadır alanlarında kalanlar, bölme olmaksızın tek alana sahip çadırlarda barınmaktadırlar. Bunun yanı sıra, haneler, iklim koşullarına aşırı hassas barınma malzemelerinden yapılan çadırlarda barınarak, kısa süreliğine değil aylar boyunca barınma yoksunluğuna maruz kalmaktadırlar.

3.5. Hanelerin temizlik koşulları

Araştırma kapsamındaki hanelerin %57.5'inin içme suyu, tankerlerle sağlanmaktadır. Bunun başlıca sebeplerinden biri, mevsimlik gezici tarım işçilerine yerleşmeleri için gösterilen yerlerin, genelde içme suyu kaynağına sahip köylerden uzak olmasıdır. Hanelerin %17.5'i de kuyu suyunu içme suyu olarak kullanırken, köye yakın alanlarda bulunan araştırma kapsamındaki hanelerin yalnızca %7.5'i köylerden hortum ile içme suyu temin etmekte ve yalnızca %5'i doğrudan şebeke suyuna ulaşabilmektedir (*Tablo 4*). Tarımsal sulama kanalından elde edilen içme sularından ya da uygun koşulları sağlamayan kuyulardan elden edilen içme sularından dolayı, hanehalkı fertleri sıklıkla karın ağrısı, ishal gibi rahatsızlıklar yaşadıklarını belirtmiştir. Sudan kaynaklanan sindirim sistemi rahatsızlıkları, çocuklarda daha fazla gözlenmiştir.

Tablo 4. Hanelerin içme suyu temin durumu

Table 4. Water supply conditions of households

İçme suyunun temin edildiği kaynak	Hane sayısı
Yalnızca şebeke suyu	4
Yalnızca köy çeşmesi (hortum ile)	6
Yalnızca tanker	46
Yalnızca kuyu	14
Hem köy çeşmesi hem sulama kanalı	5
Hem tanker hem diğer kaynak	3
Diğer	2
Toplam	80

Konteynerde kalan 10 hanenin ortak kullandığı tuvalet ve banyoları kendi konteyner yapısı içindedir. Çadır alanlarında görüşme yapılan hanelerin yalnızca birinin tuvalet ve banyosu briketten yapılmıştır. Diğer tüm banyo ve tuvaletler plastik çadır şeklindedir.

Tüm tuvalet ve banyoların giderleri, çadır ya da konteyner fark etmeksizin, foseptik çukura bağlıdır. Bu konuda, uzun süre kalınmasına rağmen foseptik çukurlarının boşaltılmaması nedeniyle sinek, koku gibi sıkıntılarla karşılaşıldığı belirtilmiştir. Genel olarak, hanelerin %71.3'ü işte bu ilkel koşullardaki kendi özel tuvaletlerine sahiptir (*Tablo 5*).

Hanelerin %73.8'i kendi özel banyolarının olduğunu belirtmişlerdir (*Tablo 5*). Ancak, banyoların çadır şeklinde olması ve yıkanma suyunun taşınarak getirilmesi zorunluluğundan dolayı, ihtiyaç duyulan banyo konforu sağlanamamaktadır. Paylaşımlı banyolarda ya da paylaşımlı olmasa da hanehalkı büyüklüklerinin yüksek olmasından dolayı, banyo kullanımında sıra zorunluluğu doğmakta, geç saatlere kadar çalışmakta olan işçiler için de yaşam ortamlarında ayrı bir zorluk oluşmaktadır.

Tablo 5. Hanelerin banyo ve tuvalet durumları

Table 5. Bathroom and toilet conditions of households

Kullanım Durumları	Tuvalet kullanım durumuna göre hane sayısı	Banyo kullanım durumuna göre hane sayısı
Kendi özel kullanımında	57	59
Diğer ailelerle ortak kullanımda	23	21
Toplam	80	80

Türkiye genelinde, 2021 itibarıyla, ikamet ettiği konutunun içinde borulu su sistemi olan hanelerin oranı %99.4, tuvalet bulunan %96.6 ve banyo bulunan hanelerin oranı ise %98,8 olarak saptanmıştır (TÜİK, 2022). Bu oranlarla kıyaslandığında ve uzun dönemli olduğu düşünüldüğünde, sanitasyon olanaklarına erişim konusunda, mevsimlik gezici tarım işçilerinin deneyimlediği koşullar, ülke genelinde erişilebilen genel düzeyden oldukça uzaktır.

Suya ve temizlik olanaklarına ulaşırken her gün rutin olarak yaşanan zorluklar ve harcanan çabalar, uzun ve zorlu çalışma koşullarını kesintisiz deneyimleyen mevsimlik gezici tarım işçilerinin, sanitasyon konusundaki yoksunluklarını ortaya koyarken, özel alan sıkıntısını da ortaya çıkarmaktadır. Bu alanda yaşadıkları yoksunluk, fiziksel sağlık durumlarını etkilemenin yanında, konfordan uzak karşılanmak zorunda kalınan temizlik ihtiyacı, bireylerde kesintisiz çalışmanın sebep olduğu yorgunluğun yanı sıra, ilave yorgunluk ve bıkkınlığa yol açmaktadır.

3.6. Hanelerin enerjiye erişimi

Gezici mevsimlik tarım işçiliği yapan haneler, çalışıp yaşadıkları yerde, elektriğe erişim konusunda genel olarak zorluk yaşadıklarından bahsetmişlerdir. Hanelerin %67.5'i (54 hane) şebekeye bağlı olarak, elektriğe her zaman erişebildiklerini belirtmişlerdir. Ancak, hanelerin %13.8'i de yalnızca çok sınırlı miktarda elektrik sağlayan güneş enerjisi panelleriyle elektrik sağlayabilmektedir (*Tablo 6*). Şebekeye bağlı elektrik temin edilememesinden dolayı, kendi güneş panelleri ile elektrik üreten bu hanelerin ürettikleri elektrik ancak aydınlatma için yeterli olabilmektedir.

Tablo 6. Hanelerin elektriğe erişim durumu

Table 6. Accession of households to electricity

Elektrik erişim durumu	Erişim şekli			
	Şebeke	**Güneş enerjisi**	**Diğer**	**Toplam**
Her zaman var	54	2	-	56
Ancak belirli zamanlarda var	14	9	-	22
Elektrik yok	-	-	1	2
Toplam	68	11	1	80

Araştırma kapsamında, elektriğe erişimin sınırlı olmasından ötürü hanelerin az sayıda elektrikli alet kullanabildiği saptanmıştır. Buna göre hanelerin %35'inin mevsimlik tarım işçisi olarak gelip yaşadığı yerde kendi kullanımında olan herhangi bir elektrik aleti bulunmamakta, %33.8'inin de yalnızca bir elektrikli aleti bulunmaktadır. Aletler itibarıyla bakıldığında, 80 hanenin %38.8'inde buzdolabı, %35'inde çamaşır makinası ve %16.3'ünde ise elektrikli ocak bulunduğu görülmektedir.

Mevsimlik tarım işçisi hanelerinde, geldikleri yerlerdeki sosyo-kültürel yapının bir uzantısı olarak, ev işleri kadınlar ve genç kızların omuzlarındadır. Ekmek ve yemek yapımı yanında yürütülen bulaşık ve çamaşır yıkama işleri de genel olarak taşıma su ile elde, zor koşullarda yapılmaktadır. Hanelerin kullandıklarını belirttikleri çamaşır makinalarının çoğunluğu merdaneli tip çamaşır makinasıdır. Bu durumda, makine yıkaması mümkün gibi olsa da, makinalar için su sağlanması ve takibi zorunlu olduğundan, yine haneleri konfordan yoksun bırakmaktadır.

Yemek pişirmek ve banyo için su ısıtmak üzere, yakıt olarak odun ateşi kullanılmaktadır. Bala ilçesinde odun ve çalı çırpı toplanması, genel olarak mümkün olmadığından, ihtiyaç duyulan odun ve çalı çırpı, çoğunlukla daha önce gidilen yerlerden toplanarak getirilmekte ya da satın alınmaktadır. LPG ya da elektrikli ocak kullanımı, yağmurlu günlerde çok nadir kullanılan bir yemek pişirme aracıdır.

Yerleşim yerlerinde, erişimi neredeyse standart olan, elektrik gibi enerji kaynaklarına, mevsimlik tarım işçiliği yaparken ulaşılamaması ya da ulaşılan kaynakların konforlu bir günlük yaşam için yeterli olmamasından dolayı, mevsimlik gezici tarım işçileri bu konuda da yoksunluk yaşamaktadır. Görüşülen bireyler, bu çerçeveden de yaşadıkları yaşamı 'sürünme' olarak nitelendirerek, barınma ve enerji erişimi gibi elzem koşulların gereğince sağlanmamasının, yaşam koşullarını ne kadar olumsuz etkilediğini dile getirmektedirler.

3.7. Hanelerin bilgi ve teknolojiye erişim durumu

Hanelerin iletişim ve teknoloji ürünlerine erişimine bakıldığında, 80 hanenin yalnızca birinin herhangi bir iletişim ve teknoloji aracı olmadığı görülmektedir. En az 16 hanenin, tablet, akıllı telefon, televizyon ve tuşlu telefon gibi bilgi ve teknoloji araçlarından en az ikisine erişimi varken, 47 hanede yalnızca akıllı telefon bulunmaktadır (*Tablo 7*). Hanelerde bulunan toplam 75 akıllı telefonun, yetişkin erkek veya erkek çocuklar ile evli kadınlar tarafından kullanıldığı öğrenilmiştir. Büyük çoğunlukla, genç kızların evlenene kadar hatlı telefonu olmadığı, akıllı telefonu olan bekâr genç kızların da akıllı telefonlarını iletişim kurmak için değil, fotoğraf çekmek ve müzik dinlemek için kullandıkları belirtilmiştir.

Internet erişimi yalnızca akıllı telefonlarla mobil internet ile gerçekleşirken, 80 hanede var olan 75 akıllı telefonun yalnızca 59'unun mobil internete erişimi bulunmaktadır. Ancak, çoğu mobil hat sahibinin aboneliğinin ön ödemeli olmasından dolayı, mobil internet erişiminin aralıklı olarak sadece kontör alımı yapıldığında sağlanabildiği öğrenilmiştir.

Teknolojik iletişim araçlarına ve internete erişim, modern iletişim kanallarının kullanılabilmesi, bilgiye erişim ve eğitim kanallarına ulaşmayı desteklemesi sebebiyle elzemdir. Bilgi ve haber alma araçlarından olan televizyonun bile 80 hanenin yalnızca 2'sinde olması, yerine radyo gibi başka bir aracın da olmayışı, mevsimlik gezici tarım işçilerini haber alma olanağından yoksunlaştırmaktadır. Akıllı telefonlarla erişilen internetin ise oyun ve eğlence amaçlı sosyal medya için, genel olarak da erkek bireyler tarafından kullanılması, eşitsiz bir teknolojik iletişim araç kullanımı geleneği ile kadın bireyleri daha fazla iletişim yoksunu kılmaktadır. Türkiye geneline bakıldığında da, kadın ve erkekler arasında internet kullanım oranı kıyaslandığında, kadınların internet kullanım oranı (%85.4) erkeklerin internet kullanım oranından (%92.2) düşüktür (TÜİK, 2024d). Sahada yapılan gözlemler, ülke genelinde daha az belirgin olan kadınların aleyhine olan durumun, araştırma kapsamındaki bireyler açısından daha da keskinleştiğini göstermektedir.

Tablo 7. Hanelerin bilgi ve teknoloji araçlarına ve internete erişim durumu

Table 7. Accession of households to information&technological devices and to internet

Araçlar	Hanelerin kullanımındaki bilgi ve teknoloji cihazlarının sayısı	İnternet erişimi olan cihaz sayısı
Akıllı telefon	75	59
Tuşlu telefon	12	-
Tablet	5	-
Televizyon	4	-
Toplam	80	59

3.8. Hanelerin sağlık durumu

Mevsimlik tarım işçileri, sürekli beden gücüyle çalışmaları ve yaşam ortamlarında istenen koşulların sağlanamamasından dolayı, sağlık sorunlarıyla sıklıkla karşılaşmaktadır. Bunun yanında, kronik rahatsızlıkları olup da olanakları dahilinde mevsimlik tarım işçiliği için göç eden, çalışmaya devam edenlerin sayısı da azımsanamayacak kadar yüksektir. Araştırma kapsamında görüşülen 80 hanenin 47'sinde (%58.8) en az bir kronik hastalığı olan fert bulunduğu saptanmıştır. Aynı zamanda, son bir ay içinde 50 hanede (%62.5) en az bir bireyin bir rahatsızlık geçirdiğini belirtmişlerdir. Özellikle son bir ayda geçirilen hastalıklara bakıldığında, hastalık geçirildiğini belirten 50 hanenin 30'unda (%60) karın ağrısı, bulantı, kusma ve ishal gibi sindirim sistemi rahatsızlıkları görüldüğü belirtilmiştir. Bu rahatsızlıkların, içilen sudan kaynaklı olarak yaşandığı hanelerce belirtilmiştir. Rahatsızlık yaşayan 50 hanenin 13'ü (%26) çocukları rahatsızlık geçirirken doktora götürmemiş, bulundukları yerde bakım sağlamayı tercih etmiştir.

Mevsimlik gezici tarım işçilerinin yaşadıkları ortamlarda, hasta olma ve bulaşma riskini artıran sağlıksız koşulların bertaraf edilmesinde, etkin çabaların yoksunluğu gözlenmiştir. Sağlıklı yaşam koşullarından yoksun olma durumu, tekrarlayan rahatsızlıklara neden olmakta ve özellikle de çocuklar fiziksel rahatsızlıklar yaşamaktadır. Fiziksel rahatsızlıkların yanında, yapılan görüşmelerde hem yetişkinler hem de çocuklar tarafından sıkça bahsedilen bıkkınlıklar ve mutsuzluklar, zihinsel sağlık konusunda da bireylerin baskı altında olduklarını göstermektedir.

3.9. Hanelerin beslenme durumu

Gezici mevsimlik tarım işçisi hanelerin %64'ü (80 hanenin 51'i) yılda 6-7 ay mevsimlik tarım işçiliği yapmaktadır. Başlangıç olarak erzaklarını geldikleri memleketlerinden getirirken, uzun süreli kalışlarından dolayı gittikleri yerlerde erzaklarını temin etmektedirler. Genel olarak soğan hasadı için geldikleri Bala ilçesinde, bu işle uğraşan büyük çoğunluğun meyve ve sebzeye erişimi oldukça güç olmaktadır. Genel fiyat artışlarından dolayı temel gıda maddelerine erişmekte zorluk çeken bu kesim, özellikle ekmek üretimini kendisi yapmakta, bu işte tamamıyla toplulukta yaşayan kadınların sorumluluğunda olup, tarım işinin yanında ekmek üretimi de kadınlar için ayrı bir iş yükü olmaktadır. Protein ihtiyaçlarını karşılamakta genel olarak güçlük geçen haneler, bulundukları mevkide eğer mevcutsa, bütçeleri ölçüsünde mandıralardan süt ürünlerini karşılamaktadır. Aynı yerleşim yerinde kalan ve olanağı bulunan kısıtlı sayıda ailenin de keçi, koyun yetiştirerek kendi ihtiyaçlarını gidermek üzere hayvansal üretim yaptığı görülmektedir.

Hanelerdeki çocukların günlük beslenme durumlarına yönelik olarak, 80 hanenin 51'inde (%64) çocukların günde en az bir kez taze meyve ve sebze yiyemediği, 68'inin de (%85) günde en az bir kez et, tavuk veya balık içeren yemek yiyemediği öğrenilmiştir. Sebze ve meyve üretimi kısıtlı alanlarda çalışan mevsimlik gezici tarım işçilerinin, hasat ettikleri meyve ve sebzelerden faydalandığı, ancak bu kesimin sınırlı olduğu gözlenmiştir. Genel olarak, bazı yerleşim yerlerinde haftalık meyve sebze satışı için gelen seyyar satıcılardan, bütçeleri el verdikçe sebze ve meyve satın alımı yapıldığı, sebzenin meyveye göre daha sıklıkla tüketildiği görülmüştür. Görüşmelerde, temel gıda maddelerinin fiyatlarının artışının, alım güçlerini olumsuz etkilediği belirtilmiştir.

Uzun saatler ve yoğun olarak tarımsal üretimde bulunan mevsimlik gezici tarım işçileri, çalışmak için iyi beslenmeleri gerektiğini ve bu konuya önem verdiklerini belirtmişlerdir. Ancak, sebze ve meyve üretiminde bulunmayan işçilerin, sebze ve meyveye kısıtlı erişimlerinin yanında, çocuklar için önemli protein kaynağı olan süt ve yumurtanın, süt ürünleri için saklama koşullarının yoksunluğu ve artan gıda fiyatları ile bazen hiç erişilemediği eklenmiştir. Hanelerde kırmızı et, tavuk ve balık tüketimi ise ayrıca çok kısıtlıdır. Balık tüketimi neredeyse hiç görülmezken, et tüketimi ise işverenin ikramı ile ya da Kurban Bayramı döneminde gerçekleşebilmektedir. Bu açıdan, yeterince meyve ve sebze tüketim tüketilememesinin yanında, hanelerin protein yoksun bir beslenme şeklini izlemek zorunda kaldığı söylenebilir.

4. Sonuç ve Öneriler

Mevsimlik gezici tarım işçilerinin refahının ve daha iyi yaşam koşullarının sağlanması, çok yönlü yaklaşım gerektiren bir konudur. Mevsimlik gezici tarım işçileri, tarım sektöründe önemli bir rol oynamalarına rağmen sıklıkla barınma ve ona bağlı sorunlarla birlikte, zor yaşam ve çalışma koşullarının getirdiği sağlık sorunları ile karşı karşıya kalmaktadır.

Bu çalışmada, barınma, temizlik, sağlık, beslenme ile enerji, teknoloji ve bilgiye erişim açısından mevsimlik gezici tarım işçilerinin hanelerin yaşadığı yoksunluklar ortaya konulmayı çalışılmıştır. Bu haneleri, diğer yoksunluk yaşayan hanelerden ayıran en önemli özellik, eş zamanlı olarak çoklu boyutta bu yoksunlukları şiddetli şekilde yaşıyor olmalarıdır. Yalnızca barınma ya da yalnızca temizlik koşulları değil, insanların iyi olma halinin bileşeni olan tüm boyutlarda mevsimlik gezici tarım işçileri ciddi yoksunluklar yaşamaktadır. İnsan Hakları Beyannamesi'nde de belirtildiği şekilde herkesin kendisi ve ailesi için insan onuruna yaraşır bir yaşam sağlayacak düzeyde, adil ve elverişli ücretlendirilmeye hakkı vardır. Mevsimlik gezici tarım işçileri, insan onuruna yaraşır yaşam koşullarından yoksun olarak, ülkenin tarımsal üretimine katkıda bulunmaya çalışmaktadırlar. İnsanoğlunun varlığının sürdürülebilirliği için elzem olan tarım sektöründe üretim yapmaya devam eden bu bireyler, tarım sektörü çarkının en önemli bileşenlerinden biridir ve üretime katkıları eşsizdir. Bu sebeple, mevsimlik gezici tarım işçilerinin refahlarının sağlanması, onların her boyutta yoksunluklarının giderilmesi konusu en başta önceliklendirilmesi gereken konulardandır.

En son olarak, 27 Nisan 2024 tarihli Resmi Gazete'de yer alan 'Mevsimlik Tarım İşçileriyle ilgili 2024/5 Sayılı Cumhurbaşkanlığı Genelgesi' ile tarım işçisi olarak çalışmak için bulundukları illerden başka illere gidenlerin ve ailelerinin bu süreçte yaşadığı sorunların giderilmesine yönelik yapılacak çalışmaların usul ve esasları belirlenmiştir. Genelge ile Valilikler, eğitim ve sosyal ihtiyaçların karşılandığı, altyapısı sağlanan 'geçici yerleşim alanları'nın oluşturulmasından sorumludur.

Mevsimlik gezici tarım işçilerinin yaşam koşulları, kendilerine özgü ihtiyaçlarını karşılayan kapsamlı politikalar uygulayarak iyileştirebilir. Onlar için, güvenli ve sağlıklı yaşam koşulları sağlamak üzere, barınma standartlarının oluşturulmasının yanında, işçilerin maddi manevi çalışma haklarının korunduğu, işçilerin sömürü ve istismardan korunduğu, iş kanunu ve yönetmeliklerinin uygulanması önem teşkil etmektedir. Örneğin, ana olarak yoksunluğun hissedildiği barınma gibi boyutun yanı sıra mevsimlik gezici tarım işçilerinin haklarını korumak için çalışma yasalarının uygulanması yanında, adil ücretlerin, makul çalışma saatlerinin ve güvenli çalışma koşullarının sağlanması ile ilgili de çalışmalıdır. Daha önce yürütülmüş araştırma sonuçları ve sunulan öneriler de yürütülecek çalışmaların planlamasında dikkate alınmalıdır. Örneğin, bu öneriler arasında Sosyal Güvenlik. Kurumu (SGK) tarafından mevsimlik gezici tarım işçilerine özgü çalışan sigortası oluşturulması ve il düzeyinde koordinasyon sağlanarak mevsimlik gezici tarım işçilerinin yaşam koşullarını iyileştirmeye yönelik yeni kaynakların oluşturulması sayılabilir (Karaman ve ark., 2020).

Genel olarak, mevsimlik gezici tarım işçilerine yaşanabilir koşulların sağlanmasına yönelik, çoklu çabaların etkinliği, ancak oluşturulan politikaların uygulanması, kaynakların ve uygulama mekanizmaların etkinliği ile tüm çabaların ortak bir bileşeni olarak ortaya çıkmalıdır. Sorunun tek boyutlu şekilde çözülmesi olanaklı olmadığı gibi, ancak tarımsal üretimin sürekliliğinin temel taşı olan mevsimlik gezici tarım işçilerinin refahının sürdürülebilirliği ile, eşitlikçi ve sürdürülebilir bir tarım sektörü sağlanabilir.

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Makale yazarları olarak aramızda herhangi bir çıkar çatışması olmadığını beyan ederiz.

Yazarlık Katkı Beyanı

Planlama: Arslan Pauli, E., Gülçubuk, B.; Materyal ve Yöntem: Arslan Pauli, E., Gülçubuk, B.; Veri toplama ve İşleme: Arslan Pauli, E.; İstatistiki Analiz: Arslan Pauli, E.; Literatür Tarama: Arslan Pauli, E.; Makale Yazımı, İnceleme ve Düzenleme: Arslan Pauli, E., Gülçubuk, B.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of the Effects of Foliar Sulfur Applications on Yield, Evapotranspiration and Water Use Efficiency of Cotton (*Gossypium hirsutum* L.) Under Different Irrigation Regimes

Farklı Sulama Rejimleri Altında Yapraktan Kükürt Uygulamalarının Pamuğun (*Gossypium hirsutum* L.) Verim, Evapotranspirasyon ve Su Kullanım Randımanına Etkilerinin Değerlendirilmesi

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Abstract

In this study, it was aimed to determine the effects of foliar sulphur applications on cotton plants exposed to water stress. It was carried out on 'Carisma' variety cotton plant with 3 irrigation level, 3 sulfur doses and 3 replicates, except for control treatments, in split plots experimental design in randomized blocks. Sulfur in elemental form was applied at doses of 150 ml da^{-1} (S_1), 250 ml da^{-1} (S_2) and 350 ml da^{-1} (S_3), except for the control (S_0) and at I_{100}, I_{66}, I_{33} irrigation levels of the available capacity and in the non-irrigated treatment (I_0). Irrigation water amounts varied between 332-1006 mm and 306-928 mm in the 2015 and 2016, and evapotranspiration ranged between 299-1096 mm and 247- 995 mm, respectively. Evapotranspiration decreased slightly in the first year and increased in the second year as the sulphur doses increased. The highest yields were 5871 kg ha^{-1} ($I_{100}S_0$) and 6148.7 kg ha^{-1} ($I_{100}S_1$) in 2015 and 2016, respectively. In comparison to I_{100}, yield decreased by 70%, 39% and 14% in 2015, 67%, 33% and 8% in 2016 in I_0, I_{33} and I_{66}, respectively. Sulphur doses caused yield to decrease in 2015 and increase in 2016. Compared to S_0 treatment, yield increased by 14%, 1.9% and 8.6% at S_1, S_2 and S_3 in 2016. With the decrease in ET, yield (relative to I_{100}) decreased by 73%-70% at I_0, 52%-39% at I_{33} and 26%-15% at I_{66} in the first year, by 75%-67% at I_0, 44%-33% at I_{33} and 20%-8% at I_{66} in the second year, and by 74%-68% at I_0, 48%-36% at I_{33} and 23%-11% at I_{66}. Water use efficiency (WUE) was approximately the same in sulfur doses, while the lowest was determined at I_{100} and the highest was determined at I_0 and I_{33}. WUE increased as the amount of irrigation water increased in the second year, but did not show a stable change in the first year. The highest WUE was calculated in the first year on I_{33} (6.3 kg ha^{-1}mm^{-1}) and in the second year on I0 (7.5 kg ha^{-1}mm^{-1}). Sulphur doses did not cause a significant difference in WUE and the highest WUE was determined at S_0 (6.0 kg ha^{-1}mm^{-1}) in the first year and in the second year at S_1 (6.5 kg ha^{-1}mm^{-1}). Sulphur doses did not affect leaf sulphur concentration in the first year, but statistically in the second year. Mean of two years, the highest leaf sulphur concentration was measured in S_3.

Keywords: Drought tolerance, Foliar application, Sulfur, Irrigation level, Cotton

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Öz

Bu çalışmada, su stresine maruz bırakılmış pamuk bitkisine yapraktan kükürt uygulamalarının etkilerinin belirlenmesi amaçlanmıştır. Araştırma, Carisma çeşidi pamuk bitkisinde 3 sulama düzeyi, 3 kükürt dozunda 3 tekerrürlü olarak tesadüf bloklarında bölünmüş parseller deneme deseninde yürütülmüştür. Denemede, elverişli kapasitenin 3 farklı sulama düzeyinde (I_{100}, I_{66}, I_{33}) ve susuz konuda (I_0) pamuk bitkilerine tanık (S_0) konusu dışında 150 ml da^{-1} (S_1), 250 ml da^{-1} (S_2) ve 350 ml da^{-1} (S_3) dozlarında elementel formda kükürt uygulanmıştır. Sulama suyu miktarları 2015 ve 2016'da sırasıyla 332-1006 mm ile 306-928 mm, evapotranspirasyon 299-1096 mm ile 247- 995 mm arasında değişmiştir. Evapotranspirasyon (ET), kükürt dozları arttıkça ilk yıl azalmış, ikinci yılda ise artmıştır. En yüksek verim 2015 ve 2016'da sırasıyla 5871.3 kg ha^{-1} ($I_{100}S_0$) ve 6148.7 kg ha^{-1} ($I_{100}S_1$) ölçülmüştür. I_{100}'e göre verim 2015'de I_0, I_{33} ve I_{66} konularında sırasıyla %70, %39 ve %14, 2016'da %67, %33 ve %8 azalmıştır. Kükürt dozları verimin ilk yıl azalmasına ikinci yılda artmasına neden olmuştur. Verim 2016'da (S_0'a göre) S_1, S_2 ve S_3 dozlarında %14, %1.9 ve %8.6 artmıştır. ET'deki azalma ile verim (I_{100}'e göre) ilk yıl I_0'da %73 - %70, I33'te %52 - %39 ve I66'da %26 - %15, ikinci yılda ise I_0'da %75-67, I_{33}'te %44-%33 ve I66'da %20-%8 ve ortalama I0'da %74 - %68, I_{33}'te %48 - %36 ve I_{66}'da %23 - %11 azalmıştır. Su kullanım etkinliği (WUE), kükürt dozlarında yaklaşık aynı, sulama konularında en düşük I_{100}'de en yüksek I_0 ve I_{33}' de belirlenmiştir. İkinci yılda sulama suyu miktarı arttıkça WUE artmış ancak ilk yıl kararlı bir değişim göstermemiştir. En yüksek WUE ilk yıl I_{33} konusunda (6.3 kg ha^{-1}mm^{-1}) ikinci yıl I_0 konusunda (7.5 kg ha^{-1}mm^{-1}) hesaplanmıştır. Kükürt dozları WUE'nde önemli bir fark oluşturmamış ve en yüksek WUE ilk yıl S_0 konusunda (6.0 kg ha^{-1}mm^{-1}) ikinci yıl S_1 konusunda (6.5 kg ha^{-1}mm^{-1}) belirlenmiştir. Kükürt dozları yaprak kükürt konsantrasyonunu ilk yıl etkilemezken ikinci yılda istatistiksel olarak etkilemiştir. İki yılın ortalamasına göre en yüksek yaprak kükürt konsantrasyonu S_3 konusundan ölçülmüştür.

Anahtar Kelimeler: Kuraklık toleransı, Yapraktan uygulama, Kükürt, Sulama düzeyi, Pamuk

1. Introduction

Fertilizer management may reduce, increase, or have no effect on the drought tolerance of plants, depending on the level of water available. This management in drought conditions is complicated, and salinity problems are also observed in most arid areas. In studies conducted for the relationship between drought and plant nutrients, it was reported that nutrients could provide additional benefits to the plant apart from their usual functions (Ma et al., 2004; Garg et al., 2004; Hu et al., 2008; Ürkmez et al., 2024). Especially during short dry periods, fertilizer applications that will prevent physiological decline in the plant and ensure that it remains healthy can increase yield when the plant is under stress. However, the effectiveness of fertilizers on the plant may change in foliar and soil applications.

The application of foliar fertilization to alleviate physiological stress has enormous potential (Fernandez et al., 2013). This is due to the fact that as a plant transitions from vegetative to reproductive stages, the quantity of photosynthate generated by the leaves is preferentially relocated to the developing fruit and seed, while the amount reaching to the roots is substantially reduced.

Sulfur is one of the key elements that can be used to increase drought tolerance (Jie et al., 2008). Sulfur, which activates in 20 days in the soil applications and 8 hours in the foliar applications, plays a significant role in the realization of photosynthesis (Kacar and Katkat, 2007). It prevents the reduction of chlorophyll content and can increase the yield of crops by increasing the amount of chlorophyll under stress conditions (Lina et al., 2005). The decrease in leaf chlorophyll concentration in water and sulfur deficiency is more pronounced in active photosynthesizing (functional) leaves (Dietz, 1989). In this case, the amount of chlorophyll can be increased with the sulfur application, and the severity of abiotic stress can be alleviated (Jie et al., 2008). Sulfur also builds protein structure and plays a fundamental role in the chlorophyll structure (Duke and Reisenaue, 1986). The most typical symptoms of sulfur deficiency in plants are yellowing of young leaves due to a decline of protein and chlorophyll synthesis, decrease in hydraulic root permeability, stomatal openings, net photosynthesis, and chloroplast numbers, and decrease in leaf area (Marschner, 1995). It was determined that the chlorophyll content of wheat under drought stress increases with the sulfur application (Lina et al., 2005), and the chlorophyll content of functional leaves decreases in cases of sulfur deficiency (Jie et al., 2008). Researchers suggested that with the application of sulfur, stress is reduced, and productivity is increased. Ghaznavi and Abdolshahi (2011) reported that drought stress reduces yield by 39.37% in wheat, and with 100 kg ha^{-1} potassium sulfate application, the yield increases by 8% in full irrigation and 10% under drought stress. The increase in yield under stress depends on sulfur metabolism, sulfate transport, and sulfate assimilation in the leaves. Besides, sulfur deficiency causes a decrease in protein synthesis and the activities and efficiency of sulfur-containing amino acids in the structure of amino acids (Chan et al., 2013).

In this study, the effect of foliar sulfur applications was investigated to reduce the effect of stress on cotton plants exposed to water stress. This research also determined the effects of sulfur applications on evapotranspiration, water use efficiency, and leaf sulfur concentration as well as seed yield.

2. Materials and Methods

2.1. Study area

The research was conducted in the Amik Plain in the Eastern Mediterranean Region. The soils of the experiment area were determined as silty clay loam, and the irrigation water was determined as C_2S_1 (*Table 1*). According to long-year (1945 - 2006) climate data, the average temperature is 20°C. The climate data measured during the experiment are given in *Table 2*.

2.2. Experimental design

The research was carried out with foliar applications of 3 doses of elemental sulfur, 4 irrigation levels, and 3 replicates for each irrigation level, in split plot experimental design in randomized blocks. Since the primary purpose of the experiment was to determine the contribution of sulfur doses to drought tolerance, irrigation levels were the main experiments, and sulfur doses were the sub-experiments. Each irrigation plot was created from 4 plant rows. The plot lengths were determined as 15 m, and the replicate plot lengths were determined as 5 meters. Two meter rows of buffer plants were left between the plots, and 2 rows of buffer plants were left between the irrigation plots. The interrow spacing was arranged as 0.70 m and the intra-row spacing as 15 cm. Thus, approximately 100 plants were planted in each row. Carisma variety cotton with high adaptability and yield potential was used as the research material.

2.3. Irrigation treatments

The first irrigation was performed when 50% of the available water was consumed, and subsequent irrigations were performed to replenish the deficit soil moisture (approximately 6 days apart). The experiments were arranged as a no-irrigation treatment (I_0), a full irrigation treatment (I_{100}) in which deficit moisture was brought to field capacity, and 66% (I_{66}) and 33% (I_{33}) of the full irrigation treatment. Soil moisture content was measured weekly by gravimetric method in all experiments and replications and the required amount of irrigation water was calculated using Equation 1.

$$I = (d * A * P) / Ea \qquad \text{(Eq.1).}$$

I: Amount of irrigation water to be applied to full irrigation treatment (100%), d: The amount of irrigation water required (mm), A: Plot area (m^2), Ea: Water application efficiency, (0.95). P: Percentage of wetted area (%). Whether or not the targeted irrigation area was reached was checked after irrigation.

Table 1. Some soil characteristics of the experimental field

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	ECe	$CaCO_3$ (%)	N (%)	Org. Mat. (%)	FC (g g^{-1})	PWP (g g^{-1})	As
0-30	59.52	15.28	25.2	SiCL	7.55	1124	2.265	1.42	0.33	21.3	13.4	1.660
30-60	57.52	19.28	23.2	SiCL	7.62	560	0.680	1.65	0.34	24.1	14.2	1.676
60-90	53.52	17.28	29.2	SiCL	7.80	429	0.905	2.01	0.38	25.0	14.5	1.540
90-120	61.52	15.28	23.2	SiCL	7.65	400	0.300	2.12	0.37	25.2	14.7	1.489

FC: field capacity and PWP: permanent wilting point are given as the percentage of water by weight. As: bulk density (g cm^{-3}), ECe: Electrical conductivity of soil paste (µmhos cm^{-1}).

Table 2. Climate data of experimental years (2015 – 2016)

Years	Climate Parameters	May	June	July	August	September	Mean
2015	Temperature (°C)	21.92	24.59	27.35	28.95	27.60	26.09
	Precipitation (mm)	19.4	0.00	0.00	1.2	0.00	20.6
	Solar Rad. (wm^{-2})	278.88	295.92	294.20	261.63	199.99	266.108
	Soil Temp. (°C)	24.88	27.74	30.17	31.57	30.09	28.89
	Wind Speed (km $h^{-1)}$	5.59	8.20	8.39	6.40	4.17	6.55
2016	Temperature (°C)	21.26	26.41	28.39	28.46	25.13	25.93
	Precipitation (mm)	3.23	14	16	119.2	0.0	149.2
	Solar Rad. (wm^{-2})	256.36	305.12	311.56	279.32	234.00	277.27
	Soil Temp. (°C)	22.44	27.37	30.29	30.63	26.65	27.48
	Wind Speed (km $h^{-1)}$	5.31	6.19	7.59	6.60	4.06	5.95

2.4. Sulfur treatments

Sulfur was not detected in the soil of the area where the experiment was conducted as a result of the analysis of the turbidimetric barium method (Kowelenko et al., 2014). A large part of Turkey's soils is insufficient in terms of sulfur content. While the absorption time of sulfur by the plant in soil application is about 20 days, this period is only 8 hours in the foliar application (Kacar and Katkat, 2007). Therefore, since it is aimed that the plant recovers from the stress in a shorter time, sulfur applications are realized only as foliar applications. The sulfur doses applied in the experiment were determined in line with the recommendations of the academicians working on sulfur.

S_0: N, P, K soil application

S_1: N, P, K soil application + 150 ml da^{-1} foliar elemental sulfur application

S_2: N, P, K soil application + 250 ml da^{-1} foliar elemental sulfur application

S_3: N, P, K soil application + 350 ml da^{-1} foliar elemental sulfur application

Liquid elemental sulfur in a volume of 720 g sulfur l^{-1} was used in the experiment. The most sensitive period to water stress in cotton plants is the flowering period (Loka and Oosterhuis, 2012). Hence, sulfur applications were applied only during the square and flowering periods of the cotton plant (10% from square to 10% boll growth). In the cotton experiments carried out before in the experimental area, it was determined that 5 irrigations were made with the drip irrigation method during the square and flowering period (Akgöl, 2012). The amount of seasonal fertilizer required for the plant was applied by dividing it equally by the number of irrigations to be made during the square and flowering periods. Fertilization was done in the middle of the two irrigations (3 or 4 days after irrigation) in the early morning hours (6.00-6.30), when the wind did not affect the fertilizer distribution adversely. In order to prevent differences in the concentration of fertilizer applied to the same experiment on different dates, the amount of water consumed from the portable pulverizator was tested with a water-filled sprayer in another area of the same size before each application, and after determining the amount of reduced water, the calculated liquid sulfur amount was mixed into this volume, and the application was carried out. Since it was planned to realize approximately 4 irrigations during the flowering period, the application was made by dividing each sulfur dose into 4. In the application with the portable pulverizator, the same person fertilized so that there was no difference between the walking speeds of the practitioners.

Nitrogen (N), Phosphorus (P), and Potassium (K) fertilizers required by cotton are equal to all experiments and at the dose rate commonly used in the region: Before planting, 20 kg da^{-1} of 18-46-0 (DAP) fertilizer was applied, and after planting, 4 kg da^{-1} of nitrogen fertigation method was applied in each of the first 4 irrigations (Singh et al., 2021).

2.5. Leaf Sulfur Analysis

Leaf samples were collected at different plant growth stages (square, flowering initiation, full flowering, and boll formation periods) to determine the effects of the applications on the sulfur concentration in the leaves. In the sampling, 5 upper leaves, which were functional in 2 plants, were collected in each replicate. The collected samples were crushed with a mortar in the laboratory, and 2-3 milligram samples for each replicate were analyzed in the Truspec CHNS Analyzer device.

2.6. Harvest

Irrigation treatments (6 plant rows and 0.70 m interrows) were formed from 4.2 m wide and 5 m long replicate plots. The harvest was made from the remaining 14 m^2 replicate area after removing 1 m from the beginning and end of each row and 1 row from the right and left. Since each treatment has 3 replicates, the total harvest area is calculated as 42 m^2.

2.7. Evapotranspiration (ET)

From the beginning of the trial to the harvest date, changes in soil moisture were measured with the gravimetric method before each irrigation, and the weekly evapotranspiration was calculated according to the “Soil Water Budget” method (Equation 2).

$$ET = I + R + Cr - Dp - Rf \pm \Delta S \qquad \text{(Eq.2).}$$

In equation, ET: Evapotranspiration (mm); I: Amount of applied irrigation water (mm); R: Precipitation (mm); Cr: Capillary rise (mm); Dp: Deep percolation (mm) (Measured from 120 cm depths of full irrigation treatments approximately 24 hours after irrigations); Rf: Runoff flow (mm); ±ΔS: The moisture changes in the soil profile (mm 90 cm^{-1}). In the equation, precipitation (R) was determined from the pluviometer in the research area, and ΔS was determined by the gravimetric method. Since drip irrigation is used in the system, the runoff flow (Rf) was not calculated.

2.8. Water Use Efficiency

Water use efficiency (WUE) was calculated using evapotranspiration and yield values (Howell et al., 1984). (Equation 3).

$$WUE = Ya \,/\, ET \qquad \text{(Eq. 3).}$$

In the equation, WUE: Water use efficiency (kg ha^{-1} mm^{-1}), Ya: Cotton yield from treatments (kg ha^{-1}), ET: Evapotranspiration (mm)

2.9. Analysis and Evaluation of Data

All data measured during the experiment were evaluated by statistical method in accordance with the split-plot experimental design in randomized blocks and subjected to analysis of variance. The averages of the data obtained as a result of measurement and analysis were compared by Duncan Test (Bek and Efe, 1988).

3. Results and Discussion

3.1. Irrigation Water

Irrigation water amounts were at the same level on average in both years. In the first and second years, 91 - 149 mm, 423 - 456 mm, 755 - 771 mm, and 1097 - 1078 mm irrigation water (including precipitation) was applied to I_0, I_{33}, I_{66}, and I_{100} irrigation experiments, respectively (*Table 3*). Full irrigation treatment (I_{100}) received 1097 mm and 1078 mm irrigation water in the first and second year. The maximum irrigation water requirement was calculated during the flowering period in both years. In the first year, 591 mm of irrigation water was applied to the sulfur treatments, and 613 mm in the second year. In the previous studies carried out in the experimental area, the irrigation water requirement was determined as 483-602 mm in 6-7 irrigations in 2012 (Can, 2017), and at the level of 1135 mm in 10 irrigations in 2017 (Kazgöz Candemir and Ödemiş, 2018). This indicates that the amount and number of irrigation water applied to cotton increases over time in the Amik Plain. Although the soil, plant variety, and irrigation method are the same, it is thought that the most important factor in increasing the irrigation water requirement is the change in climate parameters. The Amik Plain is the second region in Turkey, with continuous wind throughout the year. The fact that the plain has a large area significantly increases the cumulative temperature and the amount of evaporation in the wind direction. This causes the irrigation water requirement to be higher than other plains. Studies conducted in other regions also suggest that factors such as seasonal temperature fluctuations, wind speed, and soil moisture differences in planting dates cause changes in irrigation water requirement and irrigation number (Yavuz, 1993; Çetin and Bilgel, 2002; Yazar et al., 2002; Ünlü et al., 2011).

Table 3. Mean values of irrigation water, yield, and WUE in irrigation level and sulfur doses*

Treat.	Amount of irrigation water (mm)		Evapotranspiration (mm)		Yield (kg ha^{-1})		WUE (kg ha^{-1}mm^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016
I_0	91	149	299	247	1630.4 d	1859.7 d	5.4	7.5
I_{33}	423	456	525	558	3308.4 c	3707.8 c	6.3	6.6
I_{66}	755	772	817	797	4652.8 b	5097.0 b	5.7	6.4
I_{100}	1097	1078	1096	996	5421.6 a	5555.2 a	4.9	5.6
S_0	591	614	702	628	4222.3 a	3815.6 c	6.0	6.1
S_1	591	614	685	677	3635.2 b	4369.2 a	5.3	6.5
S_2	591	614	683	651	3599.3 b	3889.8 bc	5.3	6.0
S_3	591	614	668	641	3556.5 b	4145.1 ab	5.3	6.5

Treat.	2015-2016 (mean)	2015-2016 (mean)	2015-2016 (mean)	2015-2016 (mean)
I_0	120	273	1745.1 d	6.4
I_{33}	439	542	3508.1 c	6.5
I_{66}	763	807	4874.9 b	6.0
I_{100}	1087	1046	5488.4 a	5.2
S_0	602	665 a	4019.0 a	6.0
S_1	602	681 a	4002.2 a	5.9
S_2	602	667 b	3744.5 c	5.6
S_3	602	655 c	3850.8 b	5.9

WUE: Water use efficiency, *The values for yield and evapotranspiration presented in the table were previously published by Ödemiş et al., 2022.

3.2. Evapotranspiration

The highest and lowest evapotranspiration (ET) were measured from the I_{100} and I_0 treatments in both years. Evapotranspiration in the first and second years was determined as 299 - 247 mm in I_0, 525 - 558 mm in I_{33}, 817 - 797 mm in I_{66}, 1096 - 996 mm in I1$_{00}$ (*Table 3*). Evapotranspiration decreased slightly as the sulfur dose increased in the first year but was higher in the second year (compared to S_0). In the second year, lower ET was realized in S_1 (150 ml da^{-1}) than other doses. On average, evapotranspiration at sulfur doses ranged from 681 mm (S_1) to 655 mm (S_3). It was determined that the amount of irrigation water was more effective on the difference in evapotranspiration between the treatments, while sulfur applications did not make a significant difference. Evapotranspiration decreased as the sulfur dose increased in the cotton plant exposed to the same sulfur doses and longer stress in the same area. Especially in the vegetative period, the K_2 dose (250 ml da^{-1}) of the treatments that was non-irrigated during the other growth periods decreased by 15.35% (Kazgöz Candemir and Ödemiş, 2018). The decline in soil moisture causes a decrease in leaf water content. In cotton leaves exposed to stress, wax content (Wullschleger and Oosterhuis, 1987) and leaf cuticle thickness increase (Oosterhuis et al., 1991), transpiration, and thus evapotranspiration may decrease. Therefore, when environmental pollutants are considered in plants exposed to water stress, foliar fertilization can partially reduce evapotranspiration.

3.3. Yield

The yield was affected negatively by sulfur doses and positively by irrigation levels in the first year, while positively affected by both sulfur doses and irrigation levels in the second year (*Table 4*). The most important factor affecting yield in cotton is water stress. The yield decreases depending on the severity and duration of the stress and the plant development period in which it occurs. The water stress experienced from the square initiation period to the period when the first flower appears causes a great decrease in yield (Krieg, 1997).

Table 4. Variance analysis table for cotton yield and leaf sulfur content

Years	Yield (kg ha^{-1})			Leaf sulfur content (%)	
	Source of Variation	df	F	df	F
2015*	Irrig. lev (I)	3	***	3	***
	Sulfur Dose(S)	3	***	3	ns
	I*S	9	ns	9	**
	Error	32		155	
2016	Irrig. lev (I)	3	***	3	***
	Sulfur Dose(S)	3	**	3	**
	I*S	9	ns	9	ns
	Error	32		167	
2015 -2016	Irrig. lev (I)	3	***	3	***
	Sulfur Dose(S)	3	**	3	***
	Year (Y)	1	***	7	***
	I*S	9	ns	9	***
	I*Y	3	ns	18	***
	S*Y	3	***	19	***
	I*S*Y	9	ns	48	***
	Error	64		323	

df: degrees of freedom, ns: non significant *Sulfur doses in the first year negatively affected the yield.

In the first year, the highest yield was obtained from $I_{100}S_0$ with 5871 kg ha^{-1}, and in the second year from $I_{100}S_1$ with 6148.7 kg ha^{-1}. The average yield value of both years was determined for the highest $I_{100}S_1$ treatment (5653 kg ha^{-1}). Average seed yields were higher in the second year (*Tablo 5*). The highest and lowest yields for sulfur treatments were determined for S_0 and S_3 (3557 kg ha^{-1} and 4222.3 kg ha^{-1}). The lowest yield S_0 (3816 kg ha^{-1}) and the highest yield S_1 (4369 kg ha^{-1}) were determined in the second year. Öztürk and Korkut (2018) reported that under fully drought stress condition grain yield of wheat decreasing was 40.1%, under shooting stage of drought 28.0%, and during grain filling period of drought 26.2%.

3.4. Water use efficiency (WUE)

WUE generally increased as the amount of irrigation water decreased. It decreased linearly as the irrigation water increased in the second year, while an unsteady change was found in the first year. The mean highest WUE was calculated for the first year in the I_{33} treatment (6.3 kg ha^{-1}mm^{-1}) and the I_0 treatment for the second year (7.5 kg ha^{-1}mm^{-1}) (*Table 3*).

Sulfur doses did not cause significant differences in mean WUE. WUE was determined at the same level (5.3 kg ha^{-1}mm^{-1}) in treatments other than S_0 in the first year. In the second year, the highest WUE was observed in S_2 and S_3 doses (6.5 kg ha^{-1}mm^{-1}). The average WUE values of both years were at approximately the same level.

Table 5. Values in the experimental years of evapotranspiration, yield, and water use efficiency

Treat.	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
		ET			Yield			WUE	
I_0S_0	305.88	205.86	255.87	2060.0	1824.3	1942.2	6.7	8.9	7.6
I_0S_1	304.73	276.08	290.40	1530.8	1902.3	1716.6	5.0	6.9	5.9
I_0S_2	292.73	235.70	264.21	1309.5	1743.0	1526.3	4.5	7.4	5.8
I_0S_3	294.10	271.25	282.67	1621.4	1969.0	1795.2	5.5	7.3	6.4
$I_{33}S_0$	530.73	535.68	533.20	3752.6	3336.0	3544.3	7.1	6.2	6.6
$I_{33}S_1$	524.73	575.96	550.34	3262.2	3930.0	3596.1	6.2	6.8	6.5
$I_{33}S_2$	523.73	572.05	547.89	3097.8	3682.7	3390.2	5.9	6.4	6.2
$I_{33}S_3$	521.73	549.26	535.50	3121.1	3882.3	3501.7	6.0	7.1	6.5
$I_{66}S_0$	836.96	763.02	799.99	5205.3	5180.3	5192.8	6.2	6.8	6.5
$I_{66}S_1$	825.54	835.80	830.67	4591.1	5495.7	5043.4	5.6	6.6	6.1
$I_{66}S_2$	815.42	800.47	807.95	4499.2	4800.7	4649.9	5.5	6.0	5.8
$I_{66}S_3$	790.96	787.02	788.99	4315.5	4911.3	4613.4	5.5	6.2	5.8
$I_{100}S_0$	1133.73	1006.8	1070.2	5871.3	4921.7	5396.5	5.2	4.9	5.0
$I_{100}S_1$	1086.60	1021.5	1054.2	5156.6	6148.7	5652.6	4.7	6.0	5.4
$I_{100}S_2$	1099.35	995.40	1047.4	5490.4	5332.7	5411.5	5.0	5.4	5.2
$I_{100}S_3$	1065.57	958.38	1011.9	5168.2	5817.7	5492.9	4.9	6.1	5.4

ET: Evapotranspiration (mm), Yield, kg ha^{-1}, WUE: Water Use Efficiency, kg ha^{-1} mm^{-1}

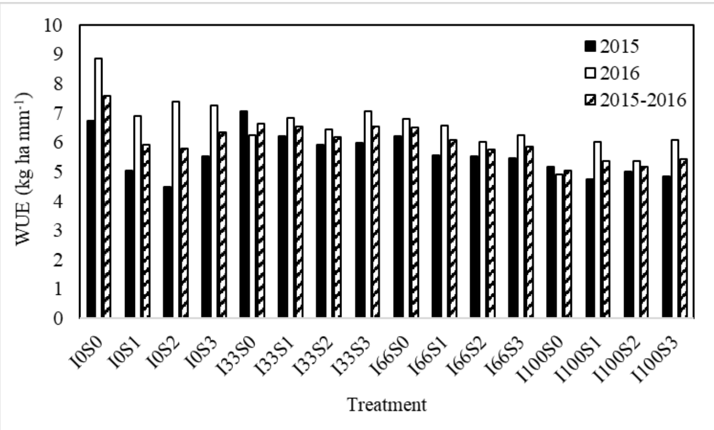

Figure 1. WUE values of irrigation and sulfur treatment

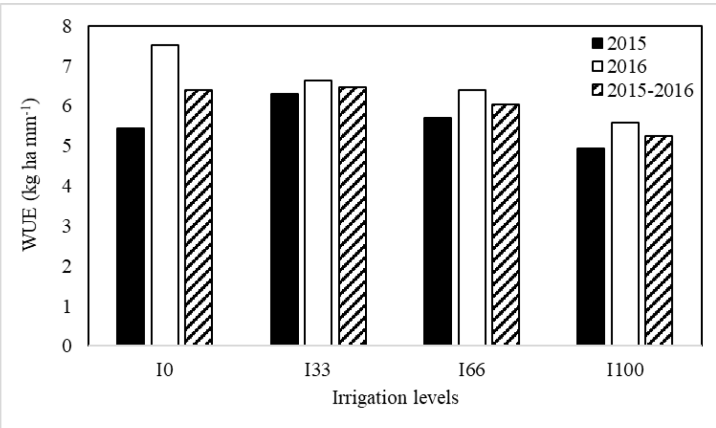

Figure 2. Mean values of WUE in irrigation treatment

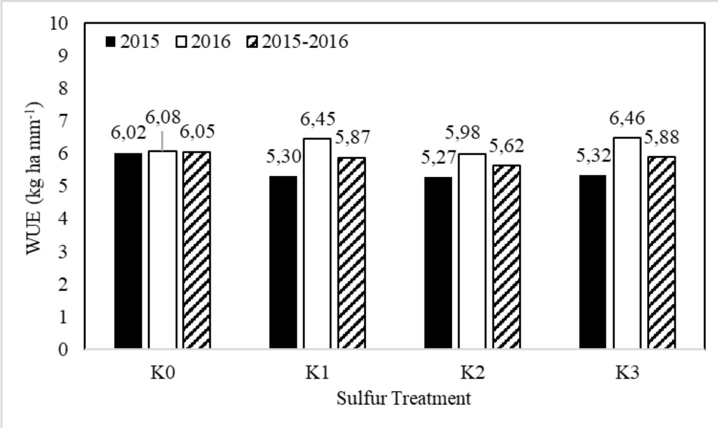

Figure 3. Mean values of WUE in sulfur doses

In the interactions of irrigation level x sulfur dose, the highest was determined for WUE $I_{33}S_0$ at 7.1 kg ha^{-1} mm^{-1} in the first year, and the lowest was determined for I_0S_2 (4.5 kg ha^{-1} mm^{-1}) (*Table 5*). WUE ranged from 8.9 kg ha^{-1} mm^{-1} (I_0S_0) to 4.9 kg ha^{-1} mm^{-1} ($I_{100}S_0$) in the second year. In the average values of both years, the highest and lowest WUE was calculated as 7.6 kg ha^{-1} mm^{-1} for I_0S_0 and 5.2 kg ha^{-1} mm^{-1}for $I_{100}S_2$.

Studies report that WUE varies depending on the plant variety, leaf shape, amount of water stored in the soil, climatic conditions, and plant development periods. Karam et al. (2006) determined WUE values as 1.3, 1.1, 1.0, and 0.80 kg ha^{-1} mm^{-1} in cotton during the first boll opening, boll formation, and the middle of the boll formation, and control. Hussein et al. (2011) determined the WUE value as 0.65 and 0.70 kg m^{-3} in the first year and as 0.65 and 0.72 kg m^{-3} in the second year in the full irrigation treatment and 80% of the full irrigation was applied, respectively. Zonta et al. (2017) calculated the WUE value between 0.39 and 0.84 kg m^{-3} in 8 cotton varieties. In studies conducted in Turkey, WUE was determined between 4.87 kg ha^{-1} mm^{-1} and 12.6 kg ha^{-1} mm^{-1} in different climatic regions (Çetin and Bilgel, 2002; Dağdelen et al., 2006). These results obtained in the literature were found to be in line with the results of current study.

3.5. Irrigation Water - Yield Relationships

As the amount of irrigation water increased in both years of the study, the seed yield also increased (*Figure 4*). Polynomial and significant regression relationships were found between irrigation water and yield in both years. The highest yield (I_{100}=5422 kg ha^{-1}) on average in the first year was obtained from the full irrigation treatment. Based on I_{100}, yield values decreased by 70%, 39%, and 14%, respectively, in I_0, I_{33}, and I_{66} treatments. It was determined that when the amount of irrigation water decreased by 31% in I_{66}, the yield decreased by 14%, and in I_{33}, when the irrigation water decreased by 61%, the yield decreased by 39%. In the second year, the yield decreased 67% in I_0, 33% in I_{33}, and 8% in I_{66}, compared to the full irrigation treatment (I_{100}= 5555 kg ha^{-1}), where the highest yield was obtained. Compared to I_{100} treatment, 28% (I_{66}) and 58% (I_{33}) reduction amounts in irrigation water caused an 8% and 33% decrease in yield.

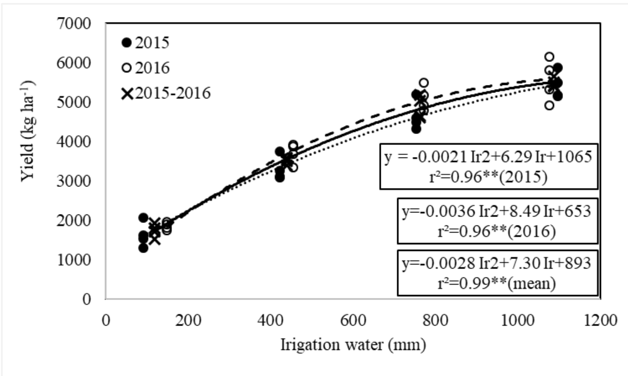

Figure 4. The relationships between the amount of irrigation water and yield

Vegetative and generative characteristics are significantly reduced in drought-exposed plants (Oguz et al., 2022). Before study indicates that irrigation has a decisive role in cotton yield. It was also reported that water stress, which occurs in conditions where irrigation is not done or not sufficient, disrupts the hormonal balance that is a key element in the shedding of square and bolls in cotton (Guin et al., 1990), irrigation increased the number of bolls per unit area by 30% and the fiber yield by 35%, but it did not change the boll seed weight (Pettigrew, 2004). Another study determined that the irrigation water requirement increased significantly in the Harran Plain, where the average temperature and vapor pressure deficit were high, and a cotton yield of 5850 kg ha^{-1} was obtained at 868 mm irrigation water requirement (Yazar et al., 2002). However, in Çukurova Plain, where the relative humidity and temperature are high, the yield was obtained between 1970-4220 kg ha^{-1} in the irrigation water requirement varying between 322 - 472 mm (Ertek and Kanber, 2003). Again, in the Harran Plain, the highest yield in irrigation applications made with row, sprinkler, and drip methods was obtained from the drip irrigation method, which is 30% higher than sprinkler irrigation and 21% higher than furrow irrigation (Çetin and Bilgel, 2002). The results of the water-yield relationship obtained in areas similar to the climate of the region where the research was conducted are in harmony with each other. However, in the area where this research was conducted, it was observed that the irrigation water requirement for cotton increased almost every year. While the irrigation water requirement was 589 mm in 6 irrigations in 2012 (Can, 2017), it increased to 1135 mm in 10 irrigations in 2017 (Kazgöz Candemir and Ödemiş, 2018). It is considered that the increase in the need for irrigation water is due to the increase in the amount of evaporation and transpiration due to the extraordinary increases in temperature and wind speed in the irrigation season in some years.

3.6. Evapotranspiration- Yield Relationships

A high correlation coefficient was obtained between evapotranspiration (ET) and yield (*Figure 5*). A 1 mm increase in ET led to an increase of 4.7 kg ha^{-1} in the first year and 5.1 kg ha^{-1} in the second year. The increase in sulfur doses did not cause a significant change in evapotranspiration. Compared to the I_{100} treatment, the yield reduction due to the decrease in ET was 73% - 70% in I_0 in the first year, 52% - 39% in I_{33}, and 26% - 15% in I_{66}. In the second year, compared to the I_{100} treatment, the reduction rate in ET decreased by 75%-67% in I_0, 44% - 33% in I_{33}, and 20% - 8% in I_{66}. The mean values of both years decreased by 74% - 68% in I_0, 48% - 36% in I_{33}, and 23% - 11% in I_{66}.

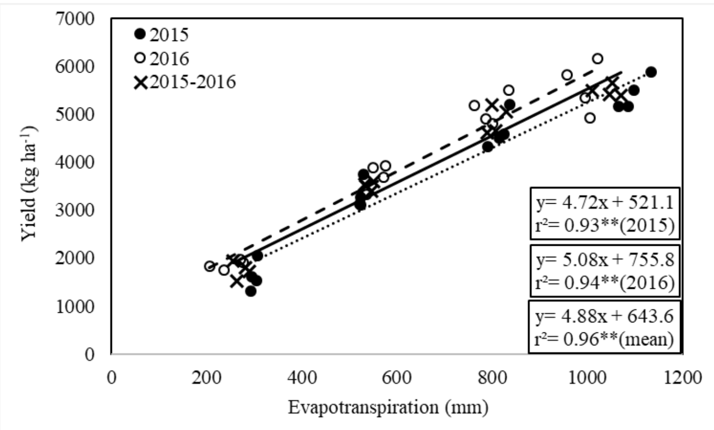

Figure 5. The relationships between evapotranspiration-yield

3.7. Sulfur Doses - Yield Relationships

The average highest yield in sulfur doses was obtained from the S_0 experiment (4222.3 kg ha^{-1}) in the first year and the S_1 treatment (4369.2 kg ha^{-1}) in the second year (*Table 5*).

It is thought that the air temperature was higher than expected in the first year of the experiment, and the desert dust that stormed in some periods partially prevented the foliar sulfur intake. This situation caused instability in the contribution of sulfur doses to yield.

The highest yield (except for I_0S_3) was obtained in the second year from the S_1 (150 ml da^{-1}) doses of irrigation treatments. The $I_{100}S_1$ treatment was the one with the highest yield (6148.7 kg ha^{-1}). Compared to the S_0 dose, the yield of the S_1 dose increased 18% in I_{33}, 6% in I_{66}, and 25% in I_{100}. The lowest average yield was obtained from a non-sulfur (S_0) treatment (3815.6 kg ha^{-1}). In the second year, the increase of the sulfur doses only up to the S_1 dose was evaluated as the result of the stress in the plant after a certain level of the sulfur dose. On the other hand, the S_1 dose caused higher efficiency than other doses in I_{33} and I_{66} treatments with deficit irrigation. Sulfur is an effective element in increasing the amount of yield (Jie et al., 2008; Lina et al., 2005). However, foliar and soil application cause differences in the assimilation time of sulfur. Kacar and Katkat (2007) expressed that sulfur can be used effectively in the plant in 20 days in the soil applications and 8 hours in the foliar applications. Xinhua et al. (2011) pointed out that the soil application of 22 and 34 kg of S ha^{-1} increased the yield by 8 - 10% on average compared to the control (non-sulfur) application, and it partially affected the fiber quality characteristics. On the other hand, Hu et al. (2008) found out that although there was a decrease in evapotranspiration, shoot fresh and dry weight, leaf fresh and dry weight in maize plant under drought and salinity stress; foliar fertilization did not improve plant growth and development under short-term drought or salt stress. It was also determined that the application of sulfur in the form of elemental S or sulfate compounds affects the usefulness, and elemental sulfur is less effective than sulfate-S fertilizer in increasing the seed yield of the canola plant. Elemental sulfur was generally found to be less effective than sulfate-S fertilizer, even after perennial applications, especially when applied in the spring (Malhi et al., 2005).

In the same period as this research, in another study conducted at the same doses and in adjacent parcels, the response of foliar application of elemental sulfur to long-term water stress was researched (Kazgöz Candemir and Ödemiş, 2018). In that study, full irrigation was applied to the cotton plant during the emergence period, and the development periods were divided into 3 (vegetative development period, flowering and boll growth period, and boll opening period). In some of these periods, full irrigation (T) was applied, and in some periods, non-irrigation (O) was applied. The study concluded that the effect of foliar application of sulfur on OOO, TTT, TOO, and TOT treatments was evident. The highest yield was determined for $TTTS_2$ (5600 kg ha^{-1}) treatment. These results show that many factors are instrumental in the effectiveness of sulfur on the plant. In addition to stress conditions, air quality also plays an important role in foliar fertilizer application. Besides the decreased transpiration due to stress, dust accumulated in the leaf surface layer prevents sulfur assimilation from the leaves.

The effect of the applied sulfur doses on the sulfur concentrations (Lsc) in the leaves differed depending on the years (*Table 4*). The foliar sulfur application did not affect the leaf sulfur concentration in the first year, but it was effective in the second year. Foliar sulfur concentration increased in the first year at I_0 and I_{33} irrigation levels depending on the sulfur doses, while it decreased at I_{66} irrigation levels. The increase in irrigation level in the second year caused a linear increase in leaf sulfur concentrations (*Table 6*). A similar case was observed in the average values of both years. The highest leaf sulfur content was measured from the treatments to which the S_3 dose was applied. Nutrients penetrate the leaf in two ways: passing through the stoma or outer cuticle. It is generally accepted that most of the nutrient uptake occurs through the cuticle (Fernandez et al., 2013), but solutions can also enter the leaf indirectly through the stoma (Fernandez and Eichert, 2009). The cuticle, in general, has a feature that limits the penetration rate of the nutrient element into the leaf (Fernandez et al., 2017). The surface tension properties of the element in the applied solution are important in stoma penetration. While the surface tension of surfactants in chemical sprays is about 30 Mn m^{-1}, organosilicon surfactants can reduce their aqueous surface tension to about 20 Mn m^{-1} and allow nutrient entry through stomata (Stevens et al., 1992). Ion uptake rates in foliar fertilization are higher at night when the stomata are closed than during the day when it is open (Oosterhuis, 2009). In cotton, nutrients dissolved in the foliar application are unlikely to penetrate directly into leaf tissue through open stomata. This is because cotton has prominent stomatal protrusions and an inner cuticular layer covering the stoma (Wullschleger and Oosterhuis, 1989). The cuticle layer here is considered a limiting factor for foliar penetration (Fernandez et al., 2017). In our study, since foliar applications were made in the morning hours, the penetration of sulfur into the leaf was possible via cuticle rather than stoma. The contraction of the cuticle caused by water stress and the atmospheric dust that limits the penetration made the penetration of sulfur through the cuticle layer almost impossible in the first year. Less exposure of the atmosphere to dust during the fertilization process in the second year may have partially facilitated the penetration of sulfur.

Table 6. Leaf Sulfur Content (%)

Treat.	2015	2016	Mean
I_0S_0	0.4406	0.7567	0.5987
I_0S_1	0.6387	0.7650	0.7018
I_0S_2	0.7148	0.7450	0.7299
I_0S_3	0.7254	0.7583	0.7419
$I_{33}S_0$	0.3766	0.7017	0.5391
$I_{33}S_1$	0.7391	0.9275	0.8333
$I_{33}S_2$	0.7421	0.7867	0.7644
$I_{33}S_3$	0.8531	0.8342	0.8436
$I_{66}S_0$	0.8124	0.7917	0.8020
$I_{66}S_1$	0.4206	1.0117	0.7161
$I_{66}S_2$	0.4082	0.8942	0.6512
$I_{66}S_3$	0.9018	0.9292	0.9155
$I_{100}S_0$	1.3364	0.9300	1.1332
$I_{100}S_1$	1.2469	1.0375	1.1422
$I_{100}S_2$	0.4703	1.0458	0.7580
$I_{100}S_3$	1.0764	0.9858	1.0311
S_0	0.7184 ab	0.7950 b	0.7567 b
S_1	0.7519 ab	0.9354 a	0.8437 a
S_2	0.5939 b	0.8679 ab	0.7309 b
S_3	0.8766 a	0.8769 a	0.8767 a
I_0	0.630 b	0.756 c	0.6930 c
I_{33}	0.678 b	0.813 c	0.7455 b
I_{66}	0.636 b	0.907 b	0.7715 b
I_{100}	1.033 a	1.000 a	1.0165 a

The relationship between leaf sulfur content and yield was significant in the second year and insignificant in the first year (*Figure 6*).

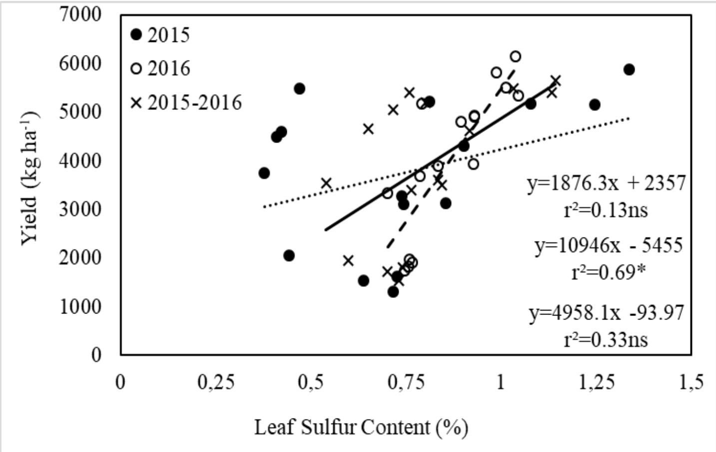

Figure 6. The relationships between yield and leaf sulfur content

4. Conclusions

The decrease in the amount of chlorophyll in drought stress causes a decrease in photosynthesis. Past research concluded that with sulfur applications, chlorophyll concentration could be increased, and the reduction of photosynthesis can be prevented. The inactivity of sulfur poses a disadvantage in soil application, and environmental conditions (atmospheric pollution, extreme temperature, and cultural practices) must be suitable for successful foliar application. To this end, the decrease in leaf moisture content due to the decrease in soil moisture content reduces the penetration area by disrupting the physical structure of the leaf cuticle (Kannan and Charnel, 1986) and may prevent the penetration of nutrients into the leaf (Oosterhuis et al., 1991). Therefore, in addition to the stressful conditions in the first year, it was thought that atmospheric dust caused stress by making it difficult to penetrate sulfur in the leaf surface layer. Besides, atmospheric dust and sulfur application caused layering on the leaf surface and decreased evapotranspiration and WUE. The absence of atmospheric pollutants (desert dust) seen in the first year during the growing period of cotton in the second year increased the penetration ability of sulfur. About 150 mg elemental sulfur application per decare increased the yield significantly. Especially at the I_{33} irrigation level, yield increased from 3340 kg ha^{-1} (S_0) to 3930 kg ha^{-1} (S_1) in the second year was evaluated as a significant increase, and it was determined that the mentioned dose could be used in the short-term drought stress condition.

Despite the necessity of S fertilization for optimum plant productivity (Chan et al., 2013), very few research was published on the use of S fertilizer in the last 10 years in cotton-growing climatic regions. The lack of information on the effects of sulfur deficiency on cotton yield elements shows a need for long-term studies in different climatic areas.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

The author declares that they have no conflict of interest.

Authorship Contribution Statement

Concept: Ödemiş, B.; Design: Ödemiş, B.; Data Collection or Processing: Ödemiş, B., Akgöl, B., Can, D.; Statistical Analyses: Ödemiş, B.; Literature Search: Ödemiş, B.; Writing, Review and Editing: Ödemiş, B.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Usability of 'Pink Pearl' 'Aiolos' and 'Blue Jacket' Hyacinth (*Hyacinthus orientalis* L.) varieties with Pre- and Postharvest Boric Acid Application as Cut Flowers*

Hasat Öncesi ve Sonrası Borik Asit Uygulanmış 'Pink Pearl' 'Aiolos' ve 'Blue Jacket' Sümbül (*Hyacinthus orientalis* L.) Çeşitlerinin Kesme Çiçek Olarak Kullanılabilirliği

Yağmur OLGAÇ[1], Rezzan KASIM[2*], Mehmet Ufuk KASIM[3]

Abstract

The study aimed to investigate the effect of boric acid (BA) treatments on availability of 'Pink Pearl' 'Aiolos' and 'Blue Jacket' hyacinth varieties as cut flower. For this purpose, 0, 50, 100 and 150 ppm boric acid doses were applied to hyacinths in pre- and post- harvest period. Boric acid (BA) was sprayed to leaves before harvest, while mixed into vase solution after harvest. The potted hyacinth plants were placed in a high plastic tunnel after stratification. The temperature in plastic tunnel kept at 18-20 ºC during the cultivation. Pre-harvest treatments were performed as spraying prepared BA solutions to the leaves when the leaves reached to full size. During the vegetation period, the qualitative and quantitative parameters such as total leaf number, spike stalk length, leaf color (L* and hue (h°)), leaf chlorophyll (SPAD) value, total floret number, leaf length, total plant length, and total blooming spike number were measured. After harvest, hyacinth plants were placed in vase solution and monitored for post-harvest strength under 12 hours light/12 hours dark photoperiod conditions. Water uptake, the spike stalk length, and the vase longevity of the spike were observed during the vase life period. The BA treatments did not show any significant effect on the vase life of the hyacinth spike. The 150-ppm BA, however, improved leaf quality by increasing leaf chlorophyll and hº values while decreasing L* values. In conclusion, it can be suggested that the 'Aiolos' cultivar has a potential as cut flower due to its longer plants and flower stems both in pre- and post-harvest period, as well as its longer vase life. Among the BA applications, it was concluded that the 100 ppm application is a viable option for increasing water uptake and reducing weight loss during the vase period.

Keywords: Hyacinth, Boric acid, Spike stalk length, Chlorophyll SPAD, Vase life

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*This study was summarized from the Yağmur Olgaç's MSc thesis.

Öz

Çalışmada borik asit (BA) uygulamalarının 'Pink Pearl' 'Aiolos' ve 'Blue Jacket' sümbül çeşitlerinin kesme çiçek olarak kullanılabilirliği üzerine etkilerinin incelenmesi amaçlanmıştır. Bu amaçla sümbüllere hasat öncesi ve sonrası dönemde olmak üzere 0, 50, 100 ve 150 ppm dozlarında borik asit uygulanmıştır. Borik asit hasat öncesi yapraklara püskürtme şeklinde uygulanırken hasat sonrasında vazo çözeltisine karıştırılarak uygulanmıştır. Soğuk katlama uygulamasının ardından sümbül bitkileri plastik tünele alınmıştır. Yetiştirme sırasında plastik tünelin sıcaklığı 18-20 °C arasında tutulmuştur. Hasat öncesi borik asit uygulamaları yapraklar tam büyüklüğünü aldığında püskürtme şeklinde yapılmıştır. Vejetasyon süresi boyunca, toplam yaprak sayısı, başak sapı uzunluğu, yaprak rengi (L* ve hue (h°)), klorofil (SPAD değeri), toplam kandil sayısı, yaprak uzunluğu, toplam bitki uzunluğu ve toplam çiçeklenen başak sayıları gibi kalitatif ve kantitatif parametreler ölçülmüştür. Hasattan sonra sümbül bitkileri vazo çözeltisine yerleştirilmiş, 12 saat aydınlık/12 saat karanlık foto periyot şartlarında hasat sonrası dayanımı açısından izlenmiştir. Bu süreç boyunca ise su alımı, başak sapı uzunluğu ve vazo ömrü gözlem ve ölçümleri yapılmıştır. Çalışma sonucunda BA uygulamalarının sümbül başaklarının vazo ömrü üzerinde önemli bir etkisi olmadığı tespit edilmiştir. Bununla birlikte 150-ppm BA uygulamasının klorofil (SPAD) ve h° renk değerlerini arttırmak ve L* değerlerini azaltmak suretiyle yaprak kalitesini arttırdığı saptanmıştır. Çalışmanın sonuçlarına göre, 'Aiolos' hem hasat öncesi hem de hasat sonrası dönemde daha uzun bitki ve çiçek saplarına sahip olması ve daha uzun vazo ömrü nedeniyle potansiyel bir kesme çiçek çeşidi olarak önerilebilir. BA uygulamaları arasında ise 100 ppm'in vazo ömrü süresince su alımını arttırması ve ağırlık kayıplarını azaltması bakımından kullanılabilecek bir uygulama olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Sümbül, Borik asit, Başak sapı uzunluğu, Klorofil SPAD, Vazo ömrü

1. Introduction

The hyacinth (*Hyacinthus orientalis* L.) is a bulbous biennial herbaceous plant, and originated Mediterranean Region (USDA, 2023). The hyacinth is a valuable flower that was highly adapted to the cut flower sector with its attractive flowers and pungent odor. The production area and production quantity of hyacinth are 37 da and 991000 pieces in Turkey, respectively (TÜİK, 2023). The hyacinth is used as an outdoor plant, and its availability as a cut flower is limited due to its short flower stalk and the fact that stalk starts to elongate after the flower buds are formed. Thus, elongating the flower stalk before opening the floret is crucial in using hyacinth as a cut flower.

Boron (B) is one of the critical micronutrients for the optimum development and quality in plants (Deliboran et al., 2020). B plays crucial role in cell division and elongation in young growing plant tissues (İkinci and Aldanmaz, 2022). Furthermore, boron participates in cell-wall synthesis and structural integrity in plants. B is taken from the soil in uncharged boric acid (BA) form (Shireen et al., 2018). Due to these important functions of boron in the plants, numerous studies have been performed recently to determine the effects of boron applications on plant growth, yield, and quality in the pre-harvest and post-harvest periods.

Preharvest spray treatment of BA on iris plant leaves improved floral properties and yield per plant (Khalifa et al., 2011). Similarly, BA has led to an increase in flower number, yield, and quality parameters of rose plants (Poornima et al., 2018). On the other hand, the BA treatment on cut carnation flowers retarded senescence as a result of slowing down in ethylene production. BA treatment also reduced weight loss, increased sugar concentration up to maximum level, increased water uptake, flower weight and flower diameter and prolonged vase life in cut carnation flowers (Serrano et al., 2001; Ahmadnia et al., 2013; Krishnamoorthy et al., 2017). Additionally, BA treatment in gladiolus was extended the vase life of cut spikes significantly, increased the spike diameter, and inhibited the proliferation of microorganisms in the vase solution, and was effective in maintaining spike quality (Jian-Bo et al., 2009). Similarly, the BA treatments extended the vase life (Liavali and Zarchini, 2012; Hashemabadi et al., 2014) and reduced bacterial count on the flower stalk tip on cut rose flowers (Hashemabadi et al., 2013).

To our knowledge no study has been conducted the effect of boric acid on plant development, cut flower quality and vase life of hyacinth. Therefore, the determination of the effect of BA treatments on plant development, elongation of spike stalk, vase life, and availability as a cut flower of three different hyacinth varieties were aimed in this research.

2. Materials and Methods

This research was conducted at a high plastic tunnel and postharvest physiology laboratory in Arslanbey Vocational School of Kocaeli University from September to March vegetation period of 2019-2020.

2.1. Plant material

Bulbs of hyacinth cultivars 'Pink Pearl', 'Aiolos', and 'Blue Jacket' were purchased from Asya Lale Construction Agriculture and Livestock Trade and Limited Company in Konya. The calibration of bulbs, in terms of width, was 14-15. The bulbs of hyacinths had a health certificate, and the conformity of bulbs has been confirmed in terms of ISO-9001 quality standards and TSE2547 flower bulb standards. The study focused on three hyacinth cultivars: ‘Aiolos,’ a white-flowered type growing up to 25 cm tall; ‘Blue Jacket,’ with purple flowers, reaching 15-20 cm in height; and ‘Pink Pearl,’ with pink flowers and grows in height up to 15-20 cm. All three varieties are planted in October, and they flower from March to May. They were chosen for their relatively short stature, vibrant colors and pleasant fragrance and their primary use in container and/or outdoor plantings. Total of 120 bulbs for each variety were used in the experiment. The bulbs were planted into production pots that were 17.5 cm wide and 25 cm tall as one bulb per pot. Pots were filled halfway with 2:1:1/4 peat (Klasmann Rec 1PN Potgrond P, 0-10 mm, pH: 6, fertilizer content: 1.5) garden soil: perlite mix, a bulb was then placed in each pot, and were topped off with the same mixture on October 24, 2019.

2.2. Cold scarification and production

Planted bulbs were placed in a cold storage room set at 9±1°C temperature and 90-95% relative humidity for cold scarification and kept for a period of seven weeks for 'Blue Jacket' and for a period of eight weeks for 'Pink Pearl' and 'Aiolos' varieties. After designated storage periods, the pots were placed in a high plastic tunnel at 18-20 ºC temperature.

2.3. BA treatments

Pre-harvest BA treatments were started fifteen weeks after planting when each plant has at least two well-developed leaves. BA was treated at doses of 50 ppm, 100 ppm, and 150 ppm per plant and a total of thirty plants were used in each treatment group, whereas the leaves of plants in the control group were sprayed with water. For postharvest treatments, BA was mixed into vase solution containing 2% sucrose. Five hyacinth spikes from each treatment group were placed in vases containing 50, 100, and 150 ppm BA separately. Spikes of control group were placed in vases containing water.

2.4. Pre-harvest observation and measurement

Total leaf number: Leaves were counted at three growth stages, when the first leaves are formed, at 50% flowering, and before spike harvest. *Spike stalk length* was measured from the soil surface to the base of the spike. *The leaf length:* The length of the longest leaf on the plant was measured. *Plant length was* determined as the distance between stem base and the tip of the spikes. *Leaf color* was measured using a colorimeter (Minolta, CR-400, Osaka, Japan), as L*, a* and b*. From the L*, a* and b* values hue angle color values were calculated using Equation (1) below:

$$h^{\circ} = 90 + tan^{-1}\, a*/_{b*} \quad (when\ a < 0\ and\ b > 0) \qquad \text{(Eq. 1)}$$

The light source of the colorimeter is a D65 lamp and has an 8 mm head. The calibration of the apparatus was done before measurement using a white calibration plate (L*=97.52; a*=-5.06; b*=3.57) (Mcguire, 1992; Radzevičius et al.; 2014, Kasım and Kasım, 2016). *Chlorophyll (SPAD value)* content of hyacinth was measured with SPAD 502 Plus (Konica Minotla, Inc., Osaka, Japan) in two leaves of per plant. *Total blooming floret number in spike* was determined by counting floret in spikes daily. *The blooming duration* was measured as the number of days from the opening of the first florets to the last florets in spikes.

2.5. Post-harvest measurement, observation, and analysis

In this section of the experiment, the 'Pink Pearl' variety was not evaluated because of the short spike stalk. *Vase life:* The day of the wilting of all the florets in spikes was accepted as completion of vase life. Hyacinths were weighed immediately after cutting and also during vase period at every other day.

The weight loss of hyacinth spikes (WL) was calculated by the following Equation (2):

$$WL\ (\%) = (initial\ weight - last\ weight)\ x\ 100/initial\ weight \qquad \text{(Eq. 2)}$$

Where; 'initial weight' denotes the weight measured right after harvest, and 'last weight' refers to the weight recorded during each analysis period.

Water uptake: During each analysis period, the vase solution was transferred to a measuring cylinder, and measured. Water uptake was calculated by subtracting the solution left in the cylinder from the initial volume.

Spike stalk length: Hyacinth plants were uprooted with their bulbs to prevent stem length shortening. After the hyacinths were transported to the laboratory, the bulb leaves at the base of the stem were removed. Spike stalk length was measured in centimeters using a ruler.

Chlorophyll (SPAD) content was measured from two points of each leaf per hyacinth plant during vase life, using SPAD 502 Plus (Soil-Plant Analysis Development, Konica Minolta, Inc. Osaka, Japan) which can measure the relative value of plant chlorophyll content.

2.6 Experimental design

The experiment was planned according to a Completely Randomized Experimental Design with a factorial arrangement of varieties and BA dosages with three replicates (ten plants per replication for pre-harvest and five plants per replication for post-harvest). The data were analyzed using statistic software SPSS 22.0 followed by Duncan's Multiple Range tests at $p<0.05$

3. Results and Discussion

3.1. Preharvest studies

Analysis showed that neither the main effects of BA dosages nor the interaction effects were significant regarding total leaf number, leaf length, spike stalk length, and plant length whereas the cultivar main effect was significant. Furthermore, it has been observed that in all dosages tested the BA treatments did not perform superior to the control treatments in the enhancement of plant growth (*Table 1*). 'Aiolos' (6.10) had the lowest leaf number whereas the leaf number of 'Pink Pearl' was the highest (7.42). The longest leaves were obtained from 'Aiolos' (20.66) followed by 'Blue Jacket (18.05 cm) and 'Pink Pearl' (14.47 cm). Similarly, the spike stalk length was the highest (23.92 cm) in 'Aiolos' compared to the other two cultivars. The highest plant length and spike stalk length was recorded in 'Aiolos' (27.85 and 21.39 cm, respectively).

No literature was found associated with the effect of BA treatments on the development of hyacinth. However, in respect to plant growth results apparently indicate that the dosages of boric acid used in this study do not necessarily have depressing effect on plant growth in hyacinth. Earlier works show that plant response to boron varies depending on species and genotypes (Vera-Maldonado et al., 2024). Poornima et al. (2018) found that BA applications increase the number of leaves in 'Mirabilis' cut rose, and Qureshi et al. (2015) reported similar results in carnation. However, researchers used different microelements such as iron and magnesium along with BA. In these studies, the combination of boric acid with micronutrients such as iron and magnesium increased plant height due to the synergistic effects of micronutrients. For example, iron is the main component of enzymes such as dehydrogenase, proteinase, and peptidase and thus stimulates the growth hormones and affects growth. It can be speculated that no fertilization other than boric acid was applied in the current study may be a reason why boric acid did not affect studied plant growth parameters.

Table 1. Variety and BA dosages main effects and their interactions for the total leaf number, leaf length, spike stalk length, and total plant length

	BA dosages	***Hyacinth varieties***			***BA dosages***
		Pink Pearl	***Aiolos***	***Blue Jacket***	***main effect***
Total leaf number	Control	7.25	6.02	6.30	**6.52**
	50 ppm	7.53	6.07	6.48	**6.69**
	100 ppm	7.61	6.13	6.49	**6.74**
	150 ppm	7.31	6.17	6.34	**6.60**
	Cultivar main effect	**7.42 A**	**6.10 C**	**6.40 B**	
Leaf length (cm)	Control	14.41	20.27	18.51	**17.73**
	50 ppm	14.64	20.34	17.72	**17.57**
	100 ppm	14.32	21.16	18.13	**17.87**
	150 ppm	14.53	20.88	17.73	**17.75**
	Cultivar main effect	**14.47 C**	**20.66 A**	**18.05 B**	
Spike stalk length (cm)	Control	10.89	20.46	19.03	**16.43**
	50 ppm	11.37	21.71	18.5	**16.90**
	100 ppm	11.03	21.97	18.36	**16.74**
	150 ppm	11.27	21.42	18.03	**16.56**
	Cultivar main effect	**11.14 C**	**21.39 A**	**18.48 B**	
Plant length (cm)	Control	16.41	26.78	24.83	**22.28**
	50 ppm	17.3	28.24	24.23	**22.88**
	100 ppm	16.61	28.15	24.23	**22.60**
	150 ppm	17.11	28.25	24.42	**22.88**
	Cultivar main effect	**16.86C**	**27.85 A**	**24.43 B**	
Significance^{z}	*Cultivar main effect ***, BA dosage main effect^{ns}, Cultivar x BA dosage^{ns}*				

^{z}Two way ANOVA; ns: not significant; *, **, ***: significant at p<0.05, 0.01 and 0.001, respectively. Values within the rows followed by the same letter are not significantly different; the numbers are averages of all replicates.

It was detected that the plant and spike stalk length and leaf length of the Aiolos variety is longer than those of the 'Blue Jacket' and 'Pink Pearl. Pasztor et al. (2020) investigated the effects of three different planting times, November 10, November 24, and December 1, on the flower height of different hyacinth varieties. They found that the stem heights of the varieties varied between 8 cm and 13.66 cm, as the 'Blue Jacket' variety being with longest flower height. In the present study, bulb planting was conducted on October 24, and the spike stalk lengths were measured as 21.39 cm and 18.48 cm for ‘Aiolos’ and ‘Blue Jacket’, respectively. The quality of hyacinth plants depends on a range of factors such as genotype, cultivation period, and growing conditions (temperature, light spectrum and intensity, etc.) (Śmigielska et al., 2014). In the conditions of experimental area of this study, the stem lengths of both varieties from bulbs planted in October were longer than those measured by Pasztor et al. (2020). Similarly, Nicu and Manda (2024) measured the stem height of the 'Blue Jacket' hyacinth variety planted in October as 24.16 cm. It is therefore likely that the planting time had an important effect on the characteristics presented here.

The highest L* value was measured in the 'Aiolos' variety as 45.31, followed by 'Blue Jacket' and 'Pink Pearl' as 44.52 and 42.65, respectively. Furthermore, BA treatments increased L values, 50 ppm was more effective compared to 150 ppm and control, 50 ppm, and 100 ppm were placed statistically in the same group (*Table 2*). The CIE L* a* b* color system defines colors using three axes: The L* value for lightness and a* and b* for chromaticity coordinates. On a color space diagram, L* is displayed vertically, ranging from 0 (black) to 100 (white) (Ly et al., 2020). A higher L value indicates increased brightness, while a lower value corresponds to dullness (Yao et al., 2023). In this study, hyacinth leaves treated with 50 ppm BA were brighter than those with 150 ppm BA which resulted in darker leaves. This finding was also supported by h° and chlorophyll SPAD measurements. Tantan et al. (2022) found that 300 ppm BA treatment led to the lightening of the leaf color. In contrast to this finding, the lowest BA level resulted in the lightening of the leaf color of the hyacinth, in the present study.

The main effect of the BA dosage on h° value was statistically significant. The h° values of leaves were increased with increasing BA levels (*Table 2*). Control treatment resulted in lower h° values (125.15) in comparison to BA treatments, and the highest values was from 150 ppm BA treatment (125.52). In the CIE L* a* b* color coordinate system, h represents the hue or color name. It is defined by the hue angle (h°) in degrees on a* b* plane, starting from the positive a* axis and progressing counterclockwise. Red corresponds to 0 (or 360°), yellow to 90°, green to 180°, and blue to 270° (Scalisi et al., 2022). An increase in h° value toward 180° indicates a shift toward green, while a decrease suggests a movement toward yellow. Thus, in this study, the increase in h° values with higher BA doses signifies that the leaf color is becoming greener or retained green color.

Table 2. Leaf L*and h° values, and chlorophyll (SPAD) content of hyacinth cultivars treated with different doses of BA.

	Treatments	*Hyacinth varieties* Pink Pearl	Aiolos	Blue Jacket	BA dosages main effect
L*	Control	42.76	45.31	44.6	**44.22 ab**
	50 ppm	42.52	45.80	44.73	**44.35 a**
	100 ppm	43.07	45.15	44.47	**44.23 ab**
	150 ppm	42.25	44.98	44.27	**43.83 b**
	Cultivar main effect	**42.65 C**	**45.31 A**	**44.52 B**	
h°	Control	126.79	123.76	124.88	**125.15 b**
	50 ppm	126.92	123.74	125.05	**125.24 ab**
	100 ppm	126.64	124.36	124.88	**125.29 ab**
	150 ppm	127.46	124.02	125.09	**125.52 a**
	Cultivar main effect	**126.95 A**	**123.97 B**	**124.98 B**	
Chlorophyll (SPAD)	Control	59.91	58.56	60.41	**59.63 b**
	50 ppm	60.78	58.13	60.06	**59.66 b**
	100 ppm	60.61	58.58	60.09	**59.76 ab**
	150 ppm	61.24	58.91	60.61	**60.23 a**
	Cultivar main effect	**60.64 A**	**58.54 B**	**60.29 A**	
Significance[z]	*Cultivar main effect***, BA dosage main effect***, Cultivar x BA dosage[ns]*				

[z]Two way ANOVA; ns: not significant; *, **, ***: significant at $p<0.05$, 0.01 and 0.001, respectively. Values within the rows and columns followed by the same letter are not significantly different; the numbers are averages of all replicates.

A chlorophyll meter, such as the SPAD-520 (Soil-Plant Analysis Development 502) is a common tool for assessment of total chlorophyll content. It measures the SPAD value, or greenness, which provides a rapid, convenient, and non-destructive evaluation of plant chlorophyll content and overall health. Higher SPAD values indicate better plant health and chlorophyll concentration, with measurements typically ranging from 24.0 to 70.6, depending on the plant type (Zhang et al., 2022). The main BA and the main cultivar effect were significant with regard to chlorophyll (SPAD) value (*Table 2*). For the BA dosages main effect, the chlorophyll (SPAD) value ranged from 59.63 to 60.23, consistent with the findings of Zhang et al. (2022). While control and 50 ppm BA treatments resulted in lowest chlorophyll (SPAD) content, 59.63 and 59.66, respectively, the highest chlorophyll (SPAD) content, 60.23, was obtained form 150 ppm BA treatment. This was also supported by the h°-value results. Although h° values showed no significant differences among BA applications, the notable increase with 150 ppm BA compared to the control, underscores its positive effect in maintaining both green color and chlorophyll content in the leaves. The significant reducing effect of 150 ppm BA on L values of leaves further confirmed these results.

It appears that the cultivars also had significant effect on chlorophyll (SPAD) content. For the cultivar main effect, the highest level of chlorophyll (SPAD) content, 60.64 and 60.29, were found in 'Pink Pearl' and 'Blue Jacket', respectively, while 'Aiolos' resulted in the lowest levels in all BA treatments. In fact, 150 ppm BA presented the highest chlorophyll (SPAD) content in all cultivars, although interaction effect was not significant.

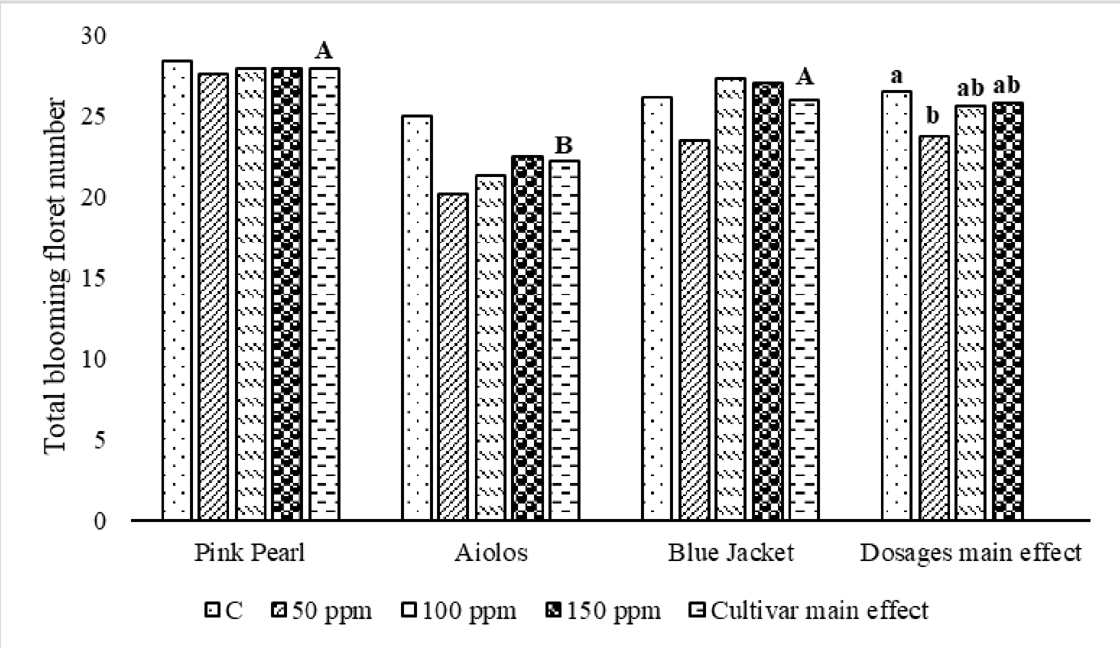

Figure 1. Total blooming floret number of spikes treated with different dosages of BA

Different lower case letters above bars indicate significant differences among the BA dosages and different capital letters indicate significant differences among cultivars (p<0.05).C: control

Main effects of dosages and cultivars were statistically significant for blooming floret numbers compared to the control. The 'Pink Pearl' (27.95 florets) and 'Blue Jacket' (25.99 florets) cultivars had more blooming florets than the 'Aiolos' cultivar (22.24 florets). In reference to the dosages main effect, all BA applications reduced the total number of blooming florets, the lowest number was found in 50 ppm BA treatment, the dosages ranking second consisted of, in descending order, 150 and 100 ppm BA (*Figure 1*). The 'Pink Pearl' cultivar produced higher total floret number due to its twin spike formation, but its shorter stem length (11.14 cm, *Table 1*) limited its suitability as a cut flower. Previous studies reported that BA applications increased flower numbers in iris (Khalifa et al., 2011) and rose (Poornima et al., 2018) plants. Qureshi et al. (2015) found that 5, 10, 15, and 20 ppm BA applications significantly increased flower numbers in carnations compared to controls. In contrast with these postulations, our results indicate that BA treatment led to a decrease in the number of florets in studied hyacinths varieties. It may be postulated that the efficiency of BA in promotion of number of florets, may depend on the plant species and dosages. However, for cut flower production, the fewer florets per spike can be beneficial as increased floret numbers can lead to heavier spikes that bend in vases, a common issue in the cut flower industry.

For instance, gerbera flowers experience this problem due to their large capitulum, prompting ongoing research to mitigate stem bending (Gerabeygi et al., 2021; Liu et al., 2021; Mohammadi et al., 2024).

The average flowering duration of the 'Pink Pearl' variety was significantly longer than those of the 'Aiolos' and 'Blue Jacket' varieties (*Figure 2*). This is due to its twin spike formation, with the second bloom extending the flowering period. In contrast, the 'Aiolos' and 'Blue Jacket' varieties fell, statistically, in same group in flowering time. BA applications did not affect the flowering duration of varieties. Similarly, Tantan et al. (2020) reported that flowering duration of gladiolus was not influenced by BA applications.

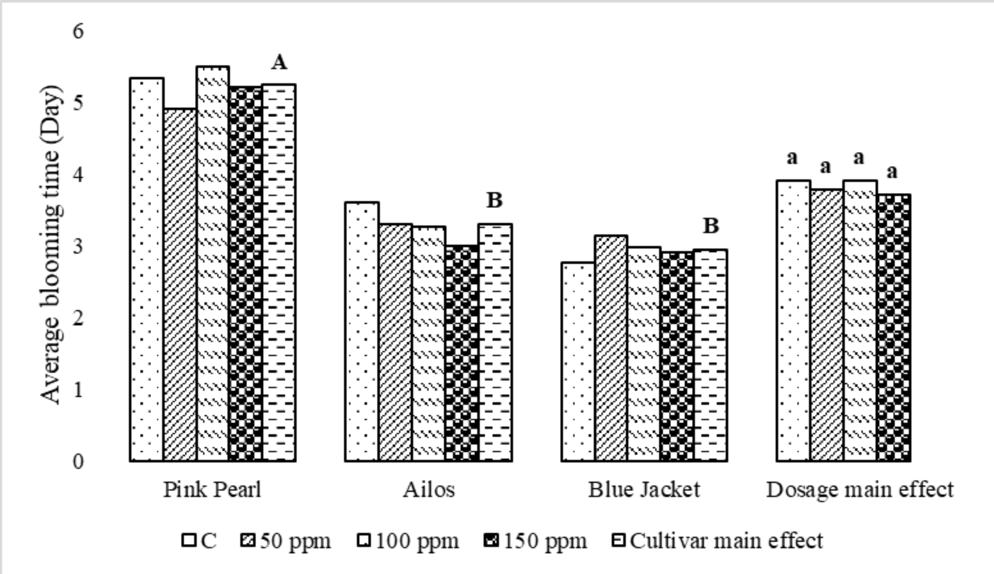

Figure 2. Average blooming duration of hyacinth cultivars treated with different dosages of BA

Different capital letters indicate a significant difference among cultivars (p<0.05).C: control

3.2. Postharvest studies

As stated in the Materials and Methods section, hyacinth plants were harvested along with their bulbs to ensure the flower stems remained long, and the bulb leaves at the base of the stem were removed. This allowed stems to prolong their longevity, enhance their quality as cut flowers. However, in terms of plant length, spike stalk length and leaf length, 'Aiolos' variety performed superior to the 'Blue Jacket' variety, emphasizing its suitability as cut flower. Stem length is a key factor for selecting flower species as cut flowers because cut flowers are graded and marketed by stem length, and is crucial for facilitating harvesting and extending vase life since re-cutting/trimming the lower ends of stems when necessary about 2 cm helps to prolong their vase life. Stem lengths vary by flower type and market; for instance, exported roses have a minimum length of 40 cm, while those for the domestic market require 25 cm. Distributors set a minimum length of 46 cm across all types, whereas growers suggest a range of 30-41 cm for marketable flowers (Yiğiter and Coşkun, 2024), and in the wholesale flower markets, hyacinths are sold in wraps of 25 stems and are sold in stem lengths of between 25 and 35cm tall (George et al., 2023).

Table 3 presents hyacinth flowers' water uptake rates, highlighting a significant interaction between variety and BA doses. Interestingly, however, cultivar responses to same BA dosages differed. While 100 ppm BA in 'Aiolos' variety resulted in the lowest water uptake, 'Blue Jacket' variety's water absorption was the highest in same BA dosage. Similarly, 150 ppm BA in 'Aiolos' variety resulted in highest water uptake, while 'Blue Jacket' variety's water absorption was the lowest in same BA dosage. However, 100 ppm BA for 'Aiolos' variety and 150 ppm BA for 'Blue Jacket' variety performed inferior to the control treatment. Boric acid delays the onset of ethylene production in carnation flowers, slowing down the aging of the flowers and thus increasing water uptake (Serrano et al., 2001). It has been reported that applying 200 ppm BA increases the water uptake of carnation flowers (Al-Attrakchii and Al-Mahdawe, 2015; Sarhan et al., 2023). Farooq et al. (2021) noted that the application of 150 µM BA postpones the aging of *Digitalis purpurea* L. cut flowers by increasing water uptake. Our results confirmed the earlier reports on the effect of different BA dosages on different species in terms of water uptake, and it seems that this effect translated into significant differences in hyacinth cultivars studied here.

Table 3. Spike stalk length, water uptake, vase life and chlorophyll SPAD content of hyacinth cultivars treated with different doses of BA.

	Treatments	***Hyacinth varieties***		***BA dosages main effect***
		Aiolos	***Blue Jacket***	
Spike Stalk length (cm)	Control	28.56	23.46	**26.01**
	50 ppm	28.79	24.33	**26.56**
	100 ppm	28.44	23.5	**25.97**
	150 ppm	27.42	23.91	**25.66**
	Cultivar main effect	**28.30 A**	**23.80 B**	
Significance[z]	*cultivar main effect***, BA dosage main effect[ns], cultivar x BA dosage[ns]*			
Water uptake (ml)	Control	28.00 **ab**	28.80 **ab**	**28.3**
	50 ppm	37.00 **a**	31.80 **ab**	**34.4**
	100 ppm	24.20 **b**	36.20 **a**	**30.2**
	150 ppm	37.40 **a**	26.00 **b**	**31.7**
	Cultivar main effect	**31.65**	**30.65**	
Significance[z]	*cultivar main effect***, BA dosage main effect[ns], cultivar x BA dosage[ns]*			
Vase life (days)	Control	11.00	9.40	**10.20**
	50 ppm	10.60	10.60	**10.60**
	100 ppm	11.00	10.60	**10.80**
	150 ppm	11.00	10.20	**10.60**
	Cultivar main effect	**10.90 A**	**10.20 B**	
Significance[z]	*cultivar main effect**, BA dosage main effect[ns], cultivar x BA dosage[ns]*			
Chlorophyl (SPAD) value	Control	60.36 **a**	58.62 **a**	**59.49**
	50 ppm	60.26 **a**	58.72 **a**	**59.49**
	100 ppm	56.54 **b**	60.96 **a**	**58.75**
	150 ppm	59.82 **a**	58.44 **a**	**59.13**
	Cultivar main effect	59.25	59.19	
Significance[z]	*cultivar main effect[ns], BA dosage main effect[ns], cultivar x BA dosage**			

[z]Two way ANOVA; ns: not significant; *, **, ***: significant at p<0.05, 0.01 and 0.001, respectively. Different capital case letters within the rows indicate significant differences among cultivars and different lower case letters within the columns indicate significant differences among the Cultivar x BA dosages interaction; the numbers are averages of all replicates.

The vase life of the 'Aiolos' variety (10.90 days) was significantly longer than that of the 'Blue Jacket' variety (10.20 days). The vase life of *Hyacinthus orientalis* as a cut flower is influenced by care and environmental conditions. On average, cut hyacinth flowers last 5-7 days in a vase, but with optimal care, they can last longer. Harvesting hyacinths with a small portion of the bulb (about 1 cm) can also extend their vase life (Rãus et al., 2023). In the present study, the vase life of both hyacinth cultivars was higher than that reported by Raus et al. (2023). BA treatments are effective in increasing the vase life of different species. Reports demonstrated that BA treatments at different doses increased the vase life of carnation (Serrano et al., 2001; Ahmadnia et al., 2013; Krishnamoorthy et al., 2017), gladiolus (Jian-Bo et al., 2009) and rose flowers (Kshirsagar et al., 2021). However, in the present study, BA was not effective in extending the vase life of hyacinth cultivars. This may be due to the fact that the effect of BA on the promotion of the vase life is dependent on species and that hyacinth is less sensitive to BA application in the vase solution than other flower species.

The interaction between cultivars and BA dosages were statistically significant for chlorophyll (SPAD) content. The application of 100 ppm BA in vase solution significantly reduced the chlorophyll (SPAD) levels of the ‘Aiolos’ variety compared to other treatments, although differences between other dosages and control plots were non-significant. On the other hand, while there were not significant differences between BA treated and untreated plants in ‘Blue Jacket’ variety, 100 ppm BA resulted in the highest chlorophyll (SPAD) levels. Pre-harvest measurements yielded similar results. Chlorophyll pigment plays a crucial role in the photosynthesis process of plants by capturing sunlight and converting light energy into chemical energy. A higher amount of chlorophyll allows the plant to absorb more light and thus perform more photosynthesis, resulting in the production of more carbohydrates. This makes it an important factor in the growth and development of the plant (Pallavolu et al., 2023). In addition, a high chlorophyll content leads to a higher carbohydrate level in plants, which in turn increases the amount of flowering. Indeed, the total number of flowers blooming in the 'Blue Jacket' variety was found to be higher than that of the 'Aiolos' variety (*Figure 1*).

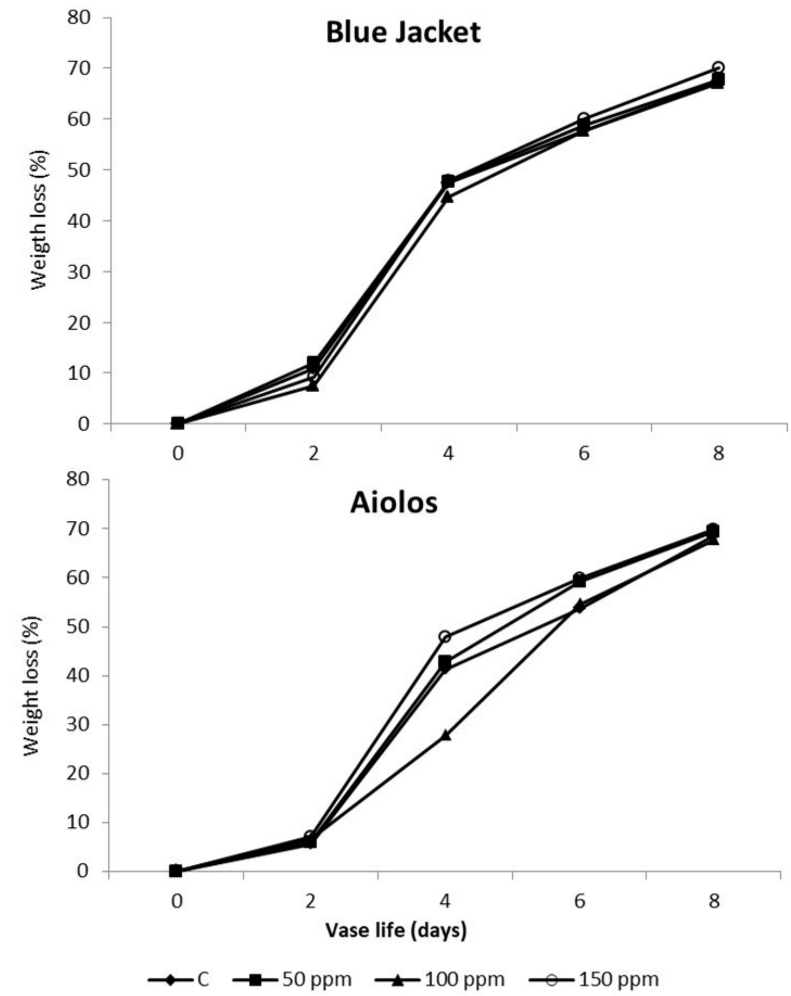

Figure 3. Weight loss of hyacinth cultivars treated with different dosages of BA

Weight losses increased in both varieties as vase life extended (*Figure 3*). Interaction between cultivar and dosages was significant for weight loss on the 4th day of the vase life, and the 100 ppm BA application significantly reduced weight loss, however, this dosage was more effective in reducing weight loss in the 'Aiolos' cultivar compared to the 'Blue Jacket' cultivar. On the 10th day of vase life, the interaction between cultivar and dose was not found to be significant, but the weight loss of the 'Aiolos' cultivar was lower than that of the 'Blue Jacket' cultivar.

4. Conclusions

The effect of Pre-harvest BA applications on vegetative characteristics of hyacinth varieties, such as total leaf count, leaf length, flower stem length, and plant height were not significant. However, cultivar main effect on these criteria varied significantly, with the highest total leaf count found in the 'Pink Pearl' cultivar, while the longest leaves, flower stems, and plant height were observed in the 'Aiolos' cultivar. The 150 ppm BA application significantly reduced the L value of the leaves, while significantly increased the h^o and chlorophyll SPAD levels. L value of the 'Aiolos' cultivar was significantly higher than the other two varieties, while the h^o value and the chlorophyll SPAD levels were significantly lower than those of other varieties.

All BA applications reduced the total number of blooming florets compared to control, the lowest number was found in 50 ppm BA treatment. Among the varieties, the total number of blooming spikes in 'Aiolos' was lower than that in 'Pink Pearl' and 'Blue Jacket'. The average flowering time was not affected by BA applications, however, it was found that the flowering time of 'Pink Pearl' was longer than that of the other two varieties.

BA applications did not significantly affect flower stem length, vase life, water uptake, and chlorophyll SPAD levels after harvest. However, the effect of BA dosages x cultivar interaction on water uptake and chlorophyll SPAD levels were significant. 100 ppm BA application significantly increased water uptake in the 'Blue Jacket' cultivar, while reducing chlorophyll SPAD levels in the 'Aiolos' cultivar. After harvest, the flower stem length and vase life of the 'Aiolos' cultivar were longer than those of the 'Blue Jacket' cultivar. Interaction between cultivar and BA dosages was significant for weight loss on the 4th day of the vase life. The 100 ppm BA application significantly reduced weight loss, and the weight loss of the 'Aiolos' cultivar was lower than that of the 'Blue Jacket' cultivar.

In conclusion, both pre- and postharvest period, the 'Aiolos' cultivar had longer plant and flower stem lengths compared to the other varieties. The vase life of the 'Aiolos' cultivar was also longer than that of the 'Blue Jacket' cultivar. But the total number of blooming spikes in the 'Aiolos' cultivar was lower than other varieties. According to BA dosages main effect, 50 ppm BA reduced the number of blooming spikes but increased water uptake. On the other hand, 100 ppm BA was effective in reducing weight loss. Therefore, it has been observed that the 'Aiolos' cultivar has potential as a cut flower. Among the BA applications, the 100 ppm BA was found to be particularly effective in reducing weight losses, but its promoting effect on water uptake was dependent on variety.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Kasım, R.; Design: Kasım, R., Kasım M.U.; Data Collection or Processing: Olgaç, Y.; Statistical Analyses: Kasım, R., Kasım, M.U.; Literature Search: Olgaç, Y.; Writing, Review and Editing: Olgaç, Y., Kasım, R.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Fertility Status of Agricultural Soils in İstanbul Province

İstanbul İli Tarım Topraklarının Temel Verimlilik Durumu

Emel KAYALI[1*], Orhan YÜKSEL[2]

Abstract

As a region of geopolitical significance and industrialization, İstanbul province has a traditional production system in which intensive agricultural production is carried out, especially in Silivri and Çatalca districts, where sunflower and wheat agriculture is carried out in alternation under irrigated conditions due to sufficient rainfall. These agricultural areas, which are also under intense urbanization pressure, need to be protected in order to be used sustainably. For this purpose, it is a priority to determine the current productivity status of agricultural areas. There is no study in the literature that reveals the current agricultural productivity status of İstanbul province. In this study, some physical and chemical soil properties of the agricultural areas where the same agricultural production system has been practiced for many years were determined in terms of sustainable agriculture. In order to determine these soil properties, surface soil sampling (0-20 cm) was carried out according to the grid system at 2.5 × 2.5 km intervals covering all agricultural areas and a total of 196 soil samples were taken and the field study was completed. All soil samples were analyzed for texture, pH, EC, organic matter, available phosphorus, available potassium and the current fertility status of the agricultural areas in the province of İstanbul was determined. According to the results of the research, the agricultural soils of İstanbul province are generally medium-heavy and heavy textured, medium alkaline and neutral pH, without salinity problems, 50% of them have very low CaCO3 content and the rest are calcareous soils with varying levels of $CaCO_3$. It was determined that the high CaCO3 content in 11% of the soils was due to the rendzina great soil group formed on marl parent material. In terms of organic matter, 59% were classified as low, 26% as moderate, 50% as high and very high in terms of available phosphorus, and 79% as high and very high in terms of extractable potassium. After the classification of all analyzed parameters, the distribution maps of a parameter were created by using Geographical Information Systems (GIS). IDW, which is an inverse distance weighting method widely used in soil science, was used to create the distribution maps.

Keywords: Istanbul province, Soil fertility, Geographic information systems, Soil quality, Geostatistical analysis

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Öz

İstanbul ili, jeopolitik önemi ve sanayileşmenin yanı sıra, özellikle Silivri ve Çatalca ilçelerinde yoğun tarımsal üretimin gerçekleştirildiği, yağışların yeterli olması sayesinde ayçiçeği ve buğday tarımının susuz koşullarda münavebe şeklinde sürdürüldüğü gelenekselleşmiş bir üretim sistemine sahiptir. Aynı zamanda yoğun şehirleşme baskısı altında da olan bu tarım alanlarının, sürdürülebilir bir şekilde kullanılabilmesi için korunması gerekmektedir. Bunun içinde tarım alanlarının mevcut verimlilik durumlarının belirlenmesi önceliklidir. Literatürde İstanbul ilinin mevcut tarımsal durumunu ortaya koyan herhangi bir çalışmaya rastlanmamıştır. Bu çalışma ile uzun yıllar boyunca aynı tarımsal üretim şeklinin uygulandığı bu tarım alanlarının sürdürülebilirliği açısından bazı fiziksel ve kimyasal toprak özelliklerini mevcut durumlarının belirlemek amaçlanmıştır. Bu toprak özelliklerini belirlemek için tüm tarım alanlarını kapsayacak şekilde 2,5 × 2,5 km aralıklarla grid sistemine göre yüzey toprak örneklemesi (0-20 cm) gerçekleştirilmiş ve toplam 196 adet toprak örneği alınarak arazi çalışması tamamlanmıştır. Alınan tüm toprak örneklerinde bünye, pH, EC, organik madde, alınabilir fosfor ve alınabilir potasyum analizleri yapılarak İstanbul ili tarım alanlarının mevcut verimlilik durumu ortaya konmuştur. Araştırma sonuçlarına göre, İstanbul ili tarım toprakları genellikle orta-ağır ve ağır bünyeli, orta alkali ve nötr pH'a sahip, tuzluluk sorunu olmayan, %50'si kireçsiz iken kalanı değişen oranlarda kireçli topraklardır. Toprakların özellikle %11'inde yüksek kireç içeriğinin, marn ana materyal üzerinde oluşmuş rendzina büyük toprak grubundan kaynaklı olduğu belirlenmiştir. Organik madde bakımından %59'u az, %26'sı orta; alınabilir fosfor bakımından %55'i yüksek ve çok yüksek; ekstrakte edilebilir potasyum bakımından ise %79'u zengin ve çok zengin sınıfa girmektedir. Tüm analiz parametrelerinin sınıflandırılmasının ardından bir parametreye ait dağılım haritaları Coğrafi Bilgi Sistemleri (CBS) kullanılarak oluşturulmuştur. Dağılım haritalarının oluşturulmasından toprak biliminde yaygın olarak kullanılan ters mesafe ağırlık yöntemi olan IDW kullanılmıştır.

Anahtar Kelimeler: İstanbul ili, Toprak verimliliği, Coğrafi bilgi sistemleri, Toprak kalitesi, Jeoistatistiksel modelleme

1. Introduction

Improper tillage practices (Abdollahi et al., 2015), over-fertilization (Aytop, 2023), uncontrolled use of pesticides (Akbay et al., 2023) and yield-oriented agricultural practices (Atmaca and Boyraz Erdem, 2016; Wang et al., 2019), are causing rapid deterioration in soil quality. Sustainable use and management of soils requires the development of new approaches to minimize or eliminate the negative impacts of modern agricultural practices.

A key factor in sustainable agriculture is soil quality. Like air and water quality, soil quality affects the quality of the ecosystem in which it is located. However, compared to water and air quality, soil quality is difficult to define and quantify (Doran and Parkin, 1994). Soil quality is a combination of physical, chemical and biological properties of soils. Therefore, improving and maintaining soil quality is possible by improving these properties. These properties of soils are important not only as a growing medium but also because of their buffering effect on harmful compounds (Larson and Pierce, 1994; Gürbüz et al., 2023; Atav et al., 2024).

Soil quality assessment is one of the key elements of sustainable soil management. The fact that soil fulfills many functions simultaneously makes it difficult to determine indicator properties related to specific functions and processes. However, it is possible to assess soil quality with indicators of physical, chemical and biological properties (Andrews and Carroll, 2001). For example, soil indicators such as water holding capacity, aeration, pH and electrical conductivity are used. In addition, approaches such as integrated soil quality index and productivity index model can be used to assess soil quality (De Lima, 2007). To maintain the productivity of our agricultural areas, the characteristics of these areas should be defined in the best way. For this purpose, establishing a database by determining and updating the physical and chemical properties of agricultural areas will provide preliminary information for new research projects for the proper use of soil resources. As a result of the analyzes to be carried out on soil samples with specific geographical coordinates, the changes of the determined properties over time can be monitored and negative changes in agricultural areas can be taken under control (Özden et al., 2018). For this purpose, studies have been carried out in many regions. Taşova and Akın (2013), in their study covering the province of İstanbul in the Marmara Region, took soil samples to identify all agricultural soils and revealed the nutrient and fertility status of the soils. By evaluating the obtained results with Geographical Information Systems (GIS), they created current soil databases and mapped them. As a result of the research, they determined that the agricultural lands of the Marmara region are generally; clay loamy, slightly alkaline, low organic matter content, non-saline and very low content of $CaCO_3$ soils. They determined that 47% of the soils in the region had very low content of available phosphorus, while 53% of the soils had high content of available phosphorus, iron and copper contents were moderate, while zinc and manganese contents were low. In Başar's study (2001), in which some fertility characteristics of Bursa province soils were determined, a total of 1018 soil samples were taken and analyzed. According to the results of the analyses, it was determined that the soils of the research area were generally medium textured, without salinity problem, with moderately and strongly alkaline reaction and containing varying amounts of $CaCO_3$. The researcher also determined that 56.49 % of the soils were low or very low contents of organic matter, 21.81 % contents of available phosphorus and 21.82 % in contents of available potassium. In the study (Özden et al., 2022) on agricultural soils of Manisa province, it was found that 33.29% of the soils were sandy loam, 62.20% were slightly alkaline, 94.36% were very low in $CaCO_3$, 33.57% were medium calcareous, 64.88% were low in organic matter, 25.39% were very high in available phosphorus and 94.07% were high in available potassium. Lopez Granados et al. (2002) determined the spatial variability parameters of composition, organic matter (OM), phosphorus (P), potassium (K), nitrate (NO_3^-), ammonium (NH_4^+) and pH as soil fertility parameters in Spain by geostatistical modeling and obtained variable rate fertilizer application maps based on these parameters. Alaboz et al. (2020), in their study in Isparta compared different interpolation methods for the creation of the distribution maps.

İstanbul is one of the centers of economy, history, culture and tourism, where two continents meet and has important transit routes. In addition to industrialization, intensive agricultural production activities are carried out, especially in the Silivri and Çatalca districts. Agricultural production in these regions helps to meet the food needs of İstanbul. This study aims to determine the nutrient contents of the agricultural soils of İstanbul province and to create a database and distribution maps of these properties. Studies on determining the fertility status of soils within the borders of the study area are limited. Therefore, the present study will make an important contribution to the literature by evaluating the fertility status of agricultural soils of İstanbul Province.

2. Materials and Methods

2.1. Study area

The province of İstanbul is located in northwestern Türkiye, on both sides of the Bosphorus, on the Çatalca peninsula to the west and the Kocaeli peninsula to the east. It is neighboring Tekirdağ in the west and Kocaeli in the east. It has a total land area of 546.078 hectares and the cultivated agricultural area is 14% of its total surface area (*Table 1*).

Table 1. Crop production cultivation areas (TÜİK, 2024)

Land Use	Land (da)
Field crops area	707.243
Fallow land	7.469
Vegetable area	26.252
Fruit area	28.303
Ornamental plants	484
Total	**769.751**

The districts in agricultural production are Çatalca, Silivri and Şile, and the main crops are wheat, sunflower, barley, canola and corn. The production amounts of some agricultural products are given in *Table 2*.

Table 2. Crop production (TÜİK, 2024)

Land Use	Land (da)
Field crops production	290.464
Vegetable production	61.970
Fruit production	6.620
Total	**359.054**

The great soil groups commonly found in the province are vertisol, non-calcareous brown and brown forest soils. The land use types map prepared according to CORINE classification system showing the land cover and land use types of İstanbul area is given in *Figure 1*.

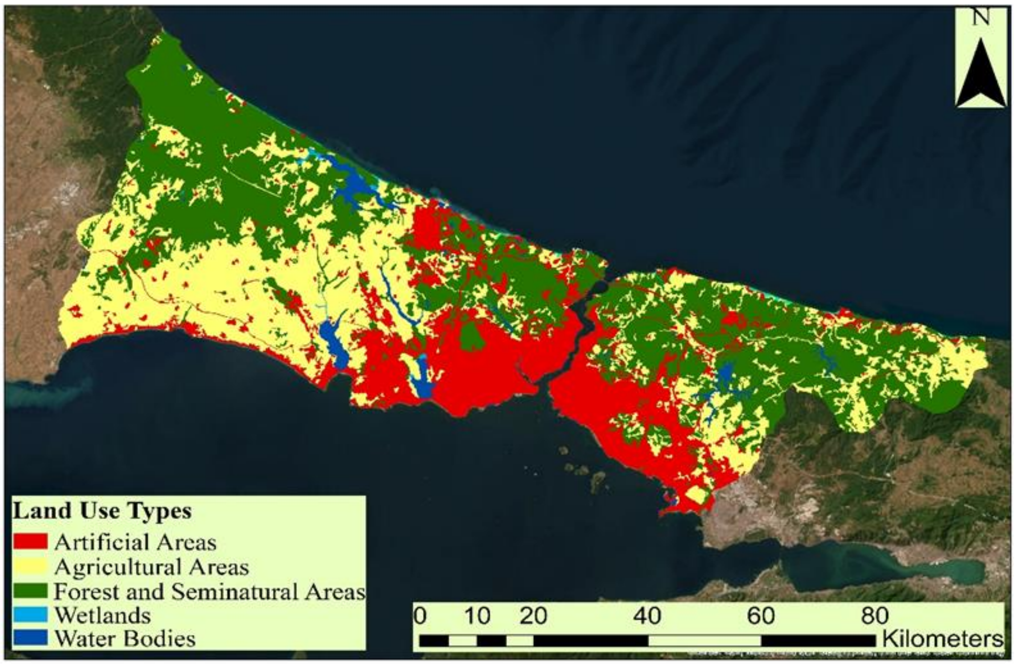

Figure 1. Land use groups of İstanbul province area (CORINE, 2018)

İstanbul has a temperate climate with transitional characteristics between the Black Sea and Mediterranean climates. Summers are hot and humid and winters are cold and rainy. The average temperature is 2°C in winter and 18-28°C in summer, with an annual average temperature of 14.4°C (MGM, 2022).

The provincial area of İstanbul is located in the Marmara region, which covers a wide variety of rock units formed in the Early Palaeozoic-Present interval and where there are current tectonic movements. There are two major rock stratigraphy unit assemblages within the provincial borders: metamorphic and non-metamorphic. The metamorphites forming most of the Istranca Mountains are the Istranca Union, while the non-metamorphosed stack is the İstanbul Union, these two communities are separated from each other by a large tectonic line (Anonim, 2011).

2.2. Soil sampling

In this study, 1/25000 scale soil maps digitized by abolished Directorate of Rural Services were used to determine the soil sampling points. On the map, 2.5 × 2.5 km grids were created and the points coming to the agricultural areas were determined (*Figure 2*). The coordinates of all sampling points were uploaded to a handheld GPS with ±3 m deviation and surface soil sampling (0-20 cm) was carried out. A total of 196 soil samples were taken.

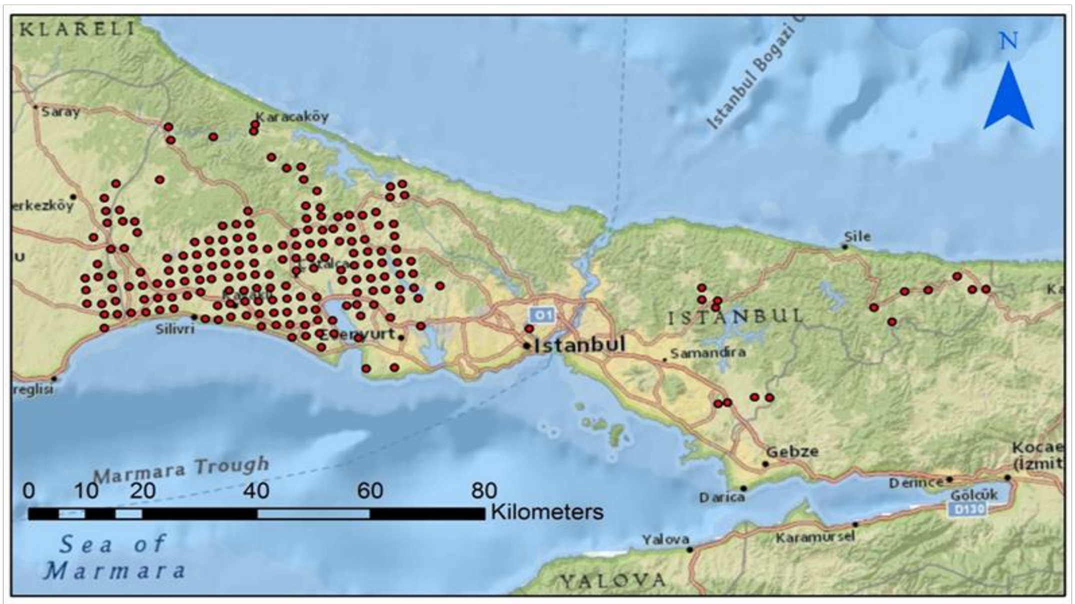

Figure 2. Soil sampling points in agricultural areas of Istanbul province

2.3. Methods of Soil Analysis

Soil samples taken from the study area were dried, grounded and sieved through a 2 mm sieve and prepared for analysis. Organic matter contents of the soil samples were determined by modified Walkley-Black method (Nelson and Sommers, 1996), pH was determined in saturation paste with a pH-meter, EC was determined in saturation paste with an EC-meter (Soil Survey Staff, 1993), CaCO3 contents were determined volumetrically by Scheibler calcimeter (Loeppert and Suarez, 1996), Available Phosphorus contents were determined according to Olsen method (Olsen and Sommers, 1982), Extractable Potassium contents were extracted with Ammonium Acetate and determined by ICP-OES. Soil texture was determined according to the Bouyoucos hydrometer method (Gee and Bauder, 1986).

2.4. Database creation and mapping

Basic descriptive statistical analysis was applied to all analyzed parameters. The data obtained from soil samples were classified according to the limit values used in Kayali and Yüksel (2020) and their distributions were calculated. All data were evaluated and transformed into distribution maps using Geographic Information Systems (GIS) with the "ArcGIS Geostatistical Analyst" module. Distribution maps were created with the inverse distance weighting (IDW) method, which is one of the interpolation methods frequently used in soil quality studies.

The inverse weighting by distance (IDW) method calculated the value of each sample point by weighting it inversely to its distance to the point to be estimated. The formula of the IDW method is given below:

$$Z^*_{IDW}(x_0) = \frac{\sum_{i=1}^{n} \frac{1}{d_i^p} \cdot Z(x_i)}{\sum_{i=1}^{n} \frac{1}{d_i^p}} \qquad \text{(Eq. 1)}$$

$Z^*\ (x_0)$: x_0 its estimated value at the point,
$Z_{(x_i)}$: x_i the sample point value at the point,
d : the distance between the sample point and the point to be estimated,
p : exponential value,
n : refers to the number of sample points

In the inverse distance weighting method, the influence distance, which significantly affects the prediction values, determines that observation values at a certain distance can be used in the calculation. Points farther away than the influence distance are not included in the calculations (Uyguçgil, 2007).

3. Results and Discussion

In 196 soil samples taken from the agricultural areas of İstanbul province and analyzed, saturation was between 38-86%; sand content between 9.5-76.5%, clay content between 7.5-69.7%, silt content between 0.3-50.9%, soil texture clay, clay loam, loam, loamy sand, sandy clay, silty clay loam, silty loam, sandy loam; pH 4.80-7.91 between strongly acid - moderately alkaline; EC 0,09-2.61 dS m^{-1} between non-saline and very slightly saline, CaCO3 0,01-54,00% between very low-very high calcerous soil, organic matter 0.46-5.23% between very low-very high. Available phosphorus content was found between 0.71-603.20 mg kg^{-1} available potassium content was found between 33.29-3449.38 mg kg^{-1}**.**

3.1. Texture

Soil texture is an important parameter that determines the physical and chemical properties of soils. It has a direct effect on many properties of soils such as water permeability and retention capacity, aeration, nutrient retention capacity and microorganism activities (Gupta, 2007). According to the results of the analysis, 70% of the soils were classified as clay, silty clay and 16% as sandy loam, sandy clay loam (*Table 3*).

Table 3. Distribution of texture classes of soils

Symbol	Number of soils	Distribution (%)
S, LS	1	1
SL, SCL	32	16
SiL, SiCL	2	1
CL, L	20	10
Si, SC	5	2
SiC, C	136	70

Most of the agricultural soils in İstanbul are composed of clay soils. Clay soils have high water holding capacity and low water permeability. These properties are advantageous in terms of meeting the water needs of plants, especially during dry periods (Brady and Weil, 2002). However, clay soils also have the potential to experience compaction and aeration problems, which can negatively affect plant root development. Taşova and Akın (2013), carried out a study in the Marmara region, including the province of İstanbul and found that clay loam (43.7%) and clay soils (34.5%) cover the most area proportionally, while the proportion of sandy soils is only 0.5%. These results are similar to the results of this study. Regarding soil texture, Özden et al. (2018) reported that 33.29% of the agricultural soils in Manisa province were sandy loam and 62.20% were moderately alkaline. This indicates that the soils of İstanbul province have a higher clay content.

3.2. pH

Soil reaction (pH) determines whether soils are acidic or basic and affects the availability of plant nutrients (Neina, 2019). In the study area, 62% of the soil samples were classified as alkaline and 20% as neutral pH (*Table 4*). The map showing the pH distribution of the study area is given in *Figure 3*.

Table 4. Distribution of soils in İstanbul according to pH classes

Value	Classes	Number of soils	Distribution (%)
<5.1	Strongly acid	5	3
5.2-6.0	Moderately acid	18	9
6.1-6.5	Slightly acid	12	6
6.6-7.3	Neutral	39	20
7.4-8.4	Moderately alkaline	122	62
>8.4	Strongly alkaline	-	-

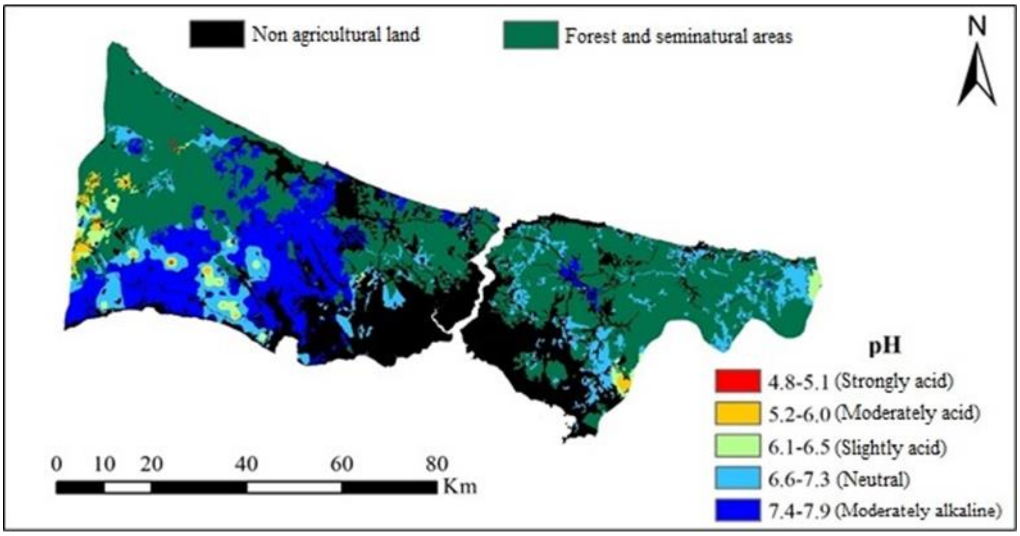

Figure 3. Soil reaction distribution map of the research area

Soil pH is a critical factor for plant growth and development (Oshunsanya, 2018). Soils in the moderately alkaline to neutral pH range are generally the soils with the best uptake of plant nutrients (Zhao et al., 2011). Most of the agricultural soils of İstanbul province have a moderately alkaline pH value. Low soil pH is considered as one of the factors affecting yield (Aktaş and Yüksel, 2020). Moderately alkaline soils are the soils where plant nutrients can be taken up in the best way (Thomas, 1996). However, the 3% with a strongly acid pH value may require regulatory measures such as CaCO3 application (Nkana et al., 2001). The 20% with a neutral pH value is quite suitable for agricultural production (Caritat et al., 2011). Taşova and Akın (2013) determined in their study that moderately alkaline soils had the highest rate with 50,6% in Marmara region, followed by neutral pH soils (30,0%) and slightly acid soils (13,8%). These results are in parallel with our study. These data reveal the pH distribution of the agricultural soils of İstanbul and the effect of this distribution on agricultural production.

3.3. EC (dS/m)

Table 5. Distribution of soils in İstanbul according to salinity classes

EC(dS/m)	Salinity Class	Number of soils	Distribution (%)
<0.75	Non-saline	68	35
0.75-2	Very low saline	125	64
2-4	Very slightly saline	3	1
4-8	Slightly saline	-	-
8-16	Moderately saline	-	-
> 16	Strongly saline	-	-

The salinity class and distribution of the results of electrical conductivity (EC) analyses of the soil samples taken from the research area are given in *Table 5*. Accordingly, 64% of the soils of İstanbul province are classified very low saline and 35% as non-saline (*Figure 4*). Approximately 98% of the soils of Edirne, Kırklareli and Tekirdağ provinces are non-saline, while 2% slightly saline areas were determined (Gürbüz et al., 2018). This result shows that there is no similar salinity problem in the study soils.

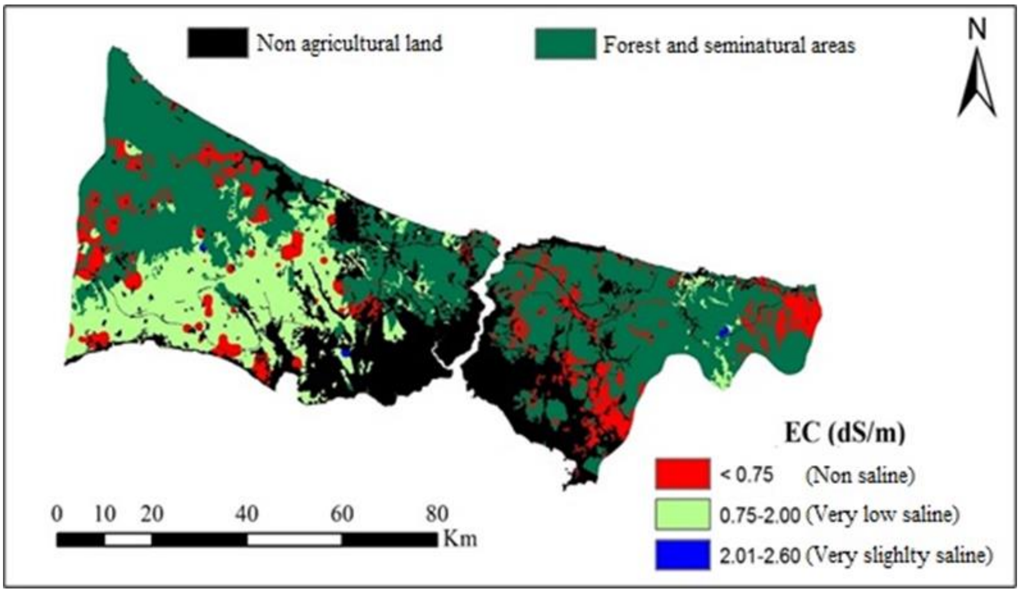

Figure 4. Soil salinity distribution map of the research area

Most of the agricultural soils in İstanbul (64%) are classified as very low saline. This is generally considered a positive characteristic for agricultural production, as low salinity allows plant roots to better absorb water and nutrients (Machado and Serralheiro, 2017). However, the 1% that is very slightly saline may require salinity management in certain areas (Alharbi, 2015). The 35% that is non-saline represents ideal agricultural conditions (Shrivastava and Kumar, 2014).

3.4. CaCO3 (%)

The CaCO3 content of soils is an important parameter for the productivity of agricultural activities (Ameyu, 2019). In İstanbul, 50% of the soils are classified as very low, 10% as medium and 11% as very high (*Table 6*; *Figure 5*).

Table 6. Distribution of soils in İstanbul according to $CaCO_3$ content classes

$CaCO_3$ (%)	Class	Number of soils	Distribution (%)
0-2	Very low	98	50
2-4	Low	18	9
4-8	Medium	20	10
8-15	Calcareous	16	8
15-30	High	23	12
> 30	Very high-marl	21	11

Half of the agricultural soils in İstanbul province have very low content of $CaCO_3$, indicating that acidic soil characteristics are dominant. In acidic soils, $CaCO_3$ applications can increase the uptake of plant nutrients by increasing the pH value (Barman et al., 2014). Medium $CaCO_3$ soils (10%) are generally more nutrient balanced and offer ideal conditions for agricultural production (Haynes and Naidu, 1998). Soils with high $CaCO_3$ content are observed in Çatalca district. Very high $CaCO_3$ containing soils (11%), on the other hand, may not be suitable for certain plant species due to their high $CaCO_3$ content and may require specialized production strategies (Corbett et al., 2021). Taşova and Akın (2013), found that 65.8 % of the soils in the Marmara region are in the very low and low class in terms of $CaCO_3$. They stated that especially high calcareous areas are located around İstanbul. These results coincide with our study

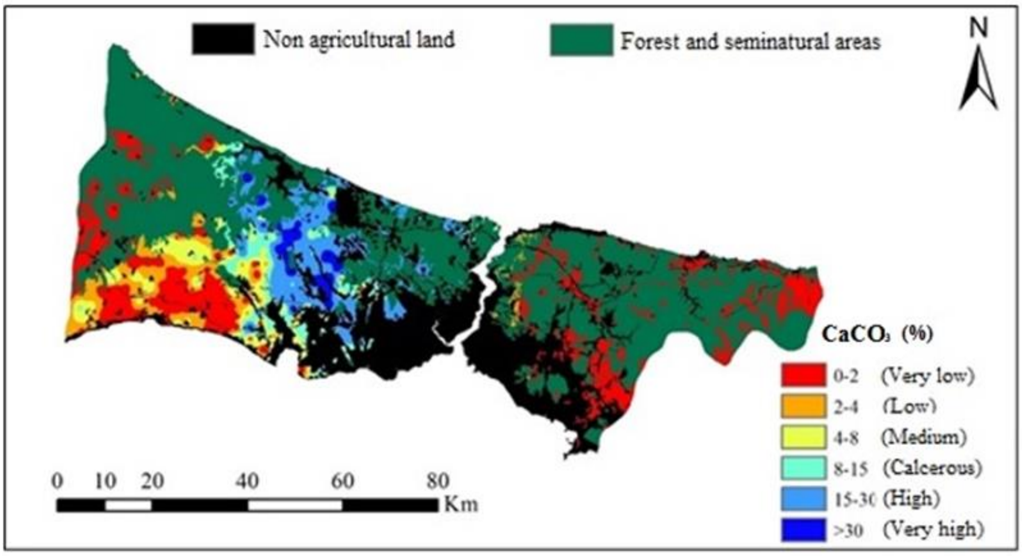

Figure 5. $CaCO_3$ distribution map of the research area

3.5. Organic matter (%)

In terms of organic matter content, 12% of the soils in İstanbul are classified as very low, 59% as low and 3% as high (*Table 7*). The map showing the distribution of organic matter is given in *Figure 6*.

Table 7. Distribution of soils in İstanbul according to organic matter content

Organic Matter (%)	Class	Number of soils	Distribution (%)
<1	Very low	23	12
1-2	Low	116	59
2-3	Moderate	150	26
3-5	High	6	3
>5	Very high	1	-

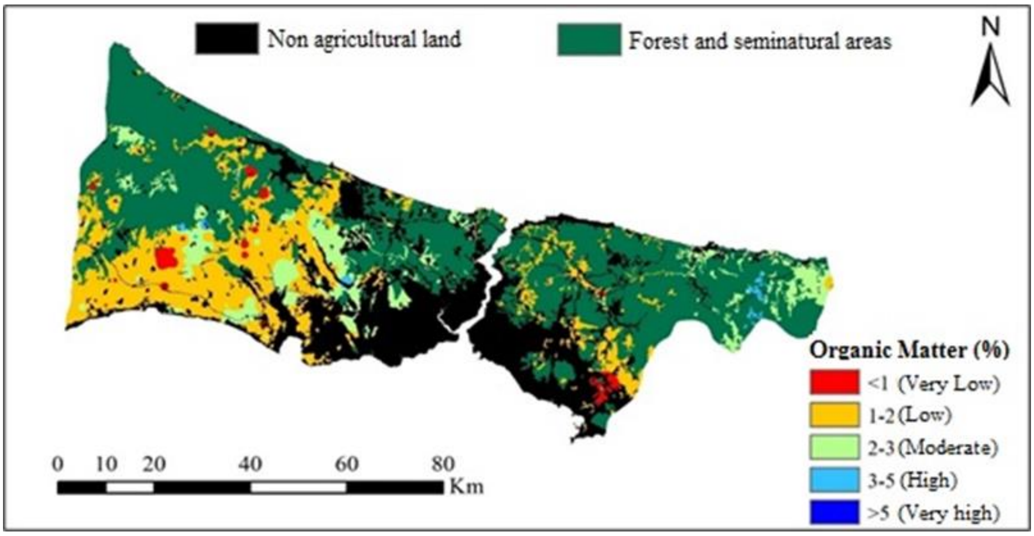

Figure 6. Organic matter distribution map of the research area

It is known that the organic matter content of soils in Türkiye is generally low and very low. However, in this study, the organic matter content of about 30% of the soils of İstanbul province was found to be at moderate and high levels. In a similar study conducted in the Marmara region, organic matter contents were found to be close to 32%. These soils show balanced characteristics in terms of retention of plant nutrients and water holding capacity (Fageria, 2012; Oldfield et al., 2018). Soils with moderate to high organic matter content (29%) have high fertility potential and provide advantages in terms of microorganism activities and soil structure improvement (Zhao et al., 2016). However, the 12% with very low organic matter content may require organic matter additions to improve soil fertility (Syers, 1997).

3.6. Available phosphorus (mg kg^{-1})

Soil samples taken from the research area were classified in terms of phosphorus and their distribution is given in *Table 8*. Accordingly, 4% of the soils in İstanbul are classified as very low, 19% as low and 28% as high (*Figure 7*). It has been reported that the amount of phosphorus in approximately 70% of the soils in Türkiye is below 12 mg $^{-1}$ (Sönmez et al., 2018). This result reveals that the amount of phosphorus in the agricultural soils of the study area is higher than Türkiye in general. Excessive fertilization applied as a result of intensive agricultural activities may have caused this result.

Table 7. Distribution of available phosphorus content of soils of İstanbul province

eP (mg kg^{-1})	Class	Number of soils	Distribution (%)
<0-5	Very low	8	4
6-12	Low	38	19
13-25	Moderate	53	27
26-50	High	55	28
> 51	Very high	42	22

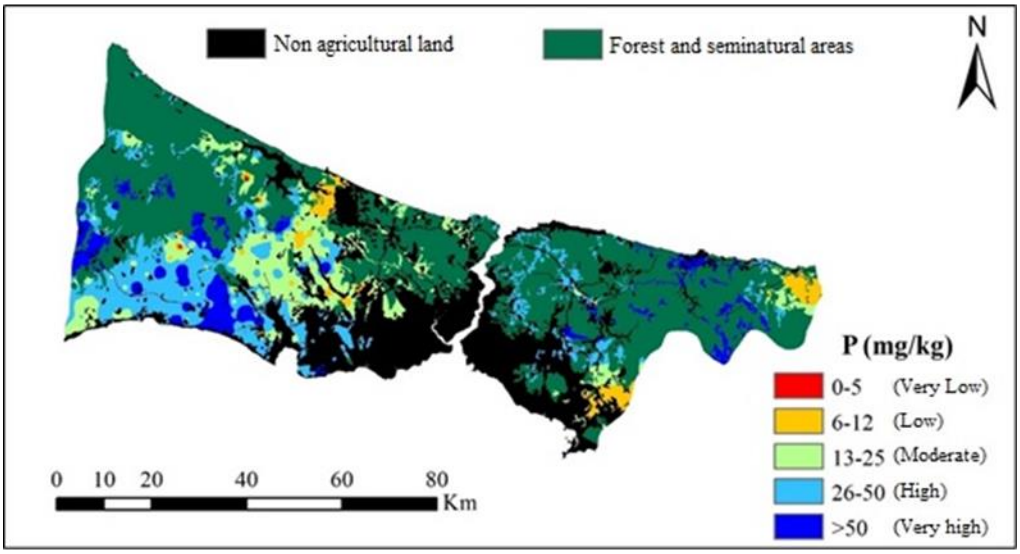

Figure 7. Available phosphorus distribution map of the research

In İstanbul, 50% of the agricultural soils have high and very high phosphorus content, mainly in Silivri district, which is a positive indicator for plant growth and development (Sharpley and Menzel, 1987). However, it should be considered that such high phosphorus levels may be due to factors such as over-fertilization (Vadas and Sims, 2013). An excess of phosphorus can prevent plant roots from taking up other nutrients and can lead to environmental problems (Sarkar, 2005). Soils with very low (4%) and (19%) phosphorus content may require phosphorus fertilization (Sharma et al., 2013). Moderate phosphorus content (27%) promotes a balanced uptake of plant nutrients (Richardson et al., 2009). In case of phosphorus deficiency, plant growth slows down and yields decrease (Bingham and Martin, 1956). Therefore, it is necessary to fertilize soils with low phosphorus content (Miranda et al., 1989).

Available phosphorus is a critical nutrient for plants and its sufficient amount in the soil directly affects plant root development and overall plant health (Chan et al., 2021). An excess of phosphorus can cause environmental pollution and contamination of water resources (Sharpley, 1995). Therefore, phosphorus management is of great importance for sustainable agricultural practices (Etesami, 2019).

3.7. Available potassium (mg kg^{-1})

In terms of potassium content, 7% of the soils of İstanbul province are classified as very low, 7% as moderate and 38% as high (*Table 9*). Due to hot and arid climatic conditions, Turkish soils have high clay content and are rich in this plant nutrient (Sönmez et al., 2018). The available potassium distribution map of the soils of the research area is given in Figure 8.

Table 9. Distribution of available potassiums content of soils of İstanbul province

eK (mg kg^{-1})	Class	Number of soils	Distribution (%)
< 80	Very low	13	7
80-120	Low	13	7
120-160	Moderate	13	7
160-320	High	76	38
>320	Very high	81	41

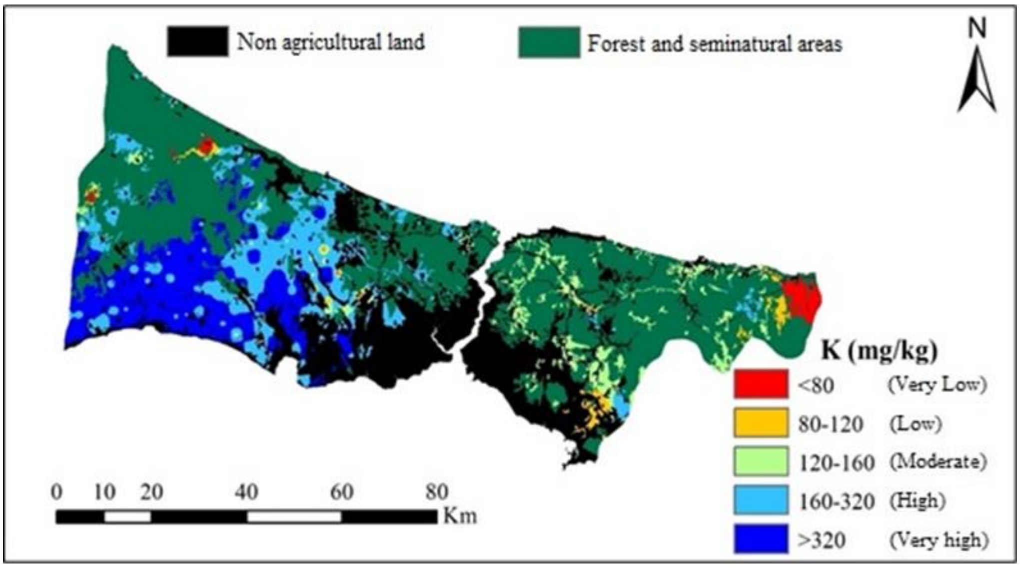

Figure 8. Available potassium distribution map of the research area

Most of the agricultural soils of İstanbul province (79%) are high and very high in potassium. The high levels of available potassium are mostly widespread in Silivri district. Potassium plays a critical role for plants to regulate water balance and develop resistance to diseases (Pettigrew, 2008). Soils with very low potassium content (7%) can lead to slow plant growth and reduced yields (Dotaniya et al., 2016). Moderate potassium content (7%) promotes a balanced uptake of plant nutrients (Ali et al., 2021). Potassium deficiency can lead to problems such as water imbalance in plant cells, wilting and susceptibility to diseases (Wakeel, 2013). Therefore, it is important to fertilize soils with low potassium content (He et al., 2022). Soils with rich potassium content positively affect plant growth and provide high yields (Nanu and Radulov, 2013).

4. Conclusion

The research area generally has a flat, almost flat and slightly sloping land structure. No stony, rocky or any other problem preventing production was detected. Most of the agricultural soils of İstanbul province (82%) are medium-heavy and heavy textured and have high clay content. Improper agricultural practices may increase soil compaction and plough layer. For this reason, tillage should be carried out at appropriate moisture levels in high clay content areas. The pH of the soils is generally in the moderately alkaline (62%) and neutral (20%) classes. Soil pH is thought to be relatively high due to the CaCO3 content of the parent material. The content of 50% of the soils are very low and the remaining soils contain varying amounts of CaCO3. Very high CaCO3 content is especially common in the Rendzina soil group and covers 11% of the area. The EC values of the soils are less than 0.75 dS m-^{1} and there is no salinity problem in the region. Due to climatic conditions, excessive tillage, erosion and insufficient organic fertilization practices, 59% of the soils are low in organic matter and 26% are at moderate level. In soils with low organic matter content, remedial measures need to be taken to increase soil fertility and ensure sustainability. 27% of the soils have moderate, 28% high and 22% very high levels of available phosphorus. In terms of extractable potassium content, 79% of the soils are classified as high and very high, 7% as moderate, and 14% as very low and low. One of the reasons for the high phosphorus and potassium content is the excessive fertilization practices applied in the region. In terms of sustainable agricultural practices, the negative effects of over-fertilization on plant growth and uptake of other nutrients should be evaluated.

Rapid population growth and increasing industrialization cause an increase in the misuse of agricultural lands and İstanbul has its share in this regard. Although approximately 14 % of the total surface area is agricultural land, intensive agricultural activities continue in Silivri and Çatalca regions. Considering the high nutrient needs of the increasing population, the importance of the region draws more attention. The high cost of transport necessitates the continuation of production in the region. Protection of these agricultural areas and sustainable agriculture are important for this region. This study is important in terms of revealing the soil characteristics of İstanbul province and will contribute to the agriculture of the region.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Author Contribution

Concept: Kayalı, E., Yüksel, O.; Design: Kayalı, E., Yüksel, O.; Data Collection or Processing: Kayalı, E., Statistical Analyses: Kayalı, E.; Literature Search: Kayalı, E., Yüksel, O.; Writing, Review and Editing: Kayalı, E., Yüksel, O.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of the Relationship Between Rainwater Harvesting and Landscape Plant Water Consumption*

Yağmur Suyu Hasadı ile Peyzaj Bitkilerinin Su Tüketimi Arasındaki İlişkinin Değerlendirilmesi

Nilay MISIRLI[1*], Elif Ebru ŞİŞMAN[2]

Abstract

If rainwater is not used, it is considered waste and ends up as surface water in underground resources or flows into oceans. In view of dwindling water resources, rainwater should not only flow as surface water but should be reused to conserve groundwater and mains water. To achieve this, rainwater must be collected and solutions produced on site. When we look at water consumption rates, we realize that a large amount of water is significantly used for the irrigation of landscaped areas. In addition, the water requirements of plants are often not known and water is wasted through unconscious irrigation. This study aims to provide the right amount of irrigation by showing the water requirements of plants according to their species. At the same time, it aims to provide the right amount of irrigation by showing the water requirements of plants according to their species. These two main objectives are aimed at learn the needs of plants and at the same time ensuring efficient water use. In this study, it is aimed to contribute to the water cycle by reusing rainwater. Various roofing and paving materials were identified in the study area. The amount of rainwater to be collected from the different materials within the study area was calculated using the Rational Method and the water consumption of each plant was calculated using the CropWat 8.0 program. In conclusion, the amount of rainwater collected on the entire campus was calculated as 494.000 m^3per year and the amount of irrigation water required by the plants was 54.530 m^3per year. This data shows that the amount of rainwater collected corresponds to the water consumption of the landscape plants. The rainwater harvested on campus is fed into tanks. The rainwater collected on the campus is channelled into tanks. The volume of the tanks was calculated. In addition to the stored rainwater, solutions were developed on-site using sustainable methods for the remaining rainwater. Plants with low or medium water requirements are recommended for use in new landscape areas.

Keywords: Rainwater harvesting, Rainwater reuse, Landscape plant water consumption, Irrigation, Sustainability, Urban stormwater management

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Öz

Yağmur suyu değerlendirilmediği sürece atık olarak görülmekte ve yüzey suyu olarak yeraltı kaynaklarına veya denizlere ulaşmaktadır. Azalan su kaynakları düşünüldüğünde, yağmur suyu sadece yüzey akış suyu olmamalıdır. Yağmur suyunun yeniden kullanımı ile yeraltı ve şebeke sularından tasarruf sağlanmalıdır. Bunun gerçekleştirilmesi için yapılması gereken yağmur suyunun toplanarak yerinde çözüm önerileri üretilmesidir. Su tüketim oranlarına bakıldığında, peyzaj alanlarının sulanması için büyük miktarda suyun kullanıldığı açıkça görülmektedir. Ayrıca bitkilerin türler özelinde su ihtiyacı genellikle bilinmemekte olup ve bilinçsiz sulama ile hem su israf edilmekte hem de bitki için gereğinden az veya fazla sulama yapılmaktadır. Bu çalışmada yağmur suyunun yeniden kullanımı ile doğal su döngüsüne katkı sağlanması amaçlanmıştır. Aynı zamanda bitkilerin türlerine göre su isteklerini ortaya koyarak, doğru miktarda sulama yapılmasını hedeflemektedir. Bu iki temel hedef suyun etkin kullanımını sağlarken, bitkilerin doğru su ihtiyaçlarını öğrenmeyi amaç edinmiştir. Çalışma alanı içerisinde yer alan farklı çatı ve yer döşeme malzemeleri tespit edilmiştir. Her bir farklı yüzeyden toplanacak yağmur suyu miktarı Rasyonel Metot ile hesaplanmıştır. Çalışma alanı içerisinde bitki tür tespiti yapılmıştır. Her bir bitkiye ait su tüketim hesabı ise CropWat 8.0 programı ile hesaplanmıştır. Sonuç olarak, toplanacak yağmur suyu miktarı 494.000 m^3yıl, bitkilerin sulama suyu ihtiyacı 54.530 m^3yıl olarak hesaplanmıştır. Bu veriler karşılaştırıldığında, toplanan yağmur suyu miktarının bitkilerin sulama suyu ihtiyacını karşıladığını göstermektedir. Yerleşke içerisinde toplanacak yağmur suları tanklara yönlendirilecektir. Bu nedenle tanklar için uygun hacim hesaplan yapılmıştır. Depolanan yağmur suları dışında arta kalan yağmur suları için sürdürülebilir yöntemlerle yerinde çözüm önerileri üretilmiştir. Su isteği az veya orta olan bitkiler, yeni yapılacak peyzaj düzenlemelerinde kullanılmak üzere öneri olarak sunulmuştur.

Anahtar Kelimeler: Yağmur suyu hasadı, Yağmur suyunun yeniden kullanımı, Peyzaj bitkisi su tüketimi, Sulama, Sürdürülebilirlik, Kentsel yağmur suyu yönetimi

1. Introduction

Today, 55% of the world's population lives in cities, andthis figure is expected to rise to 68% by 2050 (United Nations Human Settlements, 2020). The proportion of the urban population in Europe is expected to rise from 74% in 2015 to 84% in 2050. While this increase is expected to correspond to 77 million new urban dwellers, Turkey is cited as one of the most affected countries (IPCC Sixth Assessment Report, 2022). As the urban population grows, the demand for water will also proportionally increase. However globally, sufficient, and clean water is vital for the health of humans and other living beings, for industry, agriculture and energy production. By 2025, an estimated 3.5 billion people will be affected by water scarcity. This figure is expected to rise by up to 30 % by 2050 (World Resources Institute, 2022). The United Nations is conducting numerous studies on this topic. The United Nations programmes "2005-2014: UN Decade of Education for Sustainable Development" and "International Decade for Action "Water for Life", 2005-2015" underscore the current need to address water management on campus. Both programmes were launched to give special attention to sustainability and water in higher education, which are considered important for achieving environmental sustainability (Anonymous, 2023; UNESCO, 2005). As a result, the United Nations declared the period from 2018 to 2028 to be the international decade of action "Water Action Decade 2018-2028". The program focuses on the sustainable development and integrated management of water resources to achieve social, economic and environmental goals, the implementation and promotion of relevant programs and projects, and the promotion of cooperation and partnerships at all levels to achieve internationally agreed water-related goals and targets, including those of the 2030 Agenda for Sustainable Development (Water Action Decade, 2016). As part of the United Nations "Sustainable Development Goals"; at least 1.8 billion people worldwide use a completely contaminated drinking water source, 663 million people still have no improved drinking water sources between 1990 and 2015, more than 80% of wastewater from human activities is discharged untreated into rivers or oceans, it is clearly stated that more than 40 of the world's population is affected by water scarcity and this number is expected to rise, that floods and other water-related disasters are responsible for 70 of deaths caused by natural disasters and that every day nearly 1.000 children die every day from preventable waterborne and diarrheal diseases. To prevent all this, the United Nations aims to halve the rate of untreated wastewater by 2030, increase water efficiency, including rainwater harvesting, wastewater treatment, recycling and reuse technologies, integrated water resources management, improve water quality by reducing pollution, significantly increase recycling and ensure global security, universal and equitable access to safe and affordable drinking water for all (The United Nations, 2022; The United Nations Sustainable Development Goals, 2022).

Turkey's population is expected to reach 100 million by 2030. In this case, it is said that the amount of water available per capita in 2030 will be about 1100 m^3 per year. In addition, it is estimated that the demand for drinking and industrial water, which was 5 billion m^3 per year in 2000, will reach 18 billion m^3 by 2030 (Ministry of Development, 2018). The world's water systems are severely threatened by unsustainable management and climate change. The problem of climate change is exacerbated by the consequences of increasing floods and droughts, changing rainfall patterns, and rising sea levels (World Resources Institute, 2022). As most of the water used in cities cannot safely return to nature, groundwater and surface water resources are diminishing. As the economic value of clean water resources increases in urban and industrial use, wastewater is increasingly becoming a cost-effective and reliable alternative (Çakmakçı and Şahin, 2020).Water reuse in urban areas is now the first and most sought-after strategy for wastewater resource sustainability. The sustainability of water use in landscapes mainly depends on the reduction of consumption, collection and reuse of water (Amr et al., 2016). One way to increase water use efficiency in urban landscapes is to provide plants with the amount of water they need to maintain their healthy and aesthetic appearance (Nouri et al., 2013). Depending on the morphological and physiological structure of the plant, the amount of water to be consumed and the amount of irrigation water to be supplied to the plant differ. Since the amount of water consumed by each plant is different, the water consumption of the plants should be determined (Jensen, 1968). Proper pre-planning of factors such as the amount of water used by the plant, the amount of irrigation water to be applied, the duration of irrigation and the timing of irrigation are also indispensable prerequisites for the success of irrigation applications (İşbilir and Erdem, 2012). It is common practice to estimate the water consumption of crops. However, suitable methods for estimating the water requirements of urban landscapes are lacking in many respects (Nouri et al., 2012).

2. Materials and Methods

The Balkan campus of Trakya University, located at 41°38'19.3 "N and 26°36'58.1'Ein the central district of Edirne province, Turkey, was selected as the study area (*Figure 1*).

Figure 1. The study area location and out of scope areas (Source(s): Created by authors)

It covers an area of about 2.260 ha. There is currently no campus-wide application for water harvesting and recycling. The municipal water supply provides the water used in the buildings. Water for irrigation of the green areas is obtained from wells and from the municipal water supply. There are 15 wells on campus, of which 9 are active, 3 have collapsed and 3 are being rebuilt.

The irrigation, maintenance and water costs of the plants located within the boundaries of the dormitories were excluded from the study as they do not belong to Trakya University. In some areas within the campus, the necessary access for species identification was not possible due to dense shrub and tree cover. The areas outside the scope of application make up around 4% of the campus. The identification of plant species and the number of plants were determined as part of the landscaping.

The study was conducted in two phases. The amount of rainwater use on campus and the water consumption of landscape plants were calculated (*Figure 2*).

The "Rational Method" was used as a method to calculate the amount of rainwater on campus using Equation 1 (Awawdeh et al., 2012). The rational method provides good results up to 1-1.5 km^2 and can be applied in catchments up to 5 km^2 (İstanbulluoğlu, 2015; Official Gazette, 2017). This method was applied because the study area covers an area of 2.3 km^2.The calculations were performed specifically for the materials (surface types) used on campus.

$$V = Sum\ (R * A * RC)/1000 \qquad \text{(Eq.1)}$$

V: The rainwater yield in m^3 per year, R: The quantity of precipitation in liters per square millimeters (mm), A: The collecting area in square meters (m^2), RC: The efficiency coefficient in %, 1000 represents the conversion factor from mm to m. A hydraulic filter efficiency of 0.9 is achieved as a rule with filter systems that are maintained on a regular basis. Therefore, the total amount of water is multiplied by the coefficient of 0.9 (DeutschesInstitutfürNormunge.V., 2001).

The area calculations by material type are brick, 25.286; metal, 80.009; shingles, 23.061; glass, 528; concrete, 199.100; asphalt, 70.164; green areas, 884.328; and wooded areas, 196.526 m^2. The accepted yield coefficients are brick (0.8), metal (0.75), shingle (0.75), glass (0.9), concrete (0.7), asphalt (0.8), landscape (0.05), intensive woodland (0.1) and cultivated land (0.72) (DeutschesInstitutfürNormunge.V., 2001; Doğangönül and Doğangönül, 2009; Pande and Telang, 2014; Ramachandra et al., 2014; Bektaş et al., 2017).

Methods for estimating climate data are used to calculate the water requirements of crops. Among them, there are various equations such as the Blaney-Criddle Method, Radiation Method, the Penmann-Monteith Method, the Hargreaves-Samani Equation, Pan Evaporation Method (Smith et al., 1996; Kaya, 2011; Taş and Kırnak, 2011; Orta, 2017). These methods make the calculations dependent on many parameters, such as temperature, humidity, wind, precipitation, solar radiation, sunshine duration, length of daylight hours, soil type, soil moisture, plant type, plant growth stage, etc. Many studies have shown that the Penman-Monteith equation is the best method for determining plant water use based on climatic data (Smith et al., 1996; Allen et al., 1998; Kaya, 2011; Bayramoğlu, 2013). The CropWat 8.0 software was developed by the Food and Agriculture Organization of the United Nations (FAO) based on the Penman-Monteith method to perform these calculations in a computer environment.

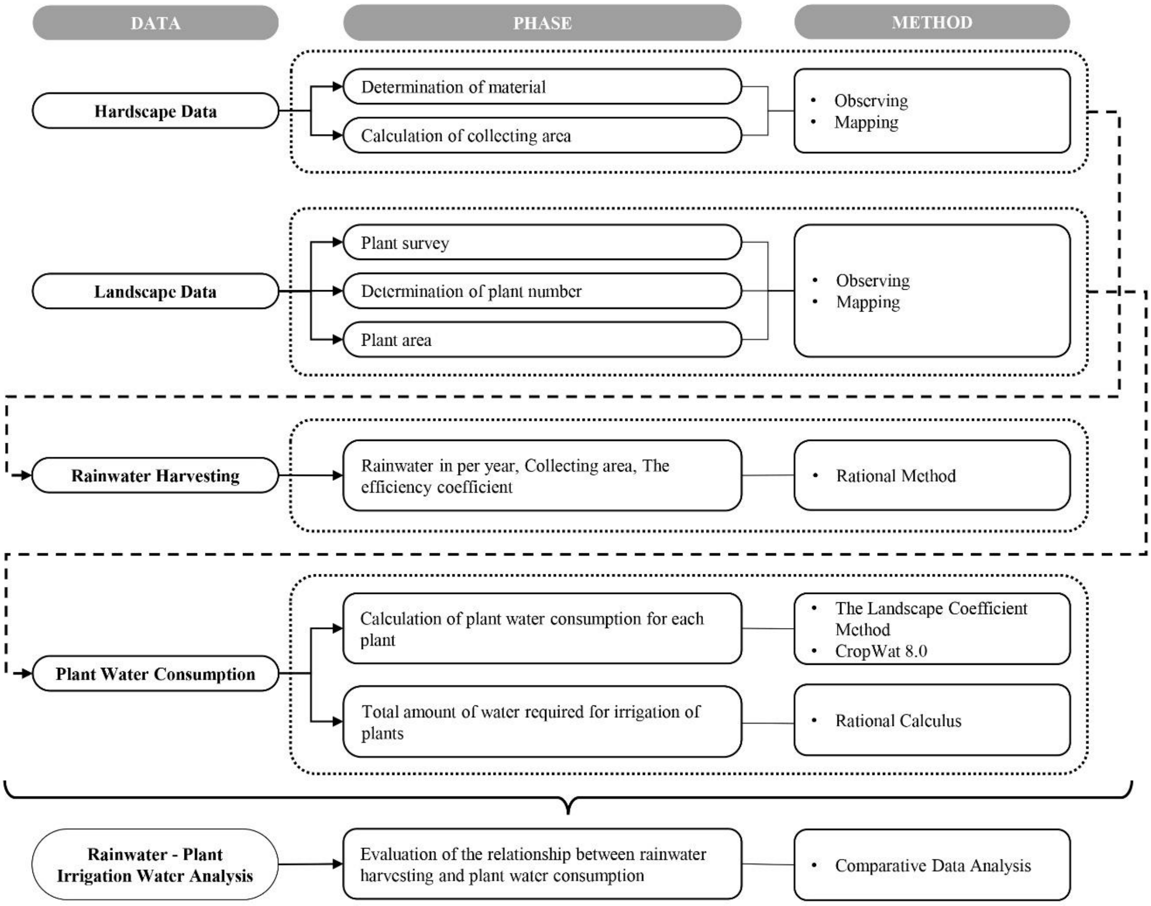

Figure 2. Research framework

In this study, the programme CropWat 8.0 is used to calculate the water consumption of plants. Within the programme, various data under 4 main headings are used: Climate, Precipitation, Plant and Soil. Summer temperatures are above 22 °C (Turkey State Meteorological Service, 2016). According to measurements taken between 1930-2021, the average annual temperature in Edirne province is 13.7 °C and the average annual precipitation is 604.4 mm (Turkey State Meteorological Service, 2022). The plant-related part of the programme includes values for kc (crop coefficient), plant growth stages and root depth. The kc value is specific to each plant and is defined as the ratio of the plant's water consumption to the water consumption of the reference plant. In other words, it is expressed as the plant's tolerance to drought. However, kc values have not been determined for plants used in the landscape (except for some grass species) (Orta, 2017). It is based on “The Landscape Coefficient Method” of the “University of California Cooperative Extension California Department of Water Resources” in California, USA (Costello et al., 2000). The use of the same method in many publications was found in the literature search (Hilaire, et al, 2008; Dayani et al., 2017; Li et al., 2017; Strbac et al., 2017; Pérez-Urrestarazu et al., 2018; Rana et al., 2019). In this study, the kc value is expressed by KL (The Landscape Coefficient). The KL value was associated with three factors. These are: Plant species (k_S), density (k_D) and microclimate (k_{MC}) (*Table 1*).

The calculation is made from the Equation 2;

$$KL = k_s * k_D * k_{MC} \quad \text{(Eq2).}$$

Table 1. Value ranges for plant species, density and microclimate (Costello et al., 2000)

	High	Medium	Low	Very Low
Plant species (k_S)	0.7-0.9	0.4-0.6	0.1-0.3	<0.1
Density (k_D)	1.1-1.3	1.0	0.5-0.9	
Microclimate (k_{MC})	1.1-1.4	1.0	0.5-0.9	

The value ranges for plant species, density and microclimate are based on another study. In this study, plant climate zones were defined. The climate zones are categorised according to the average temperatures (winter minimum, summer maximum, daily above, daily below) and average precipitation in the provinces within the California region (Perry, 2010). The closest plant zone for Edirne was determined based on the closest winter minimum, summer maximum and average rainfall in the list.

The KL values of the plants "*Aesculus hippocastanum, Cydonia oblonga, Laurocerasus officinalis*", which are not included in "The Landscape Coefficient Method", were determined as 0.6 based on Pittinger (Pittenger, 2014).

The values of the effective root depth are used for the root depth in the plant area of the programme. The effective rooting depth is defined as the depth at which the plants receive 80 % of the water required for their normal development. In general, plants take up a large part of the water they need from the upper parts of the root zone. For this reason, moistening the effective root zone instead of moistening the entire root depth can save considerable water during irrigation. The effective root depth can be 30 cm for grass plants, 45 cm for shrub plants and 60-90 cm for tree plants (Orta, 2017).

It was determined that the Balkan settlement is in the non-calcareous brown earth and the deep group within the large soil groups and depth maps of Edirne. For the soil part of the programme, the soil data developed by the FAO was used for the most important soil groups. For the total area covered by the plants on the campus, the spread of each plant was first listed. Based on the spread, the area (m^2) covered by a plant was calculated for each plant. The area covered by a plant was multiplied by the number of plants on the campus and the total area covered by the plants was calculated based on the species.

3. Results and Discussion

It is assumed that a total of 548.776 m^3year of rainwater can be harvested on the campus. Considering that not all water can be captured on the site and that 90 % of the flowing water is retained, the total amount of rainwater on the Balkan campus of Trakya University was calculated to be 494.000 m^3year.

After calculating the area each plant occupies on the campus, the water consumption of the plants was calculated based on the length of the four growing seasons of the plant. It indicates the total length of the growing period between the last frost and the first frost date for perennial plants. The total duration is divided into four development periods. If we calculate this period between March 1 and November 1 under Edirne conditions, it is determined as 8*30 = 240 days. The water consumption of the plants was calculated over 240 days. The water consumption amounts calculated in 1m^2 were determined with CropWat 8.0. The total water quantities were calculated by comparing the water consumption quantities calculated per 1m^2 with the total areas they cover on the campus. The total amount of water used by all plants was determined to be 54.530 m^3.

4. Conclusions

Structural surfacing materials such as tile, metal, shingles, glass, concrete, and asphalt, along with landscape features like trees, shrubs, and soil have been found to build up on the campus. The amount of rainwater that needs to be harvested for each of these materials totals 494.000 m^3year. 16 species of conifers, 43 species of deciduous broadleaf trees, 16 species of evergreen broadleaf shrubs, 16 species of deciduous broadleaf shrubs, 3 species of coniferous shrubs were identified. The values of the landscape coefficient (KL) of these plants were 0.098, 0.5 and 1.2. Based on these coefficients, the water consumption of the plants was classified as low (0.098), moderate (0.5) and high (1.2). Water consumption for plants with low water requirements was 70.3 mm per square meter, while moderate water-use plants require 351.3-421.6 mm, and the high water – use plants require approximately 843.2 mm per square meter (*Table 2*).

Table 2. Water consumption of the plant

Conifers (Trees)							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread (m)**	**Spread withinthecampus (m^2)**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
Cedrusatlantica(Endl.) ManettiexCarr.	162	0.5	Moderate	6	4374	351.3	1536.6
Cedrusdeodora(Roxb. exLamb.) G.Don.	1	0.5	Moderate	8	48	351.3	16.9
*Cedruslibani*A.Rich.	46	0.5	Moderate	8	2208	351.3	775.7
*Cupressusarizonica*Greene	133	0.098	Low	4	1596	70.3	112.2
*Cupressusmacrocarpa*Harw. ex Gordoncv. “Goldcrest”	46	0.5	Moderate	5	863	351.3	303.0
*Cupressussempervirens*L.	245	0.5	Moderate	6	6615	351.3	2323.8
Cupressussempervirens(O. Tarz.Tozz.) Nymancv.“Pyramidalis”	46	0.5	Moderate	2	138	351.3	48.5
*Cupressocyparis x leylandii*A.B.Jacks. &Dallim.	62	0.5	Moderate	4	744	351.3	261.4
Piceaorientalis(L.) Peterm.	5	0.5	Moderate	6	135	351.3	47.4
*Piceapungens*Engelm.cv. “Glauca”	15	0.5	Moderate	3	101	351.3	35.6
*Pinusbrutia*Ten.	10	0.098	Low	10	750	70.3	52.7
*Pinusnigra*Arnold. subsp. pallasiana (Lamb.) Holmboe.	204	0.5	Moderate	10	15300	351.3	5374.9
*Pinuspinea*L.	75	0.098	Low	15	12656	70.3	889.7
Platycladusorientalis(L.) Franco. cv.“Aurea”	125	0.5	Moderate	2	375	351.3	131.7
Platycladusorientalis(L.) Franco.	1	0.5	Moderate	4	12	351.3	4.2
*Taxusbaccata*L.	2	0.5	Moderate	12	216	351.3	75.9
DeciduousBroad-leavedTrees							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
*Acer negundo*L.	174	0.5	Moderate	6	4698	351.3	1650.4
*Acer palmatum*Thunb.cv. “Atropurpureum”	2	0.5	Moderate	2	6	351.3	2.1
*Acer platanoides*L.	116	0.5	Moderate	10	8700	351.3	3056.3
*Acer pseudoplatanus*L.	2	0.5	Moderate	8	96	351.3	33.7
*Aesculushippocastanum*L.	49	0.6	Moderate	15	8269	421.6	3486.1
*Catalpabignonioides*Walter	29	0,5	Moderate	6	783	351.3	275.1
*Cercissiliquastrum*L.	27	0.5	Moderate	4	324	351.3	113.8
*Cercissiliquastrum*L.cv. “Album”	1	0.5	Moderate	4	12	351.3	4.2
*Cydoniaoblonga*Mill.	33	0.6	Moderate	3	223	421.6	93.9
*Elaeagnusangustifolia*L.	8	0.098	Low	6	216	70.3	15.2
*Ficuscarica*L.	6	0.5	Moderate	6	162	351.3	56.9
*Fraxinusangustifolia*Vahl.	15	0.5	Moderate	10	1125	351.3	395.2
*Fraxinusexcelsior*L.	131	0.5	Moderate	15	22106	351.3	7765.9

Table 2. Water consumption of the plant (continued)

*Gleditsiatriacanthos*L.	14	0.098	Low	6	378	70.3	26.6
*Juglansregia*L.	99	0.5	Moderate	15	16706	351.3	5868.9
*Lagerstromiaindica*L.	24	0.098	Low	3	162	70.3	11.4
*Magnoliavirginiana*L.	1	0.5	Moderate	3	7	351.3	2.4
Malus x domestica Borkh.	99	0.5	Moderate	4	1188	351.3	417.3
*Malusfloribunda*Siebold. ex Van Houtte.	2	0.5	Moderate	3	14	351.3	4.7
*Meliaazedarach*L.	3	0.098	Low	4	36	70.3	2.5
*Morusalba*L.	33	0.5	Moderate	6	891	351.3	313.0
*Morusalba*L. cv. "Pendula"	7	0.5	Moderate	2	21	351.3	7.4
Paulowniatomentosa(Thunb .) Britton.	3	1.2	High	8	144	843.2	121.4
*Platanusorientalis*L.	127	0.5	Moderate	15	21431	351.3	7528.8
*Populusalba*L.	4	0.5	Moderate	10	300	351.3	105.4
Populustremula L.	13	0.5	Moderate	10	975	351.3	342.5
*Prunus armeniaca*L.	30	0.5	Moderate	4	360	351.3	126.5
*Prunus avium*L.	27	0.5	Moderate	4	324	351.3	113.8
*Prunus cerasifera*Ehrh.	29	0.5	Moderate	3	196	351.3	68.8
*Prunus cerasus*L.	1	0.5	Moderate	3	7	351.3	2.4
Prunus x domestica L.	10	0.5	Moderate	4	120	351.3	42.2
*Prunus amygdalus*Batsch	332	0.5	Moderate	4	24	351.3	8.4
Prunus persica(L.) Batsch	2	0.5	Moderate	4	396	351.3	139.1
*Pyruscommunis*L.	33	0.5	Moderate	8	1392	70.3	97.9
Robiniapseudoacacia L.	29	0.098	Low	8	48	843.2	40.5
*Salixalba*L.	1	1.2	High	8	1200	843.2	1011.8
Salixbabylonica L.	25	1.2	High	2	3	843.2	2.5
*Salixcaprea*L.	1	1.2	High	8	864	70.3	60.7
*Sophorajaponica*L.	18	0.098	Low	3	7	351.3	2.4
Sorbus domestica L.	1	0.5	Moderate	8	288	351.3	101.2
*Ulmuscampestris*L.	6	0.5	Moderate	10	20175	351.3	7087.5
*Tiliatomentosa*Moench	269	0.5	Moderate	10	150	351.3	52.7
*Quercus alba*L.	2	0.5	Moderate	10	2775	351.3	974.9
EvergreenBroad-leavedShrubs							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
Abelia x grandiflora(RovelliexAndré) Rehder	3	0.5	Moderate	1	2	351.3	0.8
*Buxussempervirens*L.	44	0.5	Moderate	3	297	351.3	104.3
*Cotoneasterhorizontalis*Decne.	60	0.098	Low	1	45	70.3	3.2
*Euonymusjaponica*L.cv. "Aurea"	79	0.098	Low	1	59	70.3	4.2
*Euonymusjaponicus*H. Jaegercv. "Microphyllus"	15	0.098	Low	0.5	3	70.3	0.2
*Laurusnobilis*L.	2	0.098	Low	3	14	70.3	0.9
*Lavandulaangustifolia*Mill.	46	0.098	Low	0.5	9	70.3	0.6

Table 2. Water consumption of the plant (continued)

*Lupustumvulgare*L.	103	0.098	Low	3	695	70.3	48.9
*Mahoniaaquifolium*Nutt.	14	0.5	Moderate	1	11	351.3	3.7
*Photinia x fraseri*Dresscv. "RedRobin"	91	0.5	Moderate	3	614	351.3	215.8
Pittosporumtobira(Thunb.) Ait.	1	0.5	Moderate	2	3	351.3	1.1
*Pyracanthacoccinea*M. J. Roemer	72	0.098	Low	2	216	70.3	15.2
Spirea x vanhouetti(Briot) Zab.	182	0.5	Moderate	2	546	351.3	191.8
*Viburnumtinus*L.	45	0.5	Moderate	2	135	351.3	47.4
*Yuccafilamentosa*L.	12	0.098	Low	0.5	2	70.3	0.2
DeciduousBroad-leavedShrubs							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
*Berberisthunbergii*DC. cv. "Atropurpurea"	54	0.098	Low	1	41	70.3	2.8
Chaenomelesjaponica(Thunb.) Lindl. &Spach	1	0.098	Low	1.5	2	70.3	0.1
*Cornusalba*L.	12	0.5	Moderate	1	10	351.3	3.4
Cornus mas L.	1	0.5	Moderate	1	35	70.3	2.5
*Forsythia x intermedia*Zabel	47	0.098	Low	1	15	351.3	5.3
*Hibiscussyriacus*L.	20	0.5	Moderate	3	95	70.3	6.6
Hydrangeamacrophylla(Thunb.) Ser.	14	0.098	Low	1	16	351.3	5.5
Kerriajaponica(L.) DC.	21	0.5	Moderate	1	2	351.3	0.8
*Loniceraetrusca*Santi	3	0.5	Moderate	1	411	351.3	144.4
*Rosa*sp. L.	548	0.5	Moderate	2	39	351.3	13.7
*Philadelphuscoronarius*L.	13	0.5	Moderate	1.5	19	70.3	1.3
Symphoricarposorbiculatus Moench	11	0.098	Low	2	9	70.3	0.6
*Syringavulgaris*L.	3	0.098	Low	2.5	56	70.3	4.0
*Tamarixtetrandra*PallasexBieb.	12	0.098	Low	2	132	351.3	46.4
*Viburnumopulus*L.	44	0.5	Moderate	1	1	351.3	0.3
Conifers (Shrubs)							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
*Juniperuscommunis*L.	24	0.098	Low	2	72	70.3	5.1
*Junıperushorizontalis*Moench.	113	0.098	Low	2	342	70.3	24.0
*Juniperussabina*L.	2	0.098	Low	1	2	70.3	0.1

To use the rainwater collected throughout the campus for watering the plants, storage areas are required. The design of storage areas can be accomplished by installing tanks of appropriate size and materials. Methods for determining tank volume based on different variables can include applications such as 5% of average annual rainfall, 14 to 30-day rainwater demand for toilet flushing, water consumption for garden irrigation in a 3-month period, and 1 m^3 tank per 25 m^2 of roof area (Madzia, 2019). To determine the size of the rainwater storage tank, calculations should be made based on different variables such as collection area, number of users, rainfall data, amount of rainwater collected, amount of water required, calculation of daily water consumption, budget, etc. (ESCAP, 2013; Okoye et al., 2015). Depending on these variables, storage areas of between 25.000 and 30.000 m^3 can be created.

Apart from this, rain garden proposals can be made to reintroduce the remaining rainwater back into the natural cycle with on-site solutions after it has been stored on campus. In this way, the need for tap water and groundwater for irrigation is reduced or eliminated. Rainwater is also incorporated into the natural cycle by using it efficiently instead of generating surface runoff. At the same time, flooding and encroachment that can occur in impermeable urban areas is prevented. By revealing the water requirements of plants, one can also contribute to effective water use by creating designs with plants that require less water in the vegetative design phase. Plants such as *Acer campestre* L., *Artemisia vulgaris* L., *Cercis siliquastrum* L., *Chrysanthemum segetum* L., *Festuca glauca* Lam., *Forsythia x intermedia* Zabel, *Gaura lindheimeri*Engelm. & Gray, *Iris pseudacorus* L., *Lagerstroemia indica* L., *Lavandula angustifolia* Mill., *Melia azedarach* L., *Ophiopogon japonicus* Thunb., *Ophiopogon japonicus* Thunb., *Populus nigra* L., *Rosmarinus officinalis* L. have low, medium, low-medium water requirements and can be used in landscape areas and rain gardens.Although the water requirements of plants vary depending on data such as climate and location, it is important to determine them on a plant-specific basis. In Turkey, there is no comprehensive study dealing with the water requirements of plants except for grass species. This study provides a basis for other studies as it shows the plant-specific plant coefficients (KL) and water consumption.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Mısırlı, N., Şişman, E. E.; Data Collection or Processing: Mısırlı, N., Şişman, E. E.; Statistical Analyses: Mısırlı, N., Şişman, E. E.; Literature Search: Mısırlı, N.; Writing, Review and Editing: Mısırlı, N., Şişman, E. E.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Detection and Identification of Wheat Pest *Chaetopteroplia segetum* (Coleoptera: Scarabaeidae)

Buğday Zararlısı *Chaetopteroplia segetum* (Coleoptera: Scarabaeidae)'un Tespiti ve Tanımlanması

Refika Ceyda BERAM[1], Nurzhan TASHIGUL[2], Alime BAYINDIR EROL[3*]

Abstract

Anisopliines are an important group of insects associated with both cultivated plants and wild weeds. *Chaetopteroplia segetum* (Herbst, 1783) (Coleoptera: Scarabaeidae), although preferring natural plants, can cause significant damage to agricultural crops such as wheat, rye, and corn, posing a major threat to agricultural fields. This species is widely distributed across Europe and Asia, and *C. segetum* has been reported in several provinces in Türkiye. However, despite its extensive geographical range, the phylogenetic relationships within the Scarabaeidae family remain poorly understood. This study aimed to detect, identify, and investigate the phylogenetic relationships of this wheat pest across various agricultural fields in the Çivril district of Denizli province, Türkiye. The surveys were systematically conducted between June and July 2023, with monthly sample collections carried out at predetermined locations within twelve different fields. The collected samples were morphologically characterized, and the morphological identification was further confirmed through molecular analysis of representative samples from each field. After DNA isolation, a partial fragment of the cytochrome oxidase I (COI) gene was amplified using universal barcode primers LCO1490F and HCO2198R. BLAST analysis revealed that all collected individuals exhibited 99%–100% similarity with previously reported *C. segetum* sequences. Furthermore, a phylogenetic tree was constructed using the neighbor-joining method with MEGA X software, based on COI gene region data, to elucidate the relationships among the individuals. Currently, there is limited information on the molecular classification of the Scarabaeidae family in Türkiye. The findings of this study contribute to bridging this gap by providing a foundation for future molecular research aimed at better understanding the genetic structure and phylogenetic relationships within this family.

Keywords: *Chaetopteroplia segetum*, Wheat, COI, DNA barcoding, Türkiye

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Öz

Anisopliines, hem kültür bitkileri hem de yabani otlarla ilişkili önemli bir böcek grubunu oluşturur. *Chaetopteroplia segetum* (Herbst, 1783) (Coleoptera: Scarabaeidae), doğal bitkileri tercih etmesine rağmen, buğday, çavdar ve mısır gibi tarım ürünlerine önemli zararlar verebilen bir türdür ve bu özelliğiyle tarım alanlarında büyük bir tehdit oluşturmaktadır. Bu tür, geniş coğrafi yayılımı ile Avrupa ve Asya'da yaygın olarak bulunmakta olup, Türkiye'de de birçok ilde *C. segetum* örneklerine rastlanmıştır. Ancak, bu türün Scarabaeidae ailesindeki filogenetik ilişkileri henüz yeterince incelenmemiştir. Bu çalışmanın amacı, Türkiye'nin Denizli ilinin Çivril ilçesinde yer alan farklı tarım alanlarında buğday zararlısı olarak görülen *C. segetum*'u tespit etmek, tanımlamak ve filogenetik ilişkilerini araştırmaktır. Haziran ve Temmuz 2023 tarihleri arasında yapılan sörveyler, on iki farklı alandan sistematik bir şekilde gerçekleştirilmiş olup, önceden belirlenen noktalardan aylık örneklem toplama işlemi yapılmıştır. Toplanan örnekler, morfolojik olarak detaylı bir şekilde karakterize edilmiş ve morfolojik tanımlamalar, her bir alandan seçilen temsilci örneklerin moleküler analizleriyle doğrulanmıştır. DNA izolasyonu sonrası, LCO1490F ve HCO2198R evrensel barkod primerleri kullanılarak mitokondriyal DNA'nın sitokrom oksidaz I (COI) gen bölgesinin bir kısmı çoğaltılmıştır. Elde edilen veriler, BLAST analizi ile toplanan tüm bireylerin, daha önce bildirilen *C. segetum* dizileriyle %99–100 benzerlik gösterdiğini ortaya koymuştur. Ayrıca, COI gen bölgesine dayalı olarak, bireyler arasındaki filogenetik ilişkileri göstermek amacıyla MEGA X yazılımı ile neighbor-joining yöntemiyle bir filogenetik ağaç oluşturulmuştur. Türkiye'de Scarabaeidae ailesinin moleküler sınıflandırmasına dair mevcut veriler sınırlı olduğundan, bu çalışma, bu aileye ait genetik yapı ve filogenetik ilişkilerin daha iyi anlaşılmasına yönelik gelecekteki moleküler araştırmalara önemli bir temel oluşturmaktadır.

Anahtar Kelimeler: *Chaetopteroplia segetum*, buğday, COI, DNA barkodlama, Türkiye

1. Introduction

The subtribe Anisopliina (Scarabaeidae: Rutelinae: Anomalini) are distributed across the Palaearctic, Oriental, Ethiopian, Nearctic, and Neotropical biogeographical regions. Anisopliina species are associated with both cultivated and wild grasses. As adults, they feed on grass pollen or immature grass seeds, while the larvae feed on grass roots. Members of this subtribe are characterized by an elongated and recurved clypeal apex, a feature that allows adults to extract and consume pollen-loaded grass anthers (Mico et al., 2001; Jameson et al., 2007). According to current classifications (Machatschke, 1972; Potts, 1974; Baraud, 1992), the subtribe Anisopliina comprises nine genera and approximately 100 species distributed across the World: *Anisoplia* Schönherr, *Anthoplia* Medvedev, *Anomalacra* Casey, *Brancoplia* Baraud, *Callirhinus* Blanchard, *Chaetopteroplia* Medvedev, *Hemichaetoplia* Baraud, *Rhinyptia* Burmeister, and *Tropiorhynchus* Blanchard (Jameson et al., 2007).

The genus *Chaetopteroplia*, revised by Baraud (1986), encompasses twelve species (Jameson et al., 2007). While *Chaetopteroplia segetum* (Herbst, 1783) prefers non-cultivated plants (Hurpin, 1962), it poses a significant threat to various crops, including wheat, rye, and corn (Jameson et al., 2007). *C. segetum* has been reported in several provinces across Türkiye: Mardin and Malatya (Sert and Özdemir, 2019), Tekirdağ (Altın and Özder, 2020), and Van (Özgökçe et al., 2024). A study conducted in Van identified *C. segetum* as the most prevalent and densely populated species (Özgökçe et al., 2024). The subspecies *C. segetum velutina* exhibits a wide distribution throughout Türkiye and is commonly observed in provinces such as Afyon, Ağrı, Antalya, Balıkesir, Bursa, Çanakkale, Çorlu, Denizli, Edirne, Erzurum, Eskişehir, İzmir, Kars, Konya, Manisa, Muğla, Ordu, Sivas, Tekirdağ (Lodos et al., 1978; Rozner and Rozner, 2009), Eskişehir (Küçükkaykı et al., 2013), Adana, Afyon, Ankara, Antalya, Artvin, Bitlis, Erzincan, Erzurum, Hatay, Iğdır, Kars, Konya, Mersin, Rize, Trabzon (Polat et al., 2018). The global distribution of *C. segetum* extends across Europe (including Greece, Rhodes, and Ukraine) and Asia (Crimea, Türkiye) (Löbl and Smetana, 2006). Despite its extensive range, the phylogeny within the Scarabaeidae family remains poorly characterized. It is recognized that the Scarabaeid lineage is exclusively confined within the Scarabaeidae family (Bell et al., 2004; Philips et al., 2004).

In this study, primary objective was to detect and identify the pests belonging to the *C. segetum* that have invaded wheat fields in the Denizli province of Türkiye. This purpose, we collected samples from 12 different wheat fields, focusing on specimens suspected of causing damage to wheat crops. The collected samples underwent comprehensive morphological characterization studies, and a representative sample from each field was subjected to detailed molecular characterization. In line with this study that molecular characterization studies on these specific species are scarce both globally and within Türkiye. Furthermore, our thorough literature review did not reveal any previous studies in Türkiye that molecularly characterized this particular insect. In light of this, our study not only contributes to the understanding of the molecular profile of *C. segetum* but also addresses a notable gap in existing research. By explaining the molecular characterization steps used in the study, it will be easier for researchers working in this field. The comprehensive data obtained from our research not only lays the groundwork for future investigations on *C. segetum* but also furnishes critical insights for the development of effective pest control strategies tailored to the unique characteristics of this species.

2. Materials and Methods

2.1. The Study Site and Sampling

Surveys were systematically conducted in June and July 2023, encompassing 12 distinct wheat fields situated in the Çivril district of Denizli province, southwestern Türkiye. (*Table 1*). Sampling was executed randomly, targeting various wheat plants within each site. A standard sweep net with a diameter of 35 cm was used for sample collection. A substantial number of collected samples were subsequently preserved in 99.5% alcohol for conservation until employed in molecular analyses. Samples of the pest species from every location were meticulously labeled and stored at –20°C, awaiting utilization in the experimental phases for molecular diagnosis. The geographical coordinates of all sampled fields were precisely determined using GPS technology and are presented in *Table 1*.

Table 1. Wheat fields where samples were collected for the study in the Denizli, Türkiye

Sampling area no	Wheat fields	Coordinates
1	Yakacık	N: 38º 28.42´3´´ E: 29º 68.84´3´´
2	Ömerköy 1	N: 38º 27.39´0´´ E: 29º 76.34´7´´
3	Emircik	N: 38º 29.11´3´´ E: 29º 79.91´6´´
4	İnceköy	N: 38º24.74´8´´ E: 29 º78.38´9´´
5	Karamanlı	N: 38º 25.38´2´´ E: 29º 82.07´3´´
6	Yalınlı	N: 38º 24.17´2´´ E: 29º 82.23´4´´
7	Menteş	N: 38º 27.50´7´´ E: 29º 71.87´8´´
8	Balçıkhisar	N: 38º 29.82´3´´ E: 29º 80.07´6´´
9	Seraserli	N: 38º 23.07´2´´ E: 29º 80.95´6´´
10	Yakasomak	N: 38º 29.71´2´´ E: 29º 72.75´4´´
11	Kızılcasöğüt	N: 38º 28.28´3´´ E: 29º 74.01´9´´
12	Ömerköy 2	N: 38º 27.39´0´´ E: 29º76.34´7´´

2.2. Identification of the Samples

2.2.1. Morphological Characterization

Chaetopteroplia segetum mature individuals are 9-13 mm in length, with a width of 6-9 mm, displaying a broad and oval-shaped body. The head and pronotum are densely covered with yellowish hairs, while the brownish elytra exhibit a sparser distribution of these hairs (*Figure 1*). Additionally, it has been reported that males have longer antennae and thickened front claws, whereas females have a paler coloration on their elytra (Machatschke, 1961).

Figure 1. Chaetopteroplia segetum adult form

2.2.2. Molecular Characterization

To confirm the morphological identification, COI gene region of rDNA was analyzed from 12 representative samples from each fields.

2.2.2.1. DNA Extraction

The total genomic DNA was extracted from the right hind legs of insects using the High Pure PCR Template Preparation Kit (Roche), following the manufacturer's instructions. The insect legs were washed with pure water and then left in the laminar box for 1 hour to dry. Subsequently, the dried insect legs were kept in the freezer at a temperature of -80°C for 15 minutes. Following these procedures, the washed and dried legs were transferred to an Eppendorf tube and thoroughly crushed with a sterile tube. All final DNA products were suspended in a 70 µL elution buffer and stored at -20°C until PCR amplification.

2.2.2.2. PCR Amplification

The partial fragment of cytochrome oxidase I (COI) gene of mtDNA was amplified using the universal barcode primers LCO1490F, 5’GGTCAACAAATCATAAAGATATTGG3’ and HCO2198R, 5’ TAAACTTCAGGCTGACCAAAAAATCA 3’of (Folmer et al., 1994). PCR reactions were performed with Xpert Fast Hotstart Mastermix (Grisp, Portugal), according to the company’s protocol instructions. Each reaction mixture for PCR with a volume of 25 µL contained 12.5 µL Master Mix (Xpert Fast Hotstart Mastermix, Grisp), 3 ml of DNA matrix, 1 µL for word primer, 1 µL of reverse primer and distilled water up to 25 µL. Negative controls were used in every PCR reaction by adding all reagents except genomic DNA. PCR was carried out using a Kyratec PCR Cycler with the following settings: 3 min at 95°C; followed by five cycles of 15 s at 94°C, 15 s at 50°C, and 1 min at 72°C; followed by a further 35 cycles a final extension of 10 min at 72°C. The quality of the PCR products was examined by electrophoresing the samples on 1.5% agarose gels and TBE buffer and staining with the Xpert Green DNA Stain (Grisp).

2.2.2.3. Sequence Analyses

The amplification products obtained through PCR were submitted for sequencing at BMLabosis in Ankara. The nucleotide sequences obtained from the PCR products were subjected to a meticulous search in the GenBank database at the National Biotechnology Information Center (NCBI). Alignment of the identified sequences, as well as selected outgroup sequences retrieved from the NCBI database, was accomplished using BioEdit version 7.2.6 software. A sequence similarity search was performed using NCBI-BLASTn (Basic Local Alignment Search Tool), and sequences exhibiting more than 98% homology were considered as belonging to the same species.

2.2.2.4. Phylogenetic Analyses

Phylogenetic analysis of the beetle sequences was conducted using MEGA X software. The Fasta files of the sequences were aligned, and pairwise estimation was carried out employing the ClustalW tool within the MEGA X software, following default settings. The aligned sequences were then exported in Mega format. The phylogenetic analysis was performed utilizing the Neighbor-Joining Method and Kimura-2-Parameter, with 1000 bootstrap supports. Both pairwise and multiple alignments were conducted with a gap opening penalty of 15.00 and a gap extension penalty of 6.66. The entire phylogenetic analysis process was repeated 1000 times with bootstrap support to ensure robustness in the results.

3. Results and Discussion

Chaetopteroplia segetum were collected from 12 distinct wheat fields. Macroscopic examinations were conducted, focusing on external traits such as general appearance, antennal structure, legs, wings, coloration, body segmentation, and other anatomical features for initial species identification (Machatschke, 1961). Following both macroscopic and microscopic assessments, it was determined that all samples belonged to the same genus (*Chaetopteroplia segetum*). within the order Coleoptera. One representative sample from each area was subsequently chosen for further molecular characterization studies. Upon successful DNA isolation, PCR was carried out for all selected samples, resulting in visible amplified products at 600-700 bp for each of the 12 samples and a 100-bp DNA ladder was used to determine and confirm the size of the PCR products (*Figure 2*).

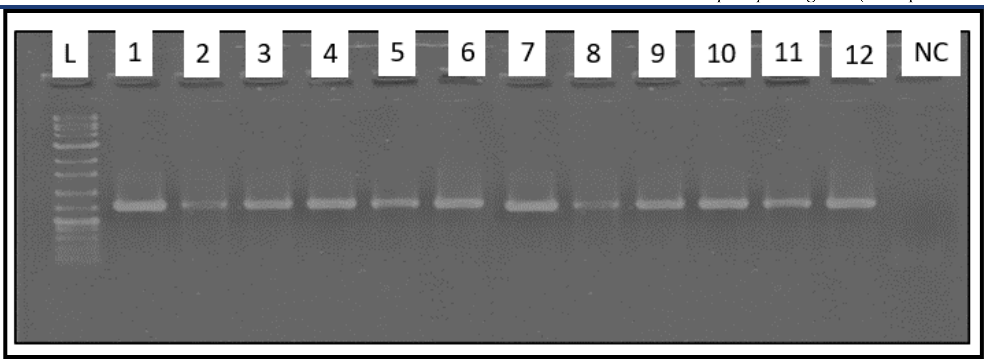

Figure 2. Polymerase Chain Reaction (PCR) bands of Chaetopteroplia segetum samples (L; DNA ladder-100 bp, NC; Negative Control)

For molecular identification, 12 representative samples from diverse wheat fields underwent sequencing. The COI sequences were subjected to BLAST analysis, validating the insect identification, exhibiting a similarity range of 98%–100% with previously documented sequences from the National Biotechnology Information Center (NCBI) for C. segetum. The COI sequences of 12 samples were deposited in GenBank (Accession Numbers; OR805470-OR807318-OR807319-OR807320-OR807321-OR807326-OR813953-OR813954-OR809195-OR809196-OR809197- PP028382).

The phylogenetic tree construction employed the neighbor-joining method through MEGA X software, utilizing data derived from the COI gene region. This approach facilitated the elucidation of intricate molecular kinship relationships among individuals, providing detailed insights through the resulting phylogenetic tree (*Figure 3*) (*Table 2*). When the phylogenetic tree created in the study was examined, *C. segetum* from the *Anisoplia austriaca* species was evaluated as an external group.

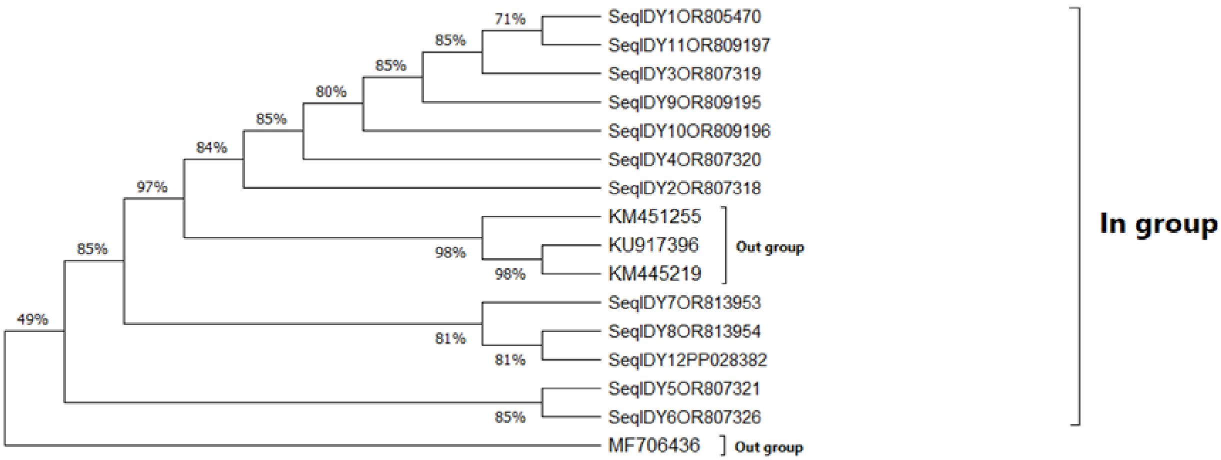

Figure 3. Neighbor-joining tree obtained as a result of phylogenetic analysis using the COI gene region

The nucleotide sequences were compared with those archived in the NCBI data bank to assess their similarities. Subsequently, a Neighbor Joining (NJ) molecular phylogenetic genealogy was constructed to analyze the sequence results of the obtained species. In the process of creating this phylogenetic tree, *C. segetum* KM451255 (Hendrich et al., 2015), KU917396 (Rulik et al., 2017), KM445219 (Hendrich et al., (2015) and *Anisoplia austriaca* MF706436 (Syromyatnikov et al., 2017), both species from the Coleoptera family, were utilized as an out group. The Bootstrap 1000 method was employed to enhance the robustness of the phylogenetic tree. The resulting optimal tree was then presented, with evolutionary distances computed using the Maximum Composite Likelihood method, expressed in units of the number of base substitutions per site. To provide additional insights, the proportion of sites where at least one unambiguous base is present in at least one sequence for each descendent clade was indicated next to each internal node in the tree. This comprehensive analysis involved a dataset comprising 16 nucleotide sequences. Ambiguities were systematically addressed by removing all ambiguous positions for each sequence pair, utilizing the pairwise deletion option. The final dataset, containing a total of 673 positions, was subjected to evolutionary analyses, which were meticulously executed using the bioinformatics software MEGA 11.

Table 2. Sequences used in phylogenetic analyzes

No	Accession no	Species	Sites
1	OR805470	*C. segetum*	Yakacık
2	OR807318	*C. segetum*	Ömerköy[1]
3	OR807319	*C. segetum*	Emircik
4	OR807320	*C. segetum*	İnciköy
5	OR807321	*C. segetum*	Karamalı
6	OR807326	*C. segetum*	Yalınlı
7	OR813953	*C. segetum*	Balçıkhisar
8	OR813954	*C. segetum*	Seraserli
9	OR809195	*C. segetum*	Yakasomak
10	OR809196	*C. segetum*	Kızılcasöğüt
11	OR809197	*C. segetum*	Menteş
12	PP028382	*C. segetum*	Ömerköy[2]
13	KM451255	*C. segetum*	Germany: Brandenburg
14	KU917396	*C. segetum*	Germany: Mecklenburg
15	KM445219	*C. segetum*	Germany: Fuerstenwalde
16	MF706436	*A. austriaca*	Russia

The results of the study highlight the efficacy of COI-based pest identification, particularly concerning beetles, as evidenced by the COI marker profile. DNA sequence data have proven instrumental in elucidating the relationships among various groups of insect species at the generic level (Murthy, 2020). Molecular sequence information obtained from NCBI has accurately portrayed the relatedness among all collected scarabaeids, consistent with their morphological characters. Our observations align with the findings reported by Blaxter (2004). Qiu et al. (2009) propose that, where sequence information is available in GenBank for morphologically defined species and can be matched with certain DNA-based clusters, close relationships can be readily identified through sequence variation in field-collected samples. These clusters are likely to correspond to previously undescribed species. Mgocheki et al. (2012) reported the utility of sequence information based on mitochondrial markers for species delineation in both adults and grubs of scarabaeids, providing insights into larval taxonomy. Our studies underscore the significance of DNA sequencing in aligning various forms of scarabs, and minimizing the risk of misdiagnosis.

To date, only limited information exists regarding a formal cladistic classification of the Scarabaeidae superfamily (Browne and Scholtz, 1995). Consequently, there is an urgent need to investigate the genetic diversity within the Scarabaeidae family (Zahoor et al., 2013). It is essential to focus on sequencing partially genomic conserved regions, such as the mitochondrial COI gene (Foottit et al., 2008; Jalalizand et al., 2012; Tayat and Özder, 2023). DNA sequencing, particularly of the mitochondrial cytochrome-c oxidase subunit 1 gene (CO1), provides a powerful tool for accurately identifying various creatures, including certain insect species, especially those with similar morphologies. The exceptional resolution of the CO1 gene makes it a valuable resource for species differentiation and exploring hidden variations among closely related species (Sharif et al., 2023).

4. Conclusions

The fact that current information on the scarabaeoid fauna in Türkiye is limited underscores the importance of research efforts in this field. In particular, the insufficient documentation of the molecular classification of the Scarabaeidae superfamily emphasizes the need for further research. Such studies focusing on genetic diversity of harmful species like *C. segetum* throughout Türkiye could significantly contribute to control strategies for these species. Furthermore, it is believed that these investigations will provide critical insights for future research and species identification. Ultimately, detailed studies utilizing methods such as molecular characterization and phylogenetic analysis could establish a crucial foundation for the conservation and management of scarabaeoid species in Türkiye and globally.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

The collection of samples: Bayındır Erol, A.; Conducting experiments: Beram, R. C. and Tashıgul, N.; Creation of the manuscript: Beram, R. C. and Tashıgul, N. and Bayındır Erol, A.

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