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Faculty of Agriculture

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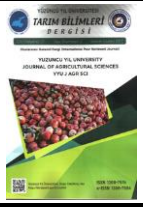

Research Article

Genetic Control and Combining Ability Effects of Certain Yield Traits in Cowpea (*Vigna unguiculata* L. (Walp)) under Conditions of Drought Stress

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Keywords
Combining ability,
Cowpea,
Drought tolerance,
Epistasis,
Genotypes,
Non-additive.

Abstract: This research was undertaken to assess genetic control and combining effects of some essential traits of yield under drought stress. Forty-two hybrids under water-stressed and well-watered conditions were tested in field experiments for two years. Evaluation of the various genetic components of variation was performed. Both the additive (D) and the dominant (H1) variance components were important in most of the traits suggesting both additive and non-additive gene effects under both conditions. The study showed that the minimum number of genes under water-stressed (WS) conditions ranged from 0.02 for pod length to 16.13 for days to 50% flowering. The narrow-sense heritability ranged from 24% for the number of pods per plant and pod length to 66% for the number of days to 50% flowering under WS condition. The impacts of SCA and GCA have been determined. In both conditions IT93K-432-1 and IT97K-499-35 showed the strongest GCA results on both of the traits. Danila×IT93K-432-1, Danilla×IT97K-499-35, and TVu7778×IT99K-573-2-1 have been observed to have the best SCA effect under both conditions for most of the traits. In most traits, additive and non-additive gene effects plus additive × additive and additive × dominance gene interactions were common. In summary, additive and non-additive gene actions were detected; however, there was a preponderance of non-additive gene action in both conditions. As a result, the enhancement of these traits would involve a repetitive selection technique as a result of the prevalence of the dominant gene effect, which would allow favorable recombination of the genes in both conditions in later generations.

Kuraklık Stresi Koşullarında Börülcede (*Vigna unguiculata* L. (Walp)) Belirli Verim Özelliklerinde Genetik kontrol ve Birleşme Yeteneğinin Etkileri

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Anahtar Kelimeler
Birleşme yeteneği,
Börülce,
Kuraklık toleransı,
Epistaz,

Öz: Bu araştırma, kuraklık stresi altında verime ait bazı temel özelliklere genetik kontrol ve uygulamaların ortak etkilerini değerlendirmek için yapılmıştır. Su stresli ve iyi sulanmış koşullar altında kırk iki hibrit, arazi deneylerinde iki yıl boyunca test edildi. Varyasyonun çeşitli genetik bileşenlerinin değerlendirilmesi yapıldı. Hem eklemeli (D) hem de baskın (H1) varyans bileşenleri, her iki koşulda da hem eklemeli hem de eklemeli olmayan gen etkilerini düşündüren özelliklerin çoğunda önemliydi. Çalışma, su stresi (WS) koşulları altında minimum gen sayısının, % 50 çiçeklenme döneminde, bakla uzunluğu için 0.02 ila 16.13 arasında değiştiğini gösterdi. Dar anlamda kalıtsallık, bitki başına bakla sayısı ve bakla uzunluğu için % 24'ten gün sayısı için % 66'ya, WS koşulunda % 50 çiçeklenmeye kadar değişmektedir. SCA ve GCA'nın etkileri belirlendi. Her iki

Genotipler,
Katkısız.

koşulda da IT93K-432-1 ve IT97K-499-35, her iki özellik üzerinde de en güçlü GCA sonuçlarını gösterdi. Danila × IT93K-432-1, Danilla × IT97K-499-35 ve TVu7778 × IT99K-573-2-1'in, özelliklerin çoğu için her iki koşulda da en iyi SCA etkisine sahip olduğu gözlemlendi. Çoğu özellikte, eklemeli ve eklemeli olmayan gen etkilerinden artı eklemeli × eklemeli ve eklemeli × baskın gen etkileşimleri yaygındı. Özetle, eklemeli ve eklemeli olmayan gen aktiviteleri tespit edildi; fakat, her iki koşulda da eklemeli olmayan gen eyleminin üstünlüğü vardı. Sonuç olarak, bu özelliklerin geliştirilmesi, baskın gen etkisinin prevalansının bir sonucu olarak her iki koşulda da genlerin sonraki nesillerde uygun şekilde yeniden birleştirilmesine izin verecek tekrarlayan bir seçim tekniğini içerecektir.

1.Introduction

Nigeria has been confirmed to be the world's highest producer of nearly 47 million metric tons of beans from an estimated 4.5 million hectares per year, making it Africa's top producer of pulses and the world's fourth-largest producer of cowpea (Daily Trust 2019, Unpublished). In Nigeria more than 60 million people consume cowpea products daily. CGIAR (Unpublished) stated that Cowpea (*Vigna unguiculata* L. (Walp)) was a protein-rich grain which supplements cereals and other tuber crops as well. It also provides livestock feed and fixes soil nitrogen to increase nutrients in the soil. It is usually grown in the African, Asian, European, United States, and Central and South American semi-arid tropics. The grains contain 25 per cent protein and other minerals and vitamins. The crop is an edible crop which has made a significant contribution to the survival of millions in both the southern and northern parts of the country (Singh et al., 1999).

The importance of Cowpea cuts across its use as the staple food and cash crop. Nearly every part of the crop is useful; grains are useful because they provide relatively poor urban communities with inexpensive and nutritious food (Singh et al., 1999). "Cowpea leaves are also found to be sold in Benin, Cameroon, Ethiopia, Ghana, Kenya, Malawi, Mali, Tanzania and Uganda" (Barret, 1987), the above-ground parts of cowpea are also harvested for fodder, except for pods, and they are also found to symbiotically fix atmospheric nitrogen by nodule bacteria (Rhizobium sp) as a vital supplement to soil fertility status (Barret, 1987).

Nevertheless, biotic and abiotic factors are the main constraints to cowpea development in Nigeria. Attaching the crop to biotic factors such as insect pests and diseases thus decreases yield (Hall and Patell, 1987; Ajeigbe HA et al., 2008). Drought is one of Nigeria’s main abiotic factors affecting cowpea development (IITA, 2000; Ishiyaku and Aliyu, 2013). However, cowpea as a plant has been recorded to be highly drought-tolerant, particularly the spreading cultivars, but under extreme drought it has suffered significantly, resulting in a substantial reduction in yield. Singh et al. (1985) and Shimelis and Shiringani (2010) reported that cowpea has a higher yield than other crops under drought stress. The irregular pattern of rainfall as a result of climate change has plunged the agricultural communities into unemployment and then famine. The water stress issue can be solved by having a practical and efficient modern irrigation network, or by breeding for genotypes that are resistant to drought. Given the high cost of introducing a modern irrigation scheme, however, breeding for drought-tolerant genotypes would be more acceptable and cheaper. Three major approaches for breeding tolerant genotypes have been suggested; the first approach is to evaluate and search for drought tolerant under optimum (non-water stress) condition for high yield varieties, expecting a high correlation between results in optimum and stress conditions (Johnson and Frey, 1967) and that varieties with higher yields under normal conditions may also perform better under water stress, but this may be influenced by genotypes, which may eventually interfere with yield. The second approach involves breeding for high yield varieties under water stress, this approach is struggling as the severity of drought is highly variable from year to year and as a result environmental selection pressure shifts from generation to generation and even low heritability will exacerbate the problem (Jiban Mitra, 2001). However, the mechanism by which plants adapted under water stress – drought escape, drought avoidance and drought tolerance – do not help high yield which is the ultimate target of breeders (Jiban Mitra, 2001), the third approach which may also serve as an alternative to the two morphological incorporations described above and agronomic and physiological function of resistance to drought in high yielding genotypes; The desired goals of evolving

high yielding drought tolerant genotypes (Ishiyaku and Aliyu, 2013) would thus be accomplished by simultaneous selections under water stressed and non-water stressed environments for yield under nonwater stressed and stability under water stressed. It will be useful to classify the correct hybrid combinations by evaluating the combination of parental ability to select drought-tolerant genotypes in cowpea in breeding programs (Hira Lal, 2009; Kadam, 2013).

Hence the purpose of this study was to understand genetic control by evaluating different genetic parameters and evaluating screened diverse drought tolerance cowpea genotypes for general and specific combining capacity of certain yield traits under drought-stressed condition.

2. Material and Methods

The experiment was performed at the Ibadan University Teaching and Research Farm. The varieties of the cowpea used are maintained by the unit of genetic resources of the International Institute for Tropical Agriculture. Genotypes are of varying resistance to drought (Table 1). In the screenhouse, ten genotypes of cowpea were evaluated using the box screening approach proposed by Singh (1991). Two seeds of each of the ten cowpea lines were planted in a pot filled with rich garden soil and then thinned two weeks after planting, to one plant per pot. The crossing block consisted of 10 mainly Latin square consisting of ten parental lines. Each column on the Latin square is a mating unit in various units with crosses between parents. Pollen from the first parent is transmitted to the second parent in each cell. The second parent's pollen is passed on to the third parent etc. From a preliminary screening experiment, crosses were selected for diallel analysis in a dialect system involving the ten parental lines, with different drought tolerances. At Teaching and Research Farm, University of Ibadan during the dry season, November to February, parental lines, 21F1, and 21RF1 hybrids were selected for evaluation in an RCBD with three replications (3 replicas for each water regime). The experiment was conducted for 2 years during the dry season from October to February of 2014/2015 and 2015/2016. Through entrance was grown 3 m long in a single row plot with a row spacing 75 cm apart and 20 cm apart within a row. Two seeds were sown per hole and subsequently thinned to one seed per hole. Upon sowing, all the plants were watered before the trifoliolate leaves appeared upon which watering on water-stressed plots was suspended. Irrigation was developed by irrigating the plots with additional water whenever necessary, while on the other plot it was kept entirely during the growing season. The soil moisture content of the parcels has also been periodically calculated. Throughout the growing season crop management has been consistent. The following agronomic characteristics were gathered at the reproductive stage, the number of days to 50 percent flowering, number of days to 50 percent ripe pod. And the following data were collected at maturity: number of pods per plant, number of seeds per pod, length of pods, 100 seed weights and total seed weight. Method 1 model II Griffing (1956), adapted for partial diallel, and was used to combine capacity analysis of the dialel crosses using F1 and RF1. Genetic variance components were measured using Hayman's formulae (1954), as shown by Askel (1963).

Descriptive statistical methods have been used to independently obtain means and variances for each system (Steel 1997). According to Griffing (1956), the genetic variation in the materials was partitioning into general combining capacity and specific combining ability.

3. Results

Table (1) showed the characteristic of cowpea parents used:

Table 1. Characteristics of the ten cowpea parents used

NO	Parent	Source	Growth Habit	Level of Drought Tolerance
1	P1	Landrace	SS	HTD
2	P2	IITA	SS	TD
3	P3	-	E	HSD
4	P4	-	E	MTD
5	P5	-	E	TD
6	P6	-	E	HTD
7	P7	-	SS	MTD
8	P8	-	E	HSD
9	P9	-	E	VMTD
10	P10	-	S	TD

P1 = Danilla, P2 = IT92KD-357-3, P3 = TVU7778, P4 = TVU12349, P5 = IT93K-432-1, P6 = IT97K-499-35, P7 = IT89KD-288, P8 = IT98K-205-8, P9 = IT98K-491-4, P10 = IT91K-513. SS = Semi Spreading, E = Erect. HTD = Highly Tolerance of Drought, TH = Tolerance of Drought, MTD = Moderately Tolerance of Drought, VMTD = Very Moderately Tolerance of Drought, HSD = Highly Susceptible of Drought.

3.1. The genetic component of variance.

Table 2 shows partial diallel mean square values for all yielding characters under water-stressed (WS) and well-watered (WW) conditions. The GCA, SCA, and RCA (General Combining Ability, Specific Combining Ability, and Reciprocal Combining Ability, respectively) were all significant for all characteristics under both conditions.

However, the values for the total seed weight property in terms of component D in Table 3 are insignificant in both conditions. In addition, the D values for the number of pods per plants (NPP) under well-watered (WW) conditions and the number of seeds per plant (NSP) under water- stress (WS) conditions are also insignificant.

The genetic components of variance (Table 3), additive (D) and dominance (H1) were very significant under both conditions, except for pod length under WS and total seed weight under WW for variance component D, but all were significant under both conditions for variance component H1. The other components of dominant variation H2 and h2 under both conditions were also important to most of the traits.

The variance variable D ranged from 72.2±16.8 for the number of pods per plant to 3.2±2.3 for the length of the pods both under WS. The H1 variance variable ranged from 914.7±120.8 for total seed weight to 14.1±1.2 for the number of seeds per pod both under the WW conditions. The Fr-component whose value indicates the proportion of dominant (+ sign) or recessive (-sign) alleles showed significant values ranging from 603.3±130.0 for total seed weight in WW condition to 4.6±5.3 for the pod length in WS condition. The calculated ratio (H1/D) 1/2 of genetic components that provide valuable information about the degree**,** order, and course of dominance ranged from 4.36 for total seed weight to 1.51 for the number of days to the first day that both flowered under WW. The ratio h2/H2 estimates the number of gene groups showing a certain dominance ranged from 6.13 for the number of days to first flowering to 0.03 for 100SW both under WS. The ratio H2/4H1 estimates the relative mean allelic frequencies for parents ranging from 1.18 for total seed weight under WS to 0.07 for 100SW under WW and the number of days for the first flowering under WS. The heritability of the narrow sense (Hns) ranged from 0.66 for the number of days to the first flowering to 0.24 for the number of pods per plant and the length of the pods under WS.

3.2. General combining ability effects

Combining ability Effects (Table 4) estimates the parents' comparative effect (GCA) and cross-combination (Table 5) (SCA) in relation to each other.

Danilla, IT92KD-357-3, TVU7778, TVU12349, IT97K-499-35, and IT89KD-288 had a relatively high GCA effect on the number of days to flower, thus appearing to possess unfavorable alleles under both conditions. IT93K-432-1, IT89KD-288, IT98K-205-8, IT98K-491-4, and IT99K-513-21 had low to negative GCA effects. The same trend has been observed for the number of days to the first ripe pod under both conditions. As for the number of pods per plant, under well-watered conditions, TVU7778, IT93K-432-1, and IT97K-499-35, had relatively high positive, meaningful GCA effects, while TVU12349 and IT89KD-288 had relatively high negative GCA effect. TVU12349, and IT89KD-288 had a high negative GCA value under water-stressed conditions, while Danilla, TVU7778, IT93K-432-1, and IT98K-205-8 were intermediates. The number of seeds per pod had a strongly positive, major GCA effect under well-watered conditions for IT92KD-357-3, TVU7778, and IT97K-499-35, while TVU7778, and IT97K-499-35 were relatively good water-stressed combiners due to their high positive GCA effect. Danilla, IT92KD-357-3, TVU7778, IT93K-432-1, had a fairly strong positive GCA effect for 100-seed weight and have therefore good combination capability under both conditions. As for total seed weight, TVU7778, IT93K-432-1, and IT97K-499-35 had strong positive GCA effects and thus good seed weight combiners under well-watered environment. However, under water-stressed circumstances, Danilla, TVU7778, and IT97K-499-35 had major positive GCA impacts, and thus were strong combiners. With respect to the pod length, Danilla, IT92KD-357-3 and IT97K-499-35, had a fairly high positive GCA effect and therefore good combiners capability under both conditions.

Table 2. Mean square values of partial diallel for yield characteristics of cowpea crosses under water-stress (WS) and well-watered (WW) conditions

SV	ENV	GE	REP	P	F1	RF1	PvF1	PvRF1	E	GCA	SCA	RCA
	DF	**51**	**2**	**9**	**20**	**20**	**1**	**1**	**102**	9	**20**	**20**
NDF	**WW**	30.39*	2.39	58.65*	29.92*	19.91*	4.67*	22.99*	0.64	1451.39*	195916.50*	6.96*
	WS	42.12*	5.55	100.98*	23.50*	25.82*	172.60*	290.04*	0.92	1668.78*	266832.68*	3.16*
NRP	**WW**	57.95*	1.74	107.34*	71.76*	26.59*	18.62*	2.11*	1.95	2779.11*	547198.13*	10.69*
	WS	55.74*	18.84	134.85*	32.70*	33.94*	303.85*	285.42*	1.01	3067.54*	655787.38*	9.90*
NPP	**WW**	222.14*	8.42	344.63*	311.78*	70.56*	0.02^{ns}	310.79*	9.69	325.64*	18814.91*	62.43*
	WS	69.98*	18.06	221.10*	27.32*	52.08*	52.08*	35.60*	5.49	82.99*	5939.63*	3.17*
NSP	**WW**	10.26*	18.19	10.17*	8.62*	9.82*	8.86*	4.45*	1.00	148.18*	12262.10*	3.01*
	WS	17.97*	0.30	16.40*	16.02*	19.35*	14.11*	78.86*	1.44	136.32*	3066.48*	3.37*
POL	**WW**	13.11*	3.73	11.48*	15.40*	12.80*	1.37*	0.37*	0.47	221.38*	5473.84*	1.58*
	WS	12.64*	3.24	10.72*	12.65*	12.36*	11.32*	54.23*	1.46	208.78*	7843.27*	4.28*
100SW	**WW**	27.26*	10.95	14.80*	38.23*	21.61*	16.83*	4.32*	0.93	346.50*	18888.11*	5.03*
	WS	41.03*	0.73	36.01*	46.14*	38.79*	9.62*	90.23*	1.78	268.07*	12015.32*	11.14*
TSW	**WW**	300.10*	86.71	308.43*	396.84*	165.89*	0.76^{ns}	658.63*	16.45	389.89*	35835.92*	74.71*
	WS	141.66*	13.94	74.78*	139.56*	145.08*	941.21*	698.85*	4.92	293.62*	9922.88*	38.75*

per Plant (NSP), Pod Length (POL), 100 Seed weight (100SW) and Total Seed Weight (TSW)Number of Days to 50% flowering (NDF), Number of Days to 50% ripe pods (NRP), Number of Pods per Plant (NPP) and Number of Seeds. Environment (ENV), Genotypes (GE), Parent (P), First filial generation (F1), Reciprocal first filial generation (RF1), Environmental Error (E), General Combining Ability (GCA), Specific Combining Ability (SCA) and Reciprocal Combining Ability (RCA).

Table 3. Estimates of genetic parameters for different yield characteristics under well-watered (WW) and water-stress (WS) conditions in cowpea

	GP	D	Fr	H1	H2	h^2	E	H1/D	H2/4H1	h^2/H2	Hns
NDF	WW	19.4±4.1*	30.2±9.6*	44.0±8.9*	23.3±7.5*	523.5±5.1*	0.2±1.3^{ns}	1.51	0.13	8.43	0.45
	WS	31.4±6.2*	63.3±14.4*	76.6±13.3*	22.3±11.3^{ns}	1249.9±7.0*	0.3±1.9^{ns}	1.56	0.07	16.13	0.66
NRP	WW	39.1±5.5*	74.9±35.8*	109.7±33.0*	50.9±28.1^{ns}	1579.8±1.0*	0.65±4.7^{ns}	1.67	0.12	9.07	0.46
	WS	41.9±10.6*	91.1±24.4*	120.6±22.0*	55.3±19.0*	1941.1±9.0*	0.5±3.2^{ns}	1.69	0.11	10.12	0.36
NPP	WW	26.8±40.0^{ns}	48.6±92.4^{ns}	288.9±85.2*	198.9±72.4*	96.8±48.5*	3.2±12.1^{ns}	3.29	0.17	0.49	0.39
	WS	72.2±16.8*	142.7±38.8*	174.6±35.8*	89.1±30.4*	141.8±20.4*	1.91±5.1^{ns}	1.55	0.13	1.59	0.24
NSP	WW	3.8±0.5*	5.2±1.3*	14.1±1.2*	8.0±0.9*	17.3±0.7*	0.4±0.2*	1.92	0.14	2.16	0.49
	WS	5.1±3.3^{ns}	11.8±7.6^{ns}	30.9±6.9*	18.1±5.9*	8.7±4.0*	0.5±0.9^{ns}	2.47	0.15	0.48	0.38
POL	WW	6.3±2.1*	9.2±4.8^{ns}	17.1±4.4*	8.7±3.7*	21.9±2.5*	0.2±0.0*	1.65	0.13	2.5	0.54
	WS	3.2±2.3^{ns}	4.6±5.3^{ns}	20.7±4.9*	16.4±4.2*	0.3±0.0*	0.5±0.7^{ns}	2.54	0.2	0.02	0.24
100SW	WW	12.3±3.4*	41.3±9.2*	56.1±8.5*	15.5±7.2*	4.7±4.8^{ns}	0.4±1.2^{ns}	2.14	0.07	0.3	0.57
	WS	11.5±5.0*	17.4±13.8^{ns}	50.6±12.8*	30.2±10.8	1.0±7.3*	0.6±1.8^{ns}	2.1	0.15	0.03	0.47
TSW	WW	48.1±56.8^{ns}	603.3±130.0*	914.7±120.8*	289.3±102.7*	22.7±68.4^{ns}	5.9±17.1^{ns}	4.36	0.08	0.08	0.31
	WS	23.4±15.5^{ns}	47.1±35.8^{ns}	192.5±33.0*	139.0±28.1*	777.1±18.8*	1.7±4.7^{ns}	2.87	1.18	5.59	0.29

Number of Days to 50% flowering (NDF), Number of Days to 50% ripe pods (NRP), Number of Pods per Plant (NPP) and Number of Seeds per Plant (NSP), Pod Length (POL), 100 Seed weight (100SW) and Total Seed Weight (TSW).

Additive Variance (D), Proportion of dominant (+ sign) or recessive (-sign) alleles (Fr), Components of Dominance Variance (H1, H2, and h2), Environmental Variance (E), Order and Degree of Dominance ((H1 / D) ½), Mean Allelic Frequencies for parent (H2/4H1).

Number of gene group (h2 / H2), and Narrow Sense Heritability (Hns).

Table 4. General combining ability effect yield characteristics of ten cowpea parents' genotypes under water stressed (WS) and non-water stressed environments

Parents	NDF		NRP		NPP		NSP		100SW		TSW		POL	
	WW	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**
P1	6.69	6.77	9.29	9.77	1.89	1.71	0.79	1.14	3.59	3.78	0.79	2.35	2.00	1.78
P2	6.63	6.75	9.58	9.61	-1.17	0.26	2.29	1.86	4.13	2.43	1.05	0.82	3.20	2.66
P3	8.36	9.08	10.50	11.60	4.48	1.43	2.76	3.17	0.98	0.96	7.82	3.49	1.94	1.97
P4	-12.33	-13.36	-16.78	-18.18	-4.89	-3.37	-4.12	-3.36	-6.59	-5.80	-5.99	-5.41	-5.19	-4.72
P5	3.59	3.45	5.23	4.49	3.07	1.30	1.26	1.27	2.07	2.88	2.37	2.10	1.03	1.24
P6	10.73	12.05	15.35	16.05	5.28	3.35	3.35	3.39	5.57	4.86	3.97	6.70	4.23	4.83
P7	-11.86	-12.49	-16.45	-17.58	-6.61	-2.33	-3.94	-3.63	-5.82	-4.85	-5.12	-4.81	-4.91	-4.69
P8	-1.84	-1.24	-2.38	-1.73	-1.32	-1.25	-0.13	-0.81	-0.46	-1.01	-2.77	-2.00	0.27	-0.17
P9	-8.22	-8.94	-11.55	-12.60	-3.07	-0.10	-2.77	-2.89	-3.49	-3.07	-4.16	-2.82	-3.31	-3.26
P10	-1.75	-2.07	-2.80	-1.83	2.34	-1.00	0.51	-0.13	0.02	-0.19	2.04	-0.43	0.75	0.36
S.E	**0.17**	**0.20**	**0.30**	**0.21**	**0.66**	**0.50**	**0.21**	**0.25**	**0.20**	**0.28**	**0.86**	**0.47**	**0.15**	**0.26**

Number of Days to 50% flowering (NDF), Number of Days to 50% ripe pods (NRP), Number of Pods, per Plant (NPP) and Number of Seeds per Plant (NSP), Pod Length (POL), 100 Seed weight (100SW) and Total Seed Weight.

3.3. Specific combining ability

With respect to the number of days to 50 per cent flowering (Table 5), all crosses except IT92KD-357-3×IT97K-499-35, Danilla×IT92KD-357-35, Danilla×IT97K-499-35 and TVU7778×IT97K-499-35 expressed positive SCA effects for this trait under well-watered conditions, the same was observed under water-stressed conditions except TVU7778×IT97K-499-35 and Danilla×IT98K-205-8 which showed significant negative SCA effects. The same pattern was observed for the number of days to 50 percent ripe pod, with the exception of Danilla×IT92KD-357-35, IT92KD-357-3×IT97K-499-35 and TVU7778×IT97K-499-35 which showed significant negative SCA effect under well-watered and TVU7778× IT97K-499-35 showing significant negative effect under both conditions.

With respect to the number of pods per plant, positive SCA effect was observed in all the hybrids under well-watered conditions except, Danilla×IT92KD-357-35, Danila× TVU7778, Danilla×IT98K-491-4, IT92KD-357-35×TVU7778, and IT93K-432-1×IT97K-499-35. However, under water-stressed condition, only IT92KD-357-35×TVU7778, IT92KD-357-35× IT98K-205-8, and IT93K-432-1×IT97K-499-35 had negative SCA effect. For the number of seeds per pod, only Danilla×IT92KD-357-35, and IT92KD-357-35×IT97K-499-35 had negative SCA effect under well-watered condition, while under water-stressed, Danilla×IT98K-205-8, and IT92KD-357-35×IT98K-205-8, had negative SCA effect.

100 seeds weight, under well-watered condition showed positive SCA effect for all the hybrids except Danilla×IT92KD-357-35, Danila×TVU7778, and IT92KD-357-35×TVU7778. Under water-stressed, Danila×TVU7778, Danilla×IT98K-205-8, IT92KD-357-35× IT98K-205-8, and TVU7778×IT97K-499-35 had negative SCA effect. Only Danilla×IT92KD-357-35, Danila×TVU7778, IT92KD-357-35×IT97K-499-35 IT92KD-357-35×IT91K-513 and IT97K-499-35× IT98K-205-8, had negative SCA effect for total seeds weight under well-watered condition, while under water-stressed Danilla×IT92KD-357-35, Danila×TVU7778, Danilla×IT98K-205-8, IT92KD-357-35×IT98K-205-8, and IT93K-432-1×IT97K-499-35 had negative SCA effect for total seed weight.

For pod length under well-watered condition, all hybrids had positive SCA effect except Danilla×IT92KD-357-35 while water-stressed condition, all the hybrids were positive except Danilla×IT98K-205-8 and IT92KD-357-35×TVU7778.

As for the number of seeds per pod, 9 and 6 hybrids showed positive RCA effects under water-stressed and well-watered conditions respectively. Fifteen hybrids were observed for a positive RCA effect for 100SW under water-stressed, while only eight hybrids were observed for a positive RCA effect under well-watered conditions. The positive RCA had effect of 6 and 7 hybrids under well-watered and water-stressed conditions. For both conditions, 16 hybrids for pod lengths were found to be the best individual combiners for this trait, whereas 12 and 8 hybrids were observed for strong, important RCA effects for well-watered and water-stressed respectively.

Table 5. Specific combining ability effect for different agronomic characteristics in cowpea under water-stressed (WS) and well-watered environments

Cross	NDF		NRP		NPP		NSP		100SW		TSW		POL	
	WW	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**
P1×P2	-11.2	7.58	-11.3	9.06	-3.85	4.34	-4.2	0.84	-2.32	3.12	-5.68	-0.96	-4.6	1.56
P1×P3	3.39	6.20	5.56	10.07	-1.66	1.88	2.78	1.23	-0.54	-2.69	-2.70	-1.98	0.61	0.91
P1×P5	9.32	23.80	13.08	31.68	12.27	7.31	1.56	5.99	5.27	14.52	11.09	9.24	3.60	10.34
P1×P6	-0.48	5.16	1.04	11.67	3.01	5.59	0.94	4.75	1.12	9.98	9.33	19.91	2.23	4.40
P1×P8	16.92	2.90	20.77	2.62	11.04	0.14	2.82	-1.59	5.69	-0.59	7.77	-4.23	5.46	-0.51
P1×P9	22.30	28.27	29.44	36.92	-1.72	0.35	5.97	4.27	9.09	9.26	5.36	6.90	7.02	6.82
P2× P3	7.45	4.83	9.93	8.22	-4.17	-1.25	2.36	3.02	-0.91	1.24	4.37	2.30	1.57	-0.39
P2× P5	8.47	25.32	12.12	35.42	1.70	8.72	2.77	6.96	4.92	11.91	3.73	14.61	5.80	9.97
P2× P6	-1.42	6.34	-2.92	10.67	0.41	1.44	-0.73	3.12	-0.17	0.13	-4.08	2.51	0.46	4.83
P2×P8	11.56	-0.25	16.06	-0.56	3.33	-4.50	3.91	-0.87	7.81	-1.74	5.03	-4.82	5.07	0.34
P2×P10	13.31	26.78	16.40	35.74	2.60	3.10	3.98	3.49	6.30	11.39	-6.26	7.77	4.00	9.07
P3× P5	11.99	12.35	14.12	14.51	11.35	8.54	4.14	1.51	3.02	2.33	5.76	1.12	4.90	4.02
P3× P6	-0.48	-0.92	-3.17	-1.89	1.30	0.55	0.93	1.72	1.42	-0.49	1.38	3.16	0.19	0.45
P3×P7	22.94	26.46	33.13	35.42	2.27	2.43	6.26	4.83	11.37	10.21	9.80	9.93	9.01	7.30
P3× P10	11.34	9.38	14.65	13.40	18.66	10.11	4.06	6.42	7.77	3.81	27.77	8.55	6.50	7.26
P4× P6	18.37	20.68	26.95	27.23	10.55	4.14	3.42	2.47	8.28	9.73	9.86	0.90	6.17	6.72
P5× P6	6.74	6.97	7.60	9.56	-3.00	-1.54	2.53	0.24	4.05	5.01	1.18	-3.76	3.80	1.63
P6× P10	15.93	16.33	21.75	23.77	9.78	4.22	4.99	6.65	8.03	1.59	11.90	10.85	7.84	5.98
P6×P8	21.67	9.86	33.38	11.62	1.37	1.28	4.37	1.44	7.76	5.53	-2.23	-0.05	8.68	2.14
P6×P9	19.02	20.93	27.05	26.98	13.19	1.61	6.91	3.89	10.05	8.16	10.53	10.99	8.96	7.47
P8 ×P10	19.19	21.69	28.36	33.17	6.50	4.94	7.36	5.81	9.98	8.18	12.38	7.37	8.52	6.42
S.E	**0.51**	**0.61**	**0.90**	**0.64**	**1.99**	**1.50**	**0.64**	**0.76**	**0.62**	**0.85**	**2.60**	**1.42**	**0.44**	**0.78**

Number of Days to 50% flowering (NDF), Number of Days to 50% ripe pods (NRP), Number of Pods, per Plant (NPP) and Number of Seeds per Plant (NSP), Pod Length (POL), 100 Seed weight (100SW) and Total Seed Weight.

Table 6. Reciprocal combining ability effects for some agronomic characteristics of cowpea crosses under water- stressed (WS) and water-watered conditions

Cross	NDF		NRP		NPP		NSP		100SW		TSW		POL	
	WW	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**	**WW**	**WS**
2*1	0.00	-0.28	-4.50	-1.17	-0.77	0.83	-0.17	-0.08	0.63	-0.02	-0.42	0.15	0.30	-0.22
3*1	0.00	1.33	1.83	2.50	-0.37	2.92	-0.58	-1.25	-2.50	-0.83	2.50	2.33	-1.33	-0.92
5*1	-3.83	0.17	-4.58	1.00	10.12	0.10	1.80	-0.55	0.00	-0.52	12.02	1.85	1.12	-0.42
6*1	-0.17	0.33	1.50	2.33	2.17	0.50	-0.33	0.63	0.08	-2.25	0.68	-4.17	2.08	0.50
8*1	0.00	-0.33	0.50	-0.83	0.60	1.25	0.73	0.18	0.12	-1.80	6.55	3.02	0.95	0.75
9*1	0.67	-0.17	-0.67	0.17	0.42	-0.45	1.08	1.17	-3.17	-4.63	5.08	-2.25	1.83	-0.33
3*2	-0.33	-0.39	-1.17	-0.50	1.20	1.83	0.50	0.25	-0.83	-1.75	5.83	7.58	-0.50	0.50
5*2	-1.75	3.67	-1.92	4.92	1.92	-1.50	0.58	-0.17	0.58	-3.33	-5.42	-7.50	-0.83	1.50
6*2	0.50	0.50	0.17	-1.50	-1.67	-1.73	0.60	-1.62	3.70	1.05	-2.80	-0.10	-0.18	-0.25
8*2	0.25	-0.50	1.42	-1.50	2.67	0.17	0.17	-0.75	-0.28	0.17	-5.43	-3.50	0.33	-0.25
10*2	-0.25	1.33	1.00	1.17	6.75	0.08	0.77	0.00	-0.65	-1.58	-1.73	-0.75	-0.92	-4.07
5*3	3.50	-0.17	2.33	-3.67	14.12	-2.67	1.05	0.48	-0.84	-1.05	13.12	3.65	1.27	-0.35
6*3	-1.33	-0.83	-1.83	0.50	4.05	0.22	1.73	0.05	-2.97	0.05	10.27	0.02	1.78	-0.43
7*3	1.00	1.00	5.00	1.50	-0.70	0.58	-1.50	-3.08	-1.50	-1.40	1.43	4.58	-1.83	-2.83
10*3	-0.83	0.17	-0.83	-0.67	-8.20	-4.65	0.78	-2.08	1.13	-3.25	0.40	1.52	0.15	0.05
6*4	0.67	0.00	3.33	0.17	-1.92	1.17	-0.08	-0.40	0.45	1.42	-5.23	-1.67	2.17	1.42
6*5	-1.62	-0.10	1.00	1.17	-6.67	-0.67	0.70	1.20	1.35	1.13	-4.22	0.98	0.48	0.02
10*5	-0.67	2.33	2.00	0.83	5.83	0.08	0.85	0.00	-0.08	-3.77	1.25	12.33	-0.08	-1.17
8*6	0.50	-1.72	-0.50	-4.00	-1.92	0.73	-0.58	-0.13	1.70	2.53	-0.17	-1.45	0.86	0.42
9*6	2.42	1.33	4.33	0.83	-4.22	-0.75	-0.73	-2.93	-0.57	0.13	-1.92	-1.33	-0.48	-2.47
10*8	-0.17	-0.33	1.00	-4.33	-2.17	1.08	-1.00	-1.58	0.00	0.10	-3.42	-4.92	0.50	-1.80
S.E	**0.57**	**0.68**	**0.99**	**0.71**	**2.20**	**1.66**	**0.70**	**0.84**	**0.68**	**0.94**	**2.87**	**1.57**	**0.49**	**0.86**

Number of Days to 50% flowering (NDF), Number of Days to 50% ripe pods (NRP), Number of Pods, per Plant (NPP) and Number of Seeds per Plant (NSP), Pod Length (POL), 100 Seed weight (100SW) and Total Seed Weight.

4. Discussion and Conclusion

Both additive variance (D) and dominance variance (H1) of genetic variance components suggested important for most study characteristics in well-watered and water-stressed environments, this indicates that the expression of all the characteristics is influenced by both additive and dominance gene behavior. However, additive variance was more pronounced for number of pods per plant but small for pod length under water-stressed condition. Dominance variance was more important for number of pods per plant and total seed weight under well-watered condition. In both conditions, however, there was the preponderance of the dominance gene action.

The H2/4H1 reflecting the proportion of dominance gene with positive or negative effects in parents was less than 0.25 for all characteristics under both conditions except total seed weight under WS indicating asymmetric distribution of positive and negative dominant genes in parents as suggested by (Amiri-Oghan et al., 2009). The Fr variable representing the sigh path showed positive with more than zero for all traits also indicated asymmetrical distribution of dominant and recessive alleles in parents, which also indicates that dominant alleles are more common in both conditions than recessive alleles. However, some Fr values are positive but insignificant for some traits indicating the symmetric distribution of dominant recessive genes in the parents.

The (H1 / D) 1/2 that reflects mean degree of dominance was more than one in all characteristics and ranged from 1.51 for the number of days to the first flowering to 4.36 for total seed weight both under well-watered indicating the importance of overdominance gene-action.

The values of h2 under all conditions except 100SW under both conditions and total seed weight under well-watered conditions indicating the existence of overall dominant gene effect for certain traits were important in all traits. The ratio h2 / H2 shows the varying number of genes that regulate these traits. This study suggested at least ten plant height genes in the water-stressed environment, and at least three and eight genes for terminal leaflet area and number of leaves per plant in well-watered and water-stressed environments respectively, thus revealing that their polygenic inheritance is a feature of quantitative traits. For all the traits, the environmental variable (E) was not important.

A very important genetic method for identifying successful parental combinations to grow superior hybrid populations is the combination of ability analysis (Hussain, 2009). General combination ability (GCA) tests an individual parent's average success in hybrid combinations and is related to additive gene effect. The Specific Combining abilities (SCA) tests the relative efficiency of specific combinations of hybrids and is correlated with a non-additive gene effect (Rojas and Sprague, 1952; Griffing, 1956). Genetic interactions influence both the GCA and SCA effects (Miranda et al., 1988). Identifying combinations of superior hybrids can effectively assist breeding of drought-tolerant hybrids.

Variance analysis for combining abilities revealed highly significant variations in both the cowpea parents' general combination (GCA) and specific combining ability (SCA) suggesting the importance of both additive and non-additive gene effects in their ancestry in one or both environments suggesting heterogeneous crosses. Hira Lal et al. (2009) testing the combination of quantitative trait ability in cowpea also suggested the important effects of GCA and SCA in most traits except for peduncle length and 100-seed weight. The predicted variances due to specific combination ability is higher than the general combination ability suggesting the predominance of the non-additive gene action in both environments in these traits. This also matches (Kadam et al., 2013; Bhavesh Patel et al., 2013; Selvarkumar et al., 2014), but contrasts with (Romanus et al., 2008; Carvallo et al., 2012; Ayo-Vaughan et al., 2013). The estimates of the predictability ratio less than unity in these characteristics indicate that hybrid success for these characteristics may be difficult to predict on the basis of parents' general combining ability due to the value of dominance. Thus, selection for better hybrids would have to wait for later generations. With regard to the number of days to 50 percent flowering and the number of days to 50 percent ripe pods, many parents seemed not to be favored due to high positive GCA effects under water stress, which is an indication of water deficit lateness. Significant numbers of parents were promising for a water deficit environment for other characteristics considered due to their high GCA effects, particularly Danilla and IT97K-499-35 observed in all the characteristics. This implies that in an intensive breeding program Danilla and IT97K-499-35 could be used for seed yield to exploit both additive and non-additive components of seed variation and were therefore good combiners in a water-stressed environment and could have contributed to a maximum number of favorable genes and possible allelomorphs (Ojo, 2005; Gouri Shankar et al, 2005).

The breeders' goal will be to grow a hybrid that will perform under drought stress in terms of yield. Despite their major SCA effects on the traits, large numbers of crosses were found to perform well under both conditions. Some parents appeared to be specific when cross-examining the performance of GCA and SCA results, therefore it is suggested that the selection should be based on success at both levels. This is the combination which will include parents with high GCA results. Most crosses with a major SCA effect often have at least one parent with a strong GCA effect, indicating the presence of additive material additive × additive material and additive × dominance gene activity. The hybridization of high combiners can be controlled by additive and additive × additive forms of gene action, so crosses can result in transgressive segregation for the trait involved in the advanced generation. Crosses that exhibit low GCA effects but high SCA effects suggest epistatic gene action. This may also mean that both parents contributed to the gene dispersion and genetic interaction between beneficial alleles. A partial superiority is demonstrated by crosses with a negative SCA estimate (Ojo, 2005).

In conclusion, in the analysis of the characters, additive and nonadditive gene actions were detected; however, under both circumstances, predominance of nonadditive gene action occurred. Consequently, enhancement for these traits would involve a recurrent selection procedure as a result of the prevalence dominance gene effect to allow favorable gene recombination in both conditions at later generations. IT97K-499-35 and Danilla could be used as parents with desirable genes for genetic improvement of the considered yield components in cowpea with relatively large, positive, and important GCA results. Also, TVU7778 × 89KD-288 and Danilla × IT97K499-35 proved to be the best specific combiners in this analysis for all the traits. The heritability of narrow-sense ranged from 24.0 percent for the number of pods per plant and pod length to 66.0 percent for the number of days to 50 percent for flowering under water-stressed conditions. This indicates that some of these characteristics could be improved in both situations.

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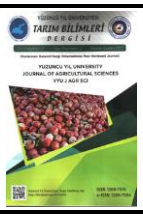

Araştırma Makalesi (Research Article)

Evaluation of Land Use Suitability for Wheat Cultivation Considering Geo-Environmental Factors by Data Dependent Approaches

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Abstract: Two techniques were investigated to be standard deviation based weighting Multi Criteria Assessment (MCA), and Artificial Neural Network (ANN) considering base environmental factors to define wheat cultivation suitability in Van region. Climate data (long term annual, maximum and minimum temperature, total mean precipitation and solar radiation), physical factors such as elevation, hillshade, slope, soil depth, accessibility to the fields and land use cover were used to produce wheat suitability map. All inputs were weighted with reference to existing wheat areas. MCA and ANN approaches were applied using same dataset to compare the performance of the two techniques. In total, 228 wheat parcels were used as training (171 parcels) and testing (57 parcels) data. Relative Operational Characteristic (ROC) was applied for accuracy assessment. ROC values of the MCA technique which was depended on existing wheat lands, and ANN techniques were derived to be 0.875 and 0.71 respectively. Results showed that 15% of the research area was very suitable for wheat farm, and today, only 67% of very suitable areas were used to be agriculture. Other areas were currently used as grassland (28%), bare ground (4%), and other (1%).

Veri Bağımlı Yaklaşımlarla Coğrafi Çevresel Faktörler Dikkate Alınarak Buğday Tarımı için Alan Kullanım Uygunluğunun Değerlendirmesi

Makale Bilgileri

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Anahtar Kelimeler
Tarımsal alan kullanım uygunluğu,
Buğday,
Çok ölçütlü değerlendirme,
Yapay sinir ağları,
CBS.

Öz: Temel çevresel faktörler dikkate alınarak, standart sapma tabanlı çok ölçütlü değerlendirme (ÇÖD) ve yapay sinir ağları (YSA) olarak iki teknik, Van Bölgesi'ndeki buğday tarımına uygun alanların belirlenmesi için araştırılmıştır. İklim verileri (uzun dönemli en yüksek, en düşük, ortalama sıcaklıklar, toplam yağış ve güneş radyasyonu), yükseklik, tepe gölgelikleri (güneşlenme), eğim, toprak derinliği, alansal erişilebilirlik ve arazi örtüsü ve kullanımı verileri buğday tarımı için uygun alanların belirlenmesinde kullanılmıştır. Bütün kullanılan girdi verileri, sezonluk buğday tarımı yapılan alanlar temel alınarak ağırlıklandırılmıştır. ÇÖD ve YSA aynı girdi verileri kullanılarak performans değerledirmesi için karşılaştırılmıştır. Toplamda 228 buğday parselinin 171'i eğitim verisi ve 57 parseli ise test verisi olarak kullanılmıştır. Göreceli çalışma karakteristiği (GÇK), doğruluk analizi için uygulanmıştır. ÇÖD ve YSA tekniklerinin GÇK doğruluk katsayıları sırasıyla; 0.875 ve 0.71 olarak elde edilmiştir. Çalışma sonuçlarına göre; Van İli arazilerinin % 15'inin buğday tarımına çok uygun olduğu ancak bu alanların % 67'sinin tarım için kullanıldığı, geri kalan alanların % 28'inin çayır-mera, % 4'ünün açık alan ve % 1'inin ise diğer alanlardan oluştuğu belirlenmiştir.

1. Introduction

Studies on climate change showed that global warming, soil erosion, land degradation and hydrological changes may cause a global famine in the near future (Arnell 1999; Parry et al. 1999). Therefore, it is necessary to determine sustainable land use strategies for optimal use of our land and water resources.

Agricultural lands were decreased around 0.1 - 0.2% between 2009 and 2013 all over the world (WB, 2013). However, world's population was increased 6.2% in the same period (UN, 2013). This situation is even severe in fast developing countries like Turkey where the population raised 5.4%, agricultural lands were decreased around 3.2% between 2009 and 2013 in Turkey (TSI, 2013). As a result of agricultural area loss, agricultural land use planning has been more important than before. Today, land use plans are required spatial information technologies including, Geographical Information System (GIS) and Remote Sensing (RS). Malczewski (2007) indicated that 8.5% of the scientific papers in between 1990 and 2004 were on MCA and GIS usage in agricultural decision making process.

Decision support systems utilised widely combined with GIS in land use planning, and this process is called spatial decision support system (SDSS). This system has a wide range of usage purpose such as urban land use planning (Mosadeghi et al. 2015), tourism and recreational area planning (Bunruamkaew and Murayama, 2011), agricultural land use planning (Kalogirou, 2002). A SDSS is included weighting factors (criteria) as a most critical stage that is directly affected the accuracy of study. There are several approaches for weighting the factors and three of them are very common in the literature to be; i) expert based weighting, ii) literature based weighting, and iii) Existed or ideal data based weighting approaches. Additionally, there are non-parametric techniques like artificial neural network (ANN) and support vector machine (SVM), and they have an internal weighting ability based on training data (ideal point or grid data) (Satir et al. 2016).

Expert-based methods are generally preferred in cases where the training data are scarce. Because, priority of the factors is evaluated by the experts through a survey. Following to this expert evaluation, the weighted factors can be integrated to analytical hierarchical process (AHP) due to pairwise comparison ability. Pairwise comparison matrix is defined weights using binary priority definition (Saaty, 1980; 2008). Although this method is easily applicable, there is still a subjective side because of expert differences and experience. Literature based technique is another approach to define the factor priorities. It is applied based on previous studies that are similar with main study. This method is easy for weighting definition, however; regional environmental and social differences are ignored, so solidity of the technique is questionable (Şatir, 2016). MCA approach based on ideal data is more objective than other techniques. In this approach, some of the indicators can be used to define ideal areas such as crop productivity or existed cropping areas to map crop suitability (Şatır, 2013; Satir and Berberoglu, 2016).

Wheat is one of the oldest cultivated crops in Anatolian region. According to the studies in Anatolian region, the history of wheat farming goes back to 8000 - 10.000 BC (Kan et al. 2015; Bilgic et al. 2016). Anatolia is still contained more than 100 wild wheat populations (Karagöz et al. 2006). In this study, wheat farming suitability was evaluated in Van city that is located in sub-alpine Eastern Turkey. According to the FAO projections on wheat crop, potential production of Turkey two times more than current version (FAO, 2002). Therefore, wheat is a good indicator for agricultural suitability detection in dry and cold regions because of wide range of the cultivated areas and species diversity in Eastern Anatolian Region (EAR). Additionally, wheat farming has been developed day by day in Eastern Anatolia because of climate change and immigrations from village to the towns (Şatır et al. 2017). Wheat cultivated areas were increased almost 3% in last 5 years (2015-2020). Additionally, crop productivity has been improved during the same period in Van region of Turkey (TSI, 2020).

Main purpose of this research was to estimate the potential wheat growth suitability in a sub-alpine region of Turkey comparing two commonly used objective data dependant approaches. In this paper, potential wheat growth suitability was evaluated by aid of existing wheat lands in Van Province, Turkey. Physical (elevation, slope, hill shade, soil depth), long term climate (annual maximum, minimum and mean temperature, total annual mean precipitation, total annual solar radiation) and social datasets (distance from roads, LUC) were used to be predictors. So that suitability maps for wheat farming were derived using these inputs and results enable for stakeholders to build more sustainable agricultural land management strategies in the physically hard conditions such as studied region.

2. Material and Methods

2.1. Study Area

Van province is located in the Eastern Turkey on the Van Lake coast (the largest lake in Turkey) and it covers 21.334 km^2 area (Figure 1). Population is 1.123.784, and it is 19th most populated city of Turkey (TSI, 2018). The main incomes are animal husbandry and processing industry, agriculture and tourism. Region has continental and sub-alpine climate characteristics dominated by cold and dry climate. Mean annual temperature is between 5 and 10 ºC, and total annual precipitation is between 400 - 850 mm in the region. Wheat, barley, clover, sainfoin and vetch farms are the common field crops. Elevation range in the region is between 1000 m and 3700 m.

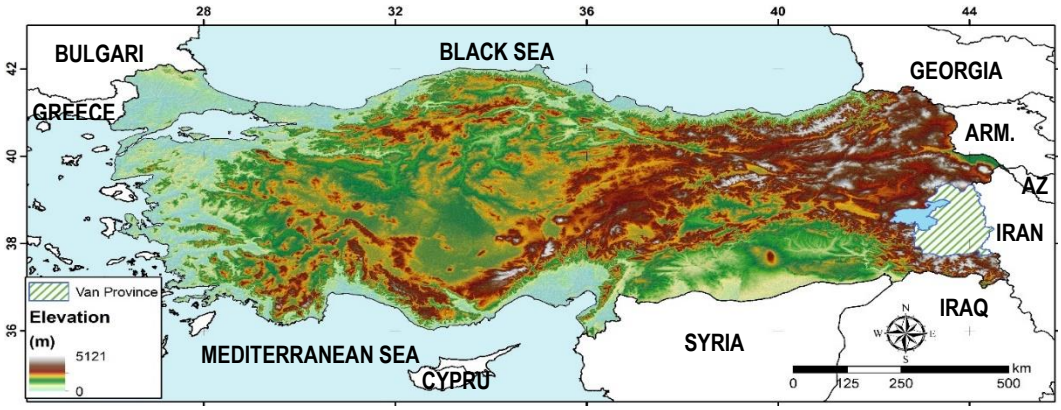


Figure 1. Location of the study area (Van Province).

2.2. Main Dataset

Five main datasets were used in the study; existed wheat fields, DEM data derived from ASTER stereo images, main road networks, long term climate dataset (2006 – 2015) and soil data (Table 1).

Table 1. Specifications of main dataset used in the study

Dataset	Usage purpose	Source
Existing wheat fields	Training and testing the results	Van provincial directorate of Agriculture (2014 – 2015)
Long term climate dataset	Mean, max. and min. temperature, precipitation and solar radiation mapping by interpolation techniques	TSMS (1975 – 2015)
Main road network	Defining the accessibility of the fields	General directorate of highways (2015)
Digital elevation model	Obtaining the physical variables such as elevation, slope, sun availability.	ASTER stereo images GDEM data
Soil dataset	Defining the Soil depth	General directorate of Village service (1996)

2.2.1. Wheat Fields Data

This data set was provided by Van provincial directorate of agriculture (VPDA) for 2014 and 2015. In total 238 winter wheat field data were collected considering elevation, slope and climatic variables. Wheat parcels were separated two parts for training (171 parcels) and testing (57 parcels) respect to the variability of inputs (Figure 2).

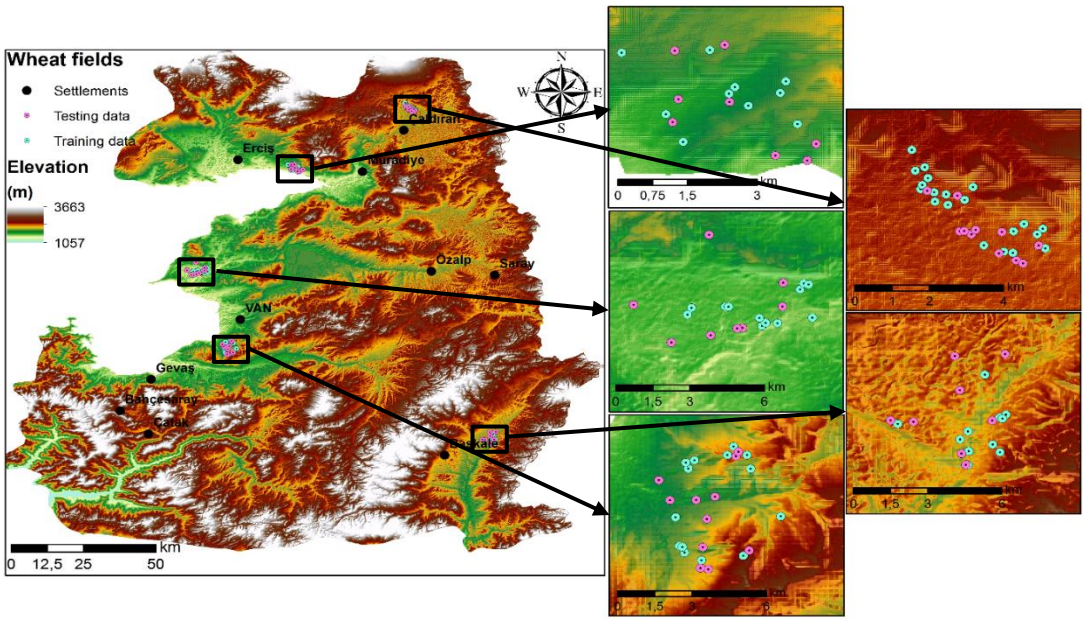


Figure 2. Distribution of existed wheat fields (location of the parcel centers).

2.2.2. DEM and Main Road Networks

DEM data was derived from ASTER stereo images in 30m spatial resolution. Slope and hillshade were produced using DEM. Main road network includes only asphalt roads and this data derived using main road network map of Turkey from General Directorate of Highways.

2.2.3. Climate Dataset

Long term (2006 – 2015) maximum, minimum and mean temperature, total annual precipitation and solar radiation dataset were obtained from 12 climate stations. These climate data were mapped using appropriate radial based function. Climate stations have been calibrated regularly by the Turkish State Meteorological Services (TSMS, 2015). Long term climate dataset was used because of avoiding the seasonal climatic variability in the region.

2.2.4. Soil Data

Soil data has course spatial resolution in raster format, only soil depth was used because of its importance in wheat cultivation. Soil dataset are also showed land use ability based on slope and erosion and main soil groups. However, slope data has already been used as a factor. Soil depth data showed five categories from 0 to 120+ cm in the map.

2.3. Method

Method of the study contains four main stages; i) criteria selection and preparation, ii) standardization and weighting of the factors, iii) ANN application and, iv) accuracy assessment. All factors were defined according to the effects on wheat growth and dataset accessibility. Climate, physical, social, soil and field datasets were pre-processed before the multi-criteria analyse (MCA) (Figure 3).

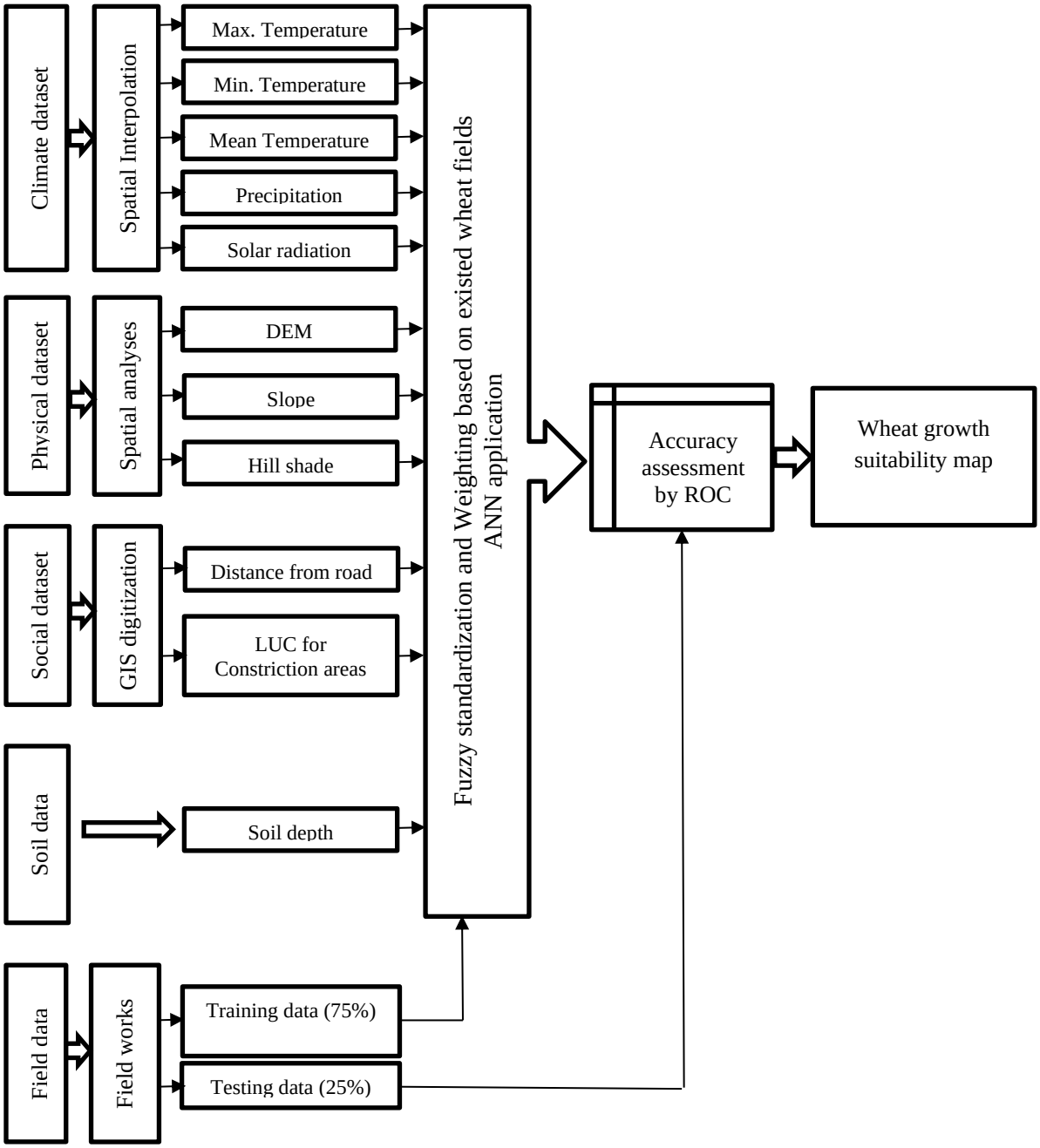


Figure 3. Research flow for mapping the wheat growth suitability.

2.3.1. Factor Selection and Preparation

Slope and hillshade were produced using standard spatial analyses tools within a GIS environment from DEM data. Elevation is very important factor for the crop productivity. It is directly related with atmospheric variables such as temperature. Additionally, slope is another factor for economic farming. Sun illumination effect was evaluated using hill shade, as a vital factor for crop growth.

Climate variables were mapped using radial basis function (RBF) interpolation technique that has been used widely in regional studies (Satir and Berberoglu, 2016). RBF is a one of the most used geo-statistical model which contains an algorithm to predict unknown spatial point values from known values (Barton et al., 1999). Simply, RBF run by Euclidian distance in a linear system. However, prediction line can be defined according to the prediction function type such as gaussian, quadratic or cubic.

Euclidian distance of the main roads were mapped using distance tools in GIS. So, accessibility of the fields was evaluated. Additionally, LUC map was used to mask restricted areas from final results such as, water bodies, existed built up areas, restricted zones and nature protection areas.

2.3.2. Standardization and Weighting

In a multiple data assessment technique, value range of input data layers can be variable such as, slope factor ranges between 0 and 90 degree, whereas elevation can be in between 1000m and 2000m. Therefore, each factor must be standardized in a pre-defined range according to the research goals, and it has been usually between 0 and 1. Thus the priority of each factor can be comparable with each other.

Fuzzy standardization technique was applied to the all inputs to obtain more accurate results (Mosadeghi et al. 2015). Fuzzy standardization idea is based on soft limits (boundaries) as hard boundaries are inapplicable between two different landscapes in the nature. So, fuzzy technique considers a transition zone between suitable and not suitable regions. Fuzzy set functions can be sigmoidal, gaussian, linear or user defined. Function form is very flexible according to the factor type and study goal like gaussian, monotonically increased or decreased forms (Kavzoglu et al. 2014).

Weighting process is one of the critical issues in a multiple data assessment technique for land use suitability or geographical risk analysis (Şatir, 2016). Ideal point based weighting was used in this study. Existing wheat fields were divided two parts as, training (75%) and testing (25%). Training dataset was used to derive weights of each factor. In this stage, factors were categorized individually with respect to impacts on wheat cultivation, and distribution of the training data in each category was detected. In the second part, standard deviation (SD) of each factor was calculated based on training data distribution. Small SD value of a factor indicates homogenous distribution of training data, which means this factor has low impact on wheat growth. Oppositely, if the training data distribution is heterogeneous in each category, it is referred that factor priority on wheat growth is high.

2.3.3. ANN Approach

The multilayer perceptron (MLP) approach that has been the most commonly encountered ANN model in data analysis and remote sensing (because of its generalization capability) was used in this study (Rumelhart et al. 1986). Crop suitability mapping by ANN was applied in three stages to be; training, allocation and testing. In training stage, ideal and non-ideal data values are matched with input variables, and neural system is trained. Backpropagation algorithm that is most commonly used algorithm were used with generalized delta rule (Rumelhart et al. 1986). In this algorithm, network is trained iteratively until: (1) the maximum number of pre-specified iteration was reached, (2) performance had met a suitable level, and (3) the gradient was below a suitable target. Optimal model can be determined experimentally. In this paper, the basic feed forward, back-propagation ANN described above is used as a regression model to estimate the wheat farm suitability based on geo-environmental inputs.

2.3.4. Relative Operating Characteristic

The Relative Operating Characteristic (ROC) is a reliable technique to test a Boolean and continuous dataset. For example, the ROC could be used to compare an estimated probability for fire risk against a fire occurrence dataset (Satir et al. 2016). The ROC is showed “how match the Boolean and continuous dataset in each category”. It is mean that how successful dataset “A” to identify dataset “B. Thus, the ROC analysis is useful for cases in which the scientist wants to see how well the probability map portrays the location of a particular category but does not have an estimate of the quantity of the category.

3. Results

The results were presented in three sub-sections (Input data preparation, wheat suitability analyses and accuracy assessments).

3.1. Input Data Preparation

Climate, physical and social datasets were mapped before the MCE process. Climate dataset was interpolated using RBF. Long term (2006 – 2015) minimum, maximum, mean temperatures, annual precipitation and solar radiation maps were produced. Annual maximum and minimum temperature were around 22 ºC and -8.5 ºC respectively. Van Lake has warming effect in the region on temperature. Long term annual total precipitation was mapped within the range of 391mm and 828mm for the study area, and particularly, south-western side receive more precipitation than other parts (Figure 4). Precipitation and solar radiation of the study area are more heterogeneous than temperatures, according to standard deviation of the climate dataset (Table 2).

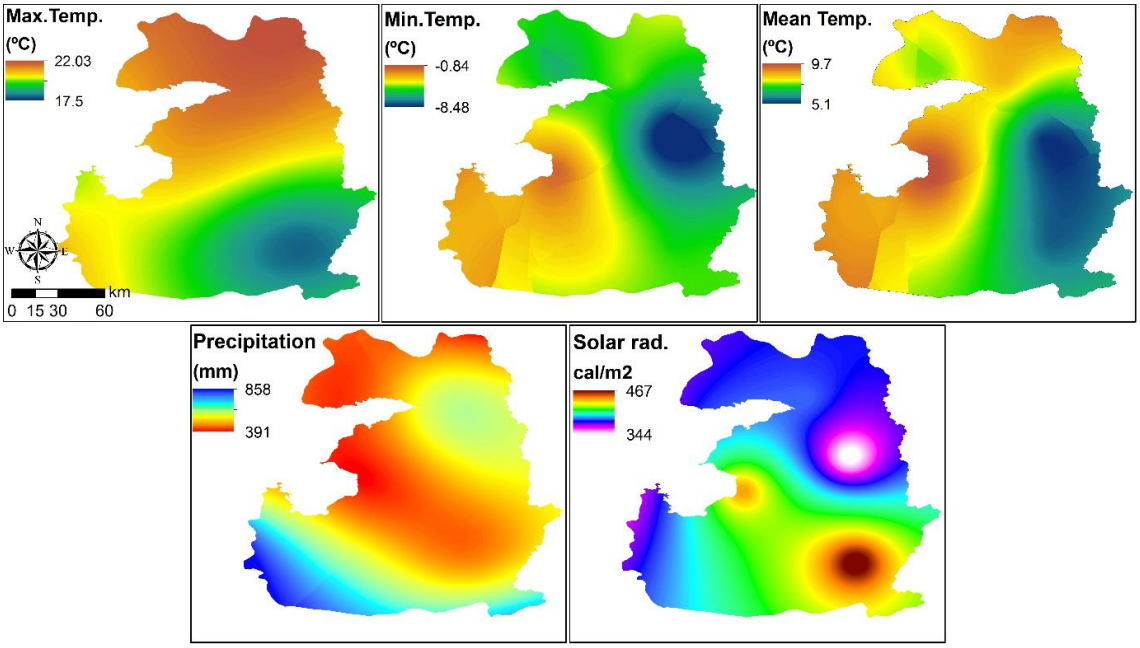


Figure 4. Interpolated long term annual climate dataset.

Table 2. Spatially distributed climate dataset characteristics of the study area

Climate data	Max. value	Min. value	Mean value	Standard deviation
Annual Maximum Temperature (ºC)	22	17.4	20	1.3
Annual Minimum Temperature (ºC)	-0.8	-8.5	-4.3	1.6
Annual Mean Temperature (ºC)	9.6	6.1	7.8	0.9
Annual Total Precipitation (mm)	858	391	524	95.1
Annual Total Solar Radiation (cal/m^2)	467	343.8	400	22.9

Physical and social dataset: Hillshade and slope data were produced from DEM, and altitude, hillshade and slope were used within the analysis. Additionally, soil depth data was provided by VPDA in grid format with scale of 1/100000. Only road network data was used to consider the accessibility of the croplands as a social factor. Additionally, distance from main road networks map was derived for these analyses in a GIS environment (Figure 5).

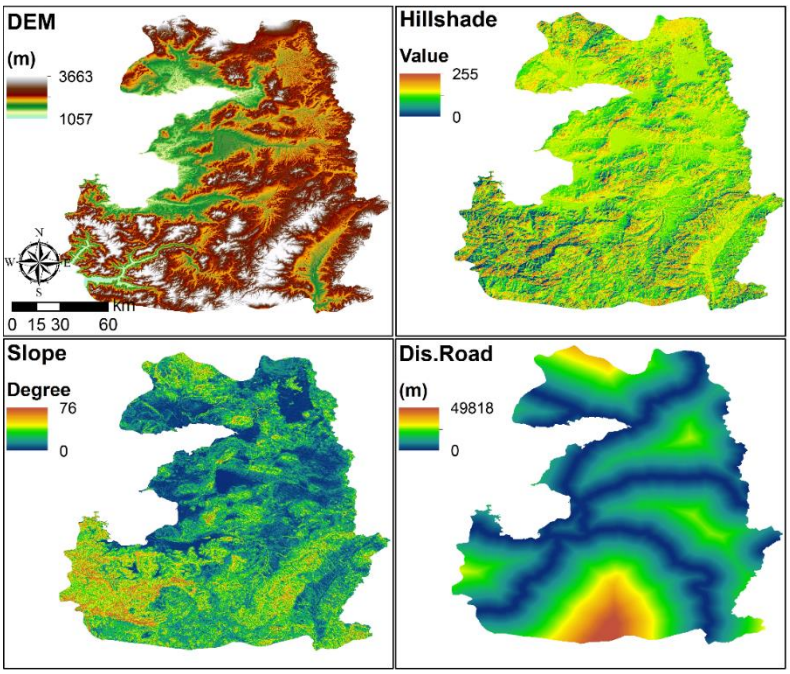


Figure 5. Produced physical and social dataset.

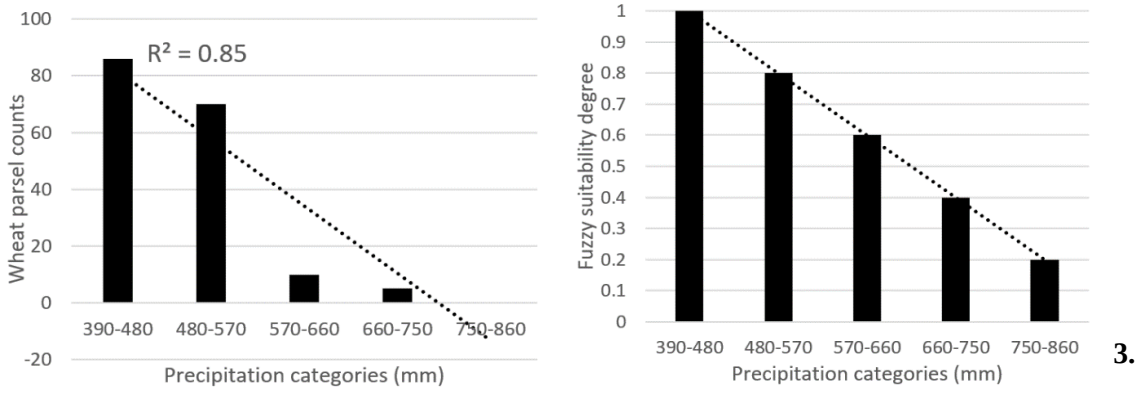
3.2. Wheat Suitability Analyses

Two approaches were applied to obtain wheat suitability map to be standard deviation based linear MCA and non-linear ANN based multi data assessment approaches.

In the first technique, suitability analysis was applied in three steps; i) Fuzzy based standardization of factors derived from existing wheat fields, ii) Weighting of inputs from first step utilising existing wheat field heterogeneity (Standard deviation) and iii) mapping the results in continuous and categorical form.

i) Standardization

Each input data has its own data range and unit, so all input variables were standardized using fuzzy approach, and range of the input dataset was set between 0 and 1 according to the wheat growth suitability. In this extent, input dataset was categorized based on distribution of the existing wheat fields to define appropriate fuzzy membership function type such as linear, sigmoidal or user defined. For example, long term total annual precipitation and distribution of wheat parcels in each precipitation categories were analysed, and a linear decreasing relationship was detected (Figure 6).



3.

Figure 6. Sample precipitation fuzzy standardization for wheat suitability.

Input variables and fuzzy membership function types for standardizations were shown in table 3. Standardized inputs variables were derived based on existing wheat field distribution (Figure 7).

Table 3. Fuzzy membership function types for standardization

Input variables	Original data range	Unit	Fuzzy membership function type	Standardized data range
Min. Temperature	-0.8 – -8.5	ºC	Gaussian	
Max. Temperature	17.5 – 22	ºC	Linear Decreasing	
Mean Temperature	5.1 – 9.7	ºC	Linear Increasing	
Precipitation	391 – 858	mm	Linear Decreasing	
Solar Radiation	344 – 467	cal/m^2	Gaussian	
Elevation	1057 – 3663	m	User defined	0 - 1
Slope	0 – 76	º	Sigmoidal Decreasing	
Hillshade	0 – 255	value	User defined	
Soil Depth	0 – 120	cm	User defined	
Distance from roads	0 – 50000	m	Sigmoidal Decreasing	

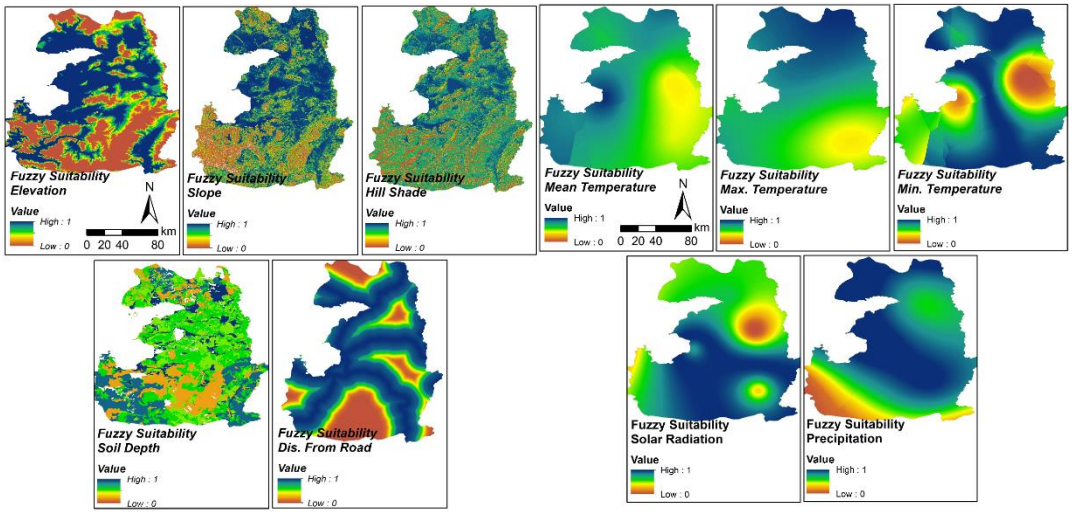


Figure 7. Fuzzy standardization results

ii) Weighting

In this study, 10 geo-environmental factors were considered to map the suitable lands for wheat growth. All factors are of different effects on wheat growth, and some of them more important than others. There are many approaches to define the priority of the factors, and some of the common techniques were described in introduction section.

Ideal point based weighting approach was used because this technique is more objective than others. In this context, 171 wheat parcels were assessed according to the parcel distribution and frequencies in each category. First of all, factors were categorized based on effects on the wheat growth. For instance, all temperature dataset was reclassified by considering 1ºC difference. In precipitation, 90 mm interval was applied for categorization. In second stage, distribution of the 171wheat parcels in each category have been detected, and in the last stage, heterogeneity of the wheat parcels in each category was evaluated through standard deviation analysis. The hypotheses of this stage are;

a) If the distribution of the wheat parcels is homogeneous, this factor has weak impact on wheat growth, because variability of the factor is ineffective.

b) If the distribution of the wheat parcels is heterogeneous, this factor has a significant effect on wheat growth. Because variability of the factors is effective on wheat growth suitability.

Priorities (weights) of the factors (inputs) were detected according to the standard deviation (SD) values of the wheat area distribution of each category. Large SD value means that heterogeneity of the factor is high, and it has a significant effect on wheat growth (Table 4).

In the second approach, ANN based wheat suitability degrees were detected. MLP based ANN consist of 5 main variables to be (1) size of the training data, (2) the network architecture, (3) the learning rate, (4) the learning momentum and (5) the number of training cycles that have direct effects on accuracy.

Size of training data must be characterized to the studied field on wheat farm suitability. In total, 238 field data were used to get the wheat suitability and distribution of the fields were selected considering physical and climatic variability.

Network architecture of the study consist of 8 input neurons (Elevation, slope, hill shade, soil depth, annual maximum, minimum and mean temperature, total precipitation and distance from road), 17 hidden neurons and 2 output neurons (suitable and non-suitable). Single hidden layer was used in the study and hidden neuron count was defined experimentally.

The learning rate determines the portion of the calculated weight change that will be used for weight adjustment. This value range is between 0 and 0.99. In this study small learning rate was used to be 0.01. However, small learning rate needs more training cycles than big one.

Learning momentum is used to allocate learning rate. It takes values between 0.1 and 0.9. Also, this value can be defined experimentally, in our study it was defined as 0.5.

The number of training cycles was defined according to the testing and training accuracy. In MLP technique, training and testing accuracy of the network has been increased in each iteration until the ketch stable line. In our study, stable line was obtained around 18000 iterations, but system has been worked until the 50000 iterations to see the late break points (Figure 8).

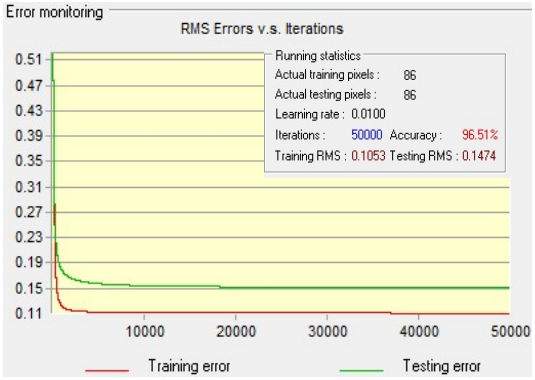


Figure 8. Testing and training error monitor of the ANN.

Table 4. Weights and priority ranks of geo-ecological factors

Factors	Categories: Data range: wheat parcel counts	SD values	Weights	Priority Rank
Max. Annual Temp. (ºC)	1: 17 – 18: 28 2: 18 – 19: 0 3: 19 – 20: 0 4: 20 – 21: 66 5: 21 – 22: 77	36.12	0.082	5
Min. Annual Temp. (ºC)	1: -0.9 – 0.3: 0 2: 0.3 – 1.5: 0 3: 1.5 – 2.7: 0 4: 2.7 – 3.9: 54 5: 3.9 – 5.1: 51 6: 5.1 – 6.3: 1 7: 6.3 – 7.5: 28 8: 7.5 – 8.7: 37	23.95	0.054	10
Mean annual Temp. (ºC)	1: 5 – 6: 28 2: 6 – 7: 0 3: 7 – 8: 10 4: 8 – 9: 68 5: 9 – 10: 65	31.16	0.071	8
Annual Total Precipitation (mm)	1: 390 – 480: 96 2: 480 – 570: 75 3: 570 – 660: 0 4: 660 – 750: 0 5: 750 – 860: 0	47.41	0.108	4
Annual total solar radiation (cal/m^2)	1: Very low: 0 2: Low : 77 3: Medium : 29 4: High : 54 5: Very high: 11	31.45	0.072	7
Slope (degree)	1: 0 – 5 : 165 2: 5 – 10 : 4 3: 10 – 15 : 2 4: 15 – 20 : 0 5: 20 – 25 : 0 6: 25 – 30 : 0 7: 30 – 35 : 0 8: 35 < …: 0	58.05	0.133	3
Hillshade (sun effect)	1: Very low : 0 2: Low : 0 3: Medium : 7 4: High : 163 5: Very high : 1	72.06	0.164	2
Elevation (m)	1: 1050 – 1350: 0 2: 1350 – 1750: 23 3: 1750 – 2150: 87 4: 2150 – 2450: 61 5: 2450 – 2750: 0 6: 2750 – 3050: 0 7: 3050 – 3350: 0 8: 3350 – 3650: 0	34.15	0.078	6
Distance from main roads (m)	1: 0 – 5000 : 171 2: 5000 – 10000 : 0 3: 10000 – 15000 : 0 4: 15000 – 20000 : 0 5: 20000 < … : 0	76.47	0.174	1
Soil depth (cm)	1: 0 – 20 : 37 2: 20 – 50 : 57 3: 50 – 90 : 6 4: 90 – 120 : 5 5: 120 < … : 66	28.22	0.064	9

iii) Wheat suitability maps and accuracy assessment

In linear technique, standardized factors were multiplied by the weights and suitability degree of the wheat areas were produced. Constrains such as water bodies, existing settlement areas and roads, airport area and bulrush areas were masked out from the final maps. Predicted wheat suitability map was tested using 57 existing wheat parcels using ROC analyse. ROC co-efficiency was 0.875. This result indicated that this method was capable to map wheat suitability accurately in the region. Suitability degree map was divided into five categories including very high, high, medium, low, very low to demonstrate the spatial diversity of wheat growth suitability clearly. In total, 19.104 km^2 area was classified to be 14% very high, 30% high, 31% medium, 17% low and 3% very low wheat growth suitability. Additionally, almost 3% of the area was ignored because of restrictive characteristics (Figure 9).

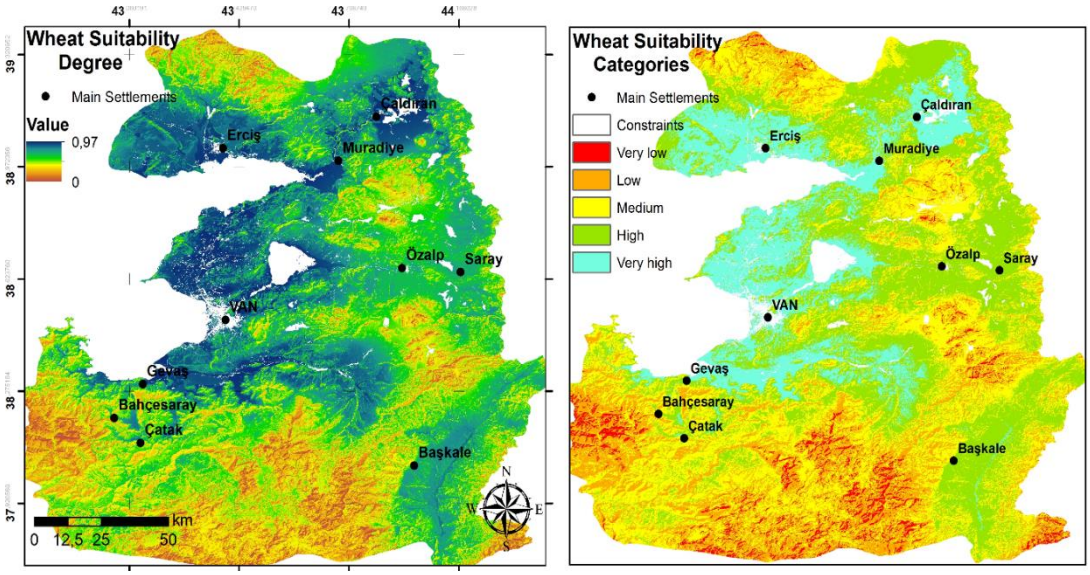


Figure 9. Wheat suitability maps by linear approach (MCA).

In ANN technique, weighting was performed automatically based on existed wheat areas. ROC statistic was applied using same testing dataset with linear method. ROC co-efficiency was obtained to be 0.71 for ANN analyses. Wheat suitability categories were classified as 32% very high, 9.4% high, 9.6% medium, 11.7% low and 34.3% very low respectively. ANN result was not match very well with testing data according to the ROC value. Because, 0.71 was lower than 0.75 threshold and it is mean that the ANN result was matched with testing data slightly (Figure 10).

The highest suitable regions (very high suitability) were compared by current Land Use Cover (LUC) maps of the region that was produced by Satir et al. (2016) according to the CORINE Level 1 classification scheme. Results showed that grasslands of the region were under the pressure of the agriculture. Because, 67% of the most suitable regions were covered by the agricultural areas. However, 28% of the most suitable areas were covered by the grasslands (Table 5). In addition, agricultural areas were increased in last 15 years period, and main aspect of the LUC change was detected from grassland to the agriculture (Satir et al. 2016).

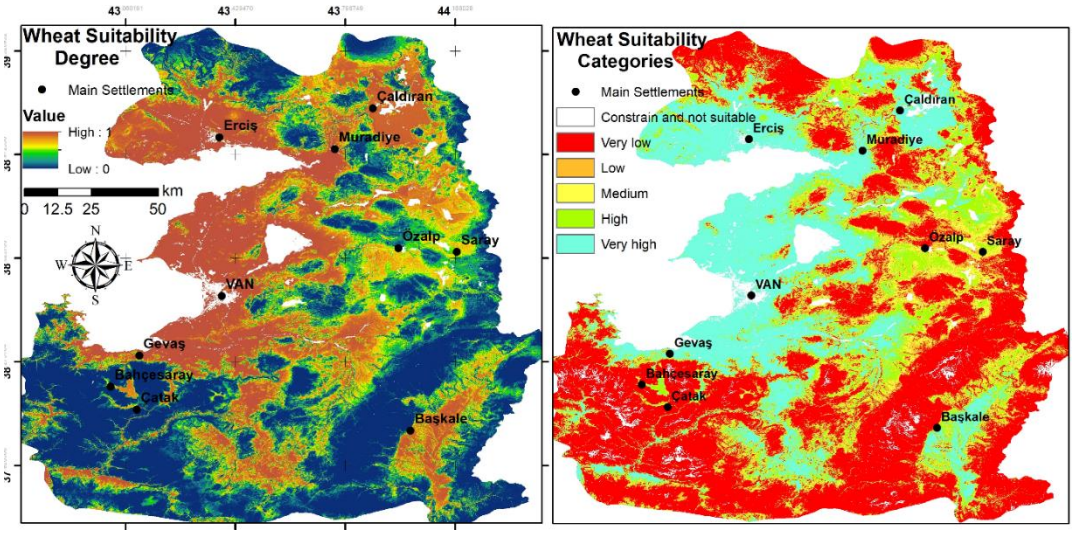


Figure 10. Wheat suitability maps by ANN approach.

Table 5. Areal analyses of the wheat suitability categories and distribution of the very high suitable areas based on current LUC

Suitability	(%) Coverage	Area (ha)	LUC	(%) Coverage	Area (ha)
Very high	15	271220	Agriculture	67	181651
High	30	582967	Grassland	28	76073
Medium	31	593026	Bareground	4	13098
Low	17	330127	Other	<1	398
Very low	3	56855			
Constraints	4	59037			

4. Discussion and Conclusions

This paper demonstrated two spatial decision support approaches considering some of the important environmental factors to map the wheat growth suitability. Agricultural areas have been decreased as a result of industrial development particularly in Turkey. The status of study area is taken as governmental subventions for the animal husbandry and field crops especially for the cereal cultivation. Therefore, this region is under the urbanization pressure due to immigration from the rural areas (Satir and Erdogan, 2016). Research was focussed on the wheat areas, also the wheat is one of the most resistant field crops in cold regions, and it is cultivated in large fields in the Eastern Turkey. Additionally, in the 2017-18 marketing year (July/June), cereal imports were increased to 7.4 million tonnes (up 4 percent) compared to previous year that was the 7.1 million tonnes particularly in wheat (FAO, 2018). Although the wheat cultivation and yield have been increased, wheat import has been in an increasing trend. However, production increase was caused by the ideal climatic conditions instead of the increase in wheat fields (USDA, 2018). Therefore, crop based protection on agricultural land management must be one of the most important priority in Turkey and fast developing countries. As a result of the priority analysis, precipitation is an important factor because cereal production is only dependent on rainfall or snow melts in the study area.

Ideal data based approaches were applied, and wheat cultivated fields were used to be ideal places covering two years growing periods in the study area. Many similar studies on agricultural suitability mapping were used expert based or literature based techniques to define priority of factors and AHP approach was used to define the weights of factors. Additionally, these studies ignored validation (Sarkar et al. 2014; Yalew et al. 2016). Therefore, this study bridges the gap between mapping and validating the crop growth suitability to get the more solid results. In this extent, two approaches were examined to be ideal data based linear and ANN. In the first approach, location of the existed wheat fields was analysed according to the spatial distribution inside the categories. So that factor importance was tried to detect for wheat growth based on hypotheses that was described in weighting section. In ANN technique, network architecture was established according to the input dataset and

experimental analyses. Results of the two techniques were validated using ROC statistic and ROC co-efficiencies were obtained to be 0.875 and 0.71 respectively. Linear technique was more successful than ANN in our study. In linear approach, weighting of the input factors was completed using standard deviation based method and this method was in user control, so user can be modified the categorization thresholds. However, in ANN technique weights were defined automatically according to the input parameters and training dataset. Additionally, distribution of the training points in each category was considered in linear technique. Başkale location (South Eastern) was more suitable than linear technique for wheat cultivation in ANN technique. Training point density was less than other regions in this part because only some limited areas have been suitable for agriculture in Başkale region and linear technique was defined successfully. On the other hand, ANN method was defined Başkale region as very high suitable for wheat cultivation. In general, this region is suitable for wheat farming, but productivity is less than lakesides.

In conclusion, suitable regions were located around the Van Lake because of appropriate climatic and topographic conditions. Combination of the ideal data and multiple data assessment technique in a GIS environment has an impressive potential to evaluate the crop growth suitability. In this extent, cultivated parcels or yield dataset can be used to extract the ideal parcels or points for the crop growth. Transportation accessibility, hill shade (sun effect), slope and precipitation were defined the most significant factors on wheat growth in the study area orderly. Another result of the study was that only the 67% of the very suitable classified areas were agriculture today. It is mean that there are some very suitable fields which has not been used for agriculture in the region. This result is important for the land use planners to calculate potential ecosystem service value, and livestock in the region.

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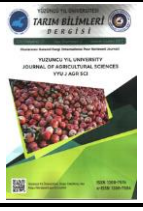

Araştırma Makalesi (Research Article)

Performance Evaluation of PR2 in Determination of Soil Water Content

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PR2,
Soil water content

Abstract: As it is known, drought is one of the most important issues of recent years. On the other hand, agriculture is the sector that uses the most water. The impact of drought can be reduced by reducing the water used in agriculture. Therefore, it is very important to determine the application time and amount of irrigation water for a successful agricultural irrigation management. One of the most important ways to achieve this success is to accurately determine and monitor the water content in the plant root zone. Soil water content can be determined in two ways; direct and indirect methods. The direct measurement method is tedious, laborious and time consuming. Instead, a large number of indirect measurement methods are developed. One of these indirect measurement methods is the PR2 Profile Probe method. In this study, the possibilities of using PR2 method under different soil water content conditions were investigated. First, the calibration of the PR2 method was made within 40 cm of soil depth. Then, the water content in the soil was monitored by the PR2 method under three different soil water content (100%, 75% and 50%) conditions. R^2 values for calibration relationships varied between 0.7947 and 0.9305. In the study, it was concluded that soil water content could be monitored with PR2 Profile Probe.

Toprak Su İçeriğinin Belirlenmesinde PR2'nin Performansının Değerlendirilmesi

Makale Bilgileri

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Anahtar Kelimeler
Gravimetrik yöntem,
Toprak su içeriği,
PR2,
Sulama yönetimi

Öz: Bilindiği gibi kuraklık, son yılların en önemli konularının başında gelmektedir. Öte yandan, tarım en fazla suyu kullanan sektör konumundadır. Tarımda kullanılan suyun azaltılmasıyla kuraklığın etkisi azaltılabilir. Bu nedenle, başarılı bir tarımsal sulama yönetimi için sulama suyunun uygulama zamanı ve miktarının belirlenmesi çok önemlidir. Söz konusu başarıya ulaşmanın en önemli yollarından biri, bitki kök bölgesindeki su içeriğinin doğru bir şekilde belirlenmesi ve izlenmesidir. Toprak su içeriği doğrudan ve dolaylı yöntemler olmak üzere iki şekilde belirlenebilmektedir. Doğrudan ölçüm yöntemi yorucu, zahmetli ve zaman alıcıdır. Bunun yerine çok sayıda dolaylı ölçüm yöntemleri geliştirilmektedir. Söz konusu dolaylı ölçüm yöntemlerinden biri de PR2 Profile Probe yöntemidir. Bu çalışmada, farklı toprak su içeriği koşullarında, PR2 yönteminin kullanılma olanakları araştırılmıştır. İlk olarak, 40 cm toprak derinliği içinde PR2 yönteminin kalibrasyonu yapılmıştır. Daha sonra üç farklı toprak su içeriği (% 100, % 75 ve % 50) koşullarında PR2 yöntemiyle topraktaki su içeriği izlemeye alınmıştır. Kalibrasyon ilişkileri için R^2 değerleri 0.7947 ile 0.9305 arasında değişim göstermiştir. Araştırmada, PR2 Profile Probe ile toprak su içeriğinin izlenebileceği sonucuna varılmıştır.

1. Introduction

The soil is a dynamic and heterogeneous system in which all living things inhabit and plants are grown. Due to the fact that soil is the most important growing environment for plants, the knowledge of the basic soil-water relations in modern agriculture concerns not only those who deal with soil and irrigation but also a wide range of fields ranging from plant breeders to forestry, environment and civil engineering.

Accordingly, the measurement of soil water content is necessary for irrigation engineering, land and water conservation studies, many environmental and engineering studies (Çetin, 2003). One of the most important problems in the agriculture sector in the coming years is the sustainability of irrigated agriculture.

The studies on increasing the efficiency of the unit production and increasing the efficiency of the water used in the agricultural production are important issues for water saving. For this aim, determination and monitoring of soil water content in irrigation agricultural lands with effortless, fast and easy-to-use methods has become very important.

There are two basic methods to determine and monitor soil water content: 1) direct measurement and 2) indirect measurement. The direct method of measurement requires the gravimetrical removal of soil samples, spoiled or intact. This method is tedious and time-consuming. With indirect methods, soil water content cannot be measured directly. Here, another parameter that varies depending on the water content in the soil is measuring and calibrating the soil water content.

In calibration studies, R^2 is one of the most important parameters that show the linear relationship between directly measured soil water content and the other indirect measurement methods. It is desirable that the value of R^2 is close to 1. Because the value of R^2 takes a value close to 1, it increases the reliability/validity of the indirect measurement method in determining the soil water content.

Numerous studies have been carried out on the indirect measurement method of soil water content (eg, Tülün, 2005, Evett et al., 2006, Köksal et al., 2011, Kirnak and Akpinar, 2016). Sometimes different and sometimes parallel results emerged depending on other factors such as the method, soil properties, etc. studied in the research. Indirect methods include many methods such as neutron probe and TDR (Time Domain Reflectometry).

The Profile Probe method can also be counted among these. With the Profile Probe method, the water contents at different depths of the soil can be measured. For example, Ekinci and Başbağ (2019) measured the soil water content using the Delta T Profile Probe device. This article deals with the determination and monitoring of soil water content by the Profile Probe method, which has become very common in recent years.

This research has two aims: 1) the first was to investigate the possibility of using the Profile Probe Type PR2 in monitoring the water content of the plant root zone under greenhouse conditions, 2) the second aim of the study was to determine the possible changes in the water content of the plant root zone at three different irrigation water levels during the spring growth season.

2. Materials and Methods

2.1. Study area

The research was carried out in a greenhouse in the Research and Application Area of the Faculty of Agriculture at Akdeniz University. The survey area is located between 30 °C 38' 30"- 30 °C 39' 45" east longitudes and 36 °C 53' 15"- 36 °C 54' 15" north latitudes. The height of the study area is 54 m (Anonymous, 1998).

In the research area where the Mediterranean climate is dominant, summers are warm and dry, winters are warm and rainy. The average temperature in Antalya is 18.0 °C, the coldest month is January with 9.2 °C, and the warmest month is July with 28.2 °C. The annual average relative humidity is 63%, the average total precipitation is 1063.5 mm and the average total evaporation is 1 886.3 mm (Anonymous, 2000).

The soil in the research area consists of Gölbaşı series. The Gölbaşı series of soils, which developed on massive travertines, were included in the Entisol order due to their lack of profile

development and young soil. All the profiles of this young series of soils with AC horizon possess clay-tin textures. They are located in almost flat and nearly flat topography (Sarı et al., 1993). Some soil characteristics of the greenhouse in which the survey was conducted are given in Table 1.

Table 1. Soil properties of the study site

Depth (cm)	Field capacity (cm^3 cm^{-3})	Wilting point (cm^3 cm^{-3})	Bulk density (g cm^{-3})
0-20	0.292	0.196	1.128
20-40	0.271	0.208	1.236
40-60	0.251	0.186	1.286

2.2. Calibration of Profile Probe Type PR2

The Profile Probe Type PR2 calibrations were first made in three different places in the greenhouse in the dimensions of 1×1 m. A large number of gravimetric soil samples were needed to perform an accurate calibration. In this case, a number of pits-holes may be formed around the PR2 access tube. For this reason, three square borders with soil embankments constructed (the soil pans) in order to avoid adversely affecting the calibration operation of cavities that may form around the PR2 access tube during the retrieval of a large number of gravimetric soil samples. At the same time, the calibrations performed in the three different places made it possible for the greenhouse soil to be better represented.

The PR2 access tube was placed in the middle of the soil pan. Then, the gravimetric soil samples (W, g g^{-1}) were taken from the depths of 10, 20, 30 and 40 cm from the first soil pan while the soil was dry. Simultaneously PR2 readings (mV) were made. The Gravimetric soil samples were taken from the second soil pan while the soil was partially wet one week later and again at depths of 10, 20, 30 and 40 cm. Simultaneous readings with PR2 were also recorded. One day later, gravimetric soil samples were taken from the third soil pan, which was completely saturated with water, again at the depths of 10, 20, 30 and 40 cm. Simultaneously PR2 readings were made. Gravimetric soil samples (W, g g^{-1}) and PR2 readings (mV) were repeated three times each time.

The water contents determined by the weight basis (W, g g^{-1}) of the gravimetric soil samples were converted to the volumetric water content (θ, cm^3 cm^{-3}) taking into account the soil unit volume mass (ρ, g cm^{-3}). Finally, a figure was made on the computer in such a way that the PR2 readings on the X axis and the volumetric water content of the soil were on the Y axis. Similarly, in a calibration study of the neutron probe, a figure was made on the computer (Soil Physics Laboratory, 1997) with the neutron probe count ratio on the X axis and the volumetric water content (θ, cm^3 cm^{-3}) on the Y axis. In another study by Kirnak and Akpinar (2016), TDR's measured dielectric constant (K) on the X axis and the volumetric water content (θ, cm^3 cm^{-3}) of the soil on the Y axis were included in the calibration process of TDR. Calibration process was completed by showing R^2 and equation on the figure.

2.3. Irrigation water for performance evaluation of PR2

The main aim of this article is only related to Profile Probe Type PR2 calibration and its possibilities for use. The irrigation water was obtained from the pumping system in the Research and Application Area at Akdeniz University.

The study lasted 129 days. A total of 24 irrigation applications were carried out beginning from the implementation of irrigation treatments. With the Profile Probe Type PR2, the water content of the root region of the plant was monitored at certain intervals throughout the season. Using the equation obtained from the Profile Probe Type PR2 calibration, the seasonal water content was also converted to the volumetric water content.

In this study, three irrigation treatments (T1, T2 and T3) were dealt with in order to check the Profile Probe Type PR2 measurements. T1 treatment was full irrigation. The remaining two irrigation treatments T2 and T3 were deficit irrigation treatment, which received 25% and 50% reduced amount of irrigation water, compared respectively to T1.

Two statistical parameters were used to compare predicted data from PR2 measurements with the observed gravimetric soil samples as (1) the coefficient of determination (R^2) and (2) mean value of data.

3. Results

3.1. Profile Probe Type PR2 Calibration

A total of 108 volumetric soil water samples and 324 times PR2 readings were used for the calibration. Three different figures were created for the calibration in the study.

In the first figure, the sampling values obtained in all the three of the dry, partly wet and full wet conditions were used (Figure 1). In Figure 2, the values in partially wet and full wet conditions were used. In Figure 3 shows the values regarding the dry and full wet conditions.

In the calibration studies, parameter R^2 is the linear relationship between the direct measurement and indirect measurement methods. It is desirable that the value of R^2 is close to 1. As seen in Figure 1, the R^2 value is 0.8625. In Figure 2, it can be seen that R^2 is 0.7947.

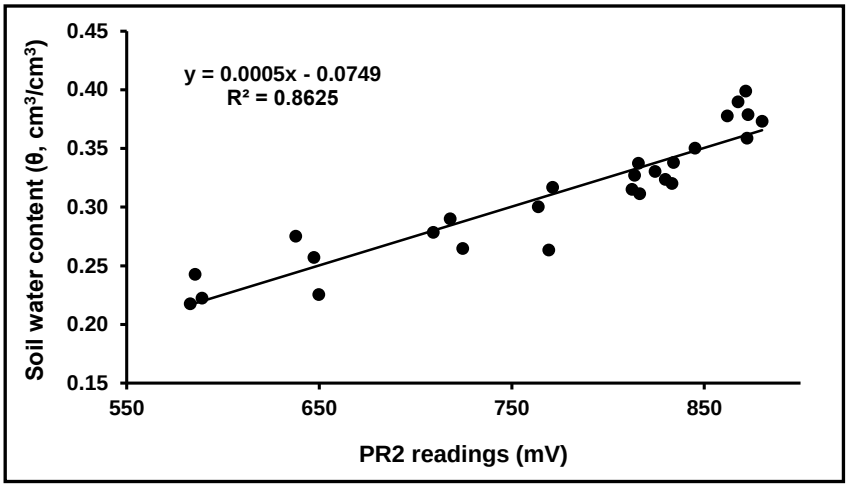

Figure 1. Profile Probe Type PR2 calibration curve in dry, partially wet and fully wet soil conditions.

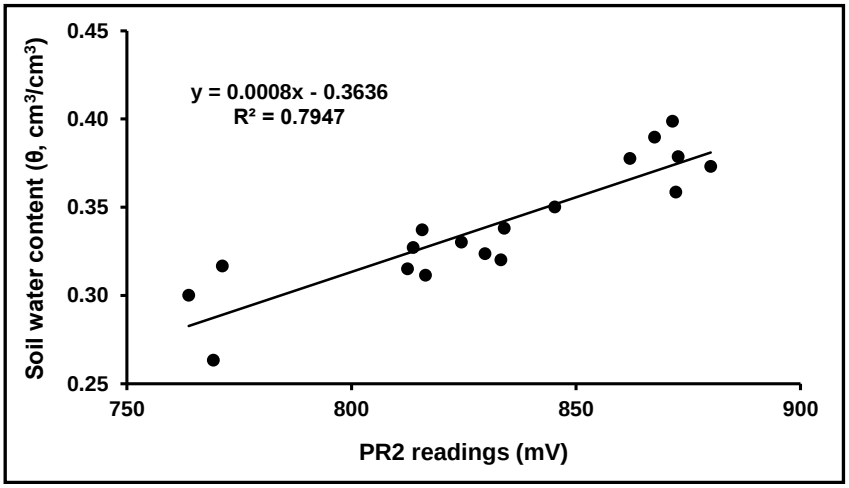

Figure 2. Profile Probe Type PR2 calibration curve in partially wet and fully wet soil conditions.

In Figure 3, the R^2 value is calculated as 0.9305. In these figures, the curve that best represents the PR2 reading with volumetric soil water is shown in Figure 3. For this reason, the PR2 readings were converted to volumetric water content using the calibration equation obtained from Figure 3. A figure of volumetric soil water and PR2 readings converted to volumetric water content can be seen in Figure 4.

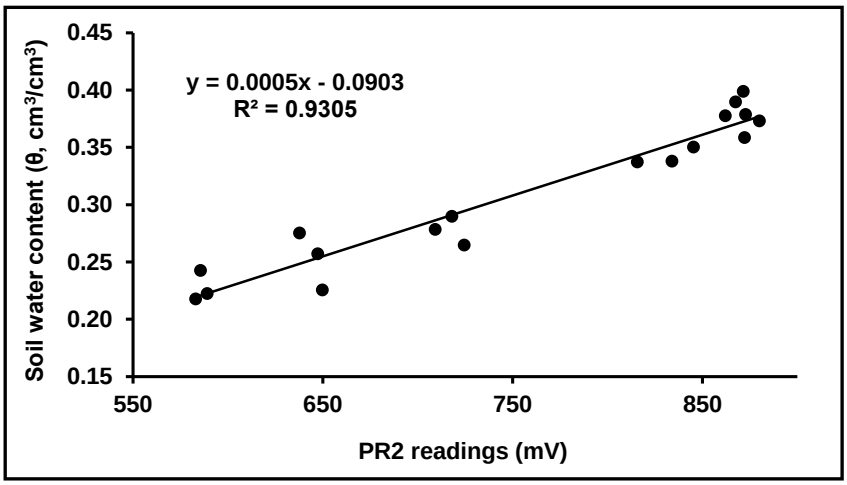

Figure 3. Profile Probe Type PR2 calibration curve in dry and fully wet soil conditions.

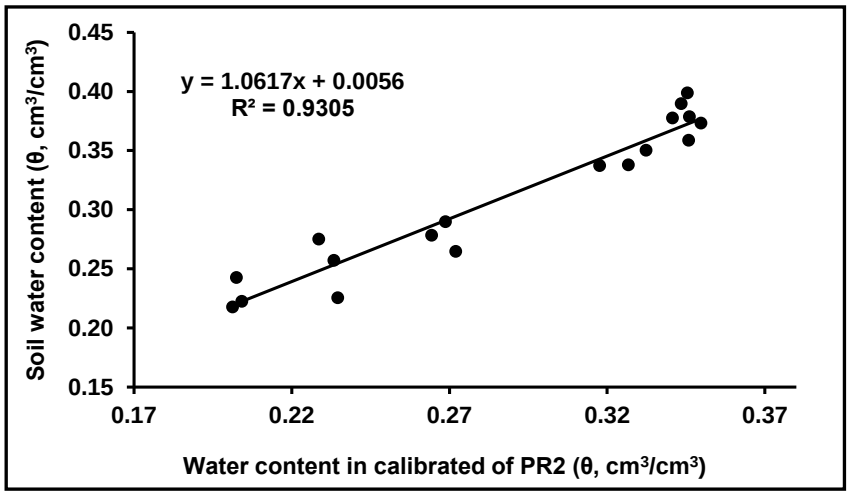

Figure 4. The relationship between calibrated volumetric water content of the Profile Probe Type PR2 reading and gravimetric water content.

3.2. Performance Evaluation of PR2 in soil water content

The change in soil water content during the season is given in Figure 5 and Figure 6. Figure 5 shows the variation of seasonal soil water content under T1 and T2. The amount of the irrigation water was about 25% less than that of T1. In the figure, it can be seen that the water content under the T2 treatment was less than the T1 treatment. This situation has come true as expected. As would be expected, the T1-rated soil water content had the highest values and the field capacity was close. In the case of a 50% deficit (T3) from the irrigation water (T1), the water content was clearly less than that of T1 (Figure 6). This shows that the research treatments discussed at the same time in this study were well planned and implemented correctly (Figure 5, Figure 6). In addition, Profile Probe Type PR2 reveals relatively accurate results for the soil water content measurement sensor.

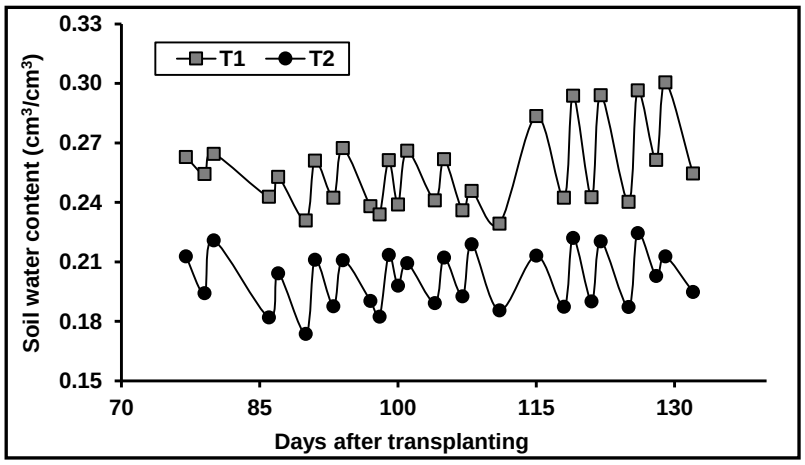

Figure 5. Seasonal variation of soil water content under T1 treatment and T2 treatment.

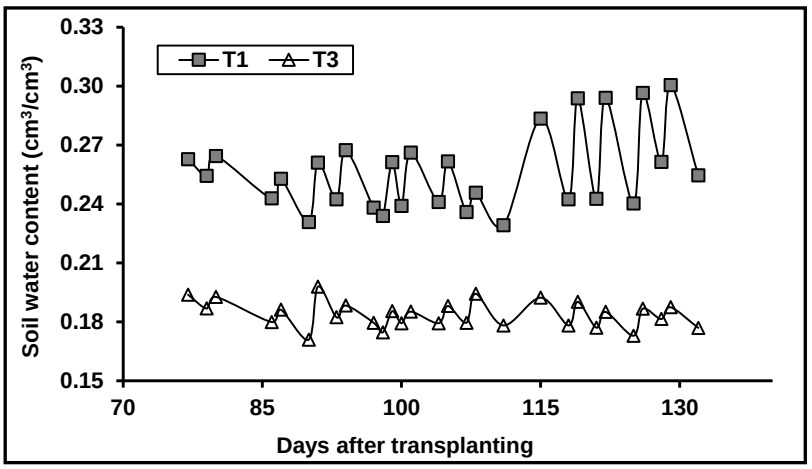

Figure 6. Seasonal variation of soil water content under T1 treatment and T3 treatment.

4. Discussion and Conclusion

Numerous studies have been conducted regarding the indirect measurement methods for measuring soil water content (eg, Tülün, 2005, Evett et al., 2006, Köksal et al., 2011, Kirnak and Akpinar, 2016).

The methods discussed in these studies have been somewhat different from one another depending on soil characteristics and other factors. Two of the most commonly used indirect measurement methods are neutron probe and Time Domain Reflectometry (TDR) methods in soil water content measurement studies.

One of the most important parameters showing the linear relationship between the direct measurement method (volumetric soil water content) and other indirect measurement methods is the R^2 value in the studies regarding calibration. For example, in a calibration study of the neutron probe, the R^2 value was found to be 0.58 for 15-165 cm soil profile depth (Soil Physics Laboratory, 1997). Another study of neutron probes showed that the calibration curve R^2 for 30 cm of different layers varied between 0.95 and 98 (Can and Kukul Kurttaş, 2009). In another study conducted by Köksal et al (2011), R^2 value; 0.86 for 0-30 cm soil depth, 0.82 for 30-60 cm soil depth, 0.81 for 60-90 cm soil depth and 0.92 for 90-120 cm soil depth. In the same study, it was found that the value of R^2 was very low (0.56) throughout the entire soil profile (0-120 cm soil depth) (Köksal et al., 2011).

Numerous studies have also been conducted on the indirect measurement of soil water content by TDR. For example, in the TDR calibration conducted by Kirnak and Akpinar (2016), the R^2 value was calculated as 0.80. Tülün (2005) found that the R^2 value varied between 0.8583 and 0.9986 in TDR calibration studies performed on different soil structures. In this study, R^2 values; 0.9716 for silty clay,

0.9797 for silty clay, 0.9986 for sand, 0.9344 for sandy clay, 0.9782 for clay, 0.8583 for clay and 0.9941 for clay.

In our study, the R^2 values for Profile Probe Type PR2 ranged from 0.7947 to 0.9305 (Figure 1, Figure 2, Figure 3). The values obtained from our Profile Probe Type PR2 study were in general parallel to the results of some neutron probe and TDR studies. However, Evett et al. (2006) report that Delta T PR1/6 was sensitive to temperature fluctuations. Evett et al. (2006) conducted a very detailed calibration study on EnviroSCAN, Diviner 2000, Delta-T PR1/6 and Trime T3 under laboratory conditions.

Our work is a more general and detailed work because our aim in this study was to measure the soil water content relative to the Profile Probe Type PR2. This situation, in fact, meets our needs. On the other hand, we think that it is necessary to study a more detailed calibration of the Profile Probe Type PR2, which takes into account the other factors such as temperature, salinity and so on.

In the study, it was determined that R^2 values for Profile Probe Type PR2 calibration varied from 0.7947 to 0.9305. These values were generally parallel to some other research results on neutron probe and TDR. On the other hand, we aimed to determine the use of the Profile Probe Type PR2 only when the soil water content was measured relatively in this study. For this aim, we think that we have achieved the goal because the results show that Profile Probe Type PR2 can measure soil water content relatively. In addition, we recommend taking into consideration the other factors such as temperature, salinity, etc. in a detailed calibration study of Profile Probe Type PR2. The water content in the root zone of the plant was highest in T1. In other parcels, soil water content was lower than T1. The lowest soil water content in the root zone of the plant was measured in terms of T3. The area with the highest water content was found to be in T1. The decrease in the content of soil water in the root zone of the plant can be seen due to the decrease in the amount of irrigation water.

Acknowledgment

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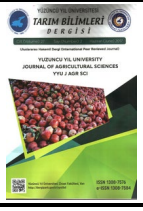

Araştırma Makalesi (Research Article)

Influence of Internal and External Factors for Youth Agripreneurship Development in Sumatra Region

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Keywords
External factors,
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SWOT analysis,
Youth agripreneurship development.

Abstract: Development of the agricultural sector is very necessary for efforts and policies to develop agricultural systems that can increase the regeneration of advanced and modern farmers**.** The research was aimed to analyze internal and external factors of youth agripreneurship development (YAD) in the Sumatra region. This research was conducted in the coordination area of Politeknik Pembangunan Pertanian Medan, which is spread over six provinces in Sumatra, including: Aceh, North Sumatra, West Sumatra, Jambi, South Sumatra, and Bengkulu provinces with all YAD participants in program period from 2017 to 2019. The internal factors include independence and knowledge, while the external factors include capital resources, innovative services, social networks and cooperation. This research was conducted from July until September 2020. The data collection method was conducted by face to face interviews with 230 respondents, field observations, and online interviews and then analyzed using Strength, Weaknesses, Opportunities, Threats (SWOT). The results showed the importance of strategy to improve the YAD through to implementing the diversification strategy. Strategies should be implemented by increasing knowledge and utilization of access to industry-based technology in customer service and product marketing; independence in increasing knowledge and communication skills by attending training; establish more intense cooperation with business partners; and increase promotion to various agencies and companies to attract and establish business cooperation.

Sumatra Bölgesinde Genç Tarım Girişimciliğinin Gelişiminde İç ve Dış Faktörlerin Etkisi

Makale Bilgileri

Geliş: 05.12.2020
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DOI: 10.29133/yyutbd.836181

Öz: Gelişmiş ve modern çiftçilerin rejenerasyonunu artırabilecek tarımsal sistemlerin geliştirilmesine yönelik çaba ve politikalar için tarım sektörünün geliştirilmesi çok gereklidir. Araştırma, Sumatra bölgesindeki genç tarım girişimciliği gelişiminin (GTG) iç ve dış faktörlerini analiz etmeyi amaçladı. Bu araştırma, Sumatra'da Aceh, Kuzey Sumatra, Batı Sumatra, Jambi, Güney Sumatra ve Bengkulu illeri olmak üzere altı ilde yayılmış olan Politeknik

Anahtar Kelimeler
Dış etkenler,
İç Etkenler,
SWOT analizi,
Genç tarım girişimciliğini geliştirme.

Pembangunan Pertanian Medan'ın koordinasyon alanında tüm GTG katılımcıları ile 2017-2019 yılları arasında gerçekleştirilmiştir. İç faktörler bağımsızlık ve bilgiyi içerirken, dış faktörler sermaye kaynakları, yenilikçi hizmetler, sosyal ağlar ve işbirliğini içermektedir. Bu araştırma Temmuz-Eylül 2020 tarihleri arasında gerçekleştirilmiştir. Veri toplama yöntemi, 230 katılımcı ile yüz yüze görüşmeler, saha gözlemleri ve çevrimiçi görüşmeler yoluyla gerçekleştirilmiş ve ardından güçlü, zayıf yönler, fırsatlar ve tehditler (SWOT) kullanılarak analiz edilmiştir. Sonuçlar, çeşitlendirme stratejisinin uygulanması yoluyla YAD'yi iyileştirme stratejisinin önemini gösterdi. Stratejiler, müşteri hizmetleri ve ürün pazarlamasında endüstri tabanlı teknolojiye erişim ve bilgi birikimi artırılarak, eğitime katılarak bilgi ve iletişim becerilerini artırmada bağımsızlığı arttırarak, iş ortakları ile daha yoğun işbirliği kurarak, ticari işbirliğini çekmek ve kurmak için çeşitli kurum ve şirketlere tanıtımı artırarak, uygulanmalıdır.

1. Introduction

The agricultural sector is the third sector in Indonesia which has contributed by 12.72% to GDP in 2019 and has decreased over the last 10 years (Statistics of Indonesia, 2020). The decrease in the contribution of the agricultural sector was influenced by decrease in crop productivity due to reduced of land (Usman and Juliyani, 2018; Santoso, 2015), climatic factors include rainfall, rainy days, and humidity (Tampubolon and Sihombing, 2017; Sihombing et al., 2020), the use of production costs such as subsidized fertilizers and pesticides (Santoso, 2015; Listiani et al., 2019), the capital used (Mamondol, 2017), skills and the total of labor required (Suwarto, 2008; Langit and Ayuningsasi, 2019) and other factors.

The labor is significant and has a positive effect on increasing farming production of citrus (Langit and Ayuningsasi, 2019). Based on data from the Ministry of Agriculture (2018) the Indonesian population working in the agricultural sector is dominated by the food sub-sector of 46.58%, followed by the plantation sub-sector by 30.79%, the livestock sub-sector by 13.47%, and the sub-sector horticulture by 9.16%. In addition, it was also reported that the age of labor in the agricultural sector was still dominated by prime until old ranging from 25 to > 60 years of 88.89% and the remaining by 11.11% at young age ranging from 15 until 24 years and education levels were dominated from primary school until senior high school/vocational school by 98.53%. The low interest of the youth generation in developing the agricultural sector has resulted in the lack of regeneration and has an impact on inhibiting innovation in the agricultural sector as well as has resulted in an imbalance between the population and the total of food available.

The low interest of the youth generation in the agricultural sector in Indonesia can be caused by several factors. Insani et al. (2018) reported that the agricultural system in Indonesia for more than 20 years was directed in a top-down, less place for innovation thus causing stagnation and homogenization of farming cycles. It is causes the young generation to be less interested in working in the agricultural sector. Gulo et al. (2018) also reported that the young generation tends to choose higher wages, agricultural yield is very long and often unsatisfactory. Maga et al. (2016) reported that the level of youth motivation in managing cocoa farming is classified as low, that youth prefer the type of work that earns money quickly compared to cocoa farming.

Efforts to increasing the spirit of young generations to work in the agricultural sector in Indonesia can be conducted by building participation, creating innovation, and the role of the government. Gulo et al. (2018) reported that the surrounding environment show that a lot of people farming with an incomes that is classified as promising to meet the necessities of life with the result that youth generations are motivated for interest in farming, especially in the food sub-sector. Insani et al. (2018) reported that the influence factors of young farmers participation in environmentally friendly agricultural programs include: (1) the characteristics of young farmers with motivation that can provide the value of enthusiasm and always a willingness, opportunity, and ability to participate; (2) innovation of young farmers in environmentally friendly agricultural programs by making natural pesticides then traded and make a profit; (3) environmental factors that affect the level of young farmers participation in environmentally friendly agricultural programs, such as locations in the mountains and government policies to implement environmentally friendly agriculture.

Therefore, the development of the agricultural sector requires efforts and policies to develop an agricultural system that is able to increase the regeneration of advanced and modern farmers. The government policies and breakthroughs by the Ministry of Agriculture with providing education of entrepreneurship for young generation in agriculture through the Youth Agripreneurship Development (YAD). YAD is an effort to raise awareness, grow, develop, and be independent of the young generation in the field of agricultural entrepreneurship which is manifested in the form of business in the agricultural sector. Young agripreneurship are expected will be able to regenerate farmers in maintaining the availability of food, able to develop more creative and innovative agriculture, able to keep up with technological developments, and able to maintain national economic stability and reduce unemployment by creating jobs. The research was aimed to analyze of internal and external factors for youth agripreneurship development (YAD) in Sumatra region.

2. Material and Methods

2.1. Determination of Location and Sample of YAD

The location was determined using a purposive method for youth agripreneurship development who received the YAD program in the coordination area of Politeknik Pembangunan Pertanian Medan, which is spread over six provinces in Sumatra region (Aceh, North Sumatra, West Sumatra, Jambi, South Sumatra, and Bengkulu Provinces). The population taken were 542 participants of YAD on the program period from 2017 to 2019 (Table 1).

Table 1. YAD participants from implementing education institutions in the coordination area of Politeknik Pembangunan Pertanian Medan from 2017 to 2019 period

No	Provinces	YAD Implementing Education Institutions	Participants (Person)		
			2017	2018	2019
1	Aceh	Universitas Syiah Kuala	2	2	5
		VA-AD Saree	6	6	8
		VA-AD Bireuen	-	-	8
		VA-AD Kutacane	-	-	10
2	North Sumatra	Politeknik Pembangunan Pertanian Medan	155	51	75
		Universitas Sumatera Utara	-	5	5
3	West Sumatra	Universitas Andalas	5	6	9
		Politeknik Pertanian Payakumbuh	-	-	12
		VA-AD Padang	9	6	9
		VA-AD Padang Mengatas	10	6	10
4	Jambi Jambi	Universitas Jambi	-	4	3
5	South Sumatra	VA-AD Sembawa	-	10	77
6	Bengkulu	Universitas Bengkulu	-	10	9
		Quantity	187	106	249
		Total		542	

Note: VA-AD (Vocational School-Agricultural Development).

The sampling method was conducted by accidental sampling and the number of samples was 230 respondents who were calculated based on the Slovin formula (Sevilla, 2007):

$$n = \frac{N}{1+Ne^2} = \frac{542}{1+(542)\times(0.05)^2} = 230 \text{ respondents}$$

Note:

n = number of samples
N = number of populations
e = acceptable error tolerance = 0.05

2.2. Data Collection Method

Data collection was conducted by face to face interviews with participants, observation, and interviews online using google form and phone or email. Data collection were conducted from July to September 2020. Measurement of internal and external factors used in this research could be seen in Table 2.

Table 2. Measurement of internal and external factors for YAD in Sumatra region

Internal factors	Score	Average	Total Score
Answer criteria for the independence variable			
Strongly agree	5	3.79	
Agree	4		
Neutral	3		
Disagree	2		
Strongly disagree	1		Independence and knowledge variables including strength and the total score = 1.00
Answer criteria for the knowledge variable (training or apprenticeship)			
More than 3 times	5	3.33	
3 times	4		
2 times	3		
Once	2		
Never	1		
External factors			
Answer criteria for the capital resources variable			
Strongly supported	5	4.20	Capital resources variable including opportunities and the total score was 1/3 = 0.33
Supporting	4		
Sufficient to supporting	3		
Not supporting	2		
Strongly not supporting	1		
Answer criteria for the innovative services variable (audiovisual, internet facilities, access to transportation, communication services, social media, online markets, brochures, pamphlets, leaflets, stickers)			
More than or equal to three choices	5	2.40	Innovative services, social networks and cooperation variables including threats and the total score were 2/3 = 0.67
More than or equal to two choices	3		
Once choice	1		
Answer criteria for the social networks and cooperation (agricultural offices, cooperatives, market companies, wholesalers, online markets)			
More than or equal to three choices	5	2.93	
More than or equal to two choices	3		
Once choice	1		

After the data from the questionnaire is obtained, the average calculation is conducted for each variable then calculated the weight with the following formula:

$$\text{Weight of independence} = \frac{\text{average IV}}{\text{average IV} + \text{average KV}} \text{ x total score (1.00)}$$

$$\text{Weight of knowledge} = \frac{\text{average KV}}{\text{average IV} + \text{average KV}} \text{ x total score (1.00)}$$

$$\text{Weight of capital resources} = \text{average CRV x total score (0.33)}$$

$$\text{Weight of innovative services} = \frac{\text{average ISV}}{\text{average ISV} + \text{average SNCV}} \text{ x total score (0.67)}$$

$$\text{Weight of social networks and cooperation} = \frac{\text{average SNCV}}{\text{average ISV + average SNCV}} \text{ x total score (0.67)}$$

Note:

IV = independence variable
KV = knowledge variable
CRV = capital resources variable
ISV = innovative services variable
SNCV = social networks and cooperation variable

2.3. Data Analysis

The data used the internal factors (independence, knowledge); and the external factors (capital resources, innovative services, social networks and cooperation) that influenced the achievement of YAD. Internal factors in the form of independence means the ability to make their own decisions and take appropriate actions, the ability to solve problems and constraints, and also well-being managerial skills. Knowledge include the suitability of educational background, entrepreneurship education received, training and internships received, and also business experience has been over done. External factors include the initial capital resources support used, the customer service provided and the marketing technology used, the social networking and cooperation partners in running a business.

The data were processed using the Strength, Weaknesses, Opportunities, Threats (SWOT) analysis. SWOT analysis was amied to compare the internal factors (strength and weaknesses) within external factors (opportunities and threats) collectively as a basis for designing strategies and work programs. Determination of S, W, O, T obtained after obtaining the average value of each variables from the results of the questionnaire compilation. Internal factors will generate strengths and weaknesses through the Internal Factors Strategic Analysis (IFAS) matrix. The variables were categorized as strength if the average value is greater compared to the median value of the calculation scale, meanwhile the variables were classified as weakness if the average value is smaller compared to the median value of the calculation scale. External factors will generate opportunities and threats through the External Strategic Factors Analysis (EFAS) matrix. The variables were classified as opportunity if the average value is greater compared to the median value of the calculation scale, meanwhile the variables were classified as threat if the average value is smaller compared to the median value of the calculation scale.

3. Results

3.1. Determination of Strengths, Weaknesses, Opportunities and Threats for Achievement of Youth Agripreneurship

Based on the results of the SWOT analysis in determining the strengths, weaknesses, opportunities and threats of strategies for youth agripreneurship development (YAD) in Sumatra region can be seen in Table 3.

Table 3. Determination of strengths, weaknesses, opportunities and threats to the strategy of YAD in Sumatra region

Internal Factors	Strengths (S)	Weaknesses (W)
Independence	√	
Knowledge	√	
External Factors	**Opportunities (O)**	**Threats (T)**
Capital resources	√	
Innovative services		√
Social networks and cooperation		√

Table 3 showed that all variables in internal factors were classified as strengths, and not found variables of weakness. The variables of external factors were classified as opportunity found in capital resources, meanwhile the variables were classified as threat found in innovative services, and social networking and cooperation.

3.2. Determination of IFAS and EFAS Matrix for Youth Agripreneurship Development Strategy

Based on the results of the IFAS matrix in determining the strategy of youth agripreneurship development (YAD) in Sumatra region can be presented in Table 4. The weights value is obtained from the level of interest each variable which the total weight for all internal factors is one. Meanwhile, the score was obtained from the average value of the questionnaire results for each variable. The results of the IFAS matrix showed that the difference in the weighted score between strengths and weaknesses found in the ordinate of 3.57.

Table 4. The IFAS matrix for the strategy of YAD in Sumatra region

Factors of Internal Strategic	Weight	Score	Weighted Score
Strengths			
Independence	0.53	3.79	2.01
Knowledge	0.47	3.33	1.56
Total score of strengths	1.00		3.57
Weaknesses			
None			
Total score of weakness	0.00	0.00	0.00
Difference (strength - weakness)	1.00		3.57

Based on the results of the EFAS matrix in determining the strategy for youth agripreneurship development (YAD) in Sumatra region can be presented in Table 5. The weight value is obtained from the importance level of each variable which the total weight value for all external factors is one. Meanwhile the score value is obtained from the average value of the questionnaire summary results for each variable. The results of the EFAS matrix showed that the difference in the weighted score between opportunities and threats found in the ordinate of -0.41.

Table 5. The EFAS matrix for the strategies of YAD in Sumatra region

Factors of External Strategic	Weight	Score	Weighted Score
Opportunities			
Capital Resource	0.33	4.20	1.39
Total score of opportunities	0.33		1.39
Threats			
Innovative services	0.30	2.40	0.72
Social networks and cooperation	0.37	2.93	1.08
Total score of threats	0.67		1.80
Difference (opportunities - threats)	1.00		-0.41

3.3. Determination of the Position Matrix in SWOT

Based on the IFAS and EFAS matrices, were obtained at two points of ordinate such as the first ordinate point with a difference of strength-weakness of 3.57 and the second ordinate point with a difference of opportunities-threats of -0.41. The SWOT position matrix can be presented in Figure 1.

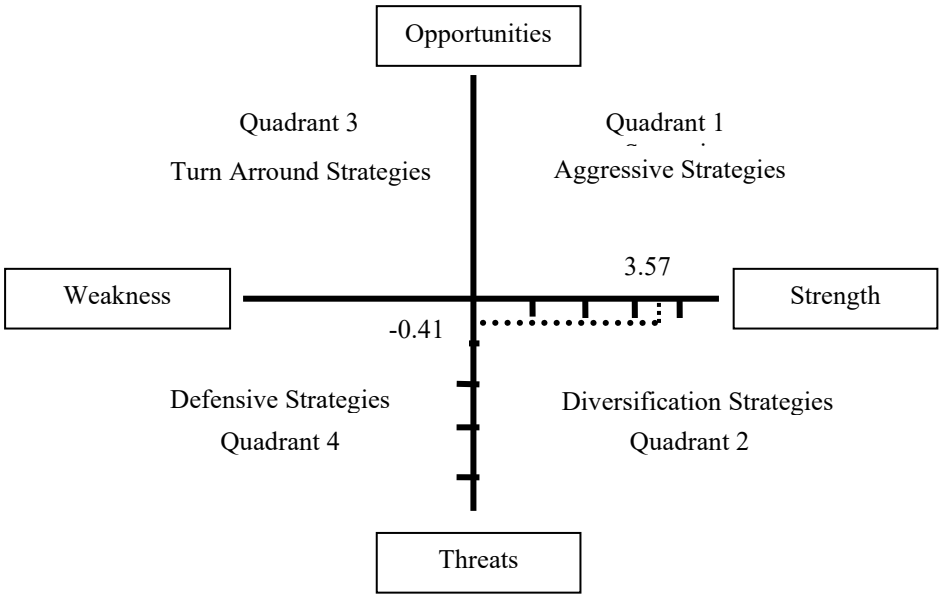

Figure 1. The SWOT position matrix for the strategy of youth agripreneurship development.

The SWOT position matrix for the strategy of YAD in Sumatra region was found in quadrant 2 or the diversification strategy. Despite facing various threats, youth agripreneurship still have strength from an internal perspective. The strategy should be applied by use the strength possessed to face and overcome the impact of the threat using the diversification strategy.

Based on the steps of the SWOT analysis, several strategies can be formulated using the SWOT matrix (Table 6).

Table 6. Strategies using the SWOT matrix

IFAS / EFAS	STRENGTHS (S) 1. Independence 2. Knowledge	WEAKNESSES (W) -
OPPORTUNITIES (O) 1. capital resources	S-O STRATEGY 1. Increase financial managerial skills and bookkeeping by training of financial management (S2, 01) 2. Improve the ability to observe opportunities and risks of using business capital (S1, S2, O1) 3. Dare to take risks in finding new sources of capital for business development (S1, O1)	W-O STRATEGY
THREATS (T) 1. Innovative services 2. Social networking and collaboration	S-T STRATEGY 1. Increase knowledge and use of technology based access industry 4.0 in customer service and product marketing (S2, T1) 2. Independence in increasing knowledge and communication skills by participating in training (S1, S2, T2) 3. Establishing more intense cooperation with business partners (S1, T2) 4. Increasing promotion to various agencies and companies to attract and establish business cooperation (S1, S2, T2)	W-T STRATEGY

4. Discussion and Conclusion

The variables of internal factors were classified as strengths, and not found variables of weakness. It was all participants in youth entrepreneurs have a education background in agricultural science and are familiar with agricultural studies with the result that all internal factors have the fairly high value in overall. In addition, participants also have the ability to make decisions, solve problems, and make the most of all the resources available. Educational background was linear with the level of independence of youth entrepreneurs in developing self-potential by searching for information and interacting with educational institutions of YAD implementing. According to Karami and Agahi (2018) empowerment of agricultural entrepreneurs can be conducted by aggressive strategies such as training and entrepreneurial skills, development and technical, finding the source of ideas, using new technology, increasing access to financial resources, create exhibitions and conferences. Malta (2016) reported that the efforts to increase farmer independence in making decisions for the achievement of farming, namely the active search for information related to farming and interactions with agricultural instructors.

The variables of external factors were classified as opportunity found in capital resources, meanwhile the variables were classified as threat found in innovative services, and social networking and cooperation. Capital resources was categorized as opportunities because the source of capital used by youth agripreneurship from the government of Indonesia through the Ministry of Agriculture. It showed that the role of the government is greatly supportive to the program of YAD in Sumatra region. In contrast, innovative services and social networking as well as cooperation were classified as threats because YAD in Sumatra region still use innovative services include easy access to transportation and 24-hour communication services as well as the marketing technology used still uses social media such as facebook, instagram, telegram and tweeter. It requires improving the skills of the youth generation of farmers in utilizing information technology such as business partners in selling agricultural products based online. According to D'Silva et al. (2009) the agricultural sector has enormous potential and a growing business with full and active support from the government provides and greater opportunities for young agricultural entrepreneurs. Abdullah and Sulaiman (2013) reported that the influence factors of young generation to be entrepreneurs include family support, government support and promotion through carnivals and festivals. Agahi and Karami (2012) social capital management in society is product quality and attention to new product development and its relationship with awareness of the global market. Addo (2018) reported that the personal factors that affect the success of agricultural entrepreneurship performance, including (1) inspiration and decisions to start agricultural entrepreneurship, (2) learning, discovery and innovation, (3) planning and coordinating business activities, (4) building and maintain relationships between customers, suppliers and business partners.

The results of the IFAS matrix showed that the difference in the weighted score between strengths and weaknesses found in the ordinate of 3.57. It showed that the educational background of YAD in Sumatra region was linearly related to the level of independence in managing farming with the result that diversification strategy is needed (Figure 1). According to Malta (2016) the effect of formal education was positively correlated by 9.40% in increasing farmer independence for decision-making for farming success include activeness searching for information related to farming and interaction with the instructor. Ommani (2011) reported that higher technical knowledge of farmers have a score of 0.24 was classified as the strength factor in managing the agricultural system business. Hormiga et al. (2011) added that basic and advanced of skills in agricultural education were needed to support agripreneurship. Magagula and Tsvakirai (2019) also stated that the agricultural knowledge was significantly (P <0.01) and has a positive effect on interest in participating for agripreneurship.

The results of the EFAS matrix showed that the difference in the weighted score between opportunities and threats found in the ordinate of -0.41. It was due to the low access to information in managing farming which makes it difficult for youth agripreneurship to collaborate with business partners with the result that the diversification strategy is needed (Figure 1). According to Karami and Agahi (2018) the challenges of agricultural entrepreneurial empowerment could be caused by a lack of suitable markets for the products produced, a lack of required facilities, and a lack of useful skills training with the weighing score of 0.25; 0.18 and 0.172, respectively. Sinyolo and Mudhara (2018) reported that the use of the entrepreneurial skills and abilities approach of farmers can be improve the food security of smallholders.

The conclusion of this research such as strategy formulation can be conducted in the development of youth agripreneurship in Sumatra region by implementing the diversification strategy, such as 1) increasing knowledge and utilization of access to industry-based technology in customer service and product marketing; 2) independence in increasing knowledge and communication skills by attending training; 3) establish more intense cooperation with business partners; and 4) increasing promotion to various agencies and companies to attract and establish business cooperation.

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Araştırma Makalesi (Research Article)

Turunçgil Unlubiti, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae)'nin Laboratuvar Koşullarında *Cucurbita moschata* Duch. Üstünde Popülasyon Büyüklüğünün ve Bazı Demografik Parametrelerinin Tahmin Edilmesi

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Anahtar Kelimeler;
Cucurbita moschata,
Planococcus citri,
Popülasyon büyüklüğü,
Yaş ve döneme özgü iki eşeyli yaşam çizelgesi.

Öz: *Planococcus citri*, dünyanın birçok bölgesinde yaygın ve 200'den fazla bitki türü üstünde beslenen önemli bir zararlıdır. Konukçuları arasında olan kabak (*Cucurbita moschata*) bitkisinin hem yaprak ve sürgünlerine hem de meyvesine saldırarak önemli ürün kayıplarına neden olmaktadır. Bu çalışmada 28 ± 1 °C sıcaklık, % 60 ± 5 orantılı nem ve 16:8 aydınlık: karanlık şartlarına ayarlanmış iklim odalarında, *P.citri*'nin kabak bitkisinin yaprakları üstünde gelişme, canlılık ve üreme oranlarına ait biyolojik verileri elde edilmiştir. Elde edilen ham veriler yaş ve döneme özgü iki eşeyli yaşam çizelgesine göre test edilmiş ve yaşam çizelgesi parametreleri Twosex MSChart paket programı kullanılarak hesaplanmıştır. Buna göre kalıtsal üreme yeteneği (r) = 0.0802 gün^{-1}, artış oranı sınırı (λ) = 1.0836 gün^{-1}, net üreme gücü (R_0) = 29.231 yumurta, ortalama döl süresi (T) = 42.10 gün olarak hesap edilmiştir. Çalışmada ayrıca Timing MSChart programı kullanılarak zararlının popülasyon büyüklüğü tahmin edilmiştir. Buna göre, başlangıç popülasyonu olarak 10 adet *P. citri* yumurtası alındığında, 3 ayın sonunda meydana gelebilecek popülasyonun toplam olarak 4 137 birey olabileceği tahmin edilmiştir.

Estimating Population Size and Some Demographic Parameters of Citrus Mealybug, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) on *Cucurbita moschata* Duch. in Laboratory Conditions

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Keywords
Cucurbita moschata,
Planococcus citri,
Population size,
The age-stage twosex life table.

Abstract: *Planococcus citri* is an important pest that is common in many parts of the world and feeds on more than 200 plant species. It attacks the leaves, shoots and fruits of the pumpkin (*Cucurbita moschata*) plant, which is among its hosts, causing significant crop losses. In this study, development, survival and fecundity data of *P.citri* were obtained on the leaves of the pumpkin plant were in the climatic room which was adjusted to 28 ± 1 °C temperature, 60 ± 5% relative humidity and 16: 8 light: dark conditions. The raw data obtained were tested according to the age-stage twosex life table and the life table parameters were calculated using the Twosex MSChart package program. Accordingly, they were calculated as follows; the intrinsic rate of increase (r) = 0.0802 d^{-1}, the finite rate of increase (λ) = 1.0836 d^{-1}, the net reproductive rate (R_0) = 29.231 eggs, and the mean generation time (T) = 42.10 days. In addition, the population size of the pest was estimated using the Timing MSChart program. According to this, when 10 *P. citri* eggs were taken as the initial population, it was estimated that the

population that could occur at the end of 3 months would be 4 137 individuals in total.

1. Giriş

Turunçgil unlubiti, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) dünyanın hemen hemen tüm zoocoğrafik bölgelerine yayılmış polifag bir zararlıdır (Williams ve Watson, 1990). En yaygın olarak çiçekli bitkilerde olmak üzere 82 familyadan 191 cinse bağlı 200'den fazla konukçu bitkisinin olduğu bildirilmektedir (Anonim, 2021a). Hem nimf ve hem de ergin dişiler sokucu emici ağız yapılarıyla konukçu bitkilerinin özsuyunu emerek beslenirler ve beslenmeleri sonucu bitkinin besin elementleri eksildiğinden bitkinin gelişmesi geriler, genellikle bodur kalır, sararır ve canlılığını büyük ölçüde kaybeder (Goldasteh ve ark., 2009). Turunçgil unlubiti önemli bazı bitki virüs hastalıklarını taşıdığı gibi (Al-Ali, 1969; Bartlett, 1978; Brunt, 1992; Lockhart ve Olszewski, 1996), beslenmesi esnasında salgıladığı tatlımsı maddeler nedeniyle de zararlı olur. Yoğun miktarda salgılanan tatlımsı maddeler yaprak, sürgün, meyve gibi bitki aksamlarının yüzeyini kaplayarak bu alanlara saprofit fungusların yerleşmesine neden olur, toksik salgılarıyla çarpık büyümeye, erken yaprak dökülmesine (Smith ve ark., 1997; Heinz ve ark., 2004) ve zamanla hem fotosentezin engellenmesine hem de bitkinin strese girmesine sebep olur (Malais ve Ravensberg, 2004).

Turunçgil unlubitinin Türkiye'de turunçgiller ve diğer bitkiler üstünde ekonomik olarak çok önemli zararlara neden olduğu (Bodenheimer, 1953; Düzgüneş, 1982; Lodos, 1986; Williams ve Watson, 1988), son yirmi yıldan fazla süredir Doğu Akdeniz Bölgesi'nde zararının arttığı ve önemli ürün kayıplarına neden olduğu (Karacaoğlu ve Satar, 2017) bildirilmektedir. Diğer yandan *P. citri*'nin iç mekân bitkilerinde yaygın zararlı olduğu ve kontrolünün başarılı olmadığı bildirilmektedir (Polat ve ark., 2008). Çok sayıda araştırmada zararlıya karşı kimyasal savaşın yetersiz olduğu, en etkili kontrol yönteminin doğal düşmanlarının kullanılması olduğu belirtilmektedir (Krishnamoorthy ve Singh, 1987; Michelakis ve ark., 1995; Afifi ve ark., 2010; Mustu ve ark., 2011; Gill ve ark., 2012; van Niekerk ve Malan, 2012). Doğal düşmanlarının kitle üretim çalışmalarında, *P. citri* üretimi için kullanılan en uygun konukçu bitkiler arasında kabak meyvesi de bulunur. Turunçgil unlubiti kabak bitkisinin sadece meyvesinde değil yapraklarında da gelişir, ancak kitle üretim çalışmalarında kabak meyvesi depo şartlarına daha iyi dayanabildiği ve uzun süre bozulmadan sağlam kalabildiği için daha çok tercih edilir.

Kabak, sebze olarak doğrudan tüketilmesinin yanı sıra, çerez, tatlı, süs araç ve gereçlerinin yapımı gibi çeşitli şekillerde de değerlendirilmektedir. Türkiye sebze üretiminde önemli olan kabak, 2019 yılı TÜİK verilerine göre toplam sebze üretim alanlarının % 10.04'ünde % 2.28'lik bir üretim payına sahiptir (Anonim, 2021b). Kabak üretiminde önemli ürün kayıplarına neden olan *P. citri*, bitkiye hem tarla koşullarında ve hem de sera, örtü altı, alçak tünel gibi üretim alanlarında saldırarak zarar verir. Bitkiye yapraklanma döneminden itibaren yerleşerek önce yaprak ve sürgünlerde, meyve oluşum döneminde ise meyvede doğrudan beslenerek bitkinin gelişmesini ve verimini büyük ölçüde geriletmektedir. Beslenirken salgıladığı yoğun miktardaki tatlımsı madde nedeniyle, meyvelerin kalitesini azalttığı gibi, yaprak, sürgün ve meyvelerin yoğun miktarda tatlımsı madde ile kaplı olması sebebiyle kısa zamanda saprofit funguslarla örtülerek çürümelere yol açmaktadır.

Bu çalışmada *P. citri*'nin kabak bitkisinin yaprakları üstünde meydana getirdiği popülasyon dinamiği parametrelerinin ortaya çıkarılması hedeflenmiştir. Yaşam çizelgesi, bir böceğin popülasyon dinamiğine ilişkin çok ayrıntılı ve karşılaştırmalı bilgiler sunabilen önemli bir araçtır (Lotka, 1907; Lewis, 1977). Bu amaçla yaş ve döneme özgü iki eşeyli yaşam çizelgesi (Chi ve Liu, 1985; Chi, 1988; Atlıhan ve ark., 2018; Chi ve ark., 2020) kullanılarak, zararlının üreme, gelişme, canlılık oranları, yaşam çizelgesi parametreleri, popülasyon artışının tahmini gibi biyolojisine ilişkin çok ayrıntılı bilgileri elde edilmiştir. *Planococcus citri*'nin kabak yaprakları üstünde meydana getirdiği popülasyona ait yaşam çizelgesi parametrelerinin elde edilmesi, zararlıya karşı yürütülecek mücadele çalışmaları için temel bilgiler sunmasının yanı sıra biyolojik savaş uygulamalarında avcı-parazitoit salım oranlarının ve zamanlarının belirlenmesi için de önemli bilgiler sağlayacaktır.

2. Materyal ve Yöntem

Çalışma 2019 yılında Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü Entomoloji laboratuvarı ve iklim odalarında yürütülmüştür. Konukçu bitki olarak bal kabağı bitkisinin yaprakları kullanılmıştır. Bu amaçla ilk olarak konukçu bitki üretimi yapılmış ve yapraklar üstünde *P. citri* kolonisi oluşturulmuştur. Denemede kullanılan bal kabağı (Arıcan 97) tohumları öncelikle viyollere ekilerek fideleri elde edilmiş, daha sonra torf ve bahçe toprağı karışımı konulmuş 5 lt hacimli (üst çapı ve yüksekliği 20 cm) saksılara şaşırtılmıştır. Fideler en az 10 yapraklı döneme geldiğinde denemelere başlanmıştır. Stok kültürden alınan son 24 saat içinde bırakılmış yumurtalar yaprak hücrelerine (silindirik, 2x2 cm çap ve yüksekliğinde, 1.8 gr ağırlığında, üst tarafı tül ile kapatılmış klips düzeneği ile yaprağa sabitlenebilen plastik hücre) konulmuştur. Her hücrede sadece bir tane olacak şekilde toplam olarak 50 adet yumurta yaprağın üst kısmına hücre içine yumuşak ince uçlu fırça yardımıyla yerleştirilmiştir. Günlük kontrollerde yumurtaların açıldığı gün ve çıkan nimflerin gelişme süreleri ergin döneme erişinceye kadar kaydedilmiştir. Ergin olduktan sonra her bir hücreye bir adet erkek ve 1 adet dişi birey konularak gözlemlere devam edilmiştir. Günlük aralıklarla hücre içine bırakılan yumurtalar sayılarak hücreden uzaklaştırılmıştır. Bazı dişi nimflerin denemeye tabi tutulan erkeklerin tamamı öldükten sonra ergin olduğu gözlenmiş, bu dişilerin tutuldukları hücrelere stok kültürde bulunan erkek bireyler konularak çiftleşmeleri sağlanmış, ancak bu erkek bireyler deneme dışı bırakılmıştır. Gözlemlere son birey ölünceye kadar devam edilmiştir.

2.1. Verilerin değerlendirilmesi

Planococcus citri'nin denemeden elde edilen gelişme, canlılık ve üreme oranına ait ham veriler Chi (1988) tarafından tanımlanan ve Chi ve Liu (Chi ve Liu, 1985; Chi, 1988; Chi, 2014) tarafından geliştirilen yaş ve döneme özgü iki eşeyli yaşam çizelgesine göre TWOSEX-MSChart bilgisayar programı (Chi, 2019b) kullanılarak değerlendirilmiştir.

Yaş ve döneme özgü canlılık oranı (s_{xj}), yaşa özgü canlılık oranı (l_x), yaşa özgü üreme oranı (m_x), ve bunlara ek olarak yaşam çizelgesi parametreleri (kalıtsal üreme yeteneği (r), artış oranı sınırı (λ), net üreme oranı (R_0), ve ortalama döl süresi (T)) hesaplanmıştır.

Bu parametreler aşağıdaki formüllere göre hesaplanmıştır:

Yaş ve döneme özgü canlılık oranı (s_{xj}) (x = yaş ve j = dönem),

$$s_{xj} = \frac{n_{xj}}{n_{01}} \tag{1}$$

n_{01}, yaşam çizelgesi çalışmasının başlangıcında kullanılan toplam birey sayısı; n_{xj}, x yaşında ve j döneminde canlı olan bireylerin sayısı.

Yaşa özgü üreme oranı (m_x) ve yaşa özgü canlılık oranı (l_x),

$$m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}} \tag{2}$$

$$l_x = \sum_{j=1}^{k} s_{xj} \tag{3}$$

k dönem sayısı ve s_{xj} yeni bırakılmış bir yumurtanın x yaşında ve j döneminde canlı kalma olasılığıdır. f_{xj}, x yaşında erginlerin üreme oranıdır (yumurtaların toplam sayısı).

Kalıtsal üreme yeteneği (r) Euler – Lotka (Goodman, 1982),

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1 \tag{4}$$

x yaş, l_x yaşa özgü canlılık oranı (x yaşında yeni bırakılmış bir yumurtanın canlı kalma olasılığı) ve m_x dişinin yaşa özgü üreme oranı eğrisidir.

Net üreme oranı (R_0) (Birch, 1948),

$$R_0 = \sum_{x=0}^{\infty} l_x m_x \tag{5}$$

dişi başına üretilen dişi yavru sayısına göre nesil başına popülasyonun artış oranı, l_x, x yaşına kadar hayatta kalan bireylerin oranıdır ve m_x, x yaşındaki dişi başına üretilen dişi sayısıdır.

Ortalama döl süresi (T) (Birch, 1948; Carey, 1993), bir populasyonun büyüklüğünü R_0 katı kadar arttırmak için ihtiyaç duyduğu periyot olarak tanımlanır.

$$T = \frac{\ln R_0}{r} \tag{6}$$

Artış oranı sınırı (λ) (Birch, 1948),

$$\lambda = e^r \tag{7}$$

birim zaman başına birey başına artış oranı.

Her bir birey (i) ve dönem (j) için beklenen ömür süresi (e_{xj}) (Chi ve Su, 2006),

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{k} s'_{iy} \tag{8}$$

x yaşında ve j dönemindeki bir bireyin yaşaması beklenen süredir.

Üreme değeri (v_{xj}) (Carey, 1993),

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=1}^{\beta} s'_{iy} f_{iy} \tag{9}$$

x yaşında ve j döneminde bir bireyin gelecek popülasyona yapacağı katkı olarak tanımlanır.

Planococcus citri'nin gelişme dönemleri, yaşam uzunluğu, üreme ve yaşam çizelgesi parametreleri 100 000 boostrap kullanılarak hesaplanmıştır. Dişi ve erkek bireylerin gelişme süreleri, toplam yaşam uzunlukları ve ömür sürelerinin ortalamaları arasındaki farklar paired boostrap test kullanılarak karşılaştırılmıştır (Efron ve Tibshirani 1993, Huang ve Chi 2013).

2.2. Popülasyon büyüklüğünün tahmin edilmesi

Yaşam çizelgesi verilerine göre Turunçgil unlubitinin populasyon büyüklüğü, Chi ve Liu (1985) ve Chi (1990) tarafından bildirilen yönteme göre Timing-MSChart (Chi, 2019a) bilgisayar program kullanılarak tahmin edilmiştir. Bu yöntemde *P. citri*'nin başlangıç popülasyonu olarak belli sayıda ve belli dönemde birey alındığında belirlenecek süre sonunda popülasyonun erişebileceği büyüklük yaş (x) ve döneme (j) özgü ve toplam birey sayısı üstünden tahmin edilebilir.

3. Bulgular

Turunçgil unlubiti, *Planoccocus citri*'nin *Cucurbita mochata* (kabak) üstünde denemeye alınan yumurtalarının tamamı açılarak nimf dönemine geçiş yapmış, ancak nimflerin sadece % 70'i ergin olabilmiştir (Çizelge 1). Ergin olan bireylerin % 31'nin dişi, % 69'unun erkek oldukları tespit edilmiştir. Cinsiyetleri belirlenen dişi ve erkek bireylere ait yumurta ve nimf dönemlerinin gelişme süreleri arasında istatistiki bir farklılık bulunamamıştır (P<0.05). Dönemlerin gelişme süreleri ortalama olarak yumurta dönemi için 5.32 gün, 1. nimf dönemi için 6.94 gün ve 2. nimf dönemi için 5.53 gün olarak kaydedilirken, dişi bireylerin 3. nimf dönemini 16.55 günde, erkek bireylerin pupa dönemlerini 7.54 günde ve ortalama olarak 10.37 günde tamamladıkları tespit edilmiştir (Çizelge 1). Toplam gelişme süresi incelendiğinde, tüm bireylerin gelişmelerini ortalama 28.31 günde tamamladıkları, ancak cinsiyetler ayrı ayrı ele alındığında dişi bireylerin 35.18 günde, erkek bireylerin ise 25.17 günde

gelişmelerini tamamladıkları ve gelişme sürelerinin istatistiksel olarak farklı olduğu bulunmuştur (P<0.05).

Denemeye alınan bireylerin toplam yaşam uzunlukları dişi bireyler için 45.82 gün ve erkek bireyler için 27.42 gün ile istatistiksel olarak farklı bulunurken, her iki cinsiyet toplamı için 35.32 gün ve ergin öncesinde ölen bireyler dahil, tüm bireylerin yaşam uzunluğu ortalama olarak 29.10 gün olarak kaydedilmiştir (P<0.05). Ergin olan bireylerin ömür süreleri karşılaştırıldığında dişi bireylerin 10.64 gün, erkek bireylerin 2.25 gün yaşadıkları ve bu sürelerin istatistiksel olarak önemli oranda farklı oldukları bulunmuş (P<0.05), her iki cinsiyet birlikte ele alındığında toplam ergin ömrünün 4.89 gün olduğu tespit edilmiştir. Diğer yaşam çizelgesi parametreleri incelendiğinde preovipozisyon (*APOP*) süresi 0.88 gün, toplam preovipozisyon (*TPOP*) (doğumdan itibaren sayılan dişilerin toplam yumurtlama öncesi süresi) 39.25 gün, yumurta bıraktığı günlerin toplamı 8.75 gün, üreme oranı 133.27 yumurta, populasyonu ikiye katlama süresi (*DT*) 8.64 gün, kalıtsal üreme yeteneği (r) 0.0802 gün^{-1}, artış oranı sınırı (λ) 1.0836 gün^{-1}, net üreme gücü (R_0) 29.321 yumurta ve ortalama döl süresi (T) 42.10 gün olarak hesaplanmıştır (Çizelge 1).

Turunçgil unlubitinin henüz yeni bırakılmış bir yumurtasının x yaşında ve j döneminde canlı kalma olasılığını yansıtan canlılık oranı (s_{xj}) eğrisi ayrıntılı olarak Şekil 1'e yansıtılmıştır. Ergin öncesi dönemlerin canlılık oranlarının kademeli olarak azaldığı, en yüksek ölüm oranının % 20 ile 2. nimf döneminde meydana geldiği ve ergin öncesi dönemlerin gelişme sürelerinin birbiri ile karıştığı, yani bir dönem tamamen bitmeden izleyen dönem bireylerinin bir kısmının gelişmeye başladıkları gözlenmiştir. Ergin döneme ulaşan bireylerin canlılık oranlarının % 70 olduğu, denemede erkek bireylerin daha erken sürede meydana geldikleri görülmüştür. İlk erkek bireyler 21. günde görülürken dişi bireyler ancak 26. günden itibaren ortaya çıkmaya başlamıştır. Erkek bireylerin tamamı 26. günde görülürken, izleyen günlerde kademeli olarak ölmeye başladıkları ve 31. günde son bireylerin de öldüğü saptanmıştır. Dişi bireyler ise 26. günden itibaren görülmeye başlamış, izleyen günlerde yeni bireyler popülasyona katılırken, kademeli olarak ölüm oranlarının arttığı ve son dişi bireyin 61. günde ortaya çıktığı kaydedilmiştir. Ancak 49. güne kadar halen 3. nimf döneminde olan az sayıda da olsa bireylerin mevcut olduğu kaydedilmiştir. Ergin olan bu bireyler aynı yaşta denemeye alınan erkek bireyler çok önceden ölmüş oldukları için deneme dışından stok kültürden alınan erkek bireylerle çiftleştirilmişler. Bu bireylerin de yaşamlarının sonuna kadar yumurta bıraktıkları kaydedilmiştir.

Turunçgil unlubitinin yaşa özgü canlılık oranı (l_x) ve üreme oranları (m_x, l_xm_x) Şekil 2'de verilmiştir. Tüm dönemlerin canlılık oranlarının bir arada yansıtıldığı l_x eğrisi incelendiğinde popülasyonda başlangıçta yavaş ancak kısa sürede % 30'a ulaşan ölüm oranından sonra ilk yumurtlamanın görüldüğü 27. günde canlılık oranının % 50 olduğu tespit edilmiştir. İzleyen günlerde 31. günde popülasyonun canlılık oranı önce % 26'ya 40. günde % 10'a kadar düşmüş, son bireyin görüldüğü 62. güne kadar ise kademeli olarak azalmaya devam etmiştir. Üreme oranı (m_x) eğrisi incelendiğinde ilk yumurtaların görüldüğü günden itibaren kademeli olarak artan yumurta oranı 41. günde 18.2 yumurta olarak kaydedilmiş, takip eden günlerde 50. güne kadar önce hızla azalma, ömrün sonuna doğru 59. güne kadar ise hızla yükselme eğimi göstererek bu tarihte günde bırakılan yumurta sayısı 45 yumurta ile en yüksek değere ulaşmıştır. Canlılık oranı ve üreme oranının etkisinde değişen ve etkili üreme oranını yansıtan maternity (l_xm_x) eğrisi ise ilk yumurtaların görüldüğü tarihlerde yüksek ölüm oranı ve düşük yumurta sayısından dolayı düşük seviyelerde iken izleyen günlerde yumurta sayılarında artış görülse de daha da artan ölüm oranından ötürü ömrün sonuna kadar düşük düzeylerde kalmıştır.

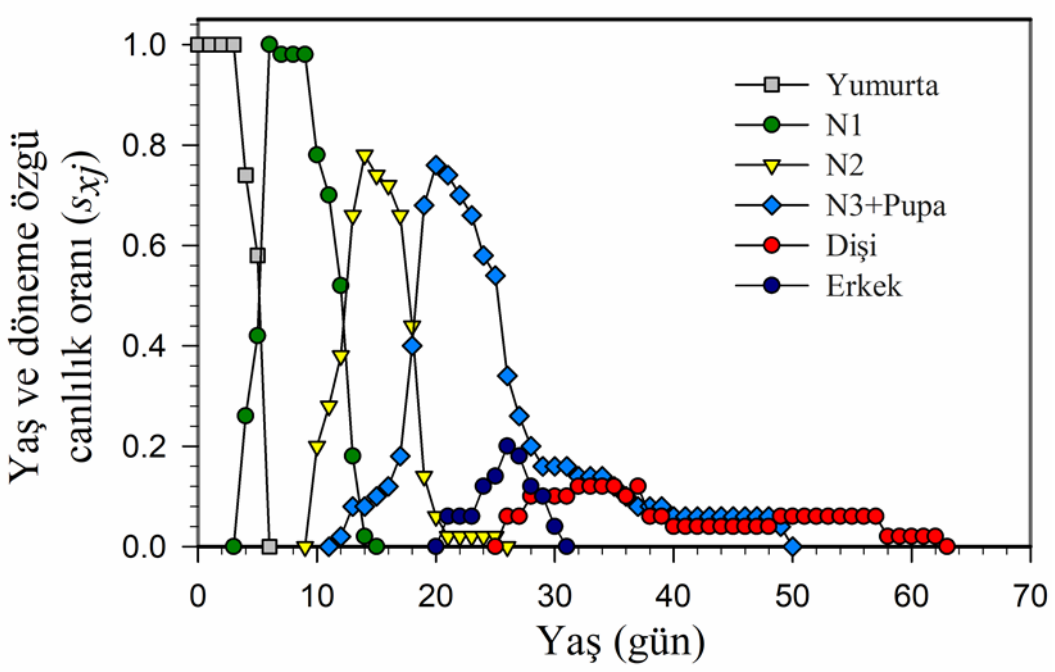
Belli bir yaşta ve dönemde bir türün beklenen yaşam uzunluğunun tahminini veren beklenen ömür (e_{xj}) eğrisi *P. citri*'nin tüm dönemleri için ayrıntılı olarak Şekil 3'e yansıtılmıştır. Yeni bırakılmış bir *P. citri* yumurtasının beklenen ömrü 29.10 gün olarak ortalama yaşam uzunluğu değeri ile tam olarak aynı bulunmuştur. Bu sonuç birçok çalışmanın benzer şekildeki bulgularına tam olarak uymaktadır (Atlıhan ve ark., 2017; Özgökçe ve ark., 2018b; Hong ve ark., 2019).

Yaş ve döneme özgü yaşam çizelgesi ayrıca x yaşında ve j dönemindeki bir bireyin gelecek popülasyona yaptığı katkıyı yansıtan üretkenlik değerini (v_{xj}) de vermektedir. Bu değer yeni bırakılmış bir yumurta için artış oranı sınırı (λ) değeri kadar (1.084) iken, 3. nimf döneminde 49. günde 84.15, dişi dönemde 40. günde 211.50 ile en yüksek değere ulaşmıştır (Şekil 4).

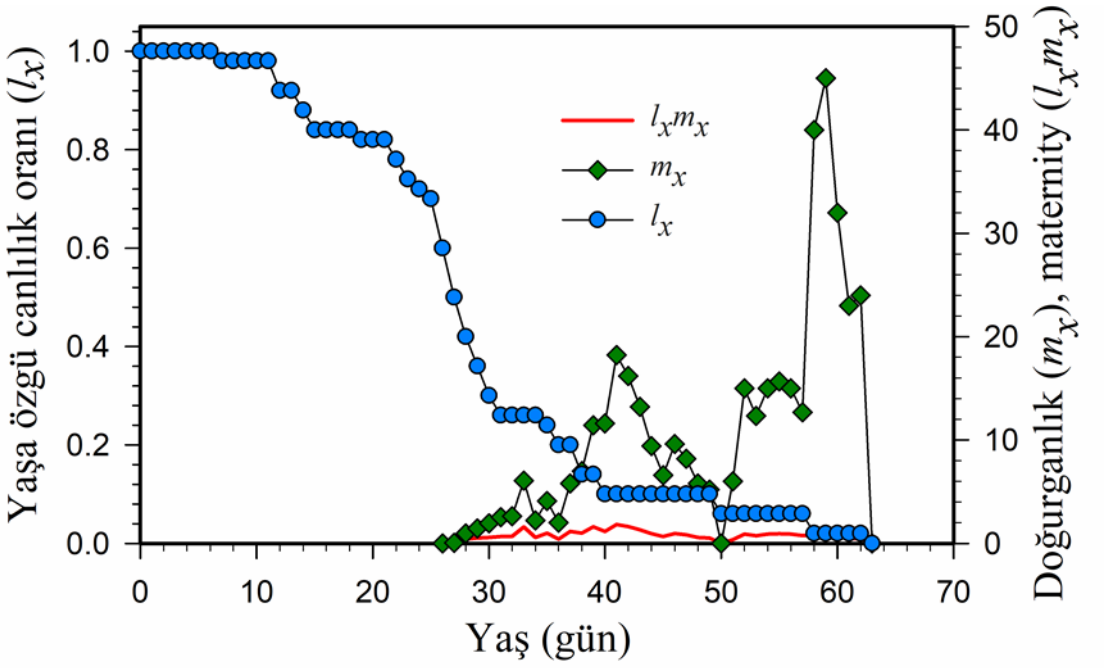
Çizelge 1. Turunçgil unlubiti, *Planoccocus citri'*nin *Cucurbita moschata* (kabak) üstünde gelişme dönemleri, yaşam uzunluğu, üreme ve yaşam çizelgesi parametreleri

		n	Ortalama±Standart Hata
Yumurta	Dişi	11	5.45±0.21 **a***
	Erkek	24	5.54±0.17 **a**
	Toplam	50	5.32±0.12
1. Nimf	Dişi	11	7.09±0.25 **a**
	Erkek	24	6.92±0.20 **a**
	Toplam	49	6.94±0.12
2. Nimf	Dişi	11	6.09±0.42 **a**
	Erkek	24	5.17±0.33 **a**
	Toplam	40	5.53±0.27
3. Nimf	Dişi	11	16.55±2.91
Pupa	Erkek	24	7.54±0.35
	Toplam	35	10.37±1.16
Toplam gelişme	Dişi	11	35.18±2.99 **a**
	Erkek	24	25.17±0.46 **b**
	Toplam	35	28.31±1.26
Toplam yaşam uzunluğu	Dişi	11	45.82±3.10 **a**
	Erkek	24	27.42±0.47 **b**
	Toplam	35	35.32±0.35
Tüm bireylerin ortalama yaşam uzunluğu		50	29.10±1.68
Ergin ömrü	Dişi	11	10.64±0.74 **a**
	Erkek	24	2.25±0.16 **b**
	Toplam	35	4.89.10±0.71
Preovipozisyon (APOP)		8	0.88±0.30
Toplam preovipozisyon (TPOP)		8	39.25±3.75
Yumurta bıraktığı günler toplamı (gün)		8	8.75±1.41
Üreme oranı (yumurta)		11	133.27±41.78
Populasyonu ikiye katlama süresi (DT) (gün)		50	8.64
Kalıtsal üreme yeteneği, r (gün^{-1})		50	0.0802±0.014
Artış oranı sınırı, λ (gün^{-1})		50	1.0836±0.015
Net üreme gücü, R_0 (yumurta)		50	29.321±0.75
Ortalama döl süresi, T (gün)		50	42.10±3.91

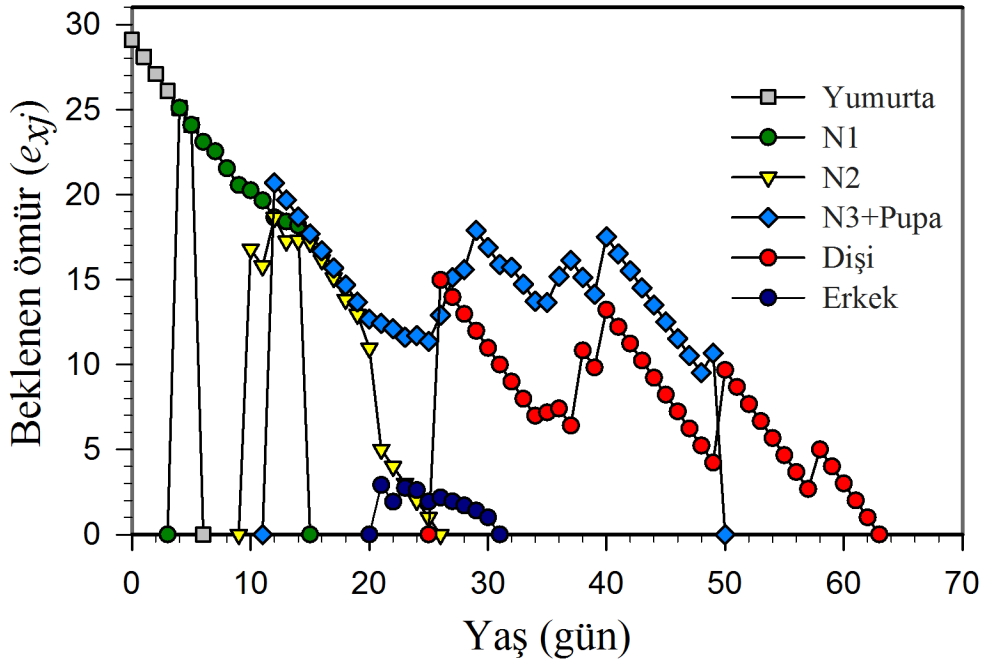
* Her bir dönemde dişi ve erkek bireylerin gelişme ve yaşam sürelerine ait aynı harf ile gösterilen ortalamalar (paired boostrap test, B=100 000 kullanılarak hesaplanmıştır) arasındaki fark istatistiksel olarak önemsizdir (P<0.05). Standart hatalar 100 000 boostrap kullanılarak tahmin edilmiştir.



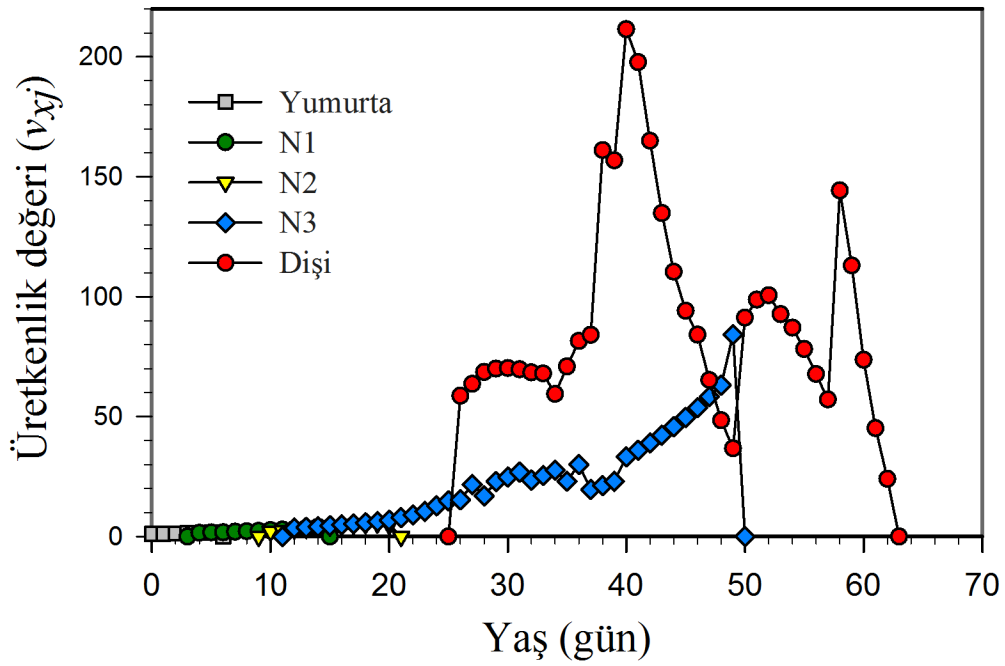
Şekil 1. Turunçgil unlubiti, *Planoccocus citri'*nin *Cucurbita moschata* (kabak) üstünde yaş ve döneme özgü canlılık oranı (s_{xj}).



Şekil 2. Turunçgil unlubiti, *Planoccocus citri*'nin *Cucurbita moschata* (kabak) üstünde canlılık oranı (l_x), üreme oranı (m_x, $l_x m_x$).



Şekil 3. Turunçgil unlubiti, *Planoccocus citri*'nin *Cucurbita moschata* (kabak) üstünde beklenen ömür (e_{xj}) eğrisi.



Şekil 4. Turunçgil unlubiti, *Planoccocus citri*'nin *Cucurbita moschata* (kabak) üstünde yaş ve döneme özgü üretkenlik değeri (v_{xj})

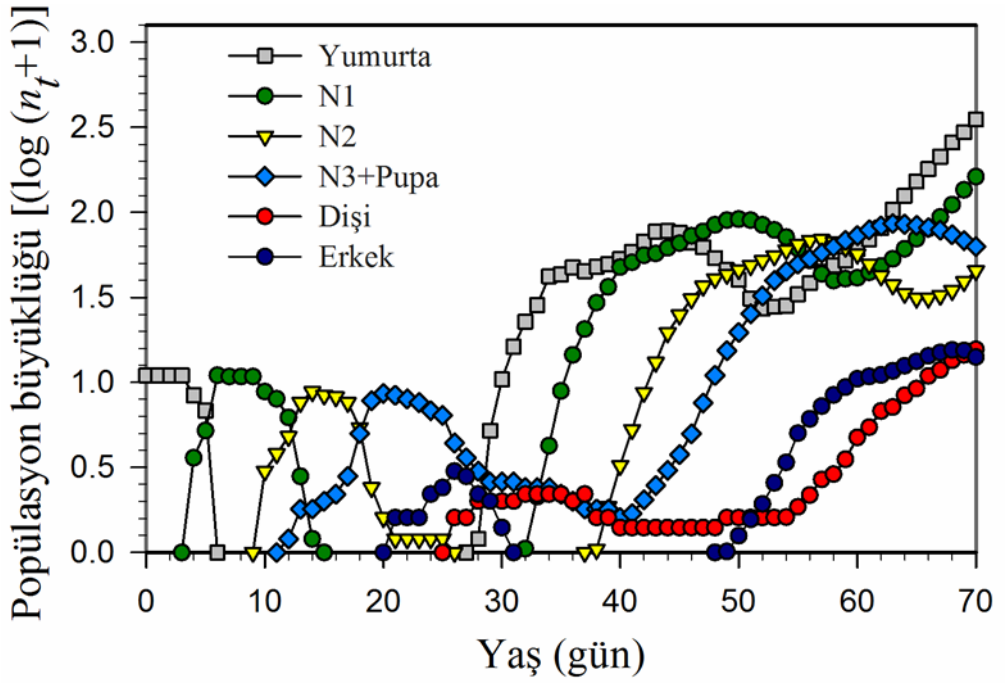
3.1. Popülasyon büyüklüğünün tahmin edilmesi

Turunçgil unlubitinin yaşam çizelgesi parametrelerine göre popülasyon büyüklüğü her bir dönem için detaylı olarak Timing MSChart paket programı ile hesaplanmıştır. Bu çalışmada başlangıç popülasyonu olarak 10 adet *P. citri* yumurtası alındığında 70 gün boyunca meydana gelecek tüm dönemlerin sayısal değişimi Şekil 5'te ve 70. günde her bir döneme ait bireylerin ulaşabileceği birey sayısı Şekil 6'da verilmiştir. Ergin öncesi dönemin sürdüğü ilk 30 günlük dönemden sonra üremenin başlamasıyla birlikte popülasyonda artış görülmeye başlamış, süre uzadıkça popülasyon büyüklüğünde

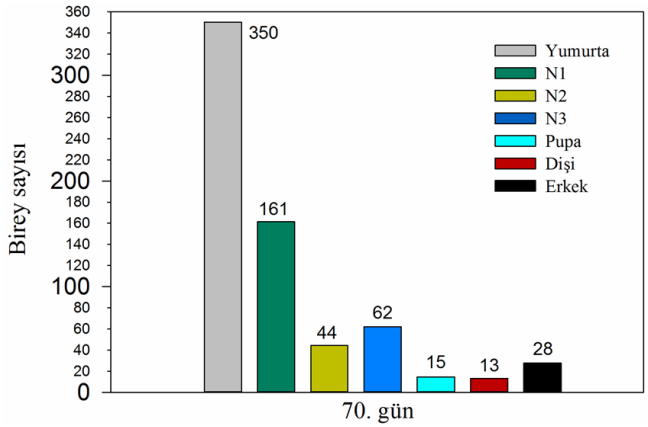
hızlı bir artış kaydedilmiştir. Popülasyon büyüklüğü 70. gün için incelendiğinde dönemlere göre birey sayısı; yumurta 350, 1. nimf dönemi (N_1) 161, 2. nimf dönemi (N_2) 44, 3. nimf dönemi (N_3) 62, pupa 15, dişi 13 ve erkek 28 olarak tahmin edilmiştir. Popülasyon artışının izleyen günlerde çok daha hızlı ve geometrik olarak arttığı görülmüştür.

Günler	Toplam popülasyon büyüklüğü
• 0	10 yumurta
• 30	12.4
• 60	240.9
• 90	4 137.1
• 120	48 409.1
• 150	482 361.4
• 180	5 133 619.3

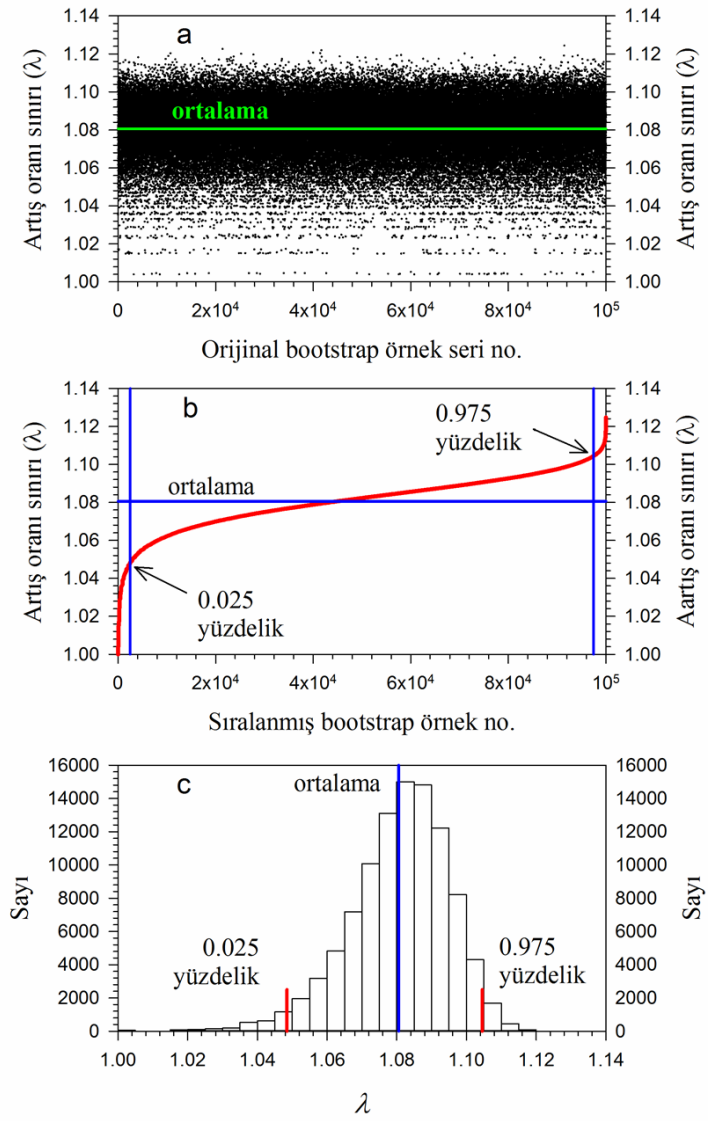
Bootstrap tekniği kullanılarak 100 000 artış oranı sınırı (λ) elde edilmiş, bu değerlerin ortalama etrafındaki rasgele dağılışları Şekil 7a'da verilmiştir (Özgökçe ve ark., 2018b, a; Özgökçe ve ark., 2018c; Kanle Satishchandra ve ark., 2019). Artış oranı sınırı değerleri artan bir sırayla Şekil 7b'ye yansıtıldığında bootstrap ile elde edilen sayıların ortalama etrafında düzgün bir eğri oluşturduğu, aynı zamanda bu verilerin normal bir dağılış gösterdikleri görülmüştür (Şekil 7c). Bunların yanı sıra Şekil 7b ve 7c'de boostrap değerlerinin 0.025, ve 0.975 yüzdelik oranları belirlenmiştir. Bu yüzdelik dilimlere karşılık gelen boostrap örnekleri popülasyon artışının değişkenliğini tahmin etmek için kullanılabilir.



Şekil 5. Turunçgil unlubiti, *Planoccocus citri*'nin *Cucurbita moschata* (kabak) üstünde başlangıç popülasyonu 10 yumurta alındığında meydana gelebilecek yaş ve döneme özgü popülasyon büyüklüğü.



Şekil 6. Turunçgil unlubiti, *Planoccocus citri*'nin *Cucurbita moschata* (kabak) üstünde başlangıç popülasyonu 10 yumurta alındığında 70. günde meydana gelebilecek yaş ve döneme özgü popülasyon büyüklüğü.



Şekil 7. (a): *Planococcus citri*'nin orijinal boostrap değerlerine (x-ekseni) göre sıralanmış 100 000 adet λ verisinin ortalama etrafındaki rastgele dağılışı. (b) Artan bir düzende sıralanmış 100 000 adet λ değeri. (c) 100 000 adet λ değeri, bir frekans dağılımı olarak gösterilmiştir. (b) ve (c)'de 0.025 ve 0.975 yüzdelik λ değerleri.

4. Tartışma ve Sonuç

Belli şartlar altında ve belli konukçular üstünde bir türün yaşam çizelgesine ait parametreleri tespit ederek karşılaştırmalar yapmak veya popülasyon dinamiğinin zarar potansiyelleri üstünde tahminler yapmak üzerine son yıllarda çok sayıda çalışma yapılmaktadır (Huang ve Chi, 2012; Hou ve ark., 2014; Tuan ve ark., 2014; Özgökçe ve ark., 2016; Tuan ve ark., 2016; Jaleel ve ark., 2017). Bu tür çalışmalardan elde edilen veriler etkin Entegre Mücadele programlarının hazırlanması için önemli kaynak bilgiler sağlamaktadır. *Planococcus citri*, konukçuları arasında olan çok sayıdaki tarla bitkileri, meyve ağaçları ve süs bitkileri (Bartlett ve Lloyd, 1958; Franco ve ark., 2004) üstünde beslenmesi sırasında bitkiye önemli oranda zarar vermesinin yanı sıra, konukçudan konukçuya geçerek zararını yayması ve aynı zamanda önemli virüs hastalıklarını taşıyarak zarar şiddetini daha da arttırmasıyla önemini büyütmektedir. Polifag böcekler farklı konukçuları üstünde farklı gelişme, canlılık ve üreme özellikleri gösterirler (Hou ve ark., 2014; Farag ve ark., 2015; Kanle Satishchandra ve ark., 2019). Hatta aynı konukçu türünün farklı çeşitleri üstünde bile bu farklılıklar dikkat çekicidir (Özgökçe ve Atlıhan, 2005; Alipour ve ark., 2016; Atlıhan ve ark., 2017; Özgökçe ve ark., 2018b; Ghorbanian ve ark., 2019). Dolayısıyla polifag bir tür olan *P. citri*'nin farklı konukçular üstündeki popülasyon dinamiğinin belirlenmesi, zararlıya karşı geliştirilecek kontrol programları için önemli temel bilgiler sağlayabilir. Bu çalışmada zararlının kabak bitkisi üstünde gelişmesini ortalama olarak 28.31 günde tamamladığı, bu sürenin dişi bireyler için 35.18 gün, erkek bireyler için 25.17 gün olduğu tespit edilmiştir. Gelişme, üreme ve canlılık oranlarından türetilen ve bir türün biyolojisinin kısa bir özetini veren ve karşılaştırılabilme özelliğinde olan kalıtsal üreme yeteneği parametresi (Huang ve Chi, 2012) incelendiğinde bu çalışmada hesaplanan 0.0802 gün^{-1} değerine karşılık farklı konukçularda yürütülen bazı çalışmalarda bu parametre aşağıdaki gibi bulunmuştur. Farklı süs bitkilerinde bu çalışmadakine benzer iklim şartları altında *P. citri*'nin kalıtsal üreme yeteneği 0.0954-0.1380 gün^{-1} olarak bulunurken (Polat ve ark., 2008), 25 ºC ve % 70 orantılı nem koşullarında farklı asma çeşitleri üstünde yürütülen bir çalışmada 0.0930-0.1392 gün^{-1} olarak tespit edilmiştir (Morandi ve ark., 2008). Bu sonuçlara göre kabak yaprakları üstünde daha düşük bir performans gösterdiği düşünülebilir. Ancak kabak meyvesi üstünde yürütülen bir araştırmada 25 ºC ve % 65 orantılı nem koşullarında kabak meyvesi üstünde *P. citri*'nin gelişme süresi dişi bireyler için 22.6 gün olarak tespit edilmiştir (Mahmoud ve ark., 2017). Bu çalışmada ise 28 ºC'de dişi ve erkek bireyler için aynı sırayla 35.18 ve 25.17 gün olarak bulunmuş, ancak çalışmada kalıtsal üreme yeteneği hesaplanmamış olduğu için sadece gelişme süresi üstünden bir değerlendirme yapmak yeterli olmaz.

Bu çalışmada kullanılan bootstrap tekniği ile denemeye alınan 50 adet bireyin yaşam çizelgesi parametreleri 100,000 kez çoğaltılarak daha homojen bir dağılım elde edilmiştir. Böylece bu teknik yetersiz veya homojen olmayan verilerin karşılaştırılabilir seviyelere yükseltilmesinde büyük avantaj sağlamaktadır (Yu ve ark., 2013; Chi ve ark., 2020). Nitekim bu çalışmada 50 adet yumurta ile denemeye başlanmış, bireylerin % 30'u ergin öncesi dönemde ölmüş, geriye kalan bireylerden sadece 11'i dişi olmuştur. Bu durum bu tür denemelerde beklenen bir durum olduğundan karşılaştırma testlerinde homojen olmayan verilerin normal dağılışlarını sağlaması açısından boostrap tekniği oldukça önemlidir (Chi ve ark., 2020). Sonuçların bootstrap tekniği ile homojenize edilmiş hali Şekil 7'de çarpıcı bir şekilde ortaya konulmuştur.

Planococcus citri'nin kabak yaprakları üstünde yaş ve döneme özgü canlılık oranı grafiği incelendiğinde (Şekil 1) ergin öncesi dönemlerinin % 30'unun öldüğü, ergin öncesi dönemlerinin iç içe geçtiği yani bir dönem bitmeden diğer dönem bireylerinin ortaya çıktığı görülmüştür. Bunların yanı sıra, 3. nimf döneminden bazı bireylerin ergin ömür süresinin yaklaşık yarısından fazla süresi geçtikten sonra ergin döneme geçtikleri, erkek bireylerin dişilerden daha yüksek bir oranda olduğu ve daha kısa süre yaşadıkları tespit edilmiştir. Popülasyonda ilk olarak erkek bireyler ortaya çıkmış, birkaç gün sonra dişi bireyler görülmüş ve kısa bir süre sonra tüm erkek bireyler ölmüştür. Denemeye alınan erkek bireylerin tamamı öldükten sonra bile popülasyona dişi bireyler uzun süre daha katılmaya devam etmiştir. Bu tür doğada çok nesil verdiği için ve bu çalışmanın sonuçlarından da görüldüğü gibi dönemler birbiri içine girerek karıştığı için doğada her döneme ait bireyin popülasyon içinde görülmesi mümkündür. Bu çalışmada denemeye alınan dişi bireyler, denemeye alınan erkek bireyler ölmüş olsa bile stok kültürden başka erkek bireyler ile bir arada tutularak çiftleşmeleri sağlanmıştır. Ancak *P. citri,* popülasyonda erkek bireyler bulunmadığında zorunlu olarak partenogenetik olarak da üremelerini sürdürebilmektedir (Nur, 1971; Miller ve Kosztarab, 1979; Gullan ve Kosztarab, 1997; Normark, 2003; da Silva ve ark., 2010).

Nur (1971) coccidlerde zorunlu olarak partenogenetik üremeyi 6 farklı kritere dayandırmaktadır. Çeşitli araştırıcılar tarafından her iki cinsiyetin bulunduğu popülasyonlarda erkek bireylerin kısa ömürlü olmasından dolayı partenogenetik üremeye devam edilmesi ve doğan yavruların dişi olması popülasyonun daha da büyümesi için bir avantaj olarak değerlendirilmektedir (Miller ve Kosztarab, 1979; Gullan ve Kosztarab, 1997; Walton ve ark., 2006).

Planococcus citri'nin çalışmada elde edilen yaşam çizelgesi parametrelerine göre popülasyon büyüklüğü hesaplanmış ve farklı zamanlarda sadece 10 yumurtanın meydana getirebileceği popülasyon büyüklükleri tahmin edilmiştir. Denemeye alınan son bireyin 63. güne kadar yaşadığı görüldüğünden buna yakın bir süre olarak 70. günde popülasyon büyüklüğü incelenmiştir. Buna göre 70. günde tüm dönemlerin dağılışı incelendiğinde 350 yumurta, 161 adet 1. nimf dönemi ve diğer dönemlerdeki bireylerin toplamı ise 162 olarak hesaplanmıştır. Bu verilere göre popülasyonun % 75.2'lik bölümünü en genç bireyler oluşturmaktadır. Genç popülasyonun bu büyük oranı gelecek günlerde popülasyonun çok hızlı artacağını gösteriyor. Nitekim 3 ay sonra toplam popülasyonun 4137.1 bireye, 4. 5. ve 6. aylarda ise sırasıyla 48409.1, 482361.4 ve 5133619.3 bireye erişebileceği tahmin edilmiştir. Bu popülasyonlarda da hâkim nüfus genç dönemler olduğu için zararlının sonraki aylara aktarabileceği artışı çok daha yıkıcı bir büyüklükte olacaktır. Sonuçlar, Turunçgil unlubitinin kabak yaprağı üstünde oldukça etkili ve büyük bir popülasyon meydana getirebildiğini göstermektedir. Zararlı, tarla koşullarında bitkinin önce yaprak ve sürgünlerinde, daha sonra ise meyvesine de geçerek popülasyonunu daha da büyütmektedir. Bu tahminler, unlubit ile bulaşık kabak bitkisi üstündeki unlubit sayısının gelecek popülasyonu hakkında önemli bilgiler verdiği için ilk bulaşmaların görülmesinden sonra popülasyonun artmasına fırsat verilmeden mücadele edilmesi gerektiğini göstermektedir.

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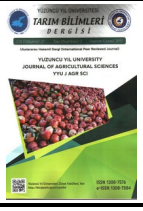

Research Article (Araştırma Makalesi)

Pollen and Physicochemical Analysis of Honey Samples from Akçakoca and Yığılca District (Western Black Sea)

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Abstract: Turkey, with its rich flora and high endemism proportion in a temperate zone, is highly favorable for beekeeping. In the studied area, two honeybees are present: *Apis mellifera anatoliaca* and the Yığılca local honeybee, which has been determined as local ecotype of *anatoliaca* in the Black Sea region. The main objective of this study was to determine the botanical sources of honey samples, which are produced by these two honeybees, from Akçakoca and Yığılca district. Chestnut and mad honey samples were obtained from local beekeepers. Pollen types in the honey samples were identified and determined the frequency classes. *Castanea sativa* was identified as the predominant pollen among the honey samples of Anatolian honeybee; these samples were classified as monofloral honey. Besides, *Rhododendron ponticum* and *Lysimachia verticillaris* pollens were found to be the important minor pollens in the mad honey samples of Anatolian honeybee. Mad honey samples from the Yığılca local honeybee were a multifloral honey and included *Rhododendron ponticum* and five other pollens as important minor pollen. In addition, physicochemical analyses were also performed. The honey samples gathered from the Yığılca district were deemed acceptable. On the other hand, the honey samples from the Akçakoca district were found acceptable except for moisture content. Also, 104 plant specimens were collected around beehives and 54 taxa were reported as melliferous plants. The Sorensen similarity coefficient, calculating among the melliferous plants of two localities (Akçakoca and Yığılca), was 51.85%. Diversity of melliferous plants was also higher in Yığılca than in Akçakoca.

Akçakoca ve Yığılca İlçelerinden (Batı Karadeniz) Bal Örneklerinin Polen ve Fizikokimyasal Analizi

Makale Bilgileri

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Anahtar Kelimeler
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Düzce,
Melissopalinoloji,
Yığılca lokal balarısı

Öz: Türkiye, ılıman bölgede zengin bitki örtüsü ve yüksek endemizm oranı ile arıcılık için oldukça elverişlidir. Çalışma alanında *Apis mellifera anatoliaca* ve Karadeniz bölgesinde *anatoliaca*'nın ekotipi olarak belirlenen Yığılca lokal bal arısı olmak üzere iki bal arısı bulunmaktadır. Bu çalışmanın temel amacı, Akçakoca ve Yığılca'dan alınan bu iki bal arısına ait balların botanik kaynaklarını belirlemektir. Kestane ve deli bal örnekleri yerel arıcılardan temin edilmiştir. Bal örneklerindeki polen türleri belirlenmiş ve frekans sınıfları belirlenmiştir. *Castanea sativa*, Anadolu bal arısı kestane ve deli bal örnekleri arasında baskın polen olarak belirlenmiştir; bu örnekler monofloral bal olarak sınıflandırılmıştır. Ayrıca Anadolu bal arısı deli bal örneklerinde *Rhododendron ponticum* ve *Lysimachia verticillaris* polenleri önemli minör polenler olarak tespit edilmiştir. Yığılca lokal

bal arısından elde edilen deli bal örnekleri, multifloral baldır ve önemli minör polen olarak *Rhododendron ponticum* ve diğer beş türün polenini içermektedir. Ayrıca fizikokimyasal analizleri de yapılmıştır. Yığılca ilçesinden toplanan bal örneklerinde değerler kabul edilen sınırlar içindedir. Öte yandan Akçakoca ilçesinden alınan bal numunelerinde, nem içeriği dışındaki değerler kabul edilebilir bulunmuştur. Ayrıca, arı kovanlarının etrafında 104 bitki örneği toplanmış ve 54 takson ballı bitki olarak belirlenmiştir. İki ilçenin (Akçakoca ve Yığılca) ballı bitkileri arasında hesaplanan Sorensen benzerlik katsayısı % 51.85 olarak bulunmuştur. Yığılca ilçesinde ballı bitki çeşitliliği de Akçakoca ilçesine göre daha fazladır.

1. Introduction

Beekeeping is a widespread profession in Turkey, where honey is an important food product for the local people of the country in question. According to FAO (2016) data on the number of beehives globally, Turkey ranks third in the world, with the third highest number of beehives across all countries surveyed. As of 2019, the number of beehives in Turkey has reached 8.1 million, and the nation's honey production measures about 110 thousand tons (TUIK, 2019). The botanical source of pollen harvested by honey bees possesses an important role in the quality of honey produced. Hence, pollen analysis of honey possesses prominent importance due to its ability to reveal the plant species foraged by honey bees for the honey source. In the literature, recently there exist numerous studies investigating the melissopalynology of Turkish honeys (Altay et al., 2018; Gencay Celemli et al., 2018; Gül and Pehlivan, 2018; Ozkok et al., 2018; Özenirler et al., 2018; Özler, 2018; Bozbeyoglu et al., 2019; Cenet, 2019; Ecem Bayram et al., 2019; Gürbüz et al., 2019a; b; Kızılpınar Temizer et al., 2019; Çakır et al., 2020; Gencay Celemli, 2020).

Turkey is home to varying climatic and ecological conditions. The nation is also a natural transition point between Europe, Asia and Africa, creating a gene pool that contains many bee race and ecotypes (Adam, 1983; Kılıç and Bilgen, 2006; Kambur Acar and Kekeçoğlu, 2020). *Apis mellifera*, which was originally discovered in Asia, Europe, and Africa, but has since spread globally due to human intervention, possesses five subspecies in Turkey (Ruttner, 1988). These subspecies are *Apis mellifera* subsp. *carnica* in the European part of Turkey (Thrace), *A. mellifera* subsp. *caucasica* in the northeast region of Turkey, *A. mellifera* subsp. *meda* in the east of Turkey, *A. mellifera* subsp. *syriaca* in the southeast of Turkey, and *A. mellifera* subsp. *anatoliaca* in the rest of Anatolia (Kandemir et al., 2000). In recent studies, the Yığılca local honey bee has been found in the Düzce province (Black Sea Region, Turkey). The Yığılca district (Düzce province) is a region with no entrances and exits for bees due to its natural geology and structure (Gösterit et al., 2012). The Yığılca local honey bee, which is considered to be an ecotype native to the specific region examined, has been studied by Kekecoglu (2010) and it is reported that, according to both COI gene SspI restriction polymorphism and 18 vessel angle coordinates, this bee is endemic to the Yığılca district of the Düzce province. In an additional study conducted by Kekecoglu and Soysal (2010), it was discovered that the morphometric characteristics of honey bees in the Yığılca district (Düzce) demonstrated a local ecotype of *anatoliaca*. In this study, Kekecoglu and Soysal (2010) also highlighted that no imported honey bees had inhabited or been brought to the Yığılca district for over 30 years, and that there exist no modern beekeeping manipulations in the population studied. *Apis mellifera* subsp. *anatoliaca* (known as the Anatolian honey bee) is also a common subspecies in Düzce, but the Yığılca district is an isolated region from other districts in Düzce.

In this study, the main objective is to determine the botanical sources of honeys of the Yığılca local honey bee and *Apis mellifera* subsp. *anatoliaca* using melissopalynological analysis in Düzce. The study also aimed to evaluated the physicochemical properties of honey samples and to determine melliferous plants around beehives. Following the aims of this study, chestnut honey and mad honey, two important honeys in the Düzce province, were selected and obtained from local beekeepers.

2. Material and Methods

2.1. Study area

The research areas of this study were the Akçakoca and Yığılca districts of the Düzce province in Turkey (Figure 1). The Düzce province is located in the Western Black Sea region of the country. The land mass area of Düzce with its eight districts (Merkez, Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı and Yığılca) is 2 593 km^2. 50% of this area is composed of forestland (Düzce Municipality, 2019). Akçakoca is the sole district within the province of Düzce containing a coastline of 30 km and possessing a sea border. The surface area of the district in question is 463 km^2. 40% of the district is forested and is home to 43 villages (Akcakoca Municipality, 2019). The district of Yığılca is bordered by the Zonguldak province in the north, Bolu province in the east and south, Akçakoca district in the northwest, and Kaynaşlı district in the southwest (Yığılca Municipality, 2019). Its surface area is 640 km^2, and 65% of the district is covered with forests (Yığılca Department of Forestry, 2019). The Yığılca district is home to 39 villages.

According to recent data of the Provincial Directorate of Agriculture and Bee Breeders in the Düzce province of Turkey, there were 594 beekeepers and 53 823 hive bees registered in 2017 in the region. Beekeepers possessing 30 or more hives are included in this data. The number of beekeepers is considered to be nearly 1 000 regardless of the number of hives. The annual production of registered beekeepers amounts to 386 268 kg honey, 8 980 kg beeswax, and 453 kg pollen. The production of royal jelly is produced by only a few beekeepers in the Düzce province, and their annual output is 4.936 kg.

According to the information sourced from local beekeepers, several types of honey are produced in the Düzce province. The types constitute chestnut honey, mad honey, plateau blossom honey, and blossom honey. Chestnut honey is produced by bees when the chestnut trees (*Castanea sativa*) bloom in June. Mad honey is produced during the intense flowering of *Rhododendron* spp. in the month of May.

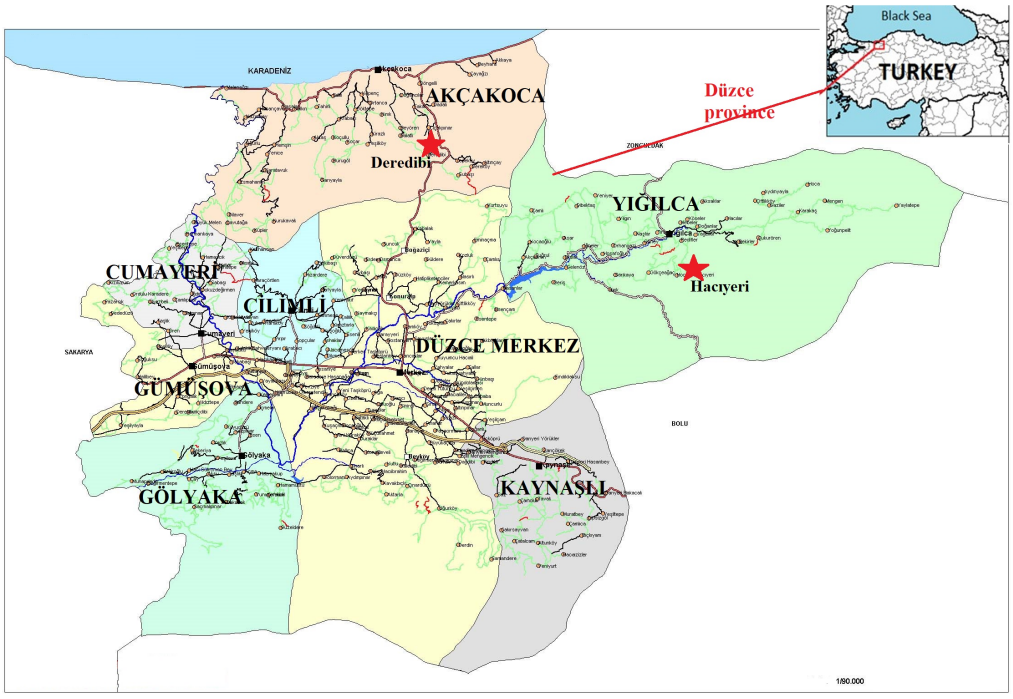

Figure 1. Study area on the map. * shows the sampling site.

2.2. Melliferous plants

The fieldwork portion of this study was carried out between May 2017 and June 2017. A total of 104 melliferous plants were collected near the hives during six field trips within the region. The plants

were collected from a 0.8 km radius around the beehives, to be compared with the pollen in the honey samples gathered. Interviews were also conducted with beekeepers during the course of the fieldwork in order to understand the melliferous flowers present, bee types, and other necessary details relevant to the study. During the fieldwork portion of this study, the plants that flowered during the honey period in question and with high patronage by the honey bees studied were in particular collected.

Melliferous plants in proximity to the beehives in this study were identified. The collected plant specimens were identified using "Flora of Turkey and the East Aegean Islands" (Davis, 1988; Güner et al., 2000) and compared to the specimens contained within the ISTE (the Herbarium of the Faculty of Pharmacy of Istanbul University). The plant materials collected in our study were kept within the ISTE-Honey Plants Herbarium as herbarium samples.

The pollen slides of the collected plants were prepared following the Wodehouse (1935) method to obtain reference pollen images from within the identified plants. Pollen photos were captured using an Olympus BX53 light microscope.

2.3. Honey samples and melissopalynological study

Honey samples were obtained directly from local beekeepers. Honeys were labeled by the beekeepers as chestnut and mad honey. Chestnut (honey 1) and mad honey (honey 2) of the Yığılca local honey bee were collected from Hacıyeri village, Yığılca district. Chestnut (honey 3) and mad honey (honey 4) of *Apis mellifera* subsp. *anatoliaca* were collected from Deredibi village, Akçakoca district. The floral sources of the honeys were determined following the mellisopalynological method. For examination procedures of the pollen and the identification of honeys, 10 samples were prepared from each honey (chestnut honey and mad honey of both the Anatolian honey bee and the Yığılca local honey bee) according to the methods of Louveaux et al., (1978) and Sorkun (2008).

Pollen counting was conducted using an Olympus BX53 light microscope. 10 slides were prepared for each honey sample. The pollen was then identified based on the number of apertures, sculptures, structures, and sizes of the pollen. Slides were prepared as homogeneously dispersed and at least 500 pollen grains per sample were counted. The average value of the results for each honey sample after counting was calculated as percentages. Based upon these results, the honey samples were classified into four different frequency classes as predominant (more than 45%), secondary (16%–45%), important minor (3%–15%) and minor (less than 3%) pollen according to their pollen percentages (Louveaux et al., 1978).

For pollen diagnosis, the prepared pollen slides from the studied honeys samples were compared with the pollen slides of melliferous plants. Books, pollen library, and related studies to our survey (Silici and Gökceoglu, 2007; Sorkun, 2008; Hesse et al., 2009; Halbritter et al., 2010; Sorkun et al., 2014) were also used in pollen diagnosis.

2.4. Physicochemical analysis

Diastase, sugar (Fructose + Glucose, Fructose / Glucose, Sucrose, Maltose), C4 sugar percentages, difference $\delta^{13}C$ protein – $\delta^{13}C$ honey, HMF (hydroxymethyl furfural), moisture, conductivity, free acidity, and proline tests were performed by the Düzce University Scientific and Technological Research Application and Research Center for each honey sample studied (Kekecoglu and Goc-Rasgele, 2013; Derebaşı et al., 2014; Kambur et al., 2015). According to the analyses of the Turkish food codex communiqué on honey (Ministry of Food, Agriculture and Livestock, 2012), tests were conducted on each sample.

2.5. Statistical analysis

Sorensen's similarity coefficient (Moraes et al., 2019) was calculated to compare the pollen/botanical sources between the Yığılca local honey bee and the Anatolian honey bee. Formula is $ISS=2a/(a+b+c)\times100$, where a refers to number of pollen/species common to x and y, b to number of pollen/species restricted to x, and c to number of pollen/species restricted to y. This coefficient indicates the pollen/species common to both honey bees.

3. Results

3.1. Melliferous plants

Field studies that we conducted in proximity to the beehives in question lead to the collection of 104 plant specimens. 54 taxa belonging to 23 families were reported as melliferous plants. Flowers visited by honey bees in addition to the observation of beekeepers were also recorded. The pollen type of each species was determined and then used as a reference collection. This information is summarized in Table 1. Pollen photos of some melliferous plants are shown in Figure 2. The Sorensen similarity coefficient (ISS), calculating among the melliferous plants of two localities (around the beehives of the Yığılca and the Anatolian honey bees), was 51.85%.

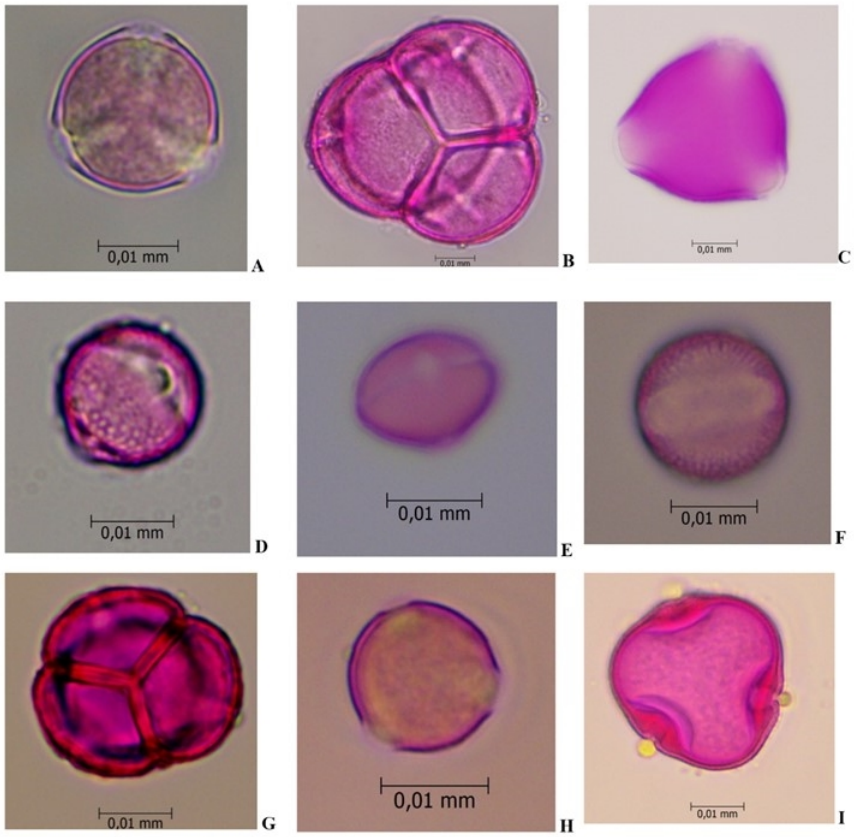

Figure 2. Pollen photos of some melliferous plants, which are determined in the studied area.

A- Polar view of *Hypericum calycinum* pollen, B- Pollen of *Rhododendron ponticum*, C- Polar view of *Prunus laurocerasus* pollen, D- Equatorial view of *Lysimachia verticillaris* pollen, E- Pollen of *Castanea sativa* F- Equatorial view of *Barbarea vulgaris* pollen, G- Pollen of *Erica arborea*, H- Polar view of *Echium vulgare* pollen, I- Polar view of *Tilia tomentosa* pollen.

3.2. Melissopalynological analysis

According to the information we received from the beekeepers interviewed, several honey types are produced in Düzce. The types produced include chestnut honey, mad honey, plateau blossom honey, and blossom honey. In the present study, melissopalynological analysis of chestnut honey and mad honey was carried out on honey belonging to different honey bees, the Yığılca local honey bee and the Anatolian honey bee, in Düzce. We obtained honey samples that were labeled as chestnut honey from the local beekeepers in the region. Honey samples are produced by the Yığılca local honey bee and the Anatolian honey bee.

Chestnut honey samples from the Yığılca local honey bee and the Anatolian honey bee were classified as monofloral, with a rate of 94.5% and 96.5% chestnut (*Castanea sativa*) pollen in the

samples, respectively. There was no group of secondary and important minor pollen grains presence in the samples investigated. Apiaceae, Caryophyllaceae, *Hypericum androsaemum*, and *Trifolium repens* are a group of minor pollen in Yığılca chestnut honey samples. On the other hand, minor pollen group was represented by *Securegia varia*, *Tilia tomentosa*, and *Trifolium repens* in Anatolian chestnut honey samples (Table 2).

Table 1. List of melliferous plants and pollen type in the studied area

Botanical name	Family	Specimen number (ISTE)
***Agrimonia eupatoria* L.**	Rosaceae	115626
***Anthemis tinctoria* var. *pallida* DC.**	Asteraceae	115628
***Asperula involucrata* Wahlenb.**	Rubiaceae	115575
***Barbarea vulgaris* R.Br.**	Brassicaceae	115559
***Calystegia silvatica* (Kit.) Griseb.**	Convolvulaceae	115586, 115607
***Campanula lyrata* Lam.**	Campanulaceae	115618
***Carduus nutans* L.**	Asteraceae	115621
***Castanea sativa* Mill.**	Fagaceae	115583,115601, 115587, 115517
***Circaea lutetiana* L.**	Onagraceae	115603
***Clinopodium vulgare* subsp. *arundanum* (Boiss.) Nyman**	Lamiaceae	115627
***Cytisus hirsutus* L.**	Leguminosae	115538
***Dorycnium graecum* (L.) Ser.**	Leguminosae	115578,115550, 115551,115581
***Echium vulgare* L.**	Boraginaceae	115629
***Erica arborea* L.**	Ericaceae	115562, 115572
***Fagus orientalis* Lipsky**	Fagaceae	115556, 115557
***Fragaria vesca* L.**	Rosaceae	115535, 115549
***Galega officinalis* L.**	Leguminosae	115591, 115624
***Geranium asphodeloides* Burm.f.**	Geraniaceae	115568
***Geranium purpureum* Vill.**	Geraniaceae	115631
***Hypericum androsaemum* L.**	Hypericaceae	115554, 115555, 115588
***Hypericum calycinum* L.**	Hypericaceae	115597, 115606, 115620
***Hypericum montbretii* Spach**	Hypericaceae	115625
***Hypericum perforatum* L.**	Hypericaceae	115604
***Hypochoeris radicata* L**	Asteraceae	115613
***Lathyrus laxiflorus* (Desf.) Kuntze**	Leguminosae	115569
***Lotus tenuis* Waldst. & Kit**	Leguminosae	115612
***Lysimachia punctata* L.**	Primulaceae	115582, 115585
***Lysimachia verticillaris* Spreng.**	Primulaceae	115609, 115632
***Medicago lupulina* L.**	Leguminosae	115635
***Mespilus germanica* L.**	Rosaceae	115573, 115574
***Myosoton aquaticum* (L.) Moench**	Caryophyllaceae	115599
Poaceae sp.	Poaceae	-
***Potentilla anglica* Laichard.**	Rosaceae	115595, 115623
***Prunella vulgaris* L.**	Lamiaceae	115602, 115634
***Prunus laurocerasus* L.**	Rosaceae	115563, 115579, 115580
***Ranunculus repens* L.**	Ranunculaceae	115558,115541, 115547, 115548
***Rhododendron ponticum* L.**	Ericaceae	115536, 115540, 115564, 115565, 115566, 115567
***Rubus hirtus* Waldst. & Kit.**	Rosaceae	115595, 115608
***Rubus ulmifolius* Schott.**	Rosaceae	115614
***Salvia forsskaolei* L.**	Lamiaceae	115616
***Salvia verticillata* L.**	Lamiaceae	115611
***Sambucus ebulus* L.**	Adoxaceae	115615
***Sambucus nigra* L.**	Adoxaceae	115584
***Saponaria glutinosa* M. Bieb.**	Caryophyllaceae	115619
***Securegia varia* (L.) Lassen**	Leguminosae	115622, 115628
***Sonchus asper* subsp. *glaucescens* (Jord.) Ball ex Ball**	Asteraceae	115636
***Tanacetum parthenium* (L.) Sch. Bip.**	Asteraceae	115589, 115633
***Tilia tomentosa* Moench**	Malvaceae	115592, 115593, 115610
***Trachystemon orientalis* D.Don**	Boraginaceae	115560, 115561
***Trifolium repens* var. *repens* L.**	Leguminosae	115577, 115552, 115598
***Vaccinium arctostaphylos* L.**	Ericaceae	115539,115571, 115576,115544
***Verbascum* sp.**	Scrophulariaceae	-
***Verbena officinalis* L.**	Verbenaceae	115605
***Veronica* sp.**	Plantaginaceae	115537, 115546

Table 2. Melissopalynological analysis of chestnut honey samples of Yığılca and Anatolian honey bee

Botanical origin	Honey 1 % (frequency)*	Honey 3 % (frequency)*
Castanea sativa	94.5 (PP)	96.5 (PP)
Apiaceae	1.5 (MP)	-
Caryophyllaceae	1.5 (MP)	-
Hypericum androsaemum	1.5 (MP)	-
Securegia varia	-	1.5 (MP)
Tilia tomentosa	-	0.5 (MP)
Trifolium repens	1.5 (MP)	0.5 (MP)
Not identified	1.5	1

* PP: predominant pollen (>45%). SP: secondary pollen (16–45%). IMP: important minor pollen (3–15%). MP: minor pollen (<3%).

In addition to chestnut honey, mad honey samples were obtained from local beekeepers. Following established procedures previously mentioned, honey samples were harvested from the Yığılca local honey bee and the Anatolian honey bee. There is no predominant pollen in Yığılca mad honey samples so the honey type is multifloral. The secondary pollen taxa were identified as *Castanea sativa* and important minor pollen group was represented predominantly by *Rhododendron ponticum*, then *Mespilus germanica, Prunus laurocerasus, Barbarea vulgaris, Lysimachia verticillaris,* and *Erica arborea* in the Yığılca mad honey. *Veronica* sp., Poaceae, *Echium vulgare*, *Ranunculus repens*, *Saponaria glutinosa* and Apiaceae were identified in the minor pollen group (Table 3).

Table 3. Melissopalynological analysis of mad honey samples of Yığılca and Anatolian honey bee

Botanical origin	Honey 2 % (frequency)*	Honey 4 % (frequency)*
Castanea sativa	31.5 (SP)	72 (PP)
Rhododendron ponticum	11 (IMP)	5 (IMP)
Mespilus germanica	8 (IMP)	-
Prunus laurocerasus	7.5 (IMP)	-
Barbarea vulgaris	7.5 (IMP)	-
Lysimachia verticillaris	5 (IMP)	7.5 (IMP)
Erica arborea	4 (IMP)	-
***Veronica* sp.**	3 (MP)	-
Poaceae	2 (MP)	-
Echium vulgare	2 (MP)	-
Ranunculus repens	1 (MP)	-
Saponaria glutinosa	0.5 (MP)	-
Apiaceae	0.5 (MP)	-
Leguminosae	-	1 (MP)
Circaeae lutetiana	-	1 (MP)
Lathyrus laxiflorus	-	0.5 (MP)
Not identified	16.5	13

* PP: predominant pollen (>45%). SP: secondary pollen (16–45%). IMP: important minor pollen (3–15%). MP: minor pollen (<3%).

According to our analysis of the sampled mad honey of Anatolian honey bee, *Castanea sativa* forms the group of dominant pollen, and an important minor pollen group was represented by *Rhododendron ponticum* and *Lysimachia verticillaris*. Minor pollen group included Leguminosae, *Circaeae lutetiana*, and *Lathyrus laxiflorus*.

The Sorensen similarity coefficient (ISS), calculating among the honey samples of the Yığılca and the Anatolian honey bees, was 38.09%.

3.3. Physicochemical analysis

According to the standards of the Turkish food codex communique on honey (Ministry of Food, Agriculture and Livestock, 2012) and additional European legislation (The Council of the European Union, 2002), the chestnut and mad honey samples of the Yığılca local honey bee were deemed acceptable. The moisture contents of the honey samples of the Anatolian honey bee, in both the chestnut honey and mad honey, were higher than the allowed limits of 20 g/100 g (22.8 and 23.5, respectively). Other parameters were also deemed acceptable. The results obtained for the various physicochemical parameters are presented in Table 4.

HMF and diastase activity were the specific parameters used to determine honey heating. These parameters were found acceptable in both the chestnut honey and the mad honey samples of both the Anatolian honey bee and the Yığılca local honey bee. Electrical conductivity and free acidity values for both chestnut honey and mad honey samples were also within the accepted limits. Honey pH is of importance during extraction and storage because it affects stability, texture, and shelf life of the honey. The pH levels of the mad honey samples were 3.84 and 4.00, respectively, from the Anatolian honey bee and the Yığılca local honey bee. In the chestnut honey samples, the pH was 5.00 and 5.25 (from the Anatolian honey bee and Yığılca local honey bee, respectively). According to the difference $\delta^{13}C$ value (limits ≥ -1), both the mad honey and the chestnut honey samples were within the defined limits. C-4 sugar content indicated adulteration in honey, which should be under 7%. All the studied honey samples were within these limits.

Table 4. Physicochemical parameters of honey samples

	by Yığılca local honey bee		**by Anatolian honey bee**	
	Honey 1	Honey 2	Honey 3	Honey 4
Diastase number	13.9	10.9	17.9	8.3
HMF mg/kg	UDL*	UDL*	UDL*	UDL*
Conductivity mS/cm	1.219	0.438	1.432	0.419
Moisture g/100 g	17.9	18.4	22.8	23.5
Free acidity mmol/kg	19	19	22	24
Sugar content g/100g ;				
Fructose	36.55	38.33	38.96	36.50
Glucose	29.78	30.21	21.87	29.80
Sucrose	UDL*	UDL*	0.12	UDL*
Maltose	UDL*	UDL*	UDL*	UDL*
pH	5.25	4.00	5.00	3.84
Proline mg/kg	160	1173.33	1226.67	106.67
Difference $\delta^{13}C$ protein – $\delta^{13}C$ honey	-0.28	-0.08	-0.31	-0.40
C4 sugar percentages	1.69	0.43	1.87	2.31

*UDL: Under the detection limit.

4. Discussion and Conclusion

Chestnut honey samples in this study identified monofloral honey, as expected. The sampled mad honey of the Yığılca local honey bee was composed of multifloral honey. The presence of chestnut pollen is the highest across all honey samples collected. Chestnut flowers are one of the most preferred melliferous flowers for honey bees in Düzce province. Both types of honey bee prefer chestnut pollen within the research area studied. Kaya et al. (2005) analyzed 13 honey samples from different regions in Turkey. They showed that two honey samples from Bartın (Black Sea Region) contain *Castanea sativa* pollen as the dominant pollen and that one of them possesses *Rhododendron* pollen as its secondary pollen. Besides, another honey sample from Bolu (Black Sea Region) contains *Rhododendron* pollen as the dominant pollen and *Erica* pollen as the secondary pollen in their study.

In this study, mad honey samples from the Yığılca local honey bees and the Anatolian honey bees could not be identified as monofloral honeys with regards to *Rhododendron* spp., but they are

known and labeled as a mad honey in the district in question. *Lysimachia verticillaris* pollens were identified in all mad honey samples, and it is a preferred plant for both types of honey bees. Plant diversity is higher among the honey of the Yığılca local honey bee than in the Anatolian honey bee's honey.

According to Sorensen similarity coefficient, pollen composition of honey samples produced by the Yığılca local honey bee and the Anatolian honey bee was 38.09% similar, while the melliferous flowers around the hives was 51.85% similar. Pollen diversity was also higher in the Yığılca local honey bee.

Mayda et al. (2018) investigated chestnut and *Rhododendron* honeys in Turkey. In their results, six mixed chestnuts and *Rhododendron*, two monofloral *Rhododendron,* and ten monofloral chestnuts honeys were identified. Kambur et al. (2015) analyzed ten honey samples from the Yığılca district. Three samples were identified as monofloral (*Rhododenron ponticum* and *Castanea sativa*) and the other remaining samples were identified as multifloral. Secondary pollen families were identified as Fabaceae, Fagaceae, Poaceae, Apiaceae, and Asteraceae in multifloral honeys.

Di Marco et al. (2017) studied different monofloral Italian honeys. In all *Rhododendron* honey, the presence of *Rhododendron* pollen frequency was measured at between 15% and 45%. *C. sativa* pollen is dominant in chestnut honeys, and it was represented with a frequency of >45%. The pollen of the other *taxa* was poor. Lamiaceae species, *Ailanthus altissima*, *Prunus*, *Tilia* sp., and *Rhododendron* sp. were found in *C. sativa* honey from North Italy. Mediterranean elements such as *Cistus* sp., *Eucalyptus* sp., *Citrus* sp., and *Olea* sp. were present in *C. sativa* honey from Southern Italy.

According to the standards of the Turkish food codex communique on honey and additional European legislation, the chestnut honey and mad honey samples of the Yığılca local honey bee were deemed acceptable. The moisture contents within the honey samples of the Anatolian honey bee, in both the chestnut honey and the mad honey, are higher than the allowed limits of 20 g/100 g (22.8 and 23.5, respectively). As a result of our interviews with the local beekeepers, it was thought that the amount of moisture present in the honey samples of the Anatolian honey bee may possibly be caused by the rainy weather during the honey season. It can also be due to the early honey harvest. Other parameters were found acceptable. Kambur et al. (2015) analyzed 10 honey samples from Yığılca. Three of them were monofloral honey (*Rhododenron ponticum* and *Castanea sativa* were dominant) and others were multifloral honey. According to physicochemical results, C4, C13 (8.72%, -1.39) and free acidity (70 meq/kg) level of two multifloral honey samples were found slightly high. Other parameters were found acceptable in studied samples. Derebaşı et al. (2014) studied physicochemical parameters (ash, moisture, pH, acidity, diastase activity, HMF, electrical conductivity, invert sugar and sucrose) of 209 honey samples which were obtained from Black Sea Region. They found the mean values for these parameters as appropriate according to standards. On the other hand, 24%, 8% and 12% of the samples are not suitable for diastase activity, invert sugar and sucrose, respectively. Besides that, residue analysis was done. Although honey samples were suitable in terms of pesticide residues, 33% and 10% of them were not suitable for antibiotic and naphthalene residues, respectively.

In conclusion, the botanical composition of the honey samples which were produced by the Yığılca local honey bee and the Anatolian honey bee were analyzed. The diversity of the Yığılca local honey bee's samples was higher than the Anatolian honey bee's samples. This study facilitated the collection of information regarding melissopalynological analysis of honey samples of the Yığılca local honey bee.

Chestnut honey samples of both honey bees were classified as monofloral honey due to the predominant pollen of *Castanea sativa*. The samples were labeled as mad honey from the Anatolian honey bee by local beekeepers, and it contained *Castanea sativa* pollen as the predominant pollen and *Rhododendron ponticum* and *Lysimachia verticillaris* pollens as important minor pollens as well. For this reason, it was classified as monofloral honey. The honey samples of the Yığılca local honey bee, which were labeled as mad honey by local beekeepers, was multifloral honey and contained *Castanea sativa* pollen as its secondary pollen and *Rhododendron ponticum*, *Mespilus germanica, Prunus laurocerasus, Barbarea vulgaris, Lysimachia verticillaris, Erica arborea* pollens as important minor pollens.

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Research Article

Some Biochemical Parameters of Black and White *Myrtle communis* L. Fruits Subjected to Different Preservation Methods

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Myrtle,
Phenolic substance,
Preservation,
Vitamins.

Abstract: In this work, black and white *Myrtus communis* L. (myrtle) fruits some biochemical parameters were investigated such as vitamins**,** carotenes**,** functional peptides, oxidative stress markers (OSM), total phenolic (TP) and flavonoid (TF) substances, antioxidant capacity (AC) and amino acids contents. The black myrtle fruits had generally higher amounts of vitamins, TP, AC and amino acid (AA) contents than the white myrtle fruits. The biochemical contents of myrtle fruits dried in the sun light and microwave (MW) were found to be lower than the frozen fruits ($P<0.05$). A significant increase was observed in the amount of oxidised glutathione (GSSG) and malondialdehyde (MDA) in myrtle fruits as a result of drying ($P<0.05$). Amounts of total AA in the black and white myrtle fruits were found to be 31.37 and 21.89 mg g^{-1} DW, respectively. From the results obtained, it can be said that black myrtle fruit is a better nutrition source than white myrtle fruits and freezing is the most appropriate preservation method.

Farklı Koruma Yöntemlerinin Uygulandığı Siyah ve Beyaz Mersin Meyvelerindeki Bazı Biyokimyasal Parametreler

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Anahtar Kelimeler
Amino asitler,
Antioksidan kapasite,
Hambeles
Fenolik madde,
Koruma,
Vitaminler.

Öz: Bu çalışmada, siyah ve beyaz *Myrtus communis L.* (mersin) meyvelerindeki vitaminler, karotenler, fonksiyonel peptidler, oksidatif stres biyomarkerları, toplam fenolik ve flavonoid madde, antioksidan kapasite ile amino asit içeriği araştırılmıştır. Siyah mersin meyvesi genellikle beyaz'a göre daha yüksek miktarda vitamin, fenolik madde, antioksidan ve amino asit içeriğine sahiptir. Güneşte ve mikrodalgada kurutulan mersin meyvelerinin incelenen biyokimyasal parametreleri dondurulmuş meyvelere göre daha düşük bulunmuştur ($P<0.05$). Kurutma işlemi sonucunda meyvelerin GSSG ve MDA miktarlarında önemli artış gözlenmiştir ($P<0.05$). Siyah ve beyaz mersin meyvelerindeki toplam amino asit içerikleri sırasıyla 31.37 ve 21.89 mg g^{-1} KM, olarak bulunmuştur. Elde edilen sonuçlardan, siyah mersin meyvesinin beyaz mersin meyvelerinden daha iyi bir besin kaynağı ve en uygun muhafaza yöntemin dondurma olduğu söylenebilir.

1.Introduction

The use of plants for human health is a well-established tradition for centuries. Therefore, medicinal plants are at the center of interest around the world. *M. communis* L. commonly known as

‘‘myrtle”, is an endemic plant specific to the Mediterranean region. Two different type of myrtle fruits (black and white) are grown, in the Mediterranean region. Up to now black myrtle fruits has no commercial values, but in recent years it drew attention because of health benefit due to the higher antioxidant properties. Myrtle fruits are also used for curing constipation, hemorrhoids and chest diseases (Fadda and Mulas, 2010). A study conducted by Mothana et al. (2011) reported that myrtle fruits have antioxidant, antimicrobial, anticancer activities. All living organism needs vitamins as well as other nutrition’s. Small quantities of vitamins are essential for organism for the proper functioning of its metabolism (Asensi-Fabad and Munne´-Bosch, 2010). Amino acids are the building blocks of proteins, and main part of food sources of living things. Amino acids are involved in neurotransmitter and biosynthesis processes in biological systems. For adequate production of protein in the body, it is necessary to take essential amino acids by diet (Davidson, 2019). Myrtle is a seasonal fruit, to be able to consume it all year around, different preservation methods are applied to the Myrtle fruits (Fadda and Mulas, 2010). Preservation techniques have a profound effect on the nutritional value and medicinal benefits of fruits. Although naturally drying in the sun is widely used, fruits can also be dried in ovens, drying tunnels, and under a vacuum as well. Microwave drying is a relatively new technique to be investigated for foodstuffs. The drying temperature, drying time, and light intensities are important factors in the nutritional content of fruits during drying processes (Maisnam et al., 2016). The aim of this study is; to compare the vitamins, carotenoids, functional peptides, OSM, TP and TF with AC of the black and white myrtle fruits. The effects of different preservation methods on these parameters with the comparison of AA contents in the white and black myrtle fruits were performed.

2. Material and Methods

2.1. Materials

Myrtle is a medicinal and aromatic plant that does not lose its leaves in winter and can grow up to 5 meters which is in tree or shrub form, and grows naturally in the form of maquis in regions with a Mediterranean climate. Due to its drought resistance, it is suitable for cultivation by planting in commercial and home gardens in other coastal regions except the eastern Black Sea. In recent years, interest in black and red colored fruits has increased due to their high antioxidant capacity.

The myrtle fruits samples were collected in November 2019 from Gözne, Mersin. The obtained fruits samples were analysed in one week of the collection. Dried samples were stored in a desiccator. Frozen samples (-20 °C) were analysed in ten days after drying. 20.0 gram of each fruit samples were homogenized and used throughout the analysis. Equipment and chemicals used were given in Bakar et al. (2020). Drying of fruit samples were performed according to Çakmak et al. (2021).

2.2. Determination of fat-soluble vitamins and lycopene

2.0 Gram of homogenized fruit samples taken and analysed according to Ibrahim et al., (2017).

2.3. Determination of B vitamins

Analyses were carried out by HPLC using Supelcosil LC-18-DB column (150 mm x 4.6 mm ID, 5 µm) according to the methods of Amidžić et al. (2005) and Ibrahim et al. (2017).

2.4. Determination of vitamin C, ghrelin, GSH, GSSG and MDA

Analyses were performed by HPLC according to Ibrahim et al. (2017).

2.5. Determination of total phenolic, flavonoid substance and antioxidant capacity

2.5.1 Extraction

The myrtle fruits, were homogenized with a blender, and 15.0 g of homogenized sample was transferred into the paper thimble and extracted with CH_3OH in Soxhlet apparatus for 4 hours. The extracts dried in rotary evaporator and dissolved in a 50 mL CH_3OH and the solution was stored in the freezer until analysis. The prepared extract was used to determine the total phenolic substance, total flavonoid and antioxidant capacity. Determination of total phenolic and flavonoid substance were determined spectrophotometrically as described by Dewanto et al. (2002) and the results are given in as gallic acid equivalent (µg GAE g^{-1} DW) with quercetin equivalent (µg QE g^{-1} DW) respectively.

Total antioxidant capacity was determined according to two different methods, DPPH and TEAC.

2.5.2. DPPH method

The AC was measured according to Nile et al. (2013)**.**

2.5.3. TEAC method

Radical-scavenging activity the of the sample was determined according to the method described by Re et al. (1999)**.**

2.6. Determination of amino acids

Sample hydrolysis: 2.0 g of homogenised fresh fruit samples were taken into a glass tube then 5.0 mL 6.0 N HCl was added and vortexed thoroughly followed by heating at 110 °C for 24 hours (Kwanyuen and Burton, 2010). The samples were then cooled to room temperature, filtered, then total volume was completed to 10 ml with water.

Derivatization: *S*tandard amino acid solutions were prepared in 0.10 N HCl at different concentrations (1.0 - 5.0 µg mL^{-1}) and 50 µL standard amino acid solutions or hydrolysed fruit samples transferred into a 5.0 mL glass tubes and dried under vacuum at 65 °C. Then 50 µL of reagent **1** [(2: 2: 1 mixture of ethanol: water: Triethylamine (TEA) (v/v)] were added, vortexed and dried under vacuum at 65 °C again. Then 50 µL of reagent **2** [7:1:1:1 mixture of ethanol: water: TEA: phenyl isothiocyanate (PITC) (v/v)] introduced to dried sample and vortexed then left at room temperature for 30 minutes for the complex formation in a dark place. At the end of this period, the samples were dried again under vacuum at 35 °C (Kwanyuen and Burton, 2010) and 1.0 mL eluent A and acetonitrile (ACN) mixture (8: 2 v/v) was added, vortexed then the samples were analysed by HPLC.

Amino acid analysis: Analysis of amino acid was performed with the modified method of Kwanyuen and Burton (2010) by HPLC using Nucleodur 100-5 C18 column (250 x 4.6 mm, 5µm). Chromatography was carried out at a constant temperature (40 °C) with the mobile phase consisting of eluent A and eluent B mixture with a flow rate of 0.8 mL $minute^{-1}$ and absorption was measured at 254 nm. Eluent A is 0.07 M CH_3COONa (pH was adjusted to 6.4 with CH_3COOH) and eluent B is a mixture of ACN and water (60:40 v/v). Gradient program for amino acid analysis was as follows; 0-12 minutes' eluents 90 % A and 10 % B; 12-16 minutes, 70 % A and 30 % B, 16-16.01 minutes, 65 % A, 35 % B, 16.01-25 minutes 50 % A, 50 % B, 25-26 minutes % 100B, followed by 26-35 minutes 90 % A and 10 %B.

2.7. Statistical Analysis

All measurements were triplicated and Variance analysis was performed by SPSS 10.0 and significance was expressed as $P<0.05$.

3. Results and Discussion

Different conservation methods, freezing and drying being the most common ones, are applied to seasonal fruits to protect both their appeal and nutritional value for year round consumer consumption. However, such preservation methods not only affect the physical appearance of fruits but also their nutritional characteristics as well. In this study, two different types of myrtle fruits, black and white, were studied by applying different preservation methods, frozen, sun and microwave dried. The experimental analysis results were given in Figures 1 to 6. As it can be seen from Figure 1-2, vitamins A, E, β-carotene, vitamin B_2, vitamin B_3, vitamin B_6, vitamin B_9, vitamin B_{12} and vitamin C in the white myrtle fruits are less than in the black fruits ($P<0.05$). The difference between lycopene and vitamin B_1 in black and white myrtle fruits is statistically insignificant ($P>0.05$). The highest amounts of vitamins, β-carotene and lycopene were found in fresh myrtle, while the lowest amounts were found in sun-dried fruit samples ($P<0.05$). Vitamin loss in sun and microwave dried fruits varies between 30.0-57.0 % compared to fresh fruits. As can be seen from Figures 1 and 2, the highest vitamin loss was in sun dried samples ($P<0.05$), while the least vitamin loss occurred in frozen samples ($P>0.05$).

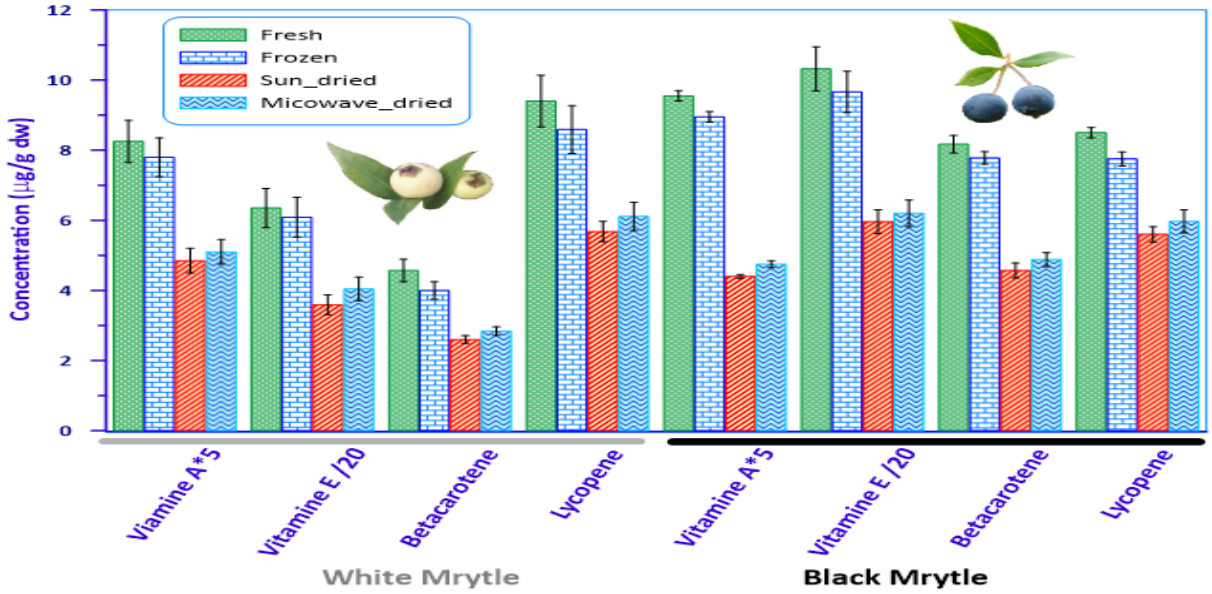

Figure 1. Contents of fat soluble vitamins and lycopene in fresh, frozen, sun and microwave dried white and black myrtle samples (for clarity and to bring into scale; vitamin A values multiplied by 5 and vitamin E values divided by 20).

Process parameters such as temperature and drying time are known to have a significant effect on the loss of vitamins. The vitamins loss in microwave dried samples was relatively less than the sun-dried samples, because of prolonged exposure to sun light. Obtained results consistent with the literature (Sheraz et al., 2014). Because, the shorter process time required for microwave drying, lead to lesser extend of vitamin loss, therefore microwave drying has an advantage over the sun-drying process. It was reported that the amounts of vitamins B_1, B_2, B_3, B_6, and B_9 in some fruit and vegetables (carrot, brinjal, okra, spinach, banana, and guava) were found in between 0.2 - 1.8, 0.16 - 2.0, 0.1 - 1.0, 0.6 - 2.8 and 0.16 - 1.9 µg g^{-1}, respectively (Ismail et al., 2013). The reason the loss of vitamin, caused by the photochemical and enzymatic reactions during the sun drying process. Vitamin loss in sun-dried fruit samples is higher than microwave-dried samples. This can be explained by higher energy of sunlight to break down the vitamins and longer exposure time to dry (Sheraz et al., 2014). The loss of vitamins observed by microwaves drying can be explained by very high temperature reach in short time causing thermal degradation of fruits.

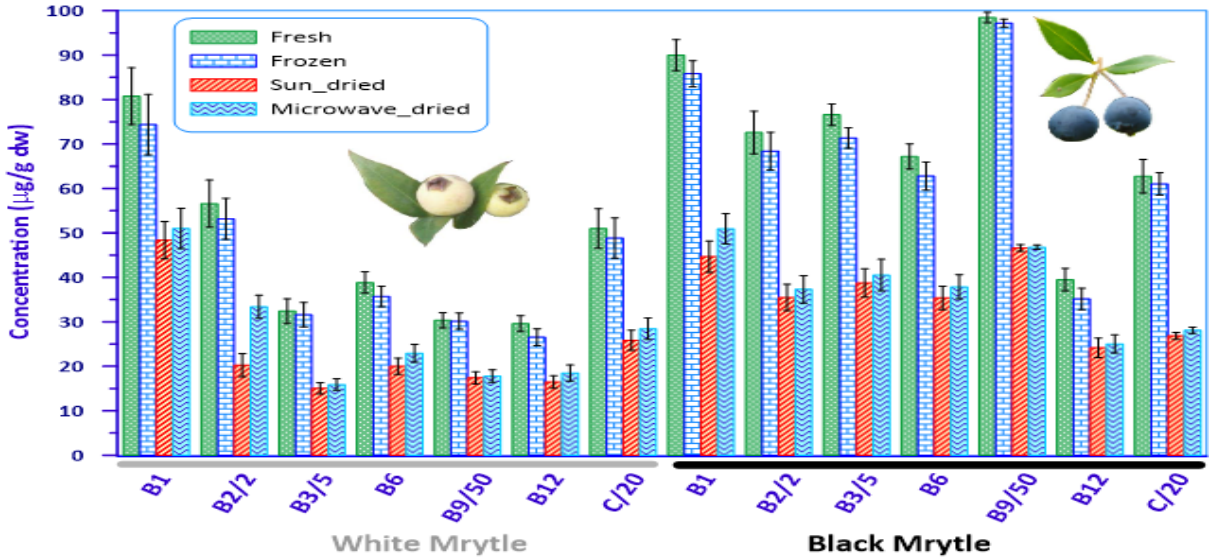

Figure 2. Contents of water soluble vitamins in fresh, frozen, sun and microwave dried white and black myrtle samples (for clarity and to bring into scale; vitamin B_2 values divided by 2, vitamin B_3 values divided by 5, vitamin B_9 values divided by 50 and vitamin C by 20).

Ghrelin, which has a peptide structure, can be affected by heat treatment. Ultrasound, heat, and irradiation processing might affect protein structure and function. The amount of ghrelin in the black myrtle fruit is higher than in the white myrtle fruit. In addition, a higher amount of ghrelin was observed in the fresh samples than frozen and microwave dried samples (Figure 3). Ghrelin content in fresh, frozen, sun and microwave dried *Opuntia ficus-indica* fruit samples found to be 19.20, 18.80, 9.90, and 10.10 µg g^{-1} DW, respectively (Çakmak et al., 2020).

Glutathione is essential for the immune system of cells and protects cells against oxidative damage by removing reactive oxygen species. The result suggests that both black and white myrtle fruits are a rich source of GSH. The amounts of both GSH and GSSG in black myrtle fruit are 30% and 100% higher than in white myrtle fruit respectively ($P<0.05$). The GSH levels in both black and white myrtle fruits are considerably higher than the GHS values in *Opuntia ficus-indica* fruits (Çakmak et al., 2020). Drying myrtle fruits in the sun or microwave, cause reduced GSH levels while increasing GSSG levels significantly ($P<0.05$) (Figure 3). Preservation methods such as heat and irradiation can significantly affect the biological activity of peptides. Additionally, these processes also can cause Maillard reactions in foods. A decrease in the ratio of GSH / GSSG is the result of oxidative stress.

The value of GSH/GSSG in fresh, frozen, microwave and sun-dried black myrtle were 3.8, 3.59, 1.33 and 1.48, respectively, while it was found to be 5.94, 5.65, 2.20 and 2.47 in white myrtle samples. As a result of the drying process, the GSH/GSSG ratio in both black and white myrtle fruits decreased significantly.

Another stress biomarker is MDA which is also a cellular stress indicator and is formed as a result of lipid peroxidation caused by free radicals (Gawel et al., 2004). It was observed that MDA in black and white myrtle varies between 6.68- 7.62 and 5.83- 8.13 µg g^{-1} DW, respectively (Figure 3). Drying processes, significantly increase the amount of MDA level in myrtle fruits ($P<0.05$). Our findings are consistent with the results obtained in apricot dried by infrared and microwave (Karatas and Kamisli, 2007). While GSH/GSSG ratio decreased, the amount of MDA increased as a result of drying processes.

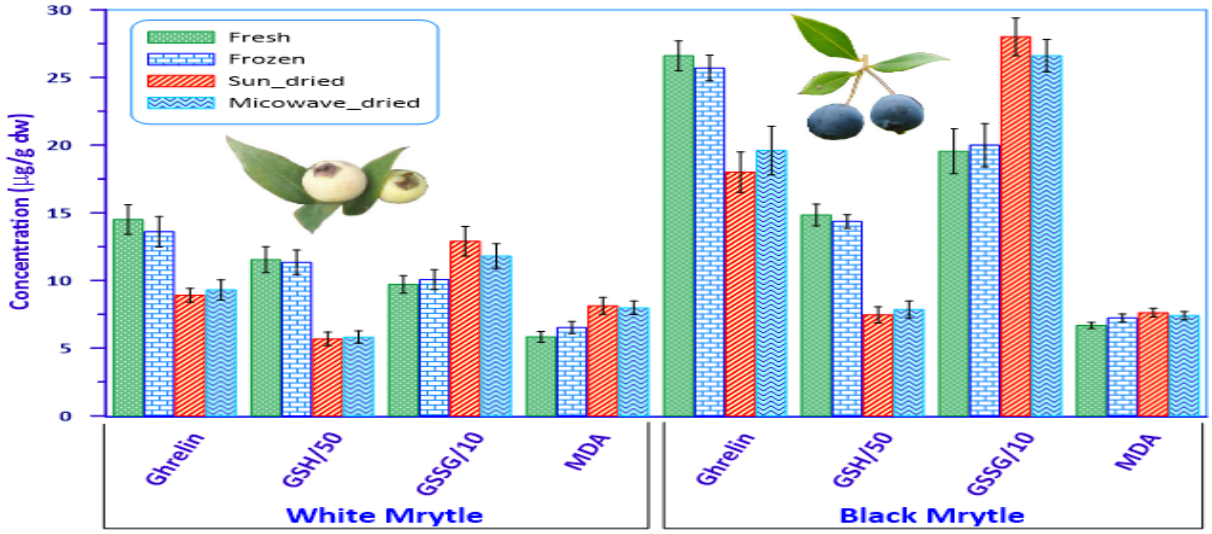

Figure 3. Contents of ghrelin, GSH, GSSG and MDA, in fresh, frozen, sun and microwave dried white and black myrtle samples (for clarity and to bring into scale; GSH value divided by 50 and GSSG value divided by 10).

Phenolic compounds found in plants function as antioxidant, antimutagenic, anticarcinogenic, and play a role in altering gene expression (Datta et al., 2019). The total of phenolic substance in the black myrtle fruit is more than that in the white fruits ($P<0.05$). The change in the total amount of phenolic substances as a result of the drying process is not statistically significant ($P>0.05$) (Figure 4). Patil et al. (2019) found the total phenolic content of *Opuntia Ficus-indica* fruits as 42.454 mg GAE/100 g. Total phenolic content, DPPH, and ABTS values of green walnuts were reported as 17842.26-6907.83 mg GAE kg^{-1}, 208.8-49.03 and 208.48-66.97 mmol TE g^{-1}, respectively (Uğurlu et al. 2019).

Different studies investigated the effect of drying on phenolic compounds in fruits. While Zanoelo et al. (2006) reported the decrease in the total amount of phenolic substances on drying fruit samples, Dewanto et al. (2002) reported that the total phenolic compound unchanged. As a result of heat treatment, some phenolic compounds may decompose or new phenolic compounds may form. Therefore, depending on the drying process and type of fruits, changes in the total phenolic substance may not be the same for each fruit after drying.

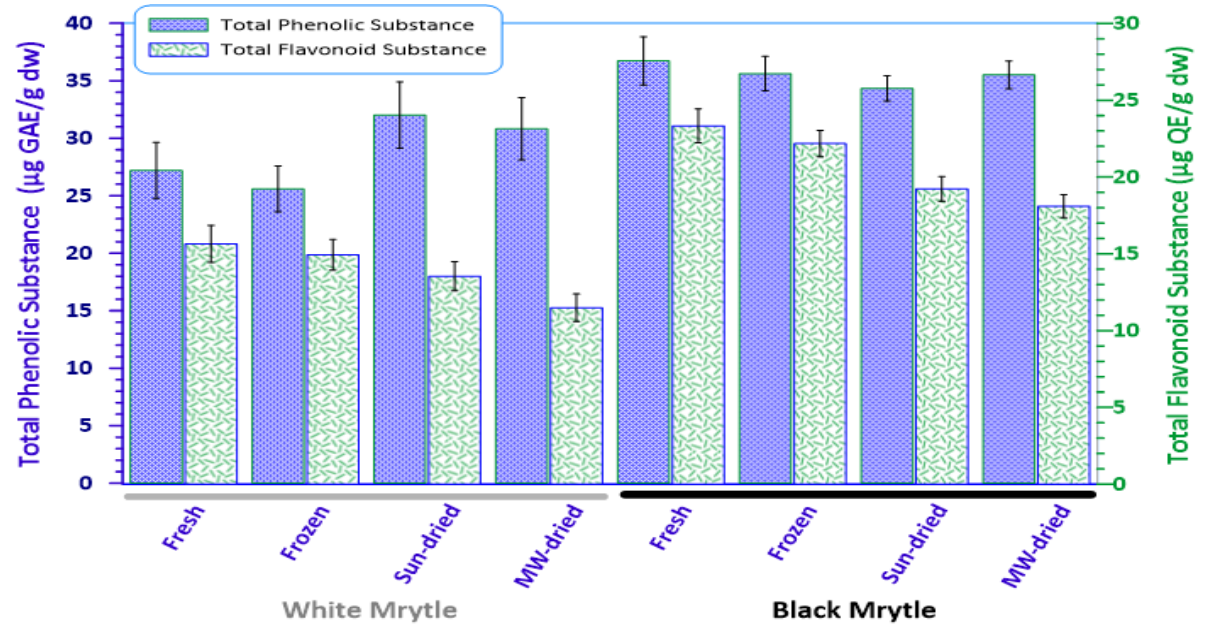

Figure 4. Contents of total phenolic substance and Flavonoid in fresh, frozen, sun and microwave dried white and black myrtle samples.

The total flavonoid content in black myrtle fruits is quite higher (23.33 µg QE g^{-1} DW) than white myrtle fruits (15.65 µg QE g^{-1} DW) ($p < 0.05$). (Figure 4). While the least flavonoid lost was observed in frozen fruits, the highest decrease was observed in MW dried samples. Flavonoids are the substances that cause the colouring of fruits which involve in the activity of some enzymes (Panche et al., 2016). The total amount of flavonoids in *Opuntia ficus-indica* fruit has been reported as 1.91 (mg QE g^{-1} DW) (Hahm et al., 2015). The results obtained showed that while the least loss of flavonoid was observed in frozen myrtle ($P>0.05$), the highest loss was observed in the microwave dried samples ($P<0.05$). This can be explained by the decomposition of some flavonoids at high temperatures during microwave drying process. Drying vegetables and fruits under different conditions has been reported to cause 3 % to 96 % decrease in the total amount of flavonoids (Kamiloglu et al., 2015).

Antioxidants are molecules that are generally produced from natural sources, contain phenolic groups and, inhibit the free radical formation or neutralize them (Su et al., 2007). IC_{50} and trolox equivalent were calculated to determine the antioxidant capacity. As can be seen from Figure 5, IC_{50} values in black myrtle fruit lower than white myrtle fruit which indicates high antioxidant activity. On the other hand, the highest IC_{50} value of myrtle fruits were observed in the sun-drying process. Surinut et al. (2005) reported that the IC_{50} values of mangosteen, orange, pomelo, grape, and papaya fruits ranged from 11.18 to 32.80 mg mL^{-1}.

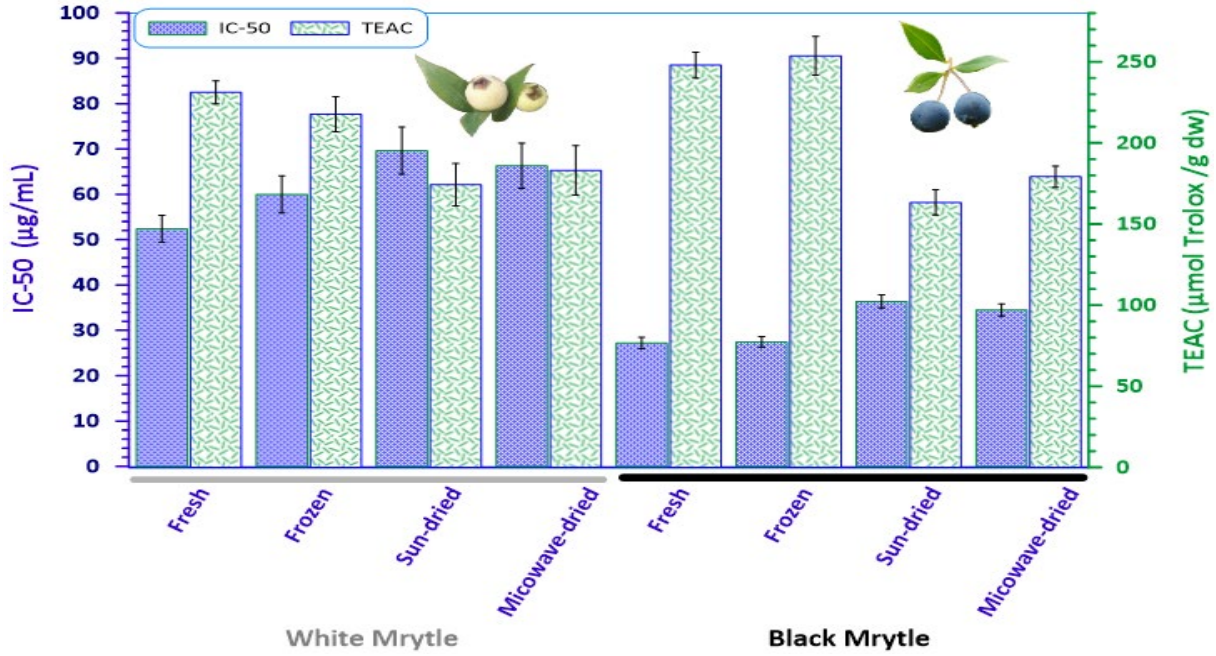

Figure 5. TEAC and IC_{50} values of fresh, frozen, sun and microwave dried black and white myrtle fruits.

TEAC values of black myrtle fruits have significantly higher than the white fruits ($P<0.05$). TEAC value decreased significantly because of drying process ($P<0.05$) (Figure 5). The decrease in total antioxidant capacity might be the result of the breakdown of vitamins, phenolic, and flavonoid substances. Su et al. (2007) reported that the antioxidant activity of rosehip fruit was 190 µmol TEAC g^{-1}.

One of the main source of amino acid is known as vegetables, fruits and plants. The determination of amino acids in vegetation has become an important subject in recent years. Essential amino acids used in protein synthesis and metabolism, must be taken with the diet. Experimental results of amino acids in black and white myrtle fruits are given in Figure 6. The essential amino acid content in black myrtle fruit ranges from 0.75 to 2.30 mg g^{-1} DW, while the total essential amino acid content was found to be 13.47 mg g^{-1} DW. The total amount of amino acids in the black myrtle fruit was found to be 31.37 mg g^{-1} DW, while it was as 21.89 mg g^{-1} DW in the white fruits ($P<0.05$) (Figure 6).

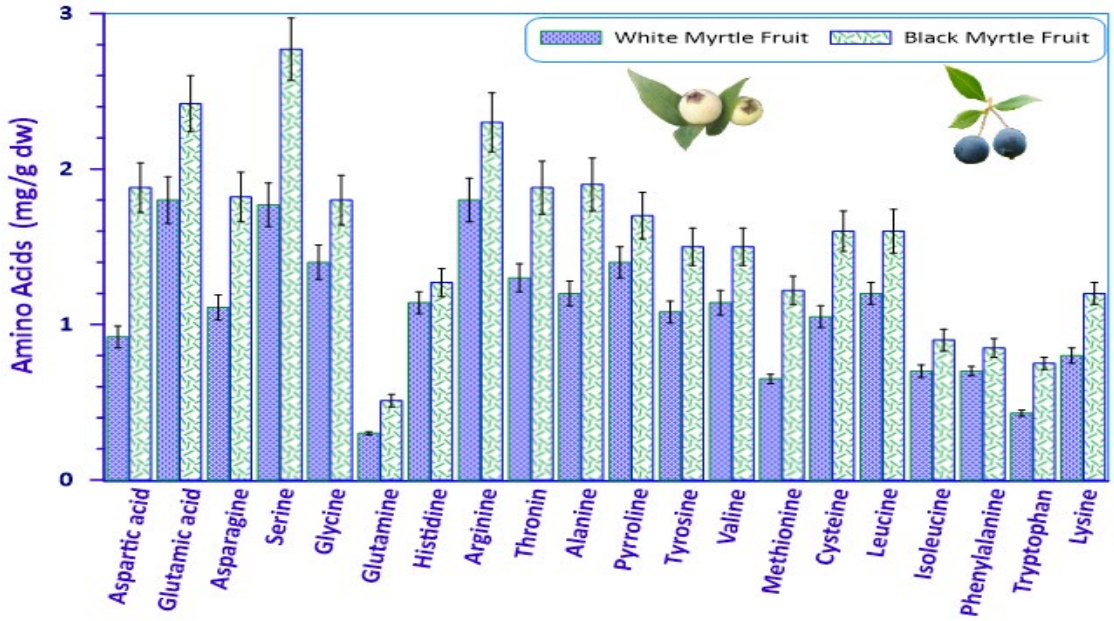

Figure 6. Contents of amino acids in black and white myrtle samples.

The amount of essential amino acid content in white myrtle fruit ranges from 0.43 to 1.84 mg g^{-1} DW, while the total essential amino acid content to be 9.86 mg g^{-1} DW. Zhou et al. (2019) in their study using *Nitraria tangutorum Bobr* pulp and peel, reported the total essential amino acids ranged from 44.39-53.51 mg g^{-1} DW, and the total non-essential amino acids ranged from 65.65-71.41 mg g^{-1} DW. According to the Food and Agriculture Organization and the World Health Organization, the total essential amino acid/total amino acid ratio in a good protein source should be over 40%, while the total essential amino acid/total non-essential amino acid ratio should be over 60 % (Zhou et al., 2019). Total essential amino acid/total amino acid and total essential amino acid/total non-essential amino acid ratio for black and white myrtle fruit were found to be 43.0, 75.0, 45.0 and 82.0 percent, respectively.

Conclusions

Myrtle fruits are a good source of nutrients in vitamins, carotenes, lycopene, glutathione, ghrelin, antioxidants capacity and amino acids. And black fruits are a good source of nutrients than white fruits. Obtained results indicate that there is no significant difference between in fresh and frozen myrtle fruits in terms of the biochemical parameters examined. Content of vitamins, total phenolic and flavonoid compounds, and antioxidant capacity in fresh and frozen myrtle fruit samples have higher than the sun and microwave-dried fruit samples. Since vitamins and antioxidants are very sensitive to light, heat, and air, drying conditions effect on these parameters. It was found that while the GSH/GSSG ratio decreased, while MDA level increased in dried myrtle fruits. It can also be said that the drying process causes stress in the fruits resulting in lipid peroxidation. Experimental findings, suggests that the most suitable method for preservation for myrtle fruits is freezing.

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Research Article

Effects of Severe Drought Stress on Some Physiological and Biochemical Parameters of AMF Inoculated *C. arietinum*

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Cicer arietinum

Abstract: In this study, physiological and biochemical changes caused by mycorrhizal symbiosis in chickpea plants under drought conditions were investigated in both root and leaf. Drought stress reduced leaf water potential, but mycorrhizal symbiosis caused a significant increase in leaf water potential. However, the application of mycorrhiza under drought stress caused an increase in the amount of elements that are very important for the development of the plant in the root and leaf. In our study, drought increased the proline concentration and MDA content, while mycorrhiza application decreased them in both leaf and root. In addition, while mycorrhizal application increased the activity of catalase, it decreased the activity of superoxide dismutase. In general, enzyme activities were found to be higher in the leaf, but no distinct pattern was obtained between root and leaf in other analyzes. The study shows that the responses of mycorrhizal symbiosis in chickpea plants may change depending on the severity of the drought. Especially antioxidant enzyme activities and proline content patterns reveal that more comprehensive studies should be conducted on these issues. However, continuing studies until determining the effects of AMF symbiosis on grain yield under drought may provide more comprehensive results.

Şiddetli Kuraklık Koşulları Altındaki *Cicer arietinum* (Nohut) Bitkisinde Mikoriza Aşılamasının Bazı Fizyolojik ve Biyokimyasal Parametreler Üzerine Olan Etkileri

Makale Bilgileri

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Anahtar Kelimeler
Kuraklık,
Glomus mosseae,
Cicer arietinum

Öz: Bu çalışmada kuraklık koşulları altındaki nohut bitkilerinde mikorizal simbiyozisin meydana getirdiği fizyolojik ve biyokimyasal değişiklikler hem kök hem de yaprakta araştırılmıştır. Kuraklık stresi ile birlikte yaprak su potansiyeli azalmışken, mikorizal simbiyozis yaprak su potansiyelinde belirgin bir artışa neden olmuştur. Bununla birlikte kuraklık stresi altında mikoriza uygulaması bitkinin gelişimi için oldukça önemli olan elementlerin miktarında kök ve yaprakta artışa neden olmuştur. Çalışmamızda kuraklık ile birlikte yükselen prolin konsantrasyonu ve MDA içeriği mikoriza uygulamasıyla birlikte azalmıştır. Ayrıca antioksidan enzimlerden katalazın aktivitesi mikoriza uygulamasıyla birlikte artarken, süperoksit dismutaz aktivitesi ise düşmüştür. Genel olarak enzim aktiviteleri yaprakta daha yüksek bulunmuşken, diğer analizlerde kök ve yaprak arasında belirgin bir desen elde edilmemiştir. Yapılan çalışma kuraklığın şiddetine bağlı olarak mikorizal simbiyozisin nohut bitkisinde meydana getirdiği yanıtların değişebileceğini göstermektedir, özellikle mikorizal simbiyozis ile antioksidan enzim aktiviteleri ve prolin içerik desenleri arasındaki ilişki konularında daha fazla çalışma yapılması gerektiğini ortaya koymaktadır. Bununla birlikte bu simbiyozisin kuraklık altında tane verimine etkilerini belirleyene kadar çalışmaların sürdürülmesi daha kapsamlı sonuçların elde edilmesini sağlayabilir.

1. Introduction

Legumes (Fabaceae) are a very valuable plant group both agriculturally and economically. Besides being used for nutritional purposes, free nitrogen digestion in the soil also increases the ecological value of this group (Pandey, 2008). According to FAO (2019), Turkey is the most chickpea-producing (630.000 tonnes) country in the world after India. Chickpea, which is one of the most grown legume products in the world and Turkey, is generally grown in semi-arid and arid areas. Although chickpeas have developed mechanisms that can cope with drought, it is known that this stress causes serious product loss in chickpeas (Canci and Toker, 2009).

Plants are continuously exposed to abiotic and biotic stress factors throughout their life in nature. Drought, one of the most important abiotic stress, affects fields, and cause serious yield losses (Sadak et al., 2021). It has been estimated that drought-induced inefficient soil levels for crop production reach up to 28 % of the world's cultivated land (Aroca et al., 2008). Drought stress is one of the most limiting factors for chickpea growth during vegetative and reproductive development stages (Günes et al., 2006). Chickpea is known to be resistant to drought, but the yield loss due to drought is around 45-50 % for chickpeas (Devasirvatham and Tan, 2018; Shah et al., 2020). Studies conducted on this subject have shown that the morphological, physiological and biochemical mechanisms of chickpea are negatively affected by drought stress, resulting in crop losses (Rani et al., 2020).

There are many strategies developed by plants against drought stress, one of which is symbiotic interactions. Many symbiotic interactions occur between plants and other organisms in nature. One of these interactions is between the plant and mycorrhiza fungi, which was established approximately 400 million years ago (Diagne et al., 2020). Arbuscular mycorrhizal fungi (AMF) colonize within the root cortex, producing large amounts of hyphae (mycelia), increasing the surface area of the infected root. This allows the nutrients and water in the form and amount that the plant cannot take from the soil, away from the root, through the mycorrhiza hyphae and transmit it to the upper parts of the plant. Thus, a symbiotic life is established where the mycorrhizal fungus provides water and minerals to the plant and the plant carbon to the mycorrhizal fungus (Wu et al., 2008).

Increasing the surface area of plant roots infected with AMF provides a great advantage for the plant to cope with stress, especially in drought stress conditions (Ortaş, 2012). This advantage is not limited to taking water and mineral substances from the soil; It also includes many physiological and biochemical events such as the mycorrhizal promoting root regeneration, accelerating plant growth, promoting intracellular soluble substance concentration, activating the antioxidant system (Kaya et al., 2009). The symbiotic relationship between AMF and plants is an important topic that has been studied for a long time. Within the scope of these studies, the role of symbiotic relationships under stressful and/or non-stressful conditions is attempted to be understood. In this study, some physiological and biochemical responses caused by drought stress in chickpea plants were investigated. It has been observed that the plant creates different stress responses with the increase of stress intensity.

2. Materials and Methods

2.1. Plant material and drought treatment

Cicer arietinum (ILC482) seeds were sterilized by soaking in 2.5 % sodium hypochlorite solution for 10 minutes, then washed thoroughly and soaked in distilled water for 1 day. Then they were transferred to plastic pots (2 L) and filled with mineral-poor soil. The soil was autoclaved at 121 °C for 2 hours before use. Half of these seeds are infected with mycorrhiza (*Glomus mosseae*), approximately 1000 spores of *G. mosseae* were used for each seed. 4 seeds were planted in each of the pots. According to the plant output, 2 plants were developed in each pot. In addition, there were three pots in each group. All pots were watered to %85 of field capacity before sowing. After sowing, all pots were also watered 75 mL every 4 days. Plants were grown at 24 ± 2 °C, 16/8 h photoperiod, irradiance 480 µmol $m^{-2}s^{-1}$, 65 ± 5 relative humidity under controlled conditions for 21 days in the plant growth room. At the end of this period, half of the seedlings were not watered for 12 days and the other half were irrigated as control plants. Afterwards, the leaves and roots were harvested and taken into liquid nitrogen quickly and stored in a freezer at -80 °C until analysis day.

2.2. Leaf water potential

The leaf water potential was measured by using a pressure chamber (PMS Instrument Co., Model 1000).

2.3. Determination of root and leaf element contents

Leaf samples (0.5 g) were extracted in a 3:1:1 ratio nitric acid/perchloric acid/hydrochloric acid solution in an oven at 200 °C. These samples were then diluted with 50 mL of ultrapure water and analyzed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Agilent 7500).

2.4. Antioxidant enzyme assays

The same extraction method was used for SOD and CAT enzymes. Leaf and root tissues (0.5 g) were homogenized with phosphate buffer (5 mL, pH 6.8) and centrifuged at +4 °C, 5 min, 16.000 g and supernatant was used for measurements. Total SOD activity was determined according to Beyer and Fridovich (1987). One unit of SOD activity was defined as the amount of enzyme that was required to cause 50% inhibition of the reduction of NBT as monitored at 560 nm. CAT activity was determined by measuring the rate of decomposition of H2O2 at 240 nm, as described by Aebi (1983).

2.5. Determination of Lipid peroxidation

Lipid peroxidation was determined by measuring the malondialdehyde (MDA) level, according to Ohkawa et al. (1979). Firstly, leaf and root tissues (0.2 g) were homogenized in trichloroacetic acid (5 %) (TCA) solution and centrifuged at 12.000 rpm. The supernatant, thiobarbituric acid (TBA) and 20 % TCA solutions were transferred to the tubes in equal volumes and incubated at 96 °C for 25 min. After that, the tubes were centrifuged at 12.000g for 5 min and the supernatant was measured at 532 and 600 nm. The MDA content was calculated using the extinction coefficient.

2.6. Determination of free proline content

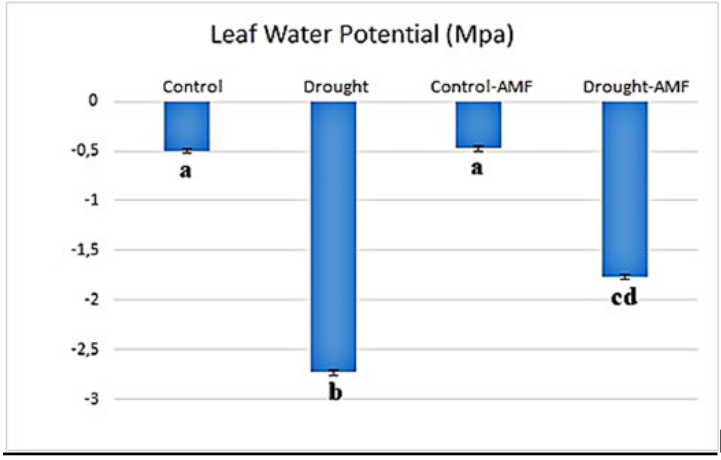
Free proline content was determined according to the method of Bates et al. (1973). Leaf and root samples were homogenized in sulfosalicylic acid (3 %) and centrifuged at 3.000 rpm, then the supernatant, acetic acid and ninhydrin were mixed well and boiled for 1h. Then, cold toluene was added to this mixture and the toluene phase was measured at 520 nm. The proline concentration was calculated by using a calibration curve and expressed as μmol proline g^{-1} FW.

2.7. Statistical analysis

Stress and mycorhiza treatments were carried out completely randomized experimental design with two factors. Treatments had three replications with three plants each. Data were subjected to ANOVA and the means were separated using the LSD multiple range test at $P<0.05$. All the statistical analyses were performed using the JMP8 Software package).

3. Results

Drought stress significantly reduced leaf water potential. However, AMF inoculation enhanced leaf water potential under drought stress (Figure 1).



	Arbuscular Mycorrhizal Fungus	LWP
Control	AMF (-)	-0.497a
	AMF (+)	-0.477a
Drought	AMF (-)	-2.733b
	AMF (+)	-1.773c
LSD		0.054***

***p<0.001.

Figure 1. Changes in leaf water potential under drought and/or AMF inoculation.

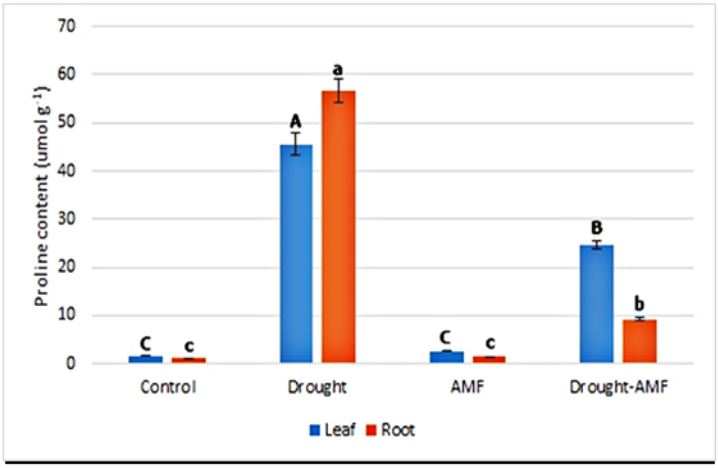
In the present study, AMF inoculation significantly increased the element contents in the root especially under drought conditions (Table 1).

Table 1. Effects of mycorrhizal symbiosis on some element content of *C.arietinum* roots under drought stress

	Arbuscular Mycorrhizal Fungus	Al (ppb)	P (ppb)	Ca (ppm)	Mn (ppb)	Fe (ppm)	Ni (ppb)	Cu (ppb)	Zn (ppb)
Control	AMF (-)	178.54c	5.92c	4.95c	10.15c	0.48c	3.45c	<1.0d	3.58c
	AMF (+)	203.05b	14.97b	6.52b	11.39b	0.49bc	3.71b	1.44b	6.26b
Drought	AMF (-)	160.05d	4.85c	4.83c	9.21d	0.52b	3.55bc	1.20c	6.25b
	AMF (+)	333.16a	19.85a	10.15a	19.22a	0.80a	5.75a	2.27a	34.78a
	LSD	3.785***	1.202***	0.382***	1.998***	0.038***	0.236***	0.181***	1.428***

***p<0.001.

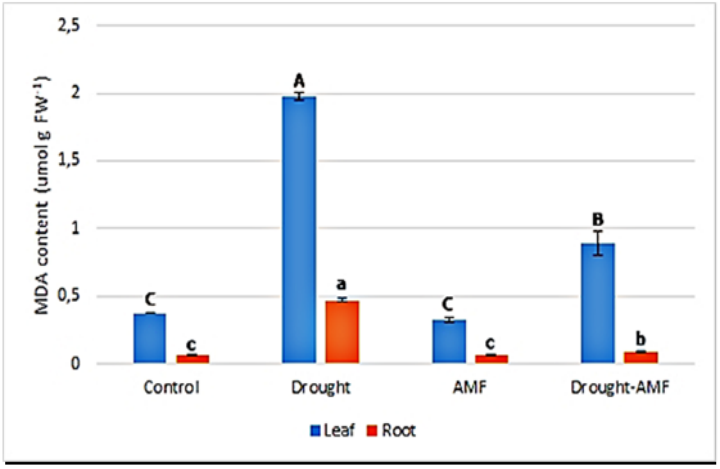
Proline (Figure 2) and MDA (Figure 3) contents of *C.arietinum* increased with drought stress compared to the control group in both leaf and root. AMF inoculation of *C.arietinum* resulted in a significant decrease in proline and MDA content in both leaf and root under drought. While the proline content was higher in the roots under drought conditions compared to the leaves, this situation reversed with AMF inoculation under drought. MDA content was found higher in leaves at all conditions.



	Arbuscular Mycorrhizal Fungus	Proline -Root-	Proline -Leaf-
Control	AMF (-)	1.153c	1.542c
	AMF (+)	1.385c	2.542c
Drought	AMF (-)	56.516a	45.593a
	AMF (+)	9.225b	24.672b
LSD		2.899***	2.760***

***p<0.001.

Figure 2. Proline content in leaves and roots of chickpea plants under drought and arbuscular mycorrhizal fungal inoculation.

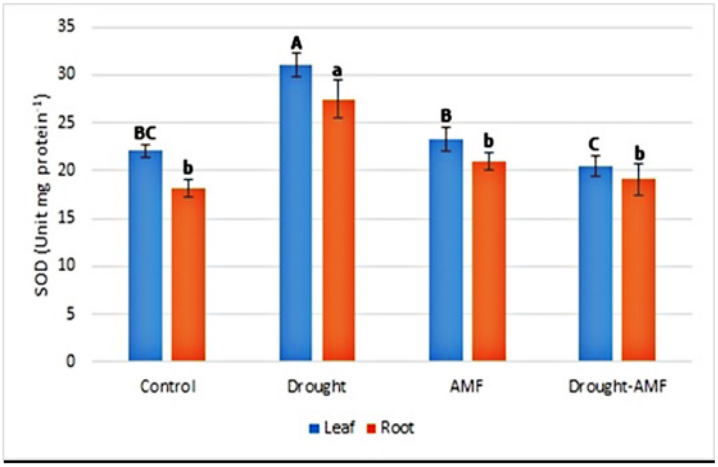


	Arbuscular Mycorrhizal Fungus	MDA -Root-	MDA -Leaf-
Control	AMF (-)	0.065c	0.378c
	AMF (+)	0.063c	0.326c
Drought	AMF (-)	0.472a	1.973a
	AMF (+)	0.092b	0.895b
LSD		0.017***	0.109***

***p<0.001.

Figure 3. MDA content in leaves and roots of chickpea plants under drought and arbuscular mycorrhizal fungal inoculation.

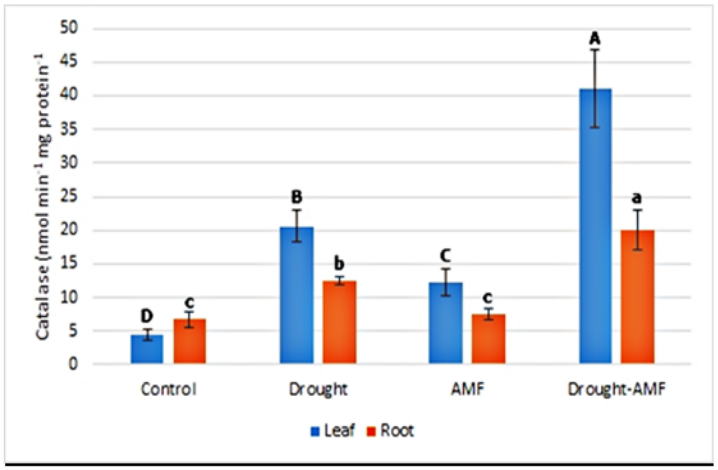
Antioxidant enzymes (SOD and CAT) activities increased under drought stress in both leaf and root. However, AMF inoculation decreased the SOD activity (Figure 4) while increasing the CAT activity (Figure 5) compared to drought stressed group. Also interestingly, AMF increased enzyme activities compared to control.



	Arbuscular Mycorrhizal Fungus	SOD -Root-	SOD -Leaf-
Control	AMF (-)	18.153b	22.110bc
	AMF (+)	20.978b	23.227b
Drought	AMF (-)	27.459a	31.056a
	AMF (+)	19.096b	20.453c
LSD		3.295***	2.544***

***p<0.001.

Figure 4. Superoxide dismutase activity in leaves and roots of chickpea plants under drought and arbuscular mycorrhizal fungal inoculation.



	Arbuscular Mycorrhizal Fungus	CAT -Root-	CAT -Leaf-
Control	AMF (-)	6.803c	4.487d
	AMF (+)	7.552c	12.261c
Drought	AMF (-)	12.483b	20.618b
	AMF (+)	19.984a	41.062a
LSD		3.802*	7.692*

***p<0.05.

Figure 5. Catalase activity in leaves and roots of chickpea plants under drought and arbuscular mycorrhizal fungal inoculation.

4. Discussion and Conclusion

In this study, it was determined that inoculation of chickpea plants with *G. mosseae* improved plant tolerance for drought stress. Although this situation has been shown in the literature in general, some data obtained from this study have the potential to provide new information to the literature and some issues related to mycorrhizal symbiosis should be studied in more detail.

AMF inoculation increased leaf water potential of *C.arietinum* under drought stress. When the roots of plants infected with AMF, the surface areas of the roots increase, resulting in the potential for

the plant to absorb more water from more areas (Bagyaraj et al., 2015). This gives the plant a great advantage, especially under drought stress conditions.

Under drought conditions, amount of some important macroelements such as phosphorus (P), calcium (Ca) and microelements such as iron (Fe), manganese (Mn), nickel (Ni), copper (Cu) and zinc (Zn) (Table1) increased by mycorrhizal symbiosis. Chen et al. (2020) explained these results by extraradical hyphal network formed in the soil upon AMF colonization. P and Ca are the main mineral elements for plant growth. Increasing the amount of these elements under drought stress leads to an increase in root growth, leaf area, photosynthesis rate, higher membrane stability, and water content (Ahanger et al., 2016). Zn, Mn and Fe are also important micronutrients, which have several vital roles for plants. Babaeian et al. (2011) showed that foliar application of these elements enhanced the yield components and alleviate the effects of drought. Peuke and Rennenberg (2011) also emphasized that Fe, Mn and Zn are important ligands for more than 1500 proteins that have catalytic, (co-)activating and/or structural functions. Ahanger et al. (2016) also well discussed in detail the importance of all these mineral elements in drought tolerance mechanisms. By mycorrhizal symbiosis, the increase in the amount of these elements under drought indicates that this symbiosis will provide an advantage for the *C.arietinum* plants to cope with stress.

Proline concentration increased with drought stress. Proline is known as a good osmolyte, and accumulation of proline under drought stress is well documented in various plant species in the literature. (Chun and Chandrasekaran, 2018; Çevik et al., 2019). Inoculation of *C.arietinum* by AMF decreased proline concentration under drought stress. There are different results related to AMF inoculation and proline accumulation under environmental stress in the literature. Some researchers reported that AMF inoculation increased proline content (Begum et al., 2019; Garg and Baher, 2013) while others reported no significant difference (Sohrabi et al., 2013) or decrease (Abdelmoneim et al., 2014) in different plants under stress conditions. Accumulation of proline in plants under drought known as a basic response to stress (Abdelmoneim et al., 2014). There is a good correlation between the increase of proline content and the intensity of the drought. As the severity of the drought increases, the proline content also increases (Keyvan, 2010). In this study, the decrease in proline content with AMF inoculation may indicate that the severity of the drought was reduced with AMF treatment.

Malondialdehyde (MDA), one of the end products of lipid peroxidation, is a good indicator of the level of oxidative stress (Gawel et al., 2004). The data of the present study showed that lipid peroxidation in chickpea plants significantly increased under drought stress. However, AMF treatment decreased lipid peroxidation compared to the drought group. Some researchers determined that the amount of MDA also increased due to the increase of radicals, especially H_20_2 (Ibrahim and Jaafar, 2012; Hasanuzzaman et al., 2020). As seen in Figure 6, AMF treatment increased the catalase activity. Catalase catalyzes the oxidation of hydrogen peroxide to water and oxygen. Increased activity of catalase with AMF treatment may have caused the scavenging of H_20_2. This situation may have caused a decrease in lipid peroxidation.

Studies have shown that antioxidant enzyme activities increase under various stresses with AMF application (Chang et al., 2018; Duc et al., 2018). However, the decrease in SOD activity may be explained by reducing the intensity of stress with AMF inoculation, but this situation cannot explain the increase in catalase activity. Total enzyme activity analyzes may occasionally lead to such contradictions. Therefore, detailed isoenzyme analyzes can contribute to the solution of this problem. However, in this study, increases in enzyme activities also occurred regardless of the stress conditions. This situation may indicate that different signalling mechanisms are stimulated with the treatment of AMF. Although some studies claimed this may be related to the increase in nutrient intake, more studies should be conducted to clarify this issue.

In conclusion, this study showed that with the inoculation of AMF, the leaf water content and the amounts of some important mineral elements increased, and the proline and MDA content decreased under drought conditions. In addition, while there was a general tendency to increase antioxidant enzyme activities with AMF treatment, the increases in enzyme activities in the control groups also suggested that the antioxidant system could be stimulated in a stress-independent way. Especially the relationships between AMF-proline and AMF-antioxidant system, which have conflicting results in the literature, should be investigated with advanced molecular techniques. In particular, proteomic analysis can provide more data on this subject.

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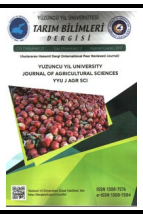

Research Article

The Impacts of Clove Extract Incorporated Gelatine/Glycerol Based Edible Film Covered PET Packaging on the Ready-to-eat 'Wonderful' Pomegranate (*Punica granatum* L.) Arils

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Minimal processing,
Sensory quality.

Abstract: Pomegranate (*Punica granatum* L.) arils are so perishable and have very short storability after extracting from the fruit peel. Therefore, several techniques have been used for the improvement of the arils' storability. Among these techniques, edible films and coatings have a long history in food preservation; where most of the studies have focused on edible coatings. Therefore, present study aimed to test the performance of clove extract incorporated gelatine/glycerine based edible film covered PET packaging on the ready-to-eat 'Wonderful' pomegranate arils. Edible films were prepared in 4 different compositions, including; EF1: only gelatine and glycerine, EF2: gelatine/glycerine with clove extract, EF3: gelatine/glycerine with clove extract and some additives and EF4: gelatine/glycerine with only additives. Un-covered PET packages were then used as a control group. Studies were conducted with 35 boxes (each with 50 arils) in each group, and the boxes were stored at 4 ± 0.5 ºC and 90-95 % relative humidity for 14 days. Quality parameters were observed with 2-days interval. Results suggested that all of the four edible films are effective in preventing weight loss, mechanical damage, loss in sensory quality, reduction of soluble solids content, decline in titratable acidity and loss of ascorbic acid content of the pomegranate arils. The highest efficacy was noted from EF2 and EF3, which were incorporated with clove extract. According to the measured parameters, the edible films together with the PET packaging make it possible to store arils for 10 days with acceptable sensory quality.

Karanfil Ekstraktı Karıştırılan Jelatin/Gliserin Bazlı Yenilebilir Film ile Kapatılan PET Ambalajın Tüketime Hazır 'Wonderful' Nar Taneleri (*Punica granatum* L.) Üzerindeki Etkileri

Makale Bilgileri

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Anahtar Kelimeler
Askorbik asit miktarı,
Mekanik hasar,
Minimum işlem,

Öz: Nar (*Punica granatum* L.) taneleri kolay bozulabilir olduğundan, meyvenin kabuklarından çıkarıldıktan sonra depolanma süresi kısalmaktadır. Dolayısıyla tanelerin depolama süresi ve kalitesinin iyileştirilmesi için çeşitli teknikler kullanılmaktadır. Bu teknikler arasında, gıda muhafazasında uzun bir geçmişi olan yenilebilir filmler ve yenilebilir kaplamalar yer almakta olup, yapılan çalışmalarda daha çok yenilebilir kaplamalarla odaklanılmıştır. Bu nedenle, mevcut çalışma, tüketime hazır 'Wonderful' nar taneleri üzerinde PET ambalajı ile karanfil ekstraktı içeren jelatin/gliserin bazlı yenilebilir film kombinasyonunun performansını test etmeyi amaçlamıştır. Yenilebilir filmler 4 farklı kompozisyonda; EF1: sadece jelatin ve gliserin, EF2: karanfil ekstraktı

Duyusal kabul edilebilirlik.

içeren jelatin/gliserin, EF3: karanfil ekstraktı ve bazı katkı maddeleri içeren jelatin/gliserin ve EF4: sadece katkı maddeleri içeren jelatin/gliserin hazırlanmıştır. Yenilebilir film kaplanmamış ambalajlar ise kontrol grubu olarak kullanılmıştır. Her uygulama grubunda 35 kutu (her birinde 50 adet nar tanesi) ile çalışmalar yapılmış ve kutular 14 gün boyunca 4 ± 0.5 ºC ve % 90-95 bağıl nemde saklanmıştır. Muhafaza süresi boyunca 2 gün aralıklarla kalite parametreleri gözlemlenmiştir. Sonuçlar, dört yenilebilir filmin tamamının nar tanelerinde ağırlık kaybını, mekanik hasar oluşmasını, duyusal kalite kaybını, suda çözünebilir kuru madde miktarı kaybını, titre edilebilir asitlik kaybını ve askorbik asit içeriğindeki azalmayı önlemede etkili olduğunu göstermiştir. En yüksek etkinlik, karanfil ekstraktı ile birleştirilen EF2 ve EF3'te kaydedilmiştir. Ölçülen parametreler doğrultusunda, PET ambalaj ile birlikte kullanılan yenilebilir filmlerin nar tanelerinin kabul edilebilir duyusal kalitesini 10 gün boyunca koruyabildiğini göstermiştir.

1. Introduction

Pomegranate (*Punica granatum* L.) fruits has a long history of cultivation, whereas their production & consumption had increased since the end of 20th Century due to the scientifically confirmed health benefits and high anti-inflammatory potential (Lansky and Newman, 2007; Çelik et al., 2019; Kahramanoğlu, 2019). Besides to that, pomegranate fruits have unique sensory qualities, high antioxidant capacities and diverse & abundant phytochemicals, which increased the consumers' interests on pomegranate fruits (Munhuweyi et al., 2017). The main problems regarding the consumption of the pomegranate fruit, is its time-consuming (hassle) characteristic of aril extraction. Furthermore, fruits with high phytochemicals (Okatan and Colak, 2019) and minimally processed ready-to-eat pomegranate arils have known to address this issue and be very popular in the market (Lopez-Rubira, 2005). However, mechanical damages (tissue wounding and aril squashing) increase the susceptibility of arils to storage conditions (Erkan and Kader, 2011). Mechanical damage induces the respiration rate, alters the metabolic activity, increase the weight loss and deteriorate the sensory quality characteristics (Venkataramudu et al., 2018). Overall, the storability of the pomegranate arils decreases to 3-5 days, even under cold storage conditions. The mechanical damage of the arils has also been reported to exude juice fluids, which is a favourable condition for microbial decay (Rodov et al., 2005).

Sanitizing is among the most important protection method against microbial load in minimally processed ready-to-eat arils, whereas the temperature reduction (cold storage), use of antioxidants and atmospheric gaseous control (i.e. modified atmosphere packaging: MAP) are the other important methods (Sepulveda et al., 2000). In such a research Ayhan and Ertürk (2009) reported that the MAP with gas compositions of 70% O_2 + 10% CO_2 + 20% N_2 prolongs the shelf life of pomegranate arils to 15-18 days. However, Sutherland et al. (2010) reported that, total production of plastic resins had an increase of 25-fold since 1970s, where only 5% of all were recycled. This is an important problem for the natural ecosystems because of its accumulation in the environment. The increase in the consumer awareness on chemical residues and environmental hazards had increased the demand for natural and sustainable materials in food packaging (Mahalik and Nambiar, 2010). Moreover, edible coatings and films may enhance or even replace some of those packaging techniques by providing a barrier against atmospheric gaseous and moisture (Kasapoğlu and Törnük, 2018; Kahramanoğlu et al., 2020). Therefore, testing of edible films alone or in combination with plastic packaging would help to reduce the use of plastics in case of successful results. The edible coatings (EC) are thin layers of biodegradable coating materials, and edible films (EF) are thin layers of the same biodegradable materials. The main difference between these materials is that, EC is applied in liquid form by immersing the fruits in, while EF is produced from the biodegradable materials as solid sheets, and applied as films by covering/packing/wrapping the fruits (McHugh, 2000). These biodegradable edible films are generally made from biopolymers, including lipids (Hassan et al., 2018), protein (Tkaczewska, 2020) and on polysaccharides such as cellulose, chitosan, starch and pectin (Niu et al., 2021). Among proteins, a denaturized animal protein collagen, the gelatine, is also known to have excellent film-forming properties (Limpisophon et al., 2010). Its optical properties are good and have high mechanical strength (Podshivalov et al., 2017). Incorporation of glycerol into gelatine was also noted to improve its potential

advantages (Niu et al., 2021). Moreover, it was also previously noted that the incorporation of *Nigella sativa* oil into a starch-based edible coating improves the storage quality of pomegranate arils (Oz and Ulukanli, 2012). Plant essential oils (i.e. lavender oil) alone or incorporation with some other materials (i.e. methyl jasomate) were also suggested to improve storability of fruits (Çavuşoğlu et al., 2020).

Although, there have been numerous studies with edible films and coatings on food preservation, there are limited studies with pomegranate arils, where most of them are with edible coatings. In such study, Ozdemir and Gokmen (2017) noted that the edible coating with a mixture of chitosan and ascorbic acid, improves the shelf life of pomegranate arils. It is also well-known that the chemical composition of the coating or film materials have important influence on the antifungal and preservative characteristics of the materials (Kahramanoğlu et al., 2020). Clove (*Eugenia carophyllata*) is a rich source of phenolics, mostly eugenol and gallic acid, and is being used for centuries as food preservative (Cortés-Rojas et al., 2014). The aqueous extracts of clove has been reported to have very high antioxidant and antifungal activity (Gülçin et al., 2004; Chatterjee and Bhattacharjee, 2013). In line with this information, present study aimed to test the performance of aqueous clove extract incorporated gelatine/glycerine based edible film covered PET (Polyethylene Terephthalate) packaging on the ready-to-eat 'Wonderful' pomegranate arils.

2. Materials and Methods

2.1. Study materials

Fruit samples of current study were collected from a 12-year-old pomegranate orchard, found in the Yayla village of Northern Cyprus. The orchard is composed of 'Wonderful' cultivar pomegranate trees, designed with a 5 x 5 m distance. The fruits were hand harvested on 2nd of November 2020 and immediately (in 30 minutes) brought to the laboratory of Research and Implementation Farm of European University of Lefke. The soluble solids content (SSC) of the harvested fruits was noted as 18.12% with a titratable acidity (TA) of 1.75%. The other materials of the study are clove, gelatine and glycerol. These materials were purchased from a local shop. Glycerine with a 95% of glycerol was used in the current studies.

2.2. Pomegranate aril processing

To extract the arils, the outer peel of the fruits was cut by using a sharp knife and removed by hand pressing. Care was taken to prevent damage on the arils. The arils were then manually extracted and put in large sterilized boxes. To avoid any possible contamination, polyethylene hand gloves were used during all processes.

2.3. Edible film preparation and packaging

Edible films of present study were prepared according to the methods described in Table 1. Totally 4 different edible films and an un-covered control group were tested in present studies. Studies were conducted with completely randomized design. The arils, which were extracted according to the above-described methods, were divided into 5 groups (belonging to the treatments) each containing 1750 arils. Each group was composed of 35 boxes (each with 50 arils). Therefore, 5 boxes (replications) for each treatment were used in each analysis period (totally 7). These boxes are made up from polyethylene terephthalate (PET) plastic materials and are circle in shape with a radius of 5 cm and a height of 5 cm. 50 arils were put in each of these boxes carefully and they were (except the control) covered with the edible films. The film materials were dressed up from the top to the sides of the boxes and tied with a rubber. Then, the boxes were all put in a chamber adjusted to a temperature of 4 ± 0.5 ºC and 90-95% relative humidity and stored for 14 days.

Table 1. Preparation of edible films

Short name	Long name	Description of preparation
EF1	Edible film	12.5 ml gelatine and 3 ml glycerine were dissolved in 500 ml of distilled water, until 80 °C and stirred for 10 min until completely gelatinized. Hereafter, the solution was casted (in the thinnest possible thickness) onto a plate (15 x 15 cm), and dried at 40 °C for 36 h in an incubator (slightly modified from Niu et al. (2021)).
EF2	Edible film + clove	First of all, 5 g of clove was mixed with 500 ml of water and the mixture was heated until 100 °C and kept for 30 min at that temperature. It was then filtered and cooled down to 80 °C. Afterwards, 12.5 ml gelatine and 3 ml glycerine were added and the same procedure was followed with EF1.
EF3	Edible film + clove + additives	5 g of clove was mixed with 500 ml of water and the mixture was heated until 100 °C and kept for 30 min at that temperature. It was then filtered and 2 g of Arabic gum was added and stirred for 10 more minutes at same temperature. The solution was then cooled down to 80 °C. Hereafter, together with 12.5 ml gelatine and 3 ml glycerine; 0.5 g citric acid and 0.5 g vitamin C were also mixed into the solution. It was stirred for 10 min until completely gelatinized. Hereafter, the solution was casted onto a plate (15 * 15 cm), and dried at 40 °C for 36 h in an incubator
EF4	Edible film + additives	This material was prepared by following a similar method of EF3, by not incorporating clove into the solution.

2.4. Quality analysis

A total of 5 boxes were used for analysis at each measurement point (day 2, 4, 6, 8, 10, 12 and 14). The total weight of 50 arils per boxes were determined with a digital balance (sensitive to 0.01 g). Thus, at each measurement point, the final weights were determined by following the same way and the weight loss was calculated according to the standard ratio method. Firstly, final weight was subtracted from the initial weight to find the weight lost. Then the weight lost was divided to the starting weight and multiplied by 100 ([weight lost/initial] x 100). Hereafter, arils with mechanical damage (chilling, bruising, browning and juice leakage) (Aliasgarian et al., 2013) were counted for each box and used to calculate the percentage of damage. Same standard ratio method was followed by dividing the number of damaged arils to the total arils and multiplying with 100. The 9-point hedonic scale of Xing et al. (2011) was then used to assess the sensory acceptability of the pomegranate arils. The texture, colour and flavour were assessed for sensory quality. The scale meanings from 1 to 9 were recommended as 1: poor, 3: fair, 5: good, 7: very good and 9: excellent.

Soluble solids concentration (SSC), titratable acidity (TA) and ascorbic acid (AsA) were all assessed one for each replication (box: a mixture of 50 arils). The juice mixture of 50 arils were used to do measurements. SSC (%) was assessed with a hand refractomer. TA was measured according to the standard titration method. Juice samples were dissolved in distilled water in a ratio of 10:50 and then titrated with 0.1 N NaOH to an endpoint of pH 8.1. Then, below given formula was used to determine the TA as g 100 g^{-1} of citric acid:

$$\text{TA (\%)} = \left(\frac{(\text{mL of NaOH used}) \text{ x } 0.0064}{\text{mL of sample used}}\right) \text{x} 100 \quad (1)$$

Finally, the AsA content of each replication was assessed through standard titration with 2,6-dichlorophenol indophenol. Five millilitres of juice was made up to 100 mL using 3% metaphosphoric acid (HPO_3). The sample was filtered with whatman No. 1 filter paper. 10 mL of solution was then taken into a conical flask and titrated with dye till pink colour appeared. The titrations were recorded and the unit of AsA expressed in mg 100 g^{-1} (Ranganna, 1999).

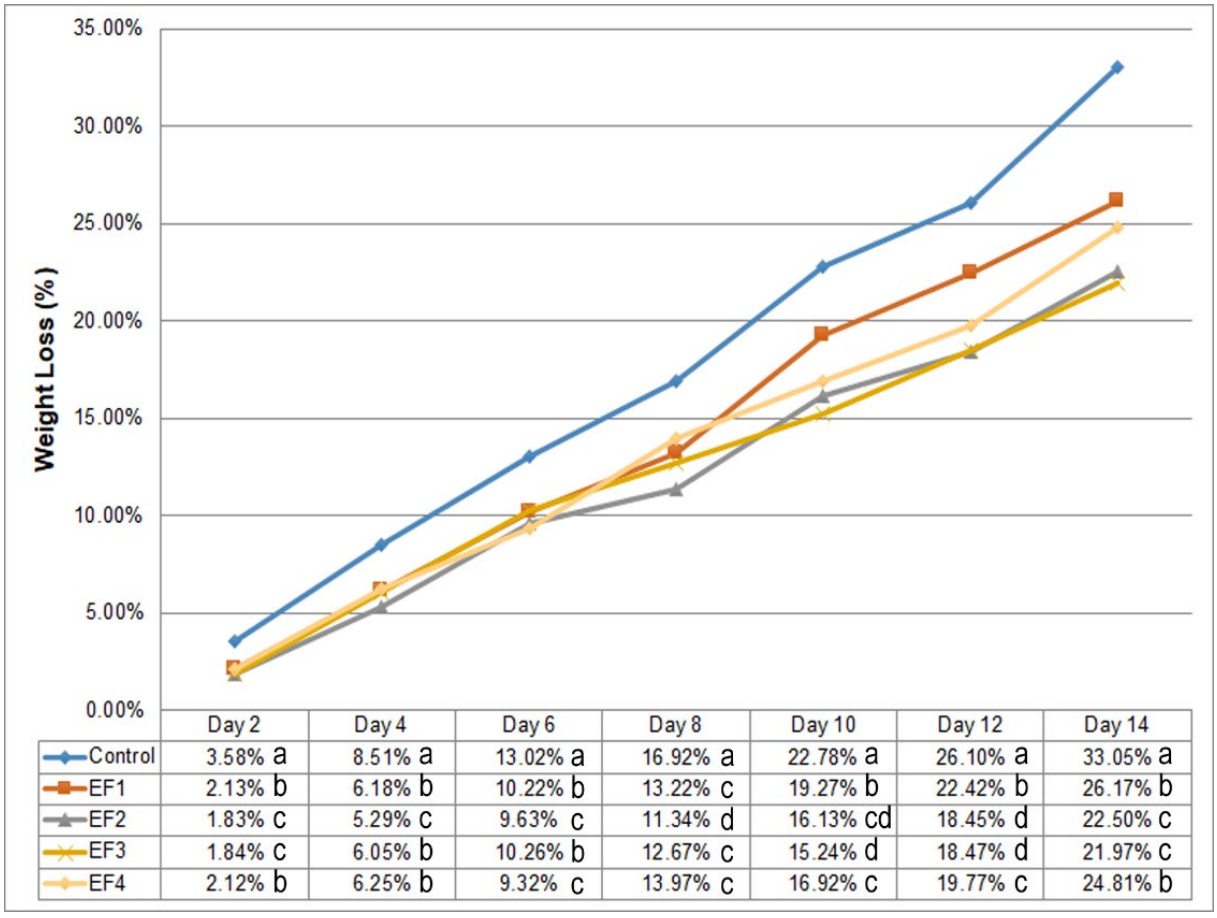
2.5. Data analysis

Raw data of the experiments were hand written into Microsoft Excel and summarized by calculating the means and standard deviations of each treatment at each storage duration. Then line graphics were used to clearly present the data. Since the completely randomized design was used in the present study, the comparison of the treatments for different storage time was assessed with one-way analysis of variance (ANOVA) by using SPSS 22.0 and in the case of statistical difference, the mean separations were done with Tukey's HSD test at $P < 0.05$ statistical significance.

3. Results

3.1. Effects on physical quality parameters

All kinds of edible films (as a covering material of PET packaging) had been found to have a slight to moderate effect on the weight of ready-to-eat pomegranate arils (Figure 1). As expected, the weight loss increased during the storage, however was found to be higher at the un-covered control arils. At the first measurement point (2 days of storage), the weight loss was 3.58% at the un-covered fruits and was 1.83% and 1.84% at the EF2 and EF3.



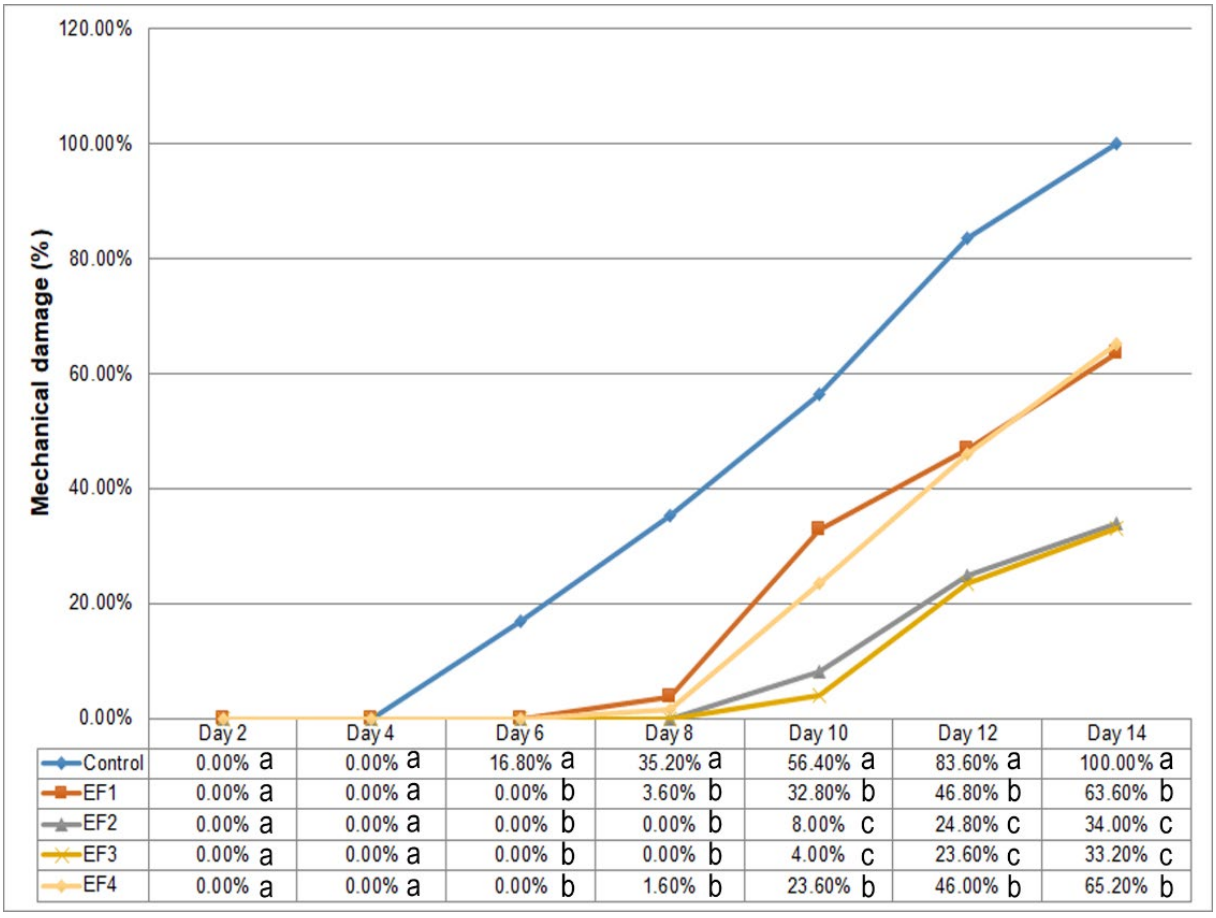
	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
Control	3.58% a	8.51% a	13.02% a	16.92% a	22.78% a	26.10% a	33.05% a
EF1	2.13% b	6.18% b	10.22% b	13.22% c	19.27% b	22.42% b	26.17% b
EF2	1.83% c	5.29% c	9.63% c	11.34% d	16.13% cd	18.45% d	22.50% c
EF3	1.84% c	6.05% b	10.26% b	12.67% c	15.24% d	18.47% d	21.97% c
EF4	2.12% b	6.25% b	9.32% c	13.97% c	16.92% c	19.77% c	24.81% b

Figure 1. Change in weight loss (%) of ready-to-eat pomegranate arils as response to clove extract incorporated gelatine/glycerol based edible film packaging. Different letters next to the means below the lines of each storage point, represents significant differences among the treatments for each measurement point according to Tukey's HSD test at $P < 0.05$.

Similar trend had been found to continue till the end of the storage period. At day 4, the weight loss of the un-covered arils found to be more than the twice of the day 2. All of the edible films, had significant influence on the prevention of the loss in the aril weight. At the end of storage duration (14 day) the highest weight loss was measured from the un-covered arils as 33.05%. The highest efficacy in

prevention of the weight was noted from the EF 3, which includes both clove and additives. No significant difference was observed between this treatment and EF2, which only include clove but not additives, at the end of the storage.

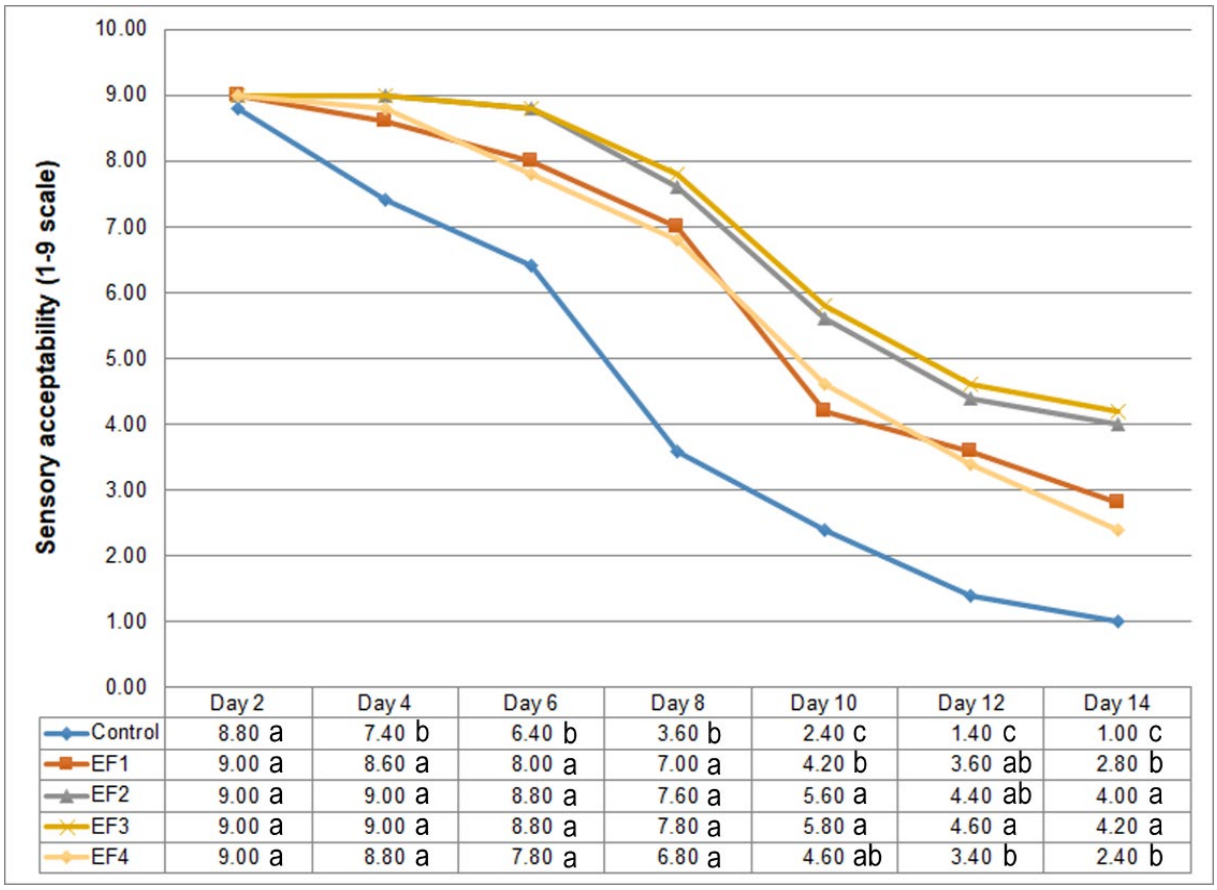
The first mechanical damage had been observed after 4 days of storage on the un-covered control arils (Figure 2). However, all of the four edible films had been observed to prevent mechanical damage until 6 days of storage. The EF2 and EF3 were also noted to prevent mechanical damage for 8 days of storage. After that day (day 8), the mechanical damage of the EF1 and EF4 increased, while the EF2 and EF3 were noted to be more effective. These results are in accordance with the weight loss results. At day 8, the mechanical damage was close to 40% in control arils which means a substantial reduction in the acceptability of the arils. At the end of the storage duration (day 14), the un-covered control fruits had 100 % mechanical damage, while at the same day, mechanical damage was only 33.20% and 34.00%, respectively, for EF3 and EF2.



	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
Control	0.00% a	0.00% a	16.80% a	35.20% a	56.40% a	83.60% a	100.00% a
EF1	0.00% a	0.00% a	0.00% b	3.60% b	32.80% b	46.80% b	63.60% b
EF2	0.00% a	0.00% a	0.00% b	0.00% b	8.00% c	24.80% c	34.00% c
EF3	0.00% a	0.00% a	0.00% b	0.00% b	4.00% c	23.60% c	33.20% c
EF4	0.00% a	0.00% a	0.00% b	1.60% b	23.60% b	46.00% b	65.20% b

Figure 2. Change in mechanical damage (%) of ready-to-eat pomegranate arils as response to clove extract incorporated gelatine/glycerol based edible film packaging. Different letters next to the means below the lines of each storage point, represents significant differences among the treatments for each measurement point according to Tukey's HSD test at $P < 0.05$.

Sensory quality is very important for the ready-to-eat pomegranate arils. The reduction in the sensory quality reduces the marketability of the products. The results of present study showed that the sensory quality decreased during storage, but decreased slowly at the packed arils as compared with the un-covered arils (Figure 3). At day 6, average sensory acceptability of the un-covered arils decreased to 6.40 and at day 8, it reduced to 3.60 (fair). According to the results obtained, the overall sensory acceptability of the arils packed with EF2 and EF3 were over 5.00 (good) still at the day 10. These results are very important for the effectiveness of the edible film packaging. According to the sensory acceptability results, it can be accepted that the EF2 and EF3 can prolong the storability of the arils for 10 days.



	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
Control	8.80 a	7.40 b	6.40 b	3.60 b	2.40 c	1.40 c	1.00 c
EF1	9.00 a	8.60 a	8.00 a	7.00 a	4.20 b	3.60 ab	2.80 b
EF2	9.00 a	9.00 a	8.80 a	7.60 a	5.60 a	4.40 ab	4.00 a
EF3	9.00 a	9.00 a	8.80 a	7.80 a	5.80 a	4.60 a	4.20 a
EF4	9.00 a	8.80 a	7.80 a	6.80 a	4.60 ab	3.40 b	2.40 b

Figure 3. Change in sensory acceptability (1-9 scale) of ready-to-eat pomegranate arils as response to clove extract incorporated gelatine/glycerol based edible film packaging. Different letters next to the means below the lines of each storage point, represents significant differences among the treatments for each measurement point according to Tukey's HSD test at $P < 0.05$.

3.2. Effects on bio-chemical quality parameters

Both the SSC and TA are very important for the fruit flavour. As a general knowledge, both of them change during storage and significantly affect the consumers' acceptability. In this experiment, the arils SSC had been noted to have a continuous increase during storage, while the TA had a reverse trend (Table 2).

The SSC of the arils was measured as 18.12% at the first day of harvest. In 14 days of storage, it was increased to 25.32% at the un-covered control arils. This is mainly a result of the high weight loss and reduce the acceptability of the arils. Since the fruit SSC was measured as percentage, the decrease in water content caused an increase in the SSC (as %). This is because, most of the weight loss in pomegranate arils was occurred as a loss of water due to transpiration. There is also a loss of carbohydrates and soluble sugars due to respiration. The SSC was also increased in other applications, which were packed in edible films, but the increase was less due to the less loss of water. At the end of the storage period, the lowest SSC (so the lowest change) was noted from the EF3 with 22.64% and followed by EF2 with 23.00%. On the other hand, the TA of the arils began from 1.75% (day 0) and decreased to 0.79% at the un-covered arils at the end of storage period. The edible films were again found to slow down the loss of TA during storage. The highest influence was noted from the EF2 and EF3 and the arils in these treatments were noted to have highest TA content at the end of the storage period. The reduction in TA caused an increase in the SSC/TA ratio, which cause an un-pleasant sweetness in the arils. At the day 0, the SSC/TA was only 10.35, but was increased to 32.05 at the un-covered arils in 14 days of cold storage. At the same time, the SSC/TA ratio of the arils packed in EF3 was only 15.94. Finally, the AsA content was found to have an increase during the first days of storage and then decreased with the development of the aril deterioration. The initial AsA content was 59.46 mg

100 g-1 and decreased to 31.89 mg 100 g-1 at the un-covered control arils. Similar with the other results, the edible films were found to have significant influence on the prevention of the loss of AsA. Thus, the AsA of the arils packed in edible films varied from 43.78 to 46.49 mg 100 g^{-1}.

Table 2. Change in SSC (%), TA (%) and AsA (mg 100 g^{-1}) of ready-to-eat pomegranate arils as response to clove extract incorporated gelatine/glycerol based edible film packaging

Treatments	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
SSC								
Control	18.12 a	18.72 a	20.56 a	21.32 a	22.44 a	23.32 a	24.28 a	25.32 a
EF1	18.12 a	18.44 ab	19.12 b	20.04 bc	21.24 bc	22.20 b	23.28 b	24.16 b
EF2	18.12 a	18.32 b	18.60 b	19.32 cd	20.24 cd	21.16 c	22.24 c	23.00 c
EF3	18.12 a	18.40 ab	18.56 b	19.08 d	19.84 d	20.76 c	21.80 c	22.64 c
EF4	18.12 a	18.36 ab	19.20 b	20.08 b	21.40 ab	22.28 b	23.36 b	24.24 b
TA								
Control	1.75 a	1.67 a	1.59 b	1.42 c	1.25 c	1.13 d	0.91 d	0.79 d
EF1	1.75 a	1.72 a	1.67 a	1.56 b	1.44 b	1.37 c	1.34 c	1.23 c
EF2	1.75 a	1.72 a	1.70 a	1.64 a	1.54 a	1.45 b	1.43 b	1.33 b
EF3	1.75 a	1.72 a	1.70 a	1.64 a	1.55 a	1.51 a	1.48 a	1.42 a
EF4	1.75 a	1.72 a	1.65 a	1.55 b	1.43 b	1.36 c	1.33 c	1.24 c
SSC/TA								
Control	10.35 a	11.21 a	12.93 a	15.01 a	17.95 a	20.64 a	26.68 a	32.05 a
EF1	10.35 a	10.72 a	11.45 b	12.85 b	14.75 b	16.20 b	17.37 b	19.64 b
EF2	10.35 a	10.65 a	10.94 b	11.78 b	13.14 b	14.59 c	15.55 c	17.29 c
EF3	10.35 a	10.70 a	10.92 b	11.63 b	12.80 b	13.75 c	14.73 c	15.94 c
EF4	10.35 a	10.67 a	11.64 b	12.95 b	14.97 b	16.38 b	17.56 b	19.55 b
AsA								
Control	59.46 a	60.54 b	62.16 b	56.22 b	47.03 b	43.24 c	36.22 c	31.89 b
EF1	59.46 a	65.95 a	64.86 ab	62.16 a	56.76 a	53.51 ab	49.73 a	44.86 a
EF2	59.46 a	68.11 a	65.95 a	63.24 a	56.76 a	52.97 ab	49.19 ab	45.41 a
EF3	59.46 a	68.11 a	66.49 a	62.70 a	58.92 a	54.59 a	49.19 ab	46.49 a
EF4	59.46 a	69.19 a	68.11 a	60.54 ab	54.59 a	49.73 b	45.95 b	43.78 a

Different letters next to the means below the lines of each storage point, represents significant differences among the treatments for each measurement point according to Tukey's HSD test at $P < 0.05$.

4. Discussion and Conclusion

Several researches have reported that the packaging films can affect the headspace gas composition in packed pomegranate arils (Adiletta et al., 2019). However, this change was noted to be slow, due to the low respiration rate of pomegranate arils at low temperatures (Caleb et al., 2013). Therefore, it was expected that the edible films would have also similar effect, which then reduce the respiration rate and delay the quality degradation in the pomegranate arils. Edible films of present study were also found to have a significant influence on the prevention of weight loss. The highest influence was noted from the ones which were incorporated with the clove extract. In a similar study, Hasheminejad and Khodaiyan (2020) suggested that the clove essential oil loaded chitosan nanoparticles as edible coating (but not film) improve the arils storage quality and also reduce the weight loss. The results of these authors support the findings of the present study. The protection of the weight loss in edible films is mainly associated with the formation of a barrier against gas and water vapor (Brasil et al., 2012).

Edible films in present study were also found to have positive influence on the prevention of mechanical damage and sensory acceptability. Similar results for clove essential oil incorporated edible coatings were noted by Hasheminejad and Khodaiyan (2020) for pomegranate arils. The cinnamon oil, for example, was also noted to improve the sensory quality of fresh-cut papaya before (Brasil et al., 2012). In this study, the SSC content of the arils had been found to increase during storage. Generally, the SSC values decrease due to the sugar degradation during storage (Fawole and Opara, 2013), but Kahramanoğlu et al. (2018) recommended that if there is high reduction in the weight loss, this may cause an increase the SSC values, as it is the percentage of soluble contents to the total volume.

The TA values had been reported to decrease during storage at the pomegranate arils as a result of the consumption of organic acids during respiration (Fawole and Opara, 2013). According to the results of present study, clove extract incorporated gelatine/glycerol based edible films delayed the change in SSC/TA and improved the consumer acceptability of the arils (Song et al., 2016). Similarly, clove essential oil in edible coatings reported to delay the changes in SSC/TA by Hasheminejad and Khodaiyan (2020). Present study also suggested that the edible films delay the decrease in AsA. Similar results were previously noted for chitosan, where the chitosan edible coatings delayed the reduction in the AsA (Munhuweyi et al., 2017).

Overall results of current research suggested that the clove extract incorporated gelatine/glycerol based edible film packaging improves the storage quality of ready-to-eat 'Wonderful' pomegranate arils. According to the measured parameters, the PET packaging covered with edible films make it possible to store arils for 10 days with acceptable sensory quality. Although the sensory acceptability results of current study include microbial observation, a laboratory analysis for microbial decay is also important to test in the future studies. Comparison and discussion of the results also made it possible to come up with an idea that, covering the arils within edible films, like a sweet candy may provide better results and may help to reduce the plastic use, but needs a scientific confirmation.

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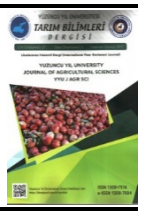

Research Article

Optimization of Meristem Culture to Obtain Virus-Free Clonal Basic Material of Grape Cultivars

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Abstract: The main purpose of this study was to obtain a clone free from viruses and virus-like diseases to rapidly reproduce these clones. Meristems were extracted and cultured for the production of the base material for the Kalecik Karası number 4 and 23-2 clones. After the explants formed shoots, the effects of 12 dissimilar auxin (IBA) and cytokine (2İP and BAP) concentrations on the growth of the root and plant were investigated. In the meristem stage clones showed a 60 % and 80 % viability rate. In the rooting stage, it was determined that shoot formation and leaf numbers were higher in the Kalecik Karası clone number 23-2 and the 1.0 mg. L^{-1} IBA+0.5 mg. L^{-1} BAP / 2 IP concentration showed the highest shoot formation and leaf number value. The highest callus levels were determined as 0.43 cm for clone number 4 and 0.72 cm for clone number 23-2. M S (Murashige & Skoog) with 2mg. L^{-1} IBA showed the highest rooting value. The longest root values were 3.47 cm with 1mg. L^{-1} IBA for clone number 4, and 3.90 cm with 0.5mg L^{-1} IBA for clone number 23-2.

Virüsten Ari Klonal Üzüm Çeşitlerine Ait Baz Materyal Eldesinde Mersitem Kültürünün Optimizasyonu

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Anahtar Kelimeler
Baz Materyal,
Meristem kültürü,
Mikroçoğaltım,
Vitis vinifera, L.,
Optimizasyon.

Öz: Bu çalışmanın temel amacı, ülkemiz ve dünya bağcılığı için en önemli etmenlerden biri olan klon kökenli sertifikalı asma fidanı üretimi için, klona dayalı kalem damızlıkların kurulabilmesinde kullanılacak, virüs ve virüs benzeri hastalıklardan ari klonal çoğaltma materyali eldesi ve bunların hızlı bir şekilde çoğaltılmasıdır. Kalecik Karası 4 ve 23-2 kodlu klonlarına ait baz materyal üretimi için meristemlerin çıkartılması, kültüre alınması ve sürgün aşamasında sabit olan ortam konsantrasyonlarının ardından köklenme aşamasında 12 değişik oksin (IBA) ve sitokinin (2 iP ve BAP) konsantrasyonunun, kök gelişimine ve bitkiye dönüşümüne etkileri incelenmiştir. Meristem aşamasında, Kalecik Karası 4 kodlu klonunda % 60, 23-2 kodlu klonunda ise % 80'lik bir yaşama oranı tespit edilmiştir. Meristem ve sürgün aşamasında kallus oluşmamıştır. Sürgün aşamasında 2.0 mg/L BAP+0.5mg/L IBA konsantrasyonu ile ortalama sürgün sayısı bakımından sırasıyla 3.67 ve 3.83 adet; ortalama sürgün uzunluğu bakımından ise 2.42 cm ve 2.04 cm uzunluk belirlenmiştir. Köklendirme aşamasında ise Kalecik Karası 23-2'de sürgün oluşumu ve yaprak sayısının daha fazla olduğu gözlemlenmiştir. 1.0 mg/L IBA+0.5 mg/L BAP/2 İP konsantrasyonunda ise en yüksek sürgün oluşumu ve yaprak sayısı değeri tespit edilmiştir. Söz konusu aşamada kallus oluşumu oksin

ve stokinin düzeylerinin artmasına paralellik göstermiştir. Kallus düzeyleri Kalecik Karası 4 kodlu klon için 0.43 cm ve 23-2 kodlu klon için 0.72 cm olarak tespit edilmiştir. En yüksek köklenme değerini 2 mg/L IBA eklenmiş olan yetiştirme ortamı vermiştir. En uzun kök değerleri ise 4 kodlu klon için 1 mg/L IBA ile 3.47 cm, 23-2 kodlu klon için 0.5 mg/L IBA ile 3.90 cm olarak gerçekleşmiştir.

1. Introduction

As in many vegetative propagating plants, significant problems arise in grapevines that are exposed to virus and virus-like diseases all over the world. This has encouraged extensive researches on an international scale for many years, providing for the continuation of such researches.

International Council for the Study of Viruses and Virus-like Diseases of the Grapevine (ICVG) recognizes that more than 75 infectious organisms (viruses, viroids and phytoplasms) recorded in grapevine may have a negative impact on plant viability and longevity, quality and amount of yield and may be very harmful for the yield. Infected propagation material is largely responsible for the spread of diseases between countries and in vineyards. Therefore, all opportunities should be mobilized to improve health conditions (Martelli, 2014).

The only way to obtain a regular, stable and healthy product in vineyards is to provide material for propagation only from clean breeding plants by removing material that has been tested for viruses and virus-like diseases and which carries the disease agent. Base material production and certification is a powerful and effective strategy to control these infectious factors and promote the quality, profitability and sustainability of the production.

Base material production, free from diseases and pests, tested and proved to be clean and provided by clonal selection, is important for world viticulture.

The propagation of grapevines with traditional methods is a slow-working system for new varieties or elite types, and *in vitro* techniques, which are complementary to traditional methods, are widely used in genetic progress programs, in obtaining and propagating healthy varieties. Thus, it provides great convenience to the plant breeders with the shortening of the time in grapevine breeding (Lavee, 2000, Mhatre et al., 2000, Torrerosa et al., 2001, Thomas and Schiefelbein, 2004).

In order to obtain virus-free certified seedlings from clones 4 and 23-2 of Kalecik Karası, which is the ‘base material’ to be used in the establishment of clone-based pen breeding parcels, which is absolutely necessary for the production of certified grapevine seedlings of clone origin that is very important for the future of viticulture, the main purpose of this study is to use *in vitro* meristem culture technique and to optimize the method in a practical and economical way.

For this purpose, it was tried to determine the most suitable combinations for rooting with various applications made at the rooting stage of the shoots obtained *in vitro* conditions after the meristem stage.

2. Material and Method

2.1. Material

As the plant material, the stocks infected with ArMV and GLRaV-3, among the clones 4 and 23-2 of Kalecik Karası grapevine variety found in the 'Clone Collection Vineyard' of the Department of Horticulture, Faculty of Agriculture, and Ankara University, were used.

2.2. Acquisition of plant material and shoot tip disinfection

Grapevine cuttings were taken from the collection vineyard during pruning and disinfected until planting medium was prepared, and stored in cold storage at 90-95% relative humidity at +4 °C in polyethylene bags. Meristems were taken from the shoot tips of cuttings planted in pots no. 7, which contain a mixture of cocopeat, perlite and peat in the greenhouse at the volumetric ratio of 1:1:1 into stratification containers and tubes in growing chamber. Shoot tip disinfection was carried out in a 20% sodium hypochlorite solution for 15 minutes and then washed 3 times with distilled water for 5 minutes.

2.3. Meristem stage tissue culture applications

Tissue culture applications were performed under aseptic conditions, and for this purpose, sterilization was performed by keeping the nutrient media in autoclave under 1.2 atmospheric pressure for 20 minutes at 121 °C. MS (Murashige and Skoog, 1962) basic place composition was used as the nutrient media. 3 % sucrose and 0.7 % agar were added to the MS medium and applications were made by adjusting the pH to 5.7.

With the removal of 0.2-0.4 mm shoot tip meristems in the sterile cabinet, disinfected shoot tips were planted in full-strength M S initial place (pH 5.7) containing 0.5 mg. L^{-1} GA_3, 2.5 mg. L^{-1} BAP with 4 explants in each petri and cultured in the climate room for approximately 4-5 weeks (Figure 1).

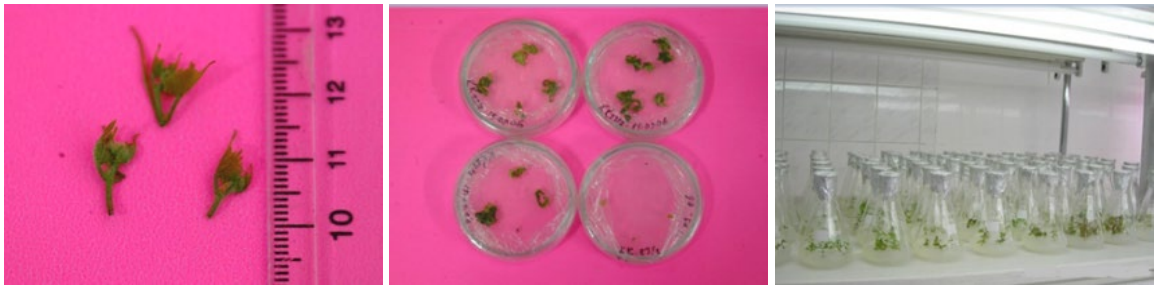

Figure 1. Views from meristem culture and shoot stages.

2.4. Shoot propagation and rooting stage

Developed in *in vitro* conditions approximately 4-5 weeks after the meristem stage, the meristems were transferred to a full-strength M S place containing '2 mg. L^{-1} BAP, 0.5 mg L^{-1} IBA' in the sterile cabinet, developed for 4 weeks (Figure 1).

The meristems developed in the shoot medium were transferred to the full-strength MS medium (pH 5.7), which was modified with the different combinations of auxin and cytokine specified in Table 1, for the rooting stage.

Table 1. Combinations of auxin and cytokine used in the medium

No	Combination	No	Combination
1	0.5 mg. L^{-1} IBA+0.0 mg. L^{-1} BAP	7	0.5 mg. L^{-1} IBA+0.0 mg. L^{-1} İP
2	0.5 mg. L^{-1} IBA+0.5 mg. L^{-1} BAP	8	0.5 mg. L^{-1} IBA+0.5 mg. L^{-1} İP
3	1.0 mg. L^{-1} IBA+0.0 mg. L^{-1} BAP	9	1.0 mg. L^{-1} IBA+0.0 mg. L^{-1} İP
4	0 mg. L^{-1} IBA+0.5 mg. L^{-1} BAP	10	1.0 mg. L^{-1} IBA+0.5 mg. L^{-1} İP
5	0 mg. L^{-1} IBA+0.0 mg. L^{-1} BAP	11	2.0 mg. L^{-1} IBA+0.5 mg. L^{-1} İP
6	0 mg. L^{-1} IBA+0.5 mg. L^{-1} BAP	12	2.0 mg. L^{-1} IBA+0.5 mg. L^{-1} İP

2.5. Culture conditions and acclimatization

Petri dishes in the initial stage, flasks in the shoot stage and cultures in the tubes at the rooting stage were grown in a climate room with a temperature of 25±1 °C, a day length of 16 hours and a light intensity of 3200-3500 lux.

The plants in the flasks were removed without any damage to the roots with the help of a forceps, washed in three separate containers filled with distilled water until there was no artificial nutrient medium in the roots, then the root part was immersed in 0.1 % benomyl-added solution and placed on blotting paper. After root pruning was done, it was transferred to the growing chamber by suturing in plastic containers with sterilized peat+perlite medium. Regularly closed containers were gradually opened and the plants were gradually acclimatized to external conditions. Plants left in plastic container were transferred to pots in the fourth week (Figure 2).

Figure 2. View from rooting stage and acclimatization stage.

2.6. Evaluation of the results

The evaluation stage took place in three stages as given in Table 2.

Table 2. Evaluation stages of the results

Initial Stage	Shoot Stage	Rooting Stage
Macro and micro elements and vitamins of MS, pH: 5.8 GA_3: 0.5 mg. L^{-1} BAP: 2.5 mg. L^{-1}	Macro and micro elements and vitamins of MS, pH:5.8 BAP: 2.0 mg. L^{-1} IBA:1 mg / l	Macro and micro elements and vitamins of MS, pH :5.7 Different hormone applications
Survival rate of meristems (%)	Shooting rate (%)	Shooting rate (%)
Development level of meristems (cm) (Width+Height/2)	Number of Shoots/Explant (n)	Number of shoots (n)
Callus formation rate and level of meristems	Shoot length (cm)	Shoot length (cm)
Vitrification	Callus creation rate (%) and level (cm)	Callus creation rate (%) and level (cm) Rooting (Transformation into complete plant) rate (%) Number of roots (n) and length

2.7. Evaluation of Data

SPSS (Version 19.0) software program was used to evaluate the data obtained from the experiments (SPSS, 2011). Duncan's multiple comparison test was used to differentiate the means of the treatments.

3. Results and Discussion

One of the most important stages is the rooting of *in vitro* shoots obtained for the production of base material at a high rate and transferring them to external conditions. Therefore, in our study that we carried out to determine the most suitable growth regulator combination for rooting *in vitro* shoots, rooting was achieved in both clones and a complete plant was obtained. In terms of the features mentioned, the study was established and evaluated according to the 'Random Parcel Trial Pattern' and in a Factorial pattern. In statistical analysis, there are two levels in the genotype factor, including Kalecik Karası clones 4 and 23-2, and 12 levels in the application factor (Table 1). As a result of the calculations regarding the variance analysis technique, the 'genotype X application' interaction was found to be statistically significant in point of average number of shoots, shoot length, callus value, longest root, root length, average number of roots ($P<0.01$). Duncan test was performed for multiple comparisons. In the calculations made in terms of average number of leaves, 'genotype x application' interaction was not statistically significant. Only the difference between the averages of Kalecik Karası clones 4 and 23-2 was statistically significant ($P<0.01$).

3.1. Initial Stage

Findings related to the survival rate (%), development levels (cm), callus formation rate (%) and levels (mm) of the grapevine shoot tip meristems cultured in MS with '0.5 mg. L^{-1} GA_3, 2.5 mg. L^{-1} BAP' as the initial stage and vitrification are given in Table 3-5, respectively.

3.2. Survival rate of meristems (%)

Z test was used to compare survival rates of shoot tip meristems of the grapevine genotypes studied. There was no statistically significant difference between Kalecik Karası clones 4 and 23-2 in terms of survival rates of the meristems cultured (Table 3).

Table 3. Survival rates of two different Kalecik Karası (K.K.) clones (c.) (%)

Genotype	Survival rates (%)
K.K. c. 4	65
K.K. c. 23 / 2	80

The fact that this difference is not statistically significant shows that our findings are compatible with the previous research results.

There was no callus formation and vitrification in Kalecik Karası clones 4 and 23-2.

3.3. Development levels of meristems (cm)

Variance analysis technique was used to compare genotypes in terms of width, height and development levels of meristems. As a result of the calculations, the width and height measurements and the development levels obtained from them are shown in Table 4. There was no statistical difference between the values obtained after measuring the width and height and their average, that is, in terms of development levels between Kalecik Karası clones (Table 4).

Table 4. Development levels of meristems and shoots of two different Kalecik Karası (K.K.) clones (c.)

Genotype	Width (cm)	Height (cm)	Development Levels (Width+Height/2)
K.K. c. 4	0.25±0.09	0.69±0.30	0.22±0.01
K.K. c. 23 / 2	0.22±0.08	0.71±0.25	0.25±0.01

On the other hand, Roubelakis-Angelakis (1990), Dalloul et al. (1990) reported that *in vitro* growth and development of meristems varied depending on the genotype, and that the development levels of the shoot tip meristems in the initial medium differed statistically. It is possible to say that the two genotypes used in our study did not exhibit different growth strengths *in vitro* conditions because they came from the same origins in terms of many features and they were different clones of the same variety. It is normal to expect that if such a study is repeated with different grapevine genotypes, different rates of development will occur among the genotypes.

3.4. Shoot propagation stage

After being developed in the initial medium for 4 weeks, as the shooting stage, findings related to the number of shoots (n), shoot length (cm), callus formation rate (%) and level (cm) were explained in the genotypes cultured in MS with '2.0 mg. L^{-1} BAP+0.5 mg. L^{-1} IBA' were explained in the sub-titles below and shown in Table 5, respectively. For Kalecik Karası clone 4, the number of shoots and the shoot length were 3.67 and 2.42 cm respectively, while they were 3.83 and 2.04 cm for the clone 23-2.

Table 5. Number and length of shoots of two different Kalecik Karası (K.K.) clones (c.)

Genotype	**Number of shoots (n)**
K.K. c. 4	3.67±0.5
K.K. c. 23 / 2	3.83±0.6
	Shoot length (cm)
K.K. c. 4	2.42±1.2
K.K. c. 23 / 2	2.04±0.3
	Callus Formation (%)
K.K. c. 4	0
K.K. c. 23 / 2	0

While comparing the number and length of shoots, the present observations were subjected to square root transformation and then examined by t test. As a result of the t test performed in terms of the number and length of the shoots, the difference between the averages of Kalecik Karası clones 4 and 23-2 was not found to be statistically significant. In terms of the number of shoots, the highest values obtained from previous studies in the literature were reported to be obtained from MS compositions in which cytokine and auxins are used together (Sudarsono and Goldy, 1991). As a result of the study carried out by Baydar (2000), it was determined that the most suitable nutrient place for adventitious shoot formation was the medium with '2mg. L^{-1} BAP' for Kalecik Karası, Çavuş, Sultani seedless and Kober 5BB.

The shoot lengths, which were obtained from meristem culture and grown *in vitro* conditions, in Çavuş, Müşküle, Hafızali, Razakı, Sultani seedless and Çal karası varieties varied between 3.783-0.858 cm (Kara, 1992). In this case, it is thought that differences in genotypes may occur in terms of shoot length, but the location and time factor where tissue culture is carried out may also have an effect on this difference. These results may be due to the development strength that will result from the genotype, as well as the variables such as different laboratory conditions, the ecology of the plant material and the nutritional status of the donor plant, and the structure of the nutrient media used. However, the values that we obtained are among the reference values given by Kara (1992) and reflect a healthy development strength. No callus formation was observed in the clones in our study.

3.5. Rooting stage

Number of shoots (n), shoot length (cm), number of leaves in shoots, callus formation rate (%) and level (mm) rooting rate (rate of transformation into complete plant) (%), number of roots (n) and length (width) in the shoots developed in the composition of 12 different nutrient media (Table 1) used to determine the most suitable rooting medium for the shoots obtained at the shooting stage were examined.

3.6. The number of shoots formed at the rooting stage (n)

As a result of the calculations regarding the analysis of variance technique, evaluations were made regarding the number of shoots formed in the shoots at the rooting stage. Genotype X application interaction was found to be statistically significant in terms of the average number of shoots. As seen in Table 7, the difference between genotypes is statistically significant in the 2nd, 4th and 6th applications, and shoot formation is higher in clone 23-2. The highest number of shoots for clone 4 was obtained from the 10th application using the doses of '1.0 mg. L^{-1} IBA+0.5 mg. L^{-1} 2İP' (2.11 pieces), while the 4th application combinations for clone 23-2 provided the highest number of axillary shoot formation. The number of shoots formed in these combinations is 2.11 in both clones (Table 6).

To report a general observation, it is possible to say that the tendency to form shoots in clone 4 is lower than in clone 23-2. However, 2 iP affected the shoot formation in combination with low doses of auxin in clone 4 in a significantly positive manner. It would not be wrong to say that in media where

clone 23-2 has a higher tendency to form shoots and BAP is added, if the auxin pressure is low, the tendency to form shoots becomes more evident.

Table 6. Number of shoots of two different Kalecik Karası (K.K.) clones (c.) at the rooting stage (pieces)

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	1.0±0.000 c* A**	1.30±0.15 bc A
2.	1.1±0.1 b B	1.9±0.35 ab A
3.	1.25±0.16b A	1.00±0.0 c A
4.	1.10±0.10 b B	2.11±0.42 a A
5.	1.25±0.16 b A	1.33±0.21 bc A
6.	1.0±0.0 b B	1.9±0.25 ab A
7.	1.0±0.0 b A	1.22±0.14 c A
8.	1.7±0.33 ab A	1.43±0.3 bc A
9.	1.3±0.15 b A	1.0±0.0 c A
10.	2.11±0.45 a A	1.0±0.0 c A
11.	1.0±0.0 b A	1.2±0.22 c A
12.	1.32±0.22 b A	1.12±0.12 c A

*According to the Duncan multiple comparison test, the differences between the averages shown with different letters are significant ($p<0.01$).
* Lowercase letters show the differences between applications.
** Uppercase letters show the differences between genotypes.

3.7. Length of the shoots formed (cm)

In our study, the highest shoot length values obtained were 2.46 cm with the 6th application for clone 4, and 3.25 cm with the 9th application for clone 23-2. We see the difference between the two genotypes in the 1st, 3rd and 5th applications (Table 7). There is no statistically significant difference between the applications for clone 4 in terms of shoot length formed at the rooting stage, whereas the difference between applications for clone 23-2 is statistically significant. Kara (1992) obtained the number of nodes between 5.958 and 1.417 and a shoot length between 3.783 and 0.858 cm in a study on some clones of Çavuş, Müşküle, Hafızali, Razakı, Sultani seedless and Çal Karası.

Table 7. Shoot lengths of two different Kalecik Karası (K.K.) clones (c.) formed at the rooting stage

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	1.37±0.11 a* B **	3.02±0.5 ab A
2.	1.87±0.26 a A	1.71±0.22 ba A
3.	1.29±0.09 a B	3.25±0.73 a A
4.	1.74±0.33 a A	1.9±0.4 bc A
5.	1.69±0.23 a B	2.67±0.53 abc A
6.	2.46±0.7 a A	2.07±0.23 abc A
7.	2.21±0.39 a A	1.53±0.2 c A
8.	1.93±0.14 a A	2.04± 0.4 abc A
9.	2.35±0.30 a A	2.42±0.52 abc A
10.	2.07±0.30 a A	1.71±0.23 bc A
11.	2.17±0.71 a A	2.13±0.45 abc A
12.	2.06±0.30 a A	1.2±0.42 abc A

*According to the Duncan multiple comparison test, the differences between the averages shown with different letters are significant ($p<0.01$).
*Lowercase letters show the differences between applications.
**Uppercase letters show the differences between genotypes.

3.8. Number of leaves (n)

In the calculations made in terms of average number of leaves, genotype X application interaction was not found to be statistically significant. The highest value in terms of the number of

leaves on a shoot was obtained from the 10th application (4.1±0.41 pieces) for clone 4, and the 9th application (5.13±1.23 pieces) for clone 23-2 (Table 8).

Table 8. Number of leaves of two different Kalecik Karası (K.K.) clones at the rooting stage (pieces)

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	2.11±0.35	4.3±0.79
2.	2.67±0.50	3.30±0.30
3.	2.31±0.69	5.13±1.23
4.	1.70±0.33	3.45±0.39
5.	1.75±0.52	4.16±0.95
6.	3.22±0.1	3.8± 0.36
7.	3.0±1.26	2.56±0.35
8.	3.85±0.85	3.45±0.84
9.	3.60±0.6	4.0±0.84
10.	4.1±0.41	2.8±0.74
11.	2.67±1.37	3.44±0.67
12.	2.57±0.5	2.70±0.76

3.9. Callus formation rate (%) and level (cm)

While callus formation was not observed in the shoot stage, callus formation appeared in the basal parts of the explants at the rooting stage and the difference between these callus levels was found to be statistically significant. The highest callus levels are 0.43 cm in the 6th application combination for Kalecik Karası clone 4 and 0.72 cm in the 12th application combination for clone 23-2 (Table 9).

Table 9. Callus levels of two different Kalecik Karası (K.K.) clones (c.) at the rooting stage

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	0.00±0.00 e* A**	0.00±0.00 d A
2.	0.13±0.05 de A	0.06±0.04 cd A
3.	0.02±0.02 e A	0.05±0.03 d A
4.	0.27±0.04 bc A	0.12±0.07 bcd B
5.	0.07±0.04 de A	0.00±0.00 d A
6.	0.43±0.04 a A	0.24±0.06 b B
7.	0.00±0.00 e A	0.05±0.02 cd A
8.	0.00±0.00 e B	0.21±0.12 bc A
9.	0.00±0.00 e A	0.02±0.02 d A
10.	0.19±0.01 cd A	0.22±0.05 b A
11.	0.08±0.06 de B	0.23±0.06 b A
12.	0.38±0.06 ab B	0.71±0.01 a A

*According to the Duncan multiple comparison test, the differences between the averages shown with different letters are significant ($p<0.01$).
* Lowercase letters show the differences between applications.
**Uppercase letters show the differences between genotypes.

3.10. Rooting (transformation into complete plant) rate (%)

In the shoots grown in rooting medium for four weeks, the rooting rate for both genotypes was found to be 100 %.

3.11. Longest root values (cm)

Genotype X application interaction was found to be statistically significant in terms of the longest root value. As can be seen in Table 10, the longest root value was obtained from the 9th application (3.47 cm) for Kalecik Karası clone 4, and from the 1st application (3.9 cm) for clone 23-2 (Table 10).

Table 10. The longest root value of two different Kalecik Karası (K.K.) clones (c.) at the rooting stage

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	0.0±0.0 b* B**	3.9±0.70 a *A
2.	0.21±0.21 b A	0.4±0.33 cd A
3.	0.11±0.11 b B	3.2±0.79 ab A
4.	0.07±0.07 b B	2.84±1.63 abcd A
5.	0.48±0.28 b B	2.66±0.66 abcd A
6.	1.64±0.83 ab A	2.4±0.90 abcd A
7.	0.86±0.86 b A	0.72±0.27 bcd A
8.	0.84±0.58 b A	1.26±0.93 bcd A
9.	3.47±1.28 a A	2.74±0.59 abcd A
10.	2.10±1.11 ab A	0.30±0.21 d B
11.	2.54±1.07 ab A	2.02±0.38 abcd A
12.	0.37±0.27 b B	2.97±1.17 abcd A

*According to the Duncan multiple comparison test, the differences between the averages shown with different letters are significant ($p<0.01$).
*Lowercase letters show the differences between applications.
**Uppercase letters show the differences between genotypes.

In the study of Kara (1992), root lengths between 6.333 and 0.33 cm were obtained in Çavuş, Müşküle, Hafızali, Razakı, Sultani seedless and Çal Karası varieties.

3.12. Average length of roots (cm)

The average root lengths obtained from the evaluation of the average of the lengths of all the roots formed in each of the *in vitro* shoots of the two different Kalecik Karası clones at the rooting stage are given in Table 11. Accordingly, it was determined that the highest value was 3.34±1.27 cm in the 9th application combination for Kalecik Karası clone 4, and 2.33±1.38 cm in the 4th application combination for clone 23-2.

Table 11. Root lengths of different Kalecik Karası (K.K.) clone (c.) at the rooting stage

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	0.0±0.0 b*B**	2.29±0.43 a A
2.	0.17±0.16 b A	0.41±0.33 ab A
3.	0.10±0.09 b B	1.95±0.41 ab A
4.	0.08±0.08 b B	2.33±1.38 a A
5.	0.27±0.14 b A	1.63±0.29 ab A
6.	1.24±0.69 b A	1.71±0.60 ab A
7.	0.69±0.68 b A	0.59±0.21 ab A
8.	0.61±0.40 b A	0.96±0.69 ab A
9.	3.34±1.27 a A	1.93±0.44 ab A
10.	1.40±0.78 b A	0.23±0.16 b A
11.	1.53±0.69 b A	1.50±0.25 ab A
12.	0.24±0.17 b A	1.31±0.45 ab A

*According to the Duncan multiple comparison test, the differences between the averages shown with different letters are significant ($p<0.01$).
*Lowercase letters show the differences between applications.
**Uppercase letters show the differences between genotypes.

3.13. Average number of roots (n)

The difference between the data of both combinations was statistically significant in terms of the number of roots ($p<0.01$), while the highest value was determined as 7.6±2.4 in the 11th application combination for clone 4 and 6.83±1.4 in the 5th application combination for clone 23-2 (Table 12).

Table 12. Average number of roots of grapevine genotypes at the rooting stage

Applications	K.K. c. 4	K.K. c. 23 / 2
1.	0.00±0.00 b* B**	3.65±0.6 bc A
2.	0.44±0.44 b A	0.40±0.3 d A
3.	0.38±0.38 b B	5.45±1.4 ab A
4.	0.10±0.1 b A	0.89±0.51 d A
5.	2.25±1.21 b B	6.83±1.4 a A
6.	2.78±1.19 b A	1.33±0.50 cd A
7.	0.40±0.4 b A	1.22±0.45 cd A
8.	0.60±0.34 b A	1.29±0.84 cd A
9.	2.7±0.95 b B	5.22±1.10 ab A
10.	1.00±0.52 b A	0.40±0.30 d A
11.	7.60±2.42 a A	5.33±0.96 ab A
12.	0.30±0.20 b B	3.75±0.75 bc A

*According to the Duncan multiple comparison test, the differences between the averages shown with different letters are significant ($p<0.01$).
*Lowercase letters show the differences between applications.
**Uppercase letters show the differences between genotypes.

In their study, Ergönül and Öztürk (2016), have eliminated the viruses identified in the certification system of the European Union countries and our country and the grapevine pathogen Agrobacterium vitis with thermotherapy and meristem culture methods by using clones of 14 grapevine varieties and 6 rootstocks, which are of economic importance for our country. Yepes et al. (2019) obtained clean material in the *V. vinifera* cv. Riesling variety, infected with Agrobacterium vitis and grown in the greenhouse, by means of the meristem culture method and propagated it through tissue culture. Most of the plants can be successfully protected from viral contamination with tissue culture-virus elimination programs, and the criteria for the use and propagation of clonal, high quality and healthy (certified) grapevine seedlings free from viruses and similar are included in the European Union directives, which are binding in the candidate countries of the European Union (Mullins, 1990).

4. Conclusions

This study, which we have conducted for the production of base material for Kalecik Karası clones 4 and 23-2, consists of extracting and culturing meristems, forming shoots from explants, rooting, transforming them into complete plants and acclimatizing them to external conditions. In addition, the number and lengths of the shoots formed by the explants during the shoot formation and rooting stages were also examined. During the meristem and shoot formation, callus formation was observed, and the survival rate in clones 4 and 23-2 was determined as 60% and 80%, respectively. In addition to the full-strength MS medium during the shoot formation stage of the explants, 2.0mg. L^{-1} BAP+0.5 mg. L^{-1} IBA was used, and the average number of shoots was 3.67 and 3.83, and the average shoot length was 2.42 cm and 2.04 cm, respectively. In addition to MS nutrient media, 12 different auxin (IBA) and cytokine (2iP and BAP) concentrations were used at the rooting stage, and the effects of these concentrations on explant root development, number of shoots, shoot length and transformation into complete plant were examined.

At the rooting stage, it was determined that the formation of shoots and the number of leaves were higher in Kalecik Karası clone 23-2, and that 1.0 mg. L^{-1} IBA+0.5 mg. L^{-1} BAP/2 iP concentration gave the highest shoot formation and number of leaves. At this stage, callus formation was in parallel with the increase of auxin and cytokine levels. The highest callus levels were determined as 0.43 cm for Kalecik Karası clone 4 and 0.72 cm for clone 23-2. MS media with 2mg. L^{-1} IBA gave the highest rooting value. The longest root values were 3.47 cm with 1mg. L^{-1} IBA for clone 4, and 3.90 cm with 0.5mg. L^{-1} IBA for clone 23-2.

One of the most important problems of grapevine cultivation in our country is that the seedlings produced are infected with viruses and these seedlings are distributed to different parts of the country. What needs to be done is to work with clean plant material, certified grapevine seedlings, that is, genotype/clone and rootstock breeds that do not contain any disease agents.

Plants taken out of controlled conditions are very sensitive to environmental conditions, so losses can occur. In our study, the rate of acclimatization to external conditions in both clones is 90%. There was no difference between clones in terms of rate of acclimatization to external conditions.

Consequently, meristem culture studies with clones 4 and 23-2 belonging to Kalecik Karası grapevine variety revealed in our conditions that this method can be used practically for the grapevine and is applicable during the production of seedlings by commercial firms.

The general feature of the tissue culture also manifested itself during the meristem culture in the grapevine, and it was observed that different results can be obtained even if all conditions are kept constant between different clones and they belong to the same variety. This difference was significant in terms of features such as the development of meristems, the number of shoots and rooting rates and rooting capacities. Therefore, when it is desired to use meristem culture technique to obtain base material in the grapevine seedling production, it should not be overlooked that the method may need to be optimized for each genotype due to the genotype effect.

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Araştırma Makalesi (Research Article)

Kısıtlı Sulama Uygulamalarının İHA Multispektral Algılamaya Dayalı Vejetasyon İndekslerine Etkisi

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Anahtar Kelimeler
Silajlık Mısır,
Su kısıtı,
Sulama yöntemi,
Multispektral sensör,
Vejetasyon indeksi,
İnsansız Hava Araçları (İHA)

Öz: Tarımsal yetiştiricilikte artan su talepleri, günümüz gelişen ve teknolojilerini daha iyi sulama yönetimi stratejilerini geliştirmeyi zorunlu hale getirmiştir. Görüntüleme teknolojilerine dayalı bilgi üretimi de bu amaçlı kullanımlar içerisinde yer almaktadır. Bu çalışmada, İHA tabanlı multispektral görüntülerin yüzey altı ve yüzey üstü damla sulama uygulamalarının değerlendirilmesinde kullanılabilirliği araştırılmıştır. Bu amaçla ET0 (0.00, 0.25, 0.50, 0.75, 1.00, 1.25, 1.5) katları olacak şekilde programlanan bir silajlık mısır denemesinin büyüme sezonu boyunca insansız hava aracı kullanılarak görüntülenmiştir. Alınan görüntülerde 9 farklı vejetasyon indeksi oluşturularak uygulamaların izlenmesinde kullanılabilirlikleri birbirleri ile karşılaştırılmıştır. Yüzey altı damlama sulama yönteminde LCI ve TGI indeksleri, yüzey üstü damlama sulama yönteminde VARI indeksinin sulama programları düzeyinde kullanılabileceği belirlenmiştir ($p<0.05$). Gelişme dönemi boyunca temporal veriler incelendiğinde 9 bitki indeksi sonuçları arasında farklılıklar olduğu tespit edilmiştir ($p<0.05$). Multispektral görüntülerin analizinden türetilen yüzey ve yüzey altı damla sulama yöntemleri Vejetasyon İndeksleri (VI) ile karşılaştırıldığında işlemler arasında istatistiksel olarak anlamlı farklılık olduğu gözlemlenmiştir. Sulama oranları karşılaştırıldığında, bitki örtüsü indeksi değerlerinde de benzer farklılıklar belirlenmiştir. Elde edilen sonuçlar, farklı sulama uygulamalarına bitkilerin tepkilerini karakterize etmek için İHA entegrasyonlu multispektral görüntülerin uygulanabilirliğini göstermiştir. İHA'lar ile yapılan Akıllı Tarım, Hassas Tarım, Organik Tarım ve İyi Tarım Uygulamalarının çiftlik düzeyinde yüksek kullanım potansiyeline sahip olacağı düşünülmektedir.

The Effect of Restricted Irrigation Applications on Vegetation Index Based on UAV Multispectral Sensing

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Keywords
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Water limited,

Abstract: Increasing water demands in agricultural cultivation have made it necessary to develop better irrigation management strategies within today's development and technologies. Information production based on imaging technologies is also included in these uses. In this study, the usability of UAV-based multispectral images in the evaluation of subsurface and surface drip irrigation applications was investigated. For this purpose, a silage maize trial programmed to be multiples of ET0 (0.00, 0.25, 0.50, 0.75, 1.00, 1.25, 1.5) was imaged using an unmanned aerial vehicle during the growing season. 9 different vegetation indexes were created in the images taken and their usability in monitoring the applications was compared with each other. It was determined that LCI and TGI indexes in subsurface drip irrigation method and VARI index in

Irrigation method, Multispectral sensor, Vegetation index, Unmanned Aerial Vehicles (UAV).

surface drip irrigation method can be used at the level of irrigation programs ($p<0.05$). When the temporal data were examined during the development period, it was determined that there were differences between the 9 plant index results ($p<0.05$). When the surface and subsurface drip irrigation methods derived from the analysis of multispectral images were compared with the Vegetation Indexes (VI), it was observed that there was a statistically significant difference between the treatments. When irrigation rates were compared, similar differences were determined in vegetation index values. The obtained results demonstrated the feasibility of UAV-integrated multispectral images to characterize the responses of plants to different irrigation applications. It is thought that Smart Agriculture, Precision Agriculture, Organic Agriculture, and Good Agricultural Practices made with UAVs will have high utilization potential at the farm level.

1. Giriş

Tüm iklim bölgelerini tehdit eden kuraklık, araştırmacıların ve yöneticilerin acil eylem planları ve uygulamaları açısında dikkatini çekmektedir. Mevcut iklim değişikliği tahminleri yakın gelecekte Akdeniz ve yarı kurak bölgelerde kurak dönemlerin sıklığında ve şiddetindeki artışlara işaret etmektedir. Ayrıca 2050 yılı için öngörülen küresel gıda talebi, tarımsal üretimin ve buna bağlı su kullanımının katlanarak artması gerektiğini göstermektedir (Danandeh Mehr ve ark., 2020). Dünyadaki tatlı su kaynaklarının çoğu (% 70) tarım için kullanılmaktadır. Aynı zamanda, diğer sektörlerde de artan su tüketimi, gıda üretimi için kullanılan su için bir rekabet oluşturmaktadır. Su talebindeki artış ve iklim değişikliği bu olumsuzlukların kuraklık üzerine etkilerini arttırmaktadır (Tiryaki, 2018). Küresel olarak dünyadaki gıda arzının % 45'i, ekilebilir alanların yalnızca % 18'ini kapsayan sulanan arazilerde üretilmektedir. Bu durum, sulama yönetiminde su kullanımını optimize etmenin önemli olduğu anlamına gelmektedir. Su kaynağı kıtlığı, tüm dünyada özellikle kurak ve yarı kurak alanlarda tarımsal su yönetiminin en önemli sorunlarından biridir (Fernández García ve ark., 2020). Su kullanım etkinliğini artırmanın önemli yollarından biri de çeşitli bitkiler için üzerinde uzun yıllardır araştırma yapılan kısıtlı sulama uygulamasıdır. Bununla birlikte, verim ve sulama suyu arasında hassas bir denge sağlamak için etkili izleme yöntemleri gerekmektedir. Bu nedenle, çevreyle ilişkili olarak bitki örtüsündeki dinamik değişiklikleri dikkate almak önemlidir (Demir ve Başayiğit, 2020).

Toprak nem içeriğinde gerçekleşen azalmaya bağlı olarak bitkilerin içsel su durumunu gösteren stoma iletkenliği ve yaprak su potansiyeli gibi çeşitli fizyolojik özellikler uzaktan algılama teknolojileri kullanılarak tespit edilebilmektedir (Uçar, 2011). Toprak su içeriğine bağlı olarak bitkilerin bazı fizyolojik özelliklerinde gerçekleşen değişimlerin yerinde ölçümleri zaman alıcı, zahmetli ve maliyetli olmaktadır. Bu yöntemlerde, toprak ile bitki arasındaki mekansal değişkenlik ilişkisi yeterince değerlendirilememekte iken, günümüzde çeşitli uzaktan algılama platformlarından çok sayıda veri elde edilebilmekte ve bitki su stresini izleme çalışmalarında kullanılmaktadır. Uzaktan algılamanın tarımsal amaçlı olarak en yaygın kullanımı uydu platformlarından temin edilen farklı özelliklerdeki görüntülerdir. Ancak uydu platformları, uzamsal-zamansal çözünürlüğe bağlı artan maliyetleri, kısıtlı gerçek zamanlı görüntüleme kabiliyetleri ve atmosfer koşullarından etkilenme gibi çeşitli dezavantajlara sahiptir. Bu nedenle günümüzde İHA'lar (insansız hava araçları) yeni nesil uzaktan algılama araçları olarak devreye girmekte ve daha esnek çalışma kabiliyetleri sunmaktadır. Sensörlerle donatılmış hava platformları kullanılarak uygun maliyetlerle bazı çalışmalar da kullanılabileceği belirtilmiştir. Ancak, bu ekipmanların izleme alanlarına taşınması ve şerit haritalama kabiliyetini azaltmasından dolayı kullanımları kısıtlanmaktadır (Calera ve ark., 2017; Demir ve Başayiğit, 2020).

Son yıllarda teknolojik gelişmeler ile birlikte İHA'ların sivil amaçlı kullanımı artmaya başlamıştır. Düşük maliyet, yapımı kolay, rahat ulaşım, yüksek esneklikte çalışma olanağı sunması, kısa çalışma döngüsü ve yüksek uzaysal-zamansal çözünürlük avantajları nedeniyle, insansız hava aracı (İHA) uzaktan algılama sistemi olarak kullanımı artmaktadır. Mahsul bilgilerini istenen bir uzaysal-zamansal çözünürlükte İHA ile toplanabilmektedir (Demir ve Başayiğit, 2020). Belirtilen özellikler İHA'ların bitki su stresini çiftlik ölçeğinde hızlı ve titizlikle izlemeyi daha uygun hale getirmiştir.

Bitki örtüsünün ve karşılık gelen banttaki diğer yer nesnelerinin yansıtımının matematiksel işlem sonucu olan bitki örtüsü indeksi (VI), yüzey bitki örtüsü durumunu izlemek için kullanılabilmektedir. Bitki indeksi; arazi örtüsü sınıflandırması, çevresel değişiklikler ve kuraklığı

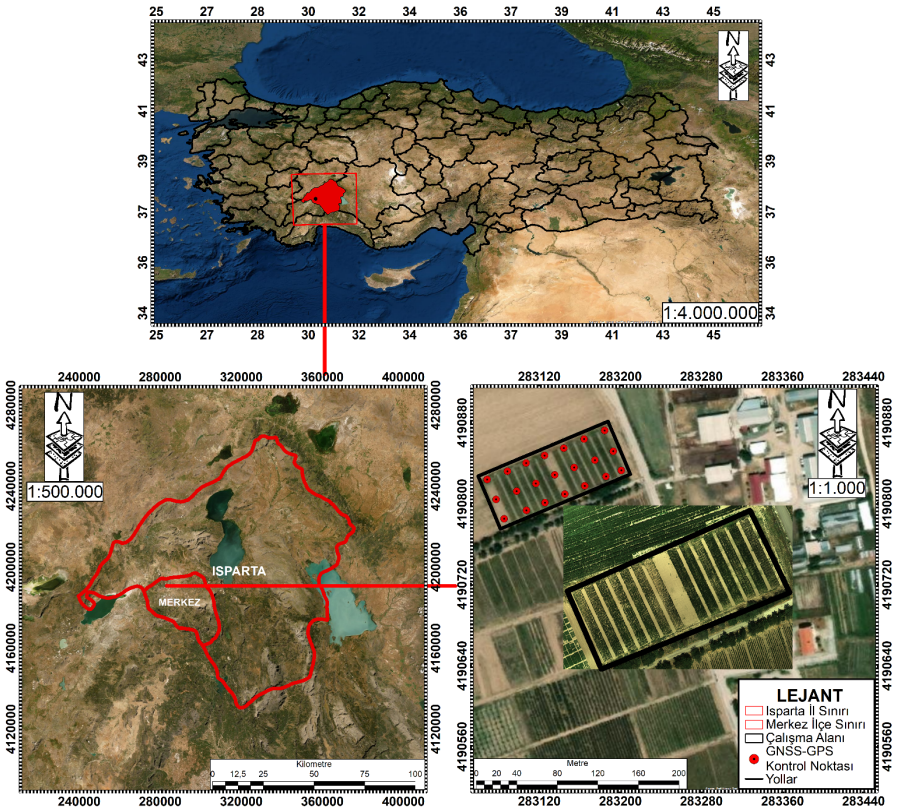
izlemek amacıyla başarıyla uygulanmaktadır (Xue ve Su ,2017; Han ve ark., 2018; Wahab ve ark., 2018; Kumar ve ark., 2020; Becker ve ark., 2020; Zhang ve ark., 2021). Suyun yeni bir değer olarak yükseldiği günümüzde teknolojiye dayalı bu araştırmaların önemi daha da artmaktadır.

Bu çalışmada; yüzey altı ve yüzey üstü damlama sulama yöntemi ile farklı düzeylerde sulama suyu uygulanan silajlık mısırın; (1) yüksek çözünürlüklü İHA tabanlı multispektral ve temporal görüntülerinin alınması, (2) vejetasyon indekslerinin üretilmesi, (3) su seviyelerindeki vejetasyon indekslerinin parsel bazlı ve dönemsel olarak yansıma verilerine dayalı sulama programlarının istatistiksel olarak belirlenmesi çalışması yer almaktadır.

2. Materyal ve Yöntem

2.1. Çalışma Alanının Konumu ve İklimi

Çalışma alanı, Isparta-Burdur Karayolunun doğusunda, üniversite yerleşim birimleri ile Isparta Mensucat fabrikası arasında, Göller Bölgesi Teknokent ile ISUBU Ziraat Fakültesi arasında kalan Eğitim, Araştırma ve Uygulama Çiftliği araştırma parseli içerisinde 4190803.07-41900845.45 N kuzey enlemleri - 283075.62-283208.54E doğu boylamları (WGS-1984, UTM-m, 36N Zon) arasında yer almaktadır. Toplam 7862 metrekare alana sahiptir (Şekil 1). Meteoroloji Genel Müdürlüğü 17240 numaralı Isparta Merkez istasyonu 2018 yılı iklim verilerine göre; yıllık ortalama sıcaklık 13.8 ^{0}C, en düşük aylık ortalama sıcaklık 3.1 ^{0}C Ocak ayında, en yüksek aylık ortalama sıcaklık 24.3 ^{0}C' ile Temmuz ve Ağustos aylarında tespit edilmiştir. Yıllık ortalama yağış 536.9 mm, en yüksek yağış 107.1 mm Aralık ayında, en düşük yağış 1.6 mm ile Eylül ayında tespit edilmiştir (MGM, 2021). McKee ve ark. (1993)'e göre Standart Yağış İndeksi (SPI) hesaplanmıştır (Danandeh Mehr ve ark., 2020). Çalışma alanının SPI değerleri 1990-2019 yılları arasındaki iklim verileri kullanılarak hesaplanmıştır. 2018 yılına ait SPI değerleri, yıllık, aylık ve kuraklık kategorisi Temmuz, Ağustos ve Eylül ayları ve 2018 yıllı "Normale Yakın Kuraklık " kuraklık kategorisi içerisinde yer almıştır.



Şekil 1. Çalışma alanının konum haritası.

2.2. Deneme Konuları

Çalışma alanı ve çevresinde silajlık mısır yetiştiriciliği yapılan dönemlerde SPI değerleri normale yakın kuraklık kategorisinde yer almıştır. Bu nedenle mısırın vejetasyon döneminde ihtiyaç duyduğu suyun uygun yöntem ve uygun programda verilmesi bölgede su kullanımı yönünden önem arz etmektedir (Çakmakçı ve ark., 2017; Alaboz ve ark., 2020; Çakmakçı ve Şahin, 2020; Alaboz ve Çakmakçı, 2020). Çalışmada, su tasarrufu yönünden etkin olan yüzey üstü ve yüzey altı damla sulama yöntemleri ile referans bitki su tüketimi (ET0)'ya göre 7 farklı sulama programı olacak şekilde deneme kurulmuştur (Şekil 2).

Şekil 2. Deneme planı.

ET0 baz alınarak oluşturulan 7 farklı sulama programı Parsel 1, 2, 3, 4, 5, 6 ve 7 için yüzey altı damla sulama yöntemi ve Parsel 8, 9, 10, 11, 12, 13 ve 14 için yüzey üstü damla sulama yöntemi olarak planlanmıştır. Parsellere ait deneme konuları Şekil 2'de gösterilmiştir.

ET0, Penman Monteith yöntemine göre hesaplanmıştır (Uçar ve ark., 2017). Deneme konularına ET0'ın (Referans bitki su tüketimi) 0.00, 0.25, 0.50, 0.75, 1.00, 1.25 ve 1.50 katı sulama suyu uygulanmıştır (Tablo 1). 22.06.2018 tarihinde bütün konuları tarla kapasitesine getirilecek kadar sulama suyu uygulanmıştır. 0 konusuna 22.06.2018 tarihinden sonra sulama suyu uygulanmamıştır.

Tablo 1. Denemede konularına uygulanan sulama suyu miktarı (mm)

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
Sulama Tarihleri	**1.50**	**1.25**	**1.00**	**0.75**	**0.50**	**0.25**	**0.00**
09.06.2018	20.2	20.2	20.2	20.2	20.2	20.2	20.2
15.06.2018	30.7	30.7	30.7	30.7	30.7	30.7	30.7
22.06.2018	40.8	40.8	40.8	40.8	40.8	40.8	40.8
29.06.2018	54.8	45.6	36.5	27.4	18.3	9.1	
06.07.2018	53.7	44.8	35.8	26.9	17.9	9.0	
13.07.2018	61.1	50.9	40.7	30.5	20.4	10.2	
20.07.2018	55.8	46.5	37.2	27.9	18.6	9.3	
27.07.2018	55.8	46.5	37.2	27.9	18.6	9.3	
03.08.2018	52.4	43.6	34.9	26.2	17.5	8.7	
10.08.2018	45.8	38.1	30.5	22.9	15.3	7.6	
17.08.2018	48.5	40.4	32.3	24.2	16.2	8.1	
TOPLAM	**519.4**	**448.1**	**376.8**	**305.5**	**234.3**	**163.0**	**91.7**

2.3. Kültürel Uygulamalar

Denemelerin kurulacağı parsel önce pullukla sürüm yapılmış ve ardından rotatiller ile sürülerek dikime hazır duruma getirilmiştir. Toprak analiz sonuçları dikkate alınarak, ekimle birlikte damla

sulama sisteminde yer alan venturi gübreleme sistemiyle ilk gübreleme (10 kg da^{-1} AquaDrip 20-20-20-TE) yapılmıştır. 1 Haziran 2018 tarihinde sıra arası 70 cm ve sıra üzeri 20 cm olmak üzere pnömatik hassas ekim makinesi ile ekim gerçekleştirilmiştir. Çiçeklenme ve hasat dönemleri arasında 5kg da^{-1} olacak şekilde 2 doz gübreleme daha uygulanmıştır. Hayvan yemi olarak kullanılacağı için kimyasal mücadele uygulanmamış, tüm yetişme periyodu boyunca ortaya çıkan yabancı otlarla mücadele elle yapılmıştır.

2.4. İnsansız hava araçları görüntülerinin alınması

Çalışmada kullanılan İHA platformu, ISUBÜ Ziraat Fakültesi Toprak Bilimi ve Bitki Besleme Bölümü Uzaktan Algılama ve Coğrafi Bilgi Sistemleri laboratuvarı envanterine 2017 yılında dahil edilen DJI Phantom 4 Pro Quadcopter (DJI, 2021) marka olup SHGM sisteminde kayıtlı ve Türk Hava Sahası içerisinde kullanılabilmektedir. İHA platformu üzerine Sentera Double 4K Multispektral sensör (Sentera, 2021) yerleştirilmiş durumdadır (Demir ve Başayiğit, 2020).

Sentera FieldAgent yazılımı ile tüm çalışma alanını kapsayacak şekilde, %70 bindirmeli, 10 mhp hızda olacak şekilde ve +70° uçuş yönünde olacak şekilde uçuş planı yapılmıştır. Uçuşlar 01.07.2018, 15.07.2018, 30.07.2018, 15.08.2018 tarihlerinde 12:00-14:00 saatleri arasında bulutsuz havada gerçekleştirilmiştir. 21 adet yer kontrol noktası verisi doğruluk değerlendirmesi için RTK GNSS GPS ile alınmıştır.

2.5. Veri işleme ve analizler

Uçuş planına göre 15 Ağustos 2018 tarihine kadar, İHA platformu üzerinde bulunan sensör tarafından kayıt edilen görüntülerde, tarımsal üretim için bilgi üretmek amacı ile Pix4D (demo), Erdas IMAGINE ve ArcGIS yazılımı kullanılarak görüntü işleme çalışmaları yapılmıştır. Verilerin analizinde vejetasyon indeksleri kullanılmıştır (Tablo 2). Çalışmada kullanılan indekslerin kısıtlı sulama uygulaması yapılan iki farklı sulama yönteminde üretilen tematik katmanlarda parsel bazlı olarak 3 tekerrürlü olarak ArcGIS programında zonal istatistik aracı kullanılarak ortalama indeks değerleri üretilmiştir. Elde edilen parsellerin indeks değerlerinin ayrı ayrı kısıtlı sulama uygulamasını belirlemede dönemsel ve parsel bazlı kullanılabilirliği araştırılmıştır.

Tablo 2. Vejetasyon indeksleri

Vejetasyon İndeksi	Kullanılan Eşitlik	Kaynak
Normalleştirilmiş Fark Bitki Örtüsü İndeksi (Normalized difference vegetation index)	$\mathrm{NDVI} = \left(\frac{(Near\ Infrared - Red)}{Near\ Inrared + Red}\right)$	Rouse ve ark., (1974)
Normalleştirilmiş Fark Kırmızı Kenar İndeksi (Normalized Difference Red Edge Index)	$NDRE = \left(\frac{(NIR - Red\ edge)}{NIR + Red\ edge}\right)$	Gitelson ve Merzlyak, (1994)
Yaprak Klorofil İndeksi (Leaf Chlorophyll Index)	$LCI = ((NIR - Red\ Edge)/(NIR + Red))$	Datt ve ark., (2003)
Modifiye Klorofil Absorpsiyon Yansıtma İndeksi (Modified Chlorophyll Absorption Reflectance Index)	$\mathrm{MCARI} = \lfloor(\mathrm{NIR} - \mathrm{Red}) - 0.2(\mathrm{NIR} - \mathrm{Green}\rfloor\ (\mathrm{NIR}/\mathrm{Red})$	Daughtry ve ark., (2000)
Üçgen Yeşillik İndeksi (Triangular Greenness Index)	$TGI = (Green - 0.39 * Red - 0.61 * Blue)$	Hunt ve ark., (2013)
Görünür Atmosferik Direnç İndeksi (Visible Atmospheric Resistant Index)	$VARI = (((Green - Red))/(Green + Red - Blue))$	Gitelson ve ark., (2002)
Yeşil Normalleştirilmiş Fark Bitki Örtüsü İndeksi (Green Normalized Difference Vegetation Index)	$GNDVI = \left(\frac{(NIR - Green)}{(NIR + Green)}\right)$	Gitelson ve ark., (1996)
Yeşil-Kırmızı Vejetasyon Endeksi (Green-Red Vegetation Index)	$GRVI = \left(\frac{(Green - Red)}{(Green + Red)}\right)$	Tucker, (1979)
Toprak Uyarlanmış Vejetasyon İndeksi (Soil Adjusted Vegetation Index)	$SAVI = \left(\frac{(NIR - Red)}{(NIR + Red + L)}\right)(1 + L)$	Huete, (1988)

2.6. Görüntülerin doğruluk değerlendirmesi

Doğruluk değerlendirmesi, İHA görüntüsünün düzenlenmesi ile ilgili hatayı tahmin etmektedir. Her bir ortomozaik konumlamanın kök ortalama kare hatası (RMSE) uzaysal doğruluğunu değerlendirmek için yaygın olarak kullanılmaktadır (Gómez-Candón ve ark., 2014; Boon ve ark., 2016). RMSE, ortomozaik görüntünün kalitesinin küresel bir göstergesini, görüntü koordinatlarının ve zemin koordinatlarının kalıntılarına dayanmaktadır (Eş. 1). Doğrulama puanına sahip bir görüntü için RMSE aşağıdaki eşitlikten hesaplanmaktadır (ERDAS, 1999):

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}[(X_s - X_r)^2 + (Y_s - Y_r)^2]\right]^{1/2} \quad (1)$$

Eşitlikte; X_s ve Y_s, İHA sensör görüntüsünün jeo-uzamsal nokta koordinatlarıdır. X_r ve Y_r, saha seviyesinde ölçülen aynı GNSS-GPS noktasının koordinatlarıdır (Demir ve Başayiğit, 2020).

2.7. İstatistiksel Analiz

Çalışmada vejetasyon indekslerinin tanımlayıcı istatistikleri 4 dönemde hesaplanarak boxplot grafik özeti düzenlenmiştir. Ayrıca 9 vejetasyon indeksinin 4 dönemde sulama programları parsellerindeki değişimini gösteren Time Series Plot grafiği hazırlanmıştır. Çalışmada üzerinde durulan özellikler bakımından elde edilen veriler faktöriyel düzende tekrarlanan ölçümlü varyans analizi tekniği ile analiz edilmiştir (Gezan ve Carvalho, 2018). Çalışmada sulama programının 7 seviyesi ve vejetasyon indeksi ölçüm metodu faktörünün 4 dönemi aynı anda denenmiştir. Tekrarlanan ölçümler vejetasyon indeksi ölçüm metodunun seviyelerinde gerçekleştirilmiştir. Varyans analizi sonrası faktörlerin alt grup ortalamaları ve grup ortalamaları arasındaki farklılıkların belirlenmesinde çoklu karşılaştırma yöntemlerinden Tukey Testi kullanılmıştır.

3. Bulgular

3.1. Veri toplama, ön işleme ve bitki indeksleri

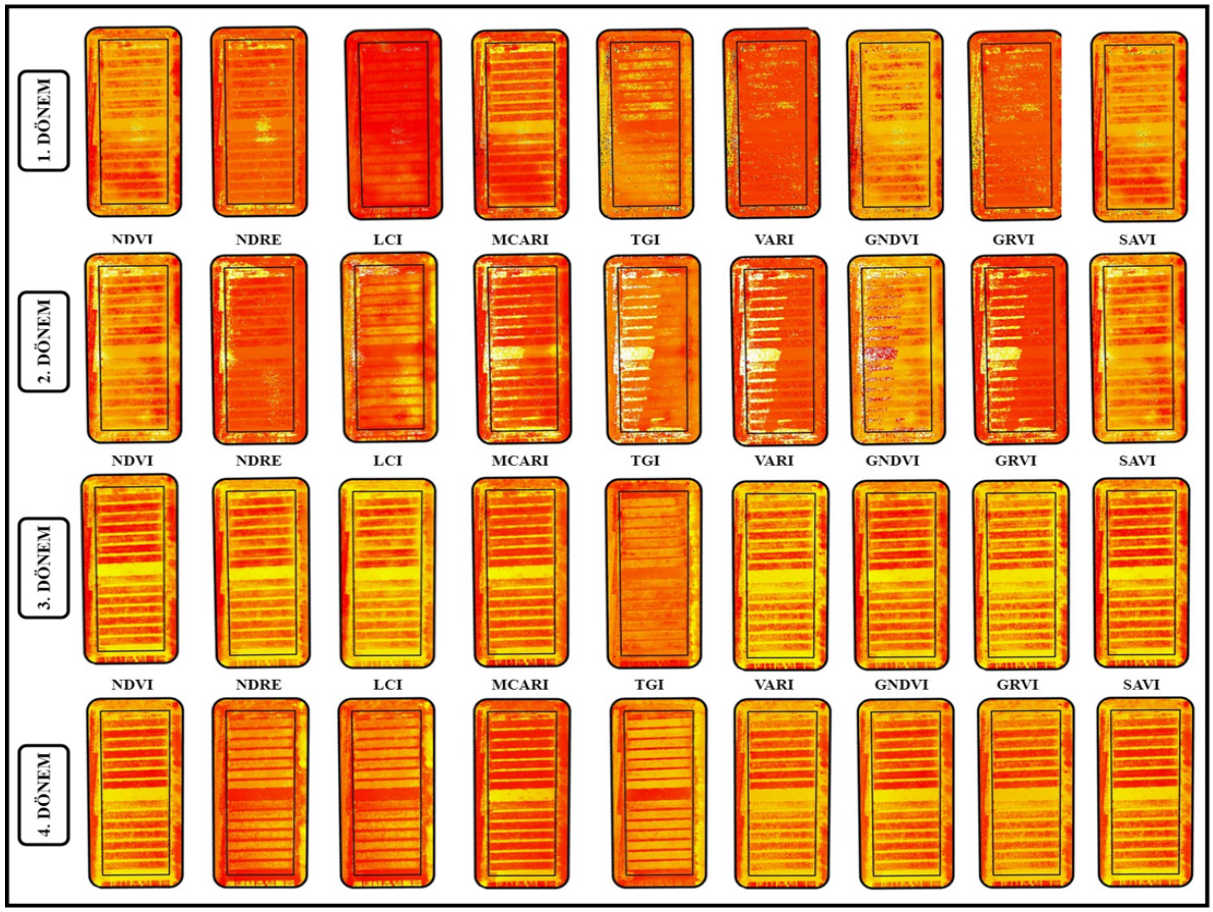
Çalışma alanında İHA ile yapılan görüntülemeler 15'er gün arayla 4 farklı tarihte gerçekleştirilmiştir. Alanda belirlenen 21 yer kontrol noktası kullanılarak görüntülerin doğruluk değerlendirilmesi hesaplanmıştır (Tablo 3). Pix4D (Demo) yazılımı kullanılarak çalışma alanının görüntü mozaikleri oluşturulmuştur. Çalışma alanına ait multispektral görüntüler işlenerek 9 tane vejetasyon indeksine ait veriler oluşturulmuştur. Çalışma alanından kayıt edilen 4 görüntüden türetilen NDVI, NDRE, LCI, MCARI, TGI, VARI, GNDVI, GRVI ve SAVI indekslerindeki değişim sunulmuştur (Şekil 3).

Tablo 3. Çalışma alanı mozaik görüntülerinin jeo-uzamsal doğruluğu

Uçuş Tarihi	X (m)	Y (m)	Z (m)	Doğruluk RMSE (m)	Kappa (derece)
1.Dönem (01.07.2018- 30.gün)	0.24	0.15	0.33	0.24	0.011
2. Dönem (15.07.2018 - 45.gün)	0.40	0.25	0.27	0.31	0.010
3. Dönem (30.07.2018 - 60.gün)	0.33	0.27	0.48	0.36	0.008
4. Dönem (15.08.2018- 76. gün)	0.36	0.33	0.57	0.42	0.009

Bitki indekslerine ait görüntülerin istatistik olarak karşılaştırılması amacıyla, sınır etkisini ortadan kaldırmak üzere parsel sınırlarında 2 metrelik bufferzone oluşturulmuş ve parsel içerisinde kalan 15.69 m^2 alan ArcGIS ortamına aktarılmıştır. Daha sonra ArcGIS yazılımında zonal istatistik tool kullanılarak belirlenen alandaki 63 pikselin vejetasyon indeks değerlerinin ortalaması elde edilmiştir

(Rhew ve ark., 2011). Yüzey altı ve yüzey üstü damla sulama yöntemi için uygulanan sulama programlarının değerlendirmesi insansız hava araçları kullanılarak elde edilen vejetasyon indeksleri ile yorumlamada kullanılmıştır. Üretilen bitki indeks görüntülerine göre parselleri oluşturan bitkilerin farklı dönemlerdeki gelişimleri indeks gruplarında farklılık göstermiştir.



Şekil 1. Çalışma alanı temporal indeks değerleri.

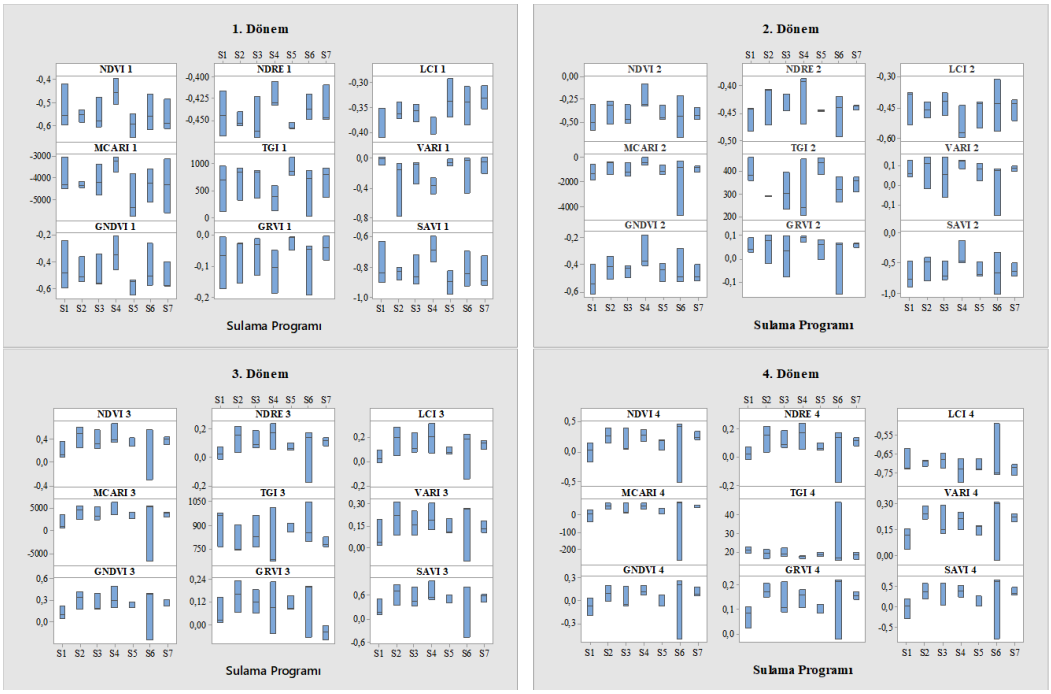
3.2. Yüzey altı damlama sulama yöntemi

1. ve 2. dönemlerde mısır bitkisinin vejetatif gelişiminin az ve kaplama oranının düşük olması nedeniyle topraktan kaynaklanan yansıma baskın olmuştur. Bu dönemlerde 9 vejetasyon indeksi sulama programları için istatistiksel olarak önemli bulunmamıştır.

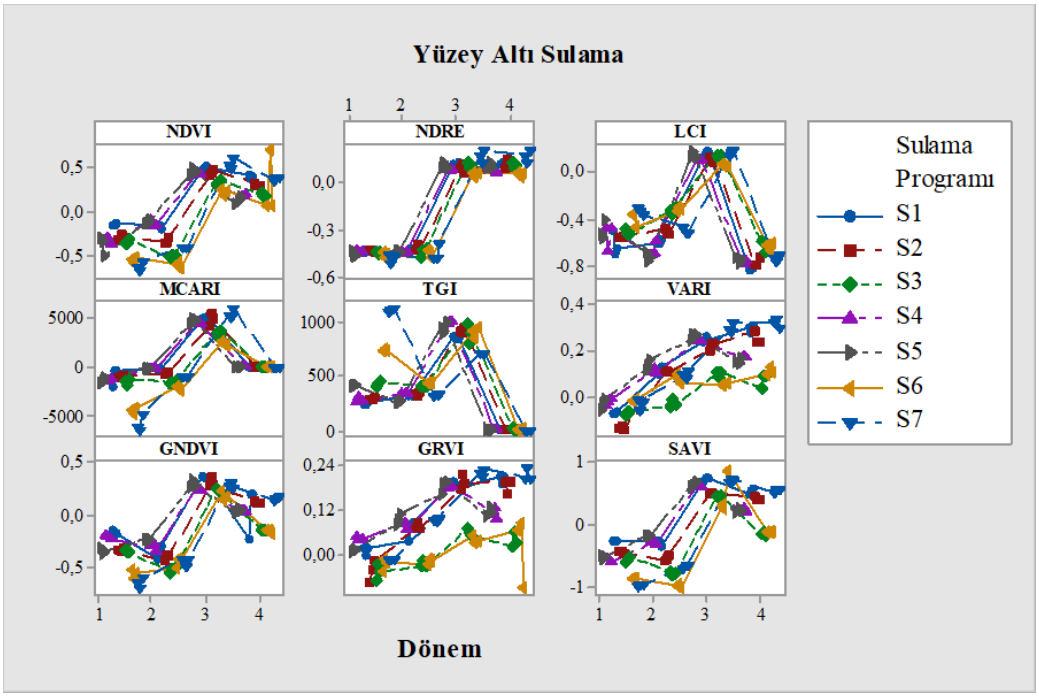
3. ve 4. dönemde yalnızca S6 (0.25) sulama programının uygulandığı parselde bitki indeks değeri tekerrürler arası değişimi fazladır. S6 (0.25) sulama programının, S7 (0.00) sulama programından ortalama piksel değeri aralığının daha yüksek çıkması, belirlenen alandaki piksel değerlerinin, toprak yansıma değerinin yüksek olmasından kaynaklanmıştır. Diğer sulama programı uygulanan parsellerin vejetasyon indeks değerlerinde tekerrürler arasında deneme başına hata düşük olduğunu göstermiştir.

4. dönemde bitki yeşil aksamındaki gelişim hızı ve yüksek kapama oranından dolayı S6 dışındaki paraleller arası yakın değerler alarak deneme başına hata düşmüştür. Sulama programlarına ait vejetasyon indekslerinin 4 dönemdeki değişimi Şekil 4'te verilmiştir. Vejetasyon indisinin 4 dönemdeki değişimi Şekil 5'te gösterilmiştir. TGI ve LCI vejetasyon indeksi hariç diğer indeksler 4 dönemde lineer artış göstermiştir. NDVI, NDRE indeksine göre sulama programları arasında düşük lineer ilişki tespit edilmiştir. NDRE indeksinden dönemsel olarak daha başarılı sonuçlar elde edilmesi daha önceki yapılan benzer çalışmalarla örtüşmektedir (Becker ve ark., 2020). Çalışma alanına ait SAVI değerleri -0.51-0.94 aralığında değer almıştır. Yüzey altı damla sulama parsellerinin 3. dönem ortalama indeks değeri 0.45 olarak hesaplanmıştır. Taghvaeian ve ark. (2012)'e göre Mısır 0,64 SAVI değerinde tam örtüye ulaşmaktadır.

LCI indeksine ait sulama programları ve dönem farklılıkları Tablo 4'te, TGI indeksine ait sulama programları ve dönem farklılıkları Tablo 5'te, diğer indekslerin dönemsel farklılıkları Tablo 6'da sunulmuştur.



Şekil 4. Sulama Programlarına ait vejetasyon indekslerinin dönemsel tanımlayıcı istatistikleri.



Şekil 2. Sulama Programlarının dönemsel vejetasyon indeks değerleri.

Tablo 4. LCI indeksine Sulama Programlarının etkileri

Sulama Programı	Dönem 1 LCI1	Dönem 2 LCI2	Dönem 3 LCI3	Dönem 4 LCI4
	Ort. ± Std. Hata	Ort. ± Std. Hata	Ort. ± Std. Hata	Ort. ± Std. Hata
S1	-0.62 ± 0.048Bd	-0.57 ± 0.055Bc	0.11 ± 0.064Aab	-0.76 ± 0.052CBb
S2	-0.50 ± 0.048Bc	-0.55 ± 0.055Cb	0.13 ± 0.064Aa	-0.77 ± 0.052Db
S3	-0.52 ± 0.048Cc	-0.37 ± 0.055Ba	0.03 ± 0.064Ab	-0.60 ± 0.052Da
S4	-0.56 ± 0.048Bcd	-0.67 ± 0.055Cd	0.07 ± 0.064Aab	-0.78 ± 0.052Db
S5	-0.51 ± 0.048Bc	-0.69 ± 0.055Cb	0.13 ± 0.064Aa	-0.75 ± 0.052Cb
S6	-0.40 ± 0.048Bb	-0.36 ± 0.055Ba	0.02 ± 0.064Ab	-0.60 ± 0.052Ca
S7	-0.33 ± 0.048Ba	-0.43 ± 0.055Ca	0.10 ± 0.064Aab	-0.63 ± 0.052Da

* Büyük harfler her bir sulama programın da vejetasyon indeksler arası farklılığı, küçük harfler ise her bir vejetasyon indeksinde sulama programları arası farklılığı göstermektedir ($p<0.05$).

Sulama programları 1. Dönemde, S7 ile S1, S2, S3, S4, S5 ve S6 arasındaki fark istatistiksel olarak farklı bulunmuştur. 2. Dönemde, S7 sulama programı ile S1, S2, S4 ve S5 sulama programları arasında istatistiksel fark önemli bulunmuştur. 3. dönemde diğer dönemlere göre LCI indeksinin istatistiksel farkı önemli bulunmuştur. 3. Dönemde, sulama programları seviyesinde S2 ve S5, S3 ve S6 arasındaki fark istatistiksel olarak önemli bulunmuştur. 4. Dönemde, S7 sulama programı ile S1, S2, S4 ve S5 arasındaki fark önemli bulunmuştur. ET0 Penman Monteith yöntemine göre uygulanan deneme konularında LCI vejetasyon indeksi ile her dönemde S2, S4 ve S5 kontrole göre farklı bulunmuştur. Bu parsellere uygulanan sulama suyu miktarlarını her dönemde izlenmesinde başarılı şekilde kullanılabileceği belirlenmiştir. Zonal istatistiksel değerler kullanılarak bu ayrımın yapılabilmesi yaygın şekilde kullanımına olanak sağlamıştır. Mısır bitkisinde gelişme dönemine göre uygulanan deneme konularında başarılı bir şekilde izlenebileceği belirlenmiştir (Tablo 4).

Tablo 5. TGI indeksine Sulama Programlarının etkileri

Sulama Programı	Dönem1 TGI 1	Dönem 2 TGI 2	Dönem 3 TGI 3	Dönem 4 TGI 4
	Ort. ± Std. Hata	Ort. ± Std. Hata	Ort. ± Std. Hata	Ort. ± Std. Hata
S1	316.3 ± 81. 81Bd	332.4 ± 148,89Bab	852.0 ± 49.8Aa	19.6 ± 5.12Ca
S2	427.9 ± 81. 81Bd	510.3 ± 148,89Bb	890.6 ± 49.8Aa	27.3 ± 5.12Ca
S3	427.9 ± 81. 81Bcd	510.3 ± 148,89Ba	890.6 ± 49.8Aa	27.3 ± 5.12Ca
S4	314.7 ± 81. 81Bd	330.9 ± 148,89Bab	1022.3 ± 49.8Aa	20.6 ± 5.12Ca
S5	536.7 ± 81. 81Bc	287.5 ± 148,89Cb	938.8 ± 49.8Aa	19.2 ± 5.12Da
S6	758.7 ± 81. 81Bb	307.1 ± 148,89Cb	898.1 ± 49.8Aa	23.8 ± 5.12Da
S7	1036.8 ± 81. 81Aa	-59.7 ± 148,89Bc	924.6 ± 49.8Aa	28.5 ± 5.12Ba

* Büyük harfler her bir sulama programın da vejetasyon indeksler arası farklılığı, küçük harfler ise her bir vejetasyon indeksinde sulama programları arası farklılığı göstermektedir ($p<0.05$).

Sulama programları 1. dönemde, S3 ile S5 ve S6 sulama programı arasındaki fark istatistiksel olarak önemli bulunmuştur. 2. dönemde, S7 sulama programı ile diğer sulama programları arasındaki fark önemli bulunmuştur. 2. dönemde, S7 sulama programı ile diğer sulama programlarında istatistiksel fark önemli bulunmuştur. 1. dönemde, S7 sulama programı ile diğer sulama programları arasında istatistiksel fark önemli bulunmuştur. 2. dönemde, S3 ile S2, S5 ve S6 sulama programı arasındaki fark istatistiksel olarak önemli bulunmuştur. Bu parsellere uygulanan sulama suyu miktarlarını 1. ve 2. dönemde izlenmesinde başarılı şekilde kullanılabileceği belirlenmiştir. Zonal istatistiksel değerlerin kullanılarak bu ayrımın yapılabilmesi yaygın şekilde kullanımına olanak sağlamıştır. Mısır bitkisinde 1. ve 2. dönemine göre uygulanan deneme konularında başarılı bir şekilde izlenebileceği belirlenmiştir. 3. ve 4. dönemde TGI vejetasyon indeksi deneme konularına göre ayrımda sınırlı kalmıştır. Bu durumun zonal istatistik değerlerin kullanılmasından kaynaklandığı düşünülmektedir (Tablo 5).

Tablo 6. Vejetasyon indekslerine Sulama Programlarının dönemsel etkileri

VEJETASYON İNDEKSİ	DÖNEM 1 Ort. ± Std. Hata	DÖNEM 2 Ort. ± Std. Hata	DÖNEM 3 Ort. ± Std. Hata	DÖNEM 4 Ort. ± Std. Hata
NDVI	-0.40 ± 0.021C	-0.34 ± 0.035B	0.30 ± 0.064B	0.07 ± 0.064A
NDRE	-0.45 ± 0.004B	-0.44± 0.006B	0.06± 0.022A	0.06 ± 0.022A
MCARI	-2528.4 ± 243.1C	-1295.2 ± 407.7BC	2687.6 ± 863.9A	-1.7998 ± 22.99B
VARI	-0.06 ± 0.013B	0.02± 0.049B	0.15± 0.029A	0.16 ± 0.024A
GNDVI	-0.39 ± 0.021C	-0.32± 0.047C	0.20± 0.047A	-0.03 ± 0.048B
GRVI	-0.01 ± 0.011C	0.0017± 0.049B	0.11± 0.021A	0.11 ± 0.017A
SAVI	-0.61 ± 0.032C	0.51± 0.052C	0.45± 0.096A	0.11 ± 0.096B

*Büyük harfler her bir vejetasyon indeksinin gelişme dönemindeki farklılığını göstermektedir ($p<0.05$).

Çalışmada üzerinde durulan özellikler bakımından elde edilen veriler faktöriyel düzende tekrarlanan ölçümlü varyans analizi tekniği ile analiz edilmiştir. Çalışmada sulama programı faktörünün 7 seviyesi ve vejetasyon indeksi ölçüm metodu faktörünün 4 seviyesi aynı anda denenmiştir. Tekrarlanan ölçümler vejetasyon indeksi ölçüm metodunun seviyelerinde gerçekleştirilmiştir. LCI ve TGI vejetasyon indekslerinin sulama programlarına ve 4 dönemde istatistiksel olarak duyarlı olmasından dolayı kullanılabileceği belirlenmiştir (Tablo 7). Bunun nedeninin piksellerin ortalama değerlerinin kullanılmasından ve elde edilen değerlerin standart sapmalarının negatif ve pozitif değer almasından dolayı olduğu düşünülmektedir. Nitekim dönemsel olarak bitkilerin toprak yüzeyini kaplama oranı arttıkça vejetasyon indekslerinin kullanılabilirliğinin arttığı bilinmektedir (Zhang ve ark., 2019; Zhang ve ark., 2021).

3.3. Yüzey üstü damla sulama yöntemi

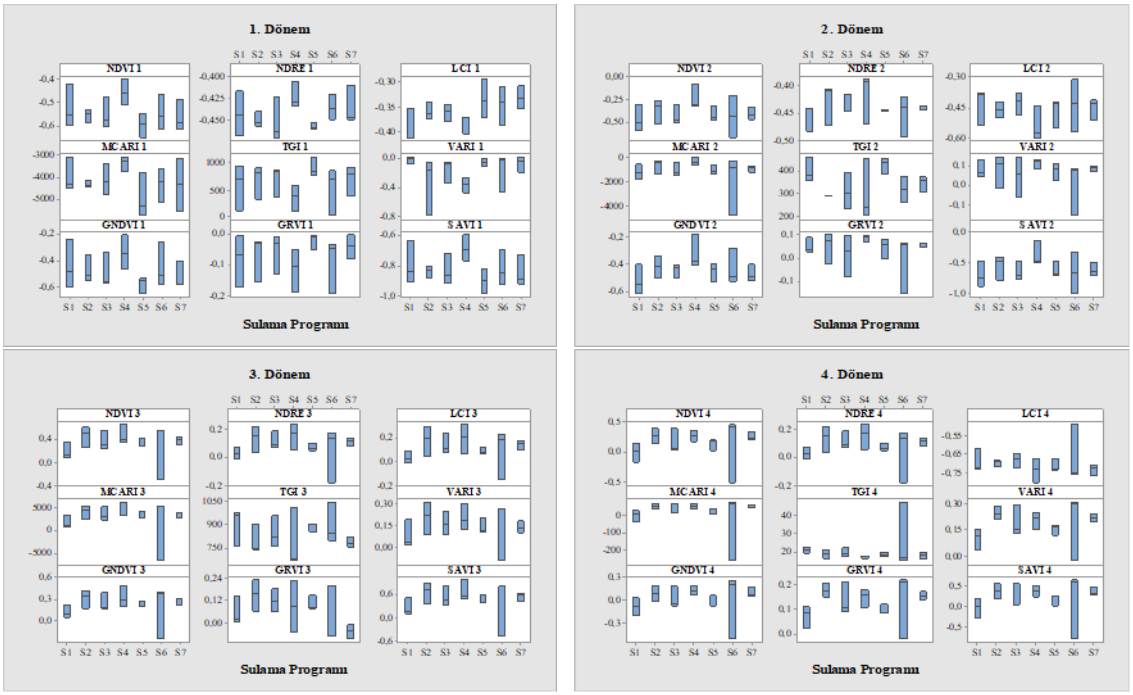
Sulama programlarına ait 9 indeks değeri elde edilmiştir. Yüzey üstü damla sulama yöntemi uygulanan sulama programlarına ait tanımlayıcı istatistik değerleri Şekil 6'da verilmiştir. Elde edilen vejetasyon indeks değerleri 1. ve 2. dönemde negatif değerler almıştır. Bu dönemlerde mısır bitkisinin vejetatif gelişimi düşük olduğu için sulama programı paralellerinde topraktan kaynaklı yansıma düşük olduğu için ortalama zonal istatistik değerleri negatif değerler almıştır. Bu dönemlerde mısır bitkisinin kapama oranı düşük olduğu için, sulama programlarında vejetasyon indeks değerlerinin topraktan yansıma değerlerini içeren piksellerin fazla olmasından kaynaklanmıştır. 3. ve 4. dönemde S6 (0.25) sulama programı haricinde sulama programı uygulanan parsellerde negatif değerler elde edilmiştir. 4. dönemde yüksek kapama oranından dolayı S6 dışında paraleller arası yakın değerler alarak deneme başına hata düşmüştür. Sulama programlarına ait vejetasyon indekslerinin 4 dönemdeki değişimi Şekil 7'de verilmiştir. TGI ve LCI vejetasyon indeksi hariç diğer indeksler 4 dönemde lineer artış göstermiştir. NDVI, NDRE indeksine göre sulama programları arasında düşük lineer ilişki tespit edilmiştir. NDRE indeksinin dönemsel olarak daha başarılı sonuçlar vermesi daha önceki yapılan çalışmalar ile benzerlik ifade etmektedir (Becker ve ark., 2020). Çalışma alanına ait SAVI değerleri 0.10-0.89 aralığında değer almıştır. Yüzey altı damla sulama yönteminde sulama programları ve dönemsel VARI indeksine ait sonuçlar verilmiştir (Tablo 7). VARI indeksine ait sulama programları ve dönem farklılıkları Tablo 7'de sunulmuştur. Diğer bitki indekslerinin dönemsel farklılıkları Tablo 8'de gösterilmiştir ($p<0.05$).

Tablo 7. VARI indeksine sulama programlarının etkileri

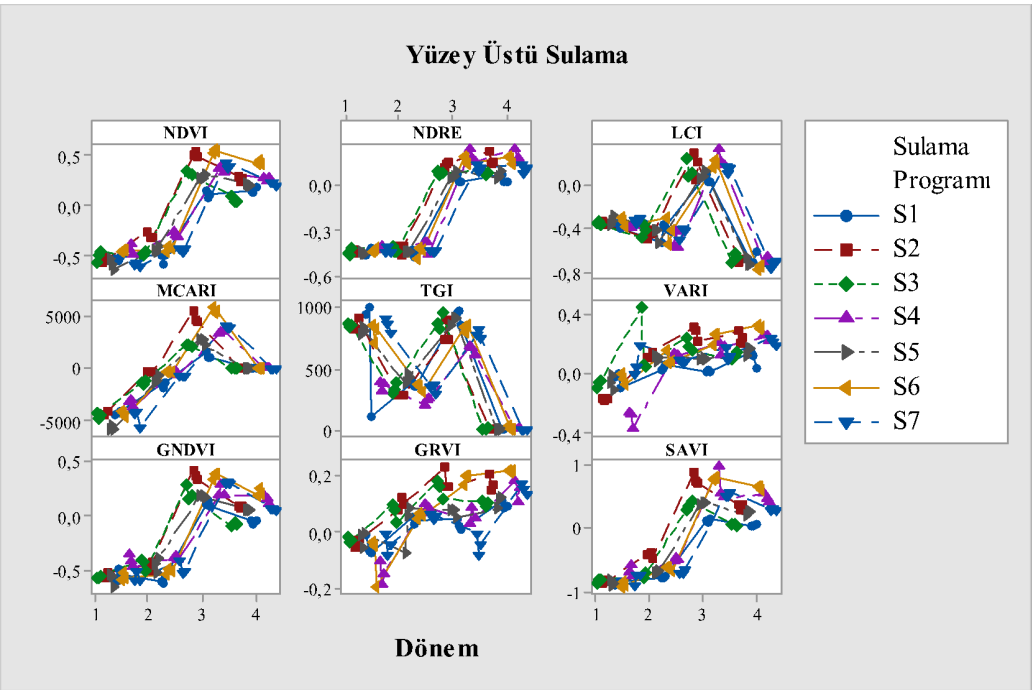
Sulama Programı	Dönem 1 VARI 1 Ort. ± Std. Hata	Dönem 2 VARI2 Ort. ± Std. Hata	Dönem 3 VARI 3 Ort. ± Std. Hata	Dönem 4 VARI 4 Ort. ± Std. Hata
S1	-0.03 ± 0.11Aa	0.07 ± 0.04Aa	0.07 ± 0.07Aa	0.10 ± 0.05Aa
S2	-0.33 ± 0.11Bc	0.08 ± 0.04Aa	0.206 ± 0.07Aa	0.24 ± 0.05Aa
S3	-0.16 ± 0.11Babc	0.05 ± 0.04Aba	0.16 ± 0.07Aa	0.19 ± 0.05Aa
S4	-0.37 ± 0.11Bbc	0.11 ± 0.04Aa	0.206 ± 0.07Aa	0.208 ± 0.05Aa
S5	-0.05 ± 0.11Aa	0.07 ± 0.04Aa	0.13 ± 0.07Aa	0.15 ± 0.05Aa
S6	-0.16 ± 0.11Babc	0.01 ± 0.04Aa	0.14 ± 0.07Aa	0.19 ± 0.05Aa
S7	-0.08 ± 0.11Bab	0.08 ± 0.04ABa	0.13 ± 0.07ABa	0.22 ± 0.05Aa

* Büyük harfler her bir sulama programın da dönemler arası farklılığı, küçük harfler ise her bir dönemde sulama programı uygulanan parseller arası farklılığı göstermektedir ($p<0.05$).

Yüzey üstü damla sulama yönteminde sulama programları ve dönemsel VARI indeksine ait sonuçlar verilmiştir ($p<0.05$). Sulama programları S1, S5'te dönemler arası fark görülmemiştir. Sulama programı S3, S4, S5 ve S6'da 1. dönem ile 2. 3. 4. dönem arasındaki fark istatistiksel olarak önemli bulunmuştur. Sulama programı S7 4. Dönem ve 1. Dönem arasındaki fark önemli bulunmuştur. Sulama programı S7 (kontrol)'e göre, 1. Dönem S2 sulama programı istatistiksel olarak fark önemli bulunmuştur. 3. ve 4. dönemde S7 (Kontrol) sulama programına göre sulama programı seviyelerinde istatistiksel olarak fark önemsiz çıkmıştır. 3. ve 4. dönemde VARI vejetasyon indeksi deneme konularına göre ayrımda sınırlı kalmıştır. Bu durumun zonal istatistik değerlerin kullanılmasından kaynaklandığı düşünülmektedir.



Şekil 6. Sulama Programlarına ait vejetasyon indekslerinin dönemsel tanımlayıcı istatistikleri.



Şekil 7. Sulama Programlarının dönemsel vejetasyon indeks değerleri.

Tablo 8. Vejetasyon indekslerine sulama programlarının dönemsel etkileri

VEJETASYON İNDEKSİ	DÖNEM 1 Ort. ± Std. Hata	DÖNEM2 Ort. ± Std. Hata	DÖNEM3 Ort. ± Std. Hata	DÖNEM4 Ort. ± Std. Hata
NDVI	-0.54 ± 0.015B	-0.39 ± 0.031B	0.33 ± 0.05A	0.16 ± 0.053A
NDRE	-0.44 ± 0.004B	-0.43 ± 0.006B	0.09 ± 0.021A	0.09 ± 0.021A
LCI	0.357±0.006B	0.460±0.017C	0.123±0.024A	0.704±0.016D
MCARI	-4208.2 ± 176.4C	-1038.5 ± 224.1B	3136.7 ± 636.5A	24.50 ± 16.80B
TGI	637.8 ± 70.3B	342.3 ± 15.1C	844.5 ± 24.7A	19.63 ± 1.54D
GNDVI	-0.47 ± 0.028C	0.43 ± 0.021C	0.24 ± 0.038A	0.04 ± 0.041B
GRVI	-0.06 ± 0.015C	0.04 ± 0.015B	0.08 ± 0.021AB	0.13 ± 0.014A
SAVI	-0.81 ± 0.02D	-0.59 ± 0.046C	0.50 ± 0.075A	0.25 ± 0.079B

Dönemsel olarak elde edilen SAVI, TGI, LCI indekslerinin vejetasyon dönemini izlemede istatistiksel olarak anlamlı sonuçlar verdiği tespit edilmiştir. Diğer indekslerde için 1. ve 2. dönem ile 3. ve 4. dönem arasında istatistiksel olarak farklılık önemli bulunmuştur ($p<0.05$). Yeşil bandın yansıması sağlıklı bitki örtüsünün bir göstergesidir. Yeşil yansıma kapasitesinin kuraklık stresini tespit etme kapasitesinin bir sonucu olarak, bu bandı kullanan birkaç vejetasyon indeksi önerilmiştir (Zhang ve ark, 2019; Zhang ve ark., 2021). Bu çalışma için kullanılan yeşil spektral bant dahil NDVI, NDRE, LCI, MCARI, TGI, VARI, GNDVI, GRVI ve SAVI indekslerinin kısıtlı sulama uygulanan mısır parsellerinde farklı sulama yöntemlerine göre etkileri değerlendirilmiştir. NDRE, Normalize Edilmiş Fark Vejetatif İndeksi (NDVI) ile hesaplamada yöntemi aynıdır. Ancak, NDVI'da kullanılan ortalama kırmızı bant yerine ortalama kırmızı kenar bandı kullanılmaktadır. Görünür bölge yansıma spektrumunun kırmızı kenarlı bölgesi, klorofilin radyasyonu absorbe etmediği bitki örtüsünün yansımasında hızlı artış gösteren bir bölge olduğu belirtilmektedir (Gitelson ve Merzlyak, 1994). Yakın kızılötesi ve görünür bölge bantlar ile üretilen vejetasyon indeksleri toprak yansıması da dikkate alınarak küçük işletmelerin arazilerindeki sulama seviyelerini ek bir düzeltme faktörü ihtiyacı hissetmeden belirlemede kullanılabileceği çalışma ile ortaya konulmuştur.

Çiftlik ölçeğinde, bitki su stresinin takibi genellikle zordur. Uydu ve uçak platformları ile uzaktan algılama, yüksek işletim zorluğu ve yüksek işletme maliyeti gibi dezavantajlara sahiptir (Zhao, 2014; Han ve ark., 2018; Zhang ve ark., 2019; Müjdeci ve ark., 2020; Demir ve Başayiğit, 2020; Zhang

ve ark., 2021). İnsansız hava aracı (İHA) uzaktan algılama sistemi, mahsul bilgilerini istenen bir uzamsal ve zamansal çözünürlükte toplanması bitki su stresini ve su kısıtını çiftlik ölçeğinde hızlı ve titizlikle izlenmesine olanak sağlayacağı belirlenmiştir. Diğer uzaktan algılama yöntemlerine göre küçük ölçekli alanlarda yapılan tarımsal uygulamaların, İHA ile izlenmesi ve takip edilmesinde önemli avantajlara sahip olması tarımsal amaçlı kullanımlarının arttıracağını göstermektedir.

4. Sonuç

Bu çalışma ile, İHA platformlarındaki yüksek uzamsal çözünürlüğe sahip Multispektral sensör kullanılarak kısıtlı sulama uygulanan parsellerin multispektral görüntülerinden (B, G, R, RE, NIR) türetilen vejetasyon indeksleri ile farklı sulama yöntemlerinin izlenebilirliği ve tarımsal uygulamalarda kullanılabilirliği belirlenmiştir. Yüzey altı damla sulama yönteminde LCI ve TGI indeksleri, yüzey üstü damla sulama yönteminde VARI indeksi S7 (Kontrol) programına göre, diğer ET0'a göre hesaplanan sulama seviyelerindeki uygulanan sulama suyu miktarlarında mısır bitkisi için daha kullanışlı olduğu belirlenmiştir ($p<0.05$).

Standart Yağış İndeksi (SPI) ile hesaplanan Normale Yakın Kuraklık kategorisi içerisindeki ayların görüldüğü bölgeler için sulama yöntemlerinde ve sulama programlarında silajlık mısır gelişiminin takip edilmesi ve su ihtiyacı kritik seviyelerinin belirlenmesi çalışmalarının gerekliliğini ortaya koymak için uygulanan yaklaşımın kullanılabilir olduğu sonucuna varılmıştır.

Multispektral sensör bulunan İHA'lara sahip yerel çiftçiler için, silajlık mısır bitkisinin sulama seviyelerinde izlenmesi ve değerlendirmesini gerçekleştirmek için önemli sonuçlar ortaya konulmuştur. İHA sensörlerine belirtilen indeks değerini hesaplayan algoritmaların programlanması ile çiftçiler için daha kullanılabilir hale gelebileceği düşünülmektedir. Çalışmaların, sulama suyu seviyesi ve arazi koşullarında elde edilen verilerin değerlendirilmesinde dijital tarım teknikleri yönünden katkı sağlayacağı beklenmektedir. Nitekim bu çalışma, Akıllı Tarım, Hassas Tarım, Organik Tarım ve İyi Tarım uygulamalarında İHA kullanımlarına yönelik bir alternatif uygulama örneği olmuştur.

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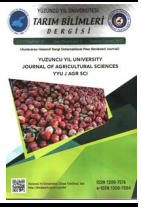

Araştırma Makalesi (Research Article)

İstanbul Piyasasında Satılan Soğuk Pres Yağların Kimyasal Özelliklerinin Belirlenmesi

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Anahtar Kelimeler
Soğuk pres yağlar,
FFA,
Peroksit değeri,
Yağ asit kompozisyonu,
İyot sayısı.

Öz: Bitkisel yağlar, yüksek besleyici özellikleri ile insan beslenmesinde büyük öneme sahiptir. Günümüzde başta çörek otu olmak üzere soğuk pres yağlara talep, her geçen gün artmaktadır. Bu çalışmada gıda takviyesi olarak tüketilen ve soğuk pres özelliği vurgulanarak satılan yağların, bazı kalite ve karakteristik özelliklerinin gıda güvenliği açısından değerlendirilmesi amaçlanmıştır. Çalışmada İstanbul piyasasında satışa sunulan altı marka ve dört çeşit (çörek otu, rüşeym, üzüm çekirdeği ve kayısı çekirdeği) numunenin, % serbest yağ asitliği (FFA), peroksit değerleri (PV), yağ asitleri kompozisyonları ve iyot sayıları incelenmiştir. Analiz sonuçlarına göre yağların ortalama FFA değerleri, çörek otunda % 8.1, rüşeymde % 1.43, üzüm çekirdeğinde % 1.90 ve kayısı çekirdeğinde % 4.31; ortalama PV (meq O_2/kg yağ) değerleri ise, çörek otunda 24.30, rüşeymde 21.42, üzüm çekirdeğinde 12.39, kayısı çekirdeğinde 26.23 olarak tespit edilmiştir. Numunelerin toplam (Σ) SFA, MUFA, PUFA değerleri sırasıyla, çörek otunda % 7.14-11.42, % 16.43-42.78, % 29.09-48.81; rüşeymde % 6.83-11.35, % 22.64-51.87, % 22.27-54.87; üzüm çekirdeğinde % 6.89-11.86, % 22.68-41.82, % 30.76-44.27; kayısı çekirdeğinde % 5.62-10.29, % 22.58-59.24, % 21.15-43.93 aralıklarında değiştiği tespit edilmiştir. Ortalama iyot sayıları (g I_2/100 g yağ) ise, çörek otunda 95.17, rüşeymde 97.58, üzüm çekirdeğinde 99.00 ve kayısı çekirdeğinde 92.62 olarak hesaplanmıştır. İncelenen numunelerden sadece üzüm çekirdeği yağı, Türk Gıda Kodeksi'nde yer aldığından, diğer numunelerin değerlendirilmesi Kodeks'e göre yapılamamıştır. Üzüm çekirdeği yağı numunelerinden 2 adedinin PV değerinin, 3 adedinin ise FFA değerinin tebliğe göre uygun olmadığı tespit edilmiştir. Numune analizlerinden elde edilen sonuç farklılıklarının hammadde kalitesi ve depolama koşulları, proses şartları ve son ürün muhafaza koşullarından kaynaklandığı düşünülmektedir.

Determination of Chemical Properties of Cold Pressed Oils Sold in Istanbul Market

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Cold pressed oils,
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Abstract: Vegetable oils are important in human nutrition with their nutritional properties. Today the demand for cold pressed oils, especially black cumin, is increasing day by day. In this study, it was aimed to evaluate the quality and characteristics of the oils consumed and sold by highlighted as cold pressed as food supplements in terms of food safety. In the study, % free fatty acidity (FFA), peroxide values (PV), fatty acid compositions and iodine numbers of samples (six brands and four varieties; black cumin, wheat germ, grape seed and apricot kernel) sold in the Istanbul market were investigated. According to results, average FFA values were 8.1% in black cumin, 1.43% in germ, 1.90% in grape

Peroxide values,
Fatty acids composition,
Iodine value.

seed, 4.31% in the apricot kernel. Average PVs (meq O_2 kg^{-1} oil) were 24.30 in black cumin, 21.42 in germ, 12.39 in grape seed, 26.23 in the apricot kernel. Total(Σ) SFA, MUFA, PUFA values were determined between 7.14-11.42%, 16.43-42.78%, 29.09-48.81% in black cumin; 6.83-11.35%, 22.64-51.87%, 22.27-54.87% in germ; 6.89-11.86%, 22.68-41.82%, 30.76-44.27% in grape seed; 5.62-10.29%, 22.58-59.24%, 21.15-43.93% in apricot kernel, respectively. Also, average iodine numbers (g I_2 / 100 g oil) were calculated 95.17 in black cumin, 97.58 in germ, 99 in grape seed, 92.62 in the apricot kernel. Since only grape seed oil is included in the Turkish Food Codex, evaluation of the other samples couldn't be made according to the Codex. It was determined that the PV value of 2 grape seed oil samples and the FFA value of 3 samples were not suitable according to the communiqué. The differences in the analysis results are thought to be caused by raw material quality and storage, process and final product storage conditions.

1. Giriş

Bitkisel yağlar gerek biyoaktif gerekse yüksek besleyici özelliğiyle insan beslenmesinde önemli bir gıda maddesidir. İnsanlar, günlük besin ihtiyacının % 25'ini yağlardan karşılamaktadır (Akoh ve Min, 2008; Demirci, 2012). Meyve ya da tohumlarından elde edilen bitkisel yağlar tüketiciye gelene kadar pek çok aşamadan geçmektedir. Bu aşamalarda yağların besin değeri ve önemli biyoaktif bileşenleri kayba uğramaktadır. Soğuk preslenmiş yağlar; doğrudan tüketime uygun olan, ısıl işlem olmaksızın sadece mekanik yöntemle elde edilen ve su ile yıkanarak, çökeltme, filtreleme ya da santrifüj işlemleri uygulanarak saflaştırılan yağlar olarak tanımlanır (CAC,1999; TGK, 2020). Soğuk pres yöntemiyle elde edilen yağlar yüksek sıcaklıklara maruz kalmazlar, küspe sıcaklığının sürtünme etkisiyle maksimum 50 °C'ye çıkması, yağın ise maksimum 37 °C'de işlem görmesi sağlanır (Gurgenova ve Wawrzyniak, 2012; Panfilis ve ark., 1998).

Çörek otu, buğday rüşeymi, üzüm çekirdeği ve kayısı çekirdeği yağlarının biyoyararlılıkları üzerine *in-vitro* ve *in-vivo* pek çok çalışma mevcuttur. Doymamış yağ asitleri, uçucu bileşikler, fitosterol ve E vitamini içerikleriyle zengin olan bu yağların antihiperlipidemik, antioksidatif, antikanserojenik, antiinflamatuar, antimikrobiyel özellikleri bilinmektedir (Arıcı ve ark., 2005; Çakmakçı ve Çakır, 2011; Çetinyürek, 2012). Bu özelliklerinden dolayı, son dönemlerde soğuk pres yağlar (değerli yağlar) üzerine çalışmalar artmıştır. Günümüzde, özellikle aktarlarda soğuk pres adı altında çeşitli yağlar satılmaktadır. Ancak söz konusu yağların etiket bilgilerinin yetersizliği, satılan tüm yağ çeşitlerinin Kodekste yer almaması gıda güvenliği açısından risk oluşturmaktadır.

Bu nedenle çalışmamızda piyasada gıda takviyesi olarak kullanılan ve en çok satılan soğuk pres yağların hem gıda güvenliği açısından risk oluşturup oluşturmadığının incelenmesi hem de bu yağların standart kalitede üretimlerinin gerçekleştirilebilmesi için ilgili tebliğde limit değerlerinin belirlenmesi gerekliliğinin ortaya konulması amaçlanmıştır.

Bu çalışmalardan elde edilen sonuçlar ve literatür değerleri hammaddenin, ambalajın, proses koşullarının, depolamanın ve kontrolsüz üretimin, elde edilen soğuk pres yağların tüketilebilirliği, kalitesi ve raf ömrü üzerine son derece önemli olduğunu göstermektedir.

2. Materyal ve Yöntem

2.1. Materyal

Bu çalışmada İstanbul'un farklı ilçelerindeki (Fatih, Bakırköy ve Güngören) aktarlardan alınan altı farklı yerli markaya ait satış hacmi hızlı dört çeşit yağ numunesi (çörek otu, buğday rüşeymi, üzüm çekirdeği ve kayısı çekirdeği yağı) materyal olarak kullanılmıştır. Yağ numuneleri üretim ve son kullanma tarihleri arasında en fazla bir ay süre olacak şekilde temin edilmiştir.

2.2. Metot

24 adet numuneye ait tüm analizler ikişer paralel olarak gerçekleştirilmiştir.

2.2.1. % Serbest Yağ Asitliği (FFA) ve Peroksit Değeri (PV)

Çalışmada numunelerin % serbest yağ asitliği (FFA) ve peroksit değerleri (PV) klasik titrimetrik yöntemlerle belirlenmiştir (TSE, 2015; 2017).

2.2.2. Yağ Asitleri Kompozisyonu Analizi

Yağ asitleri kompozisyonu, Thermo Scientific Trace 1300 Gaz Kromatografisi cihazında (AOAC, 2017a) metoduna göre belirlenmiştir.

2.2.3. İyot Sayısı

İyot sayısı yağ asitleri kompozisyonundan faktör katsayısından yararlanılarak direkt olarak hesaplanmıştır (Petursson, 2002; AOAC, 2017b).

2.2.4. İstatistiksel Analiz

Elde edilen veriler arasındaki farklar, JMP 6.0 programı kullanılarak $p<0.05$ anlamlılık düzeyinde bağımsız "t" testi ve tek yönlü varyans analizi ile belirlenmiştir.

3. Bulgular ve Tartışma

Çalışmamıza ait numunelerin serbest asitlik (% FFA) değerleri Çizelge 1'de verilmiştir. Çizelge 1 incelendiğinde çörek otu yağının % FFA değeri, en düşük % 3.35 ile C markasında, en yüksek değer ise % 11.88 ile D markasında tespit edilmiştir. Pakistan'da yetişen çörek otunun farklı cinsleri üzerine yapılan bir araştırmada, çörek otu yağının % FFA değerlerinin; % 4.7 ile % 20.5 arasında değiştiği bildirilmektedir (Sultan ve ark., 2009). Yapılan başka bir araştırmada, Tunus ve İran'da yetişen çörek otundan hekzan ile ekstrakte edilmiş yağın % FFA değerleri sırasıyla % 22.7 ve %18.6 olarak saptanmıştır (Aftab ve ark., 2014). Kiralan ve ark.'nın (2014), çörek otu yağının soğuk pres, soxhlet ve mikrodalga destekli ekstraksiyonla eldesi üzerinde yaptığı araştırmaya göre, % FFA değerleri sırasıyla; % 7.5, % 9.28 ve % 9.51 arasında tespit edilmiştir. Mohammed ve ark.'nın (2016), yaptığı çalışmaya göre ise soğuk pres ektraksiyonla elde edilen çörek otu yağında % FFA değeri % 6.15 bulunmuştur. Çalışmamıza ait sonuçlar literatür çalışmaları ile benzerlik göstermektedir.

Çizelge 1'deki değerlere göre, buğday rüşeymi yağlarında % FFA en düşük % 0.56 (E markası), en yüksek % 1.94 (F markası) olup, altı markanın ortalama % FFA ise % 1.43'tür. Eisenmenger'in (2005), rüşeymlerden süperkritik akışkan (SFE) ve hekzan ekstraksiyonlarıyla yağ elde ettiği çalışmasında % FFA, SFE'de % 6.2; hekzan ekstraksiyonunda ise % 7.9 olarak saptamıştır. Mahmoud ve ark. (2015)'nın, Mısır orijinli buğday rüşeymlerinden hekzan ekstraksiyonuyla elde edilen yağlarında ise % FFA değeri % 8.33 olarak tespit edilmiştir. Çalışmamızda incelenen numunelerin % FFA değerleri literatürdeki değerlere göre düşüktür.

Üzüm çekirdeği yağlarının %FFA değerleri incelendiğinde en düşük % 0.31 (B markası), en yüksek %3.31 (A markası) ve ortalama % 1.89 değeri tespit edilmiştir. El-Shami ve ark.'nın (1992), Mısır orijinli üzümlerden elde ettikleri yağların % FFA değerinin % 3.45 olduğunu bildirmektedir. Yousefi ve ark. (2013), İran orijinli iki farklı üzüm çeşidi yağlarının % FFA değerlerini % 0.61 ve % 0.67, Chander (2010) ise çalışmasında % FFA değerini % 0.7 olarak tespit etmiştir. Çalışmamıza ait sonuçlar literatür çalışmaları ile benzerlik göstermektedir.

Çizelge 1'deki değerlere göre, kayısı çekirdeği yağlarında % FFA değeri en düşük % 1.09 (E markası), en yüksek % 11.85 (D markası) olup, altı markanın ortalama değeri ise % 4.27'dir. Pakistan'da Manzoor ve ark. (2012) hekzan ekstraksiyonu ile elde edilen çekirdek yağlarında % FFA değerini % 0.41- 1.28 arasında, Hussain ve ark. (2011) mekanik presleme ile elde edilen acı kayısı çekirdeği yağlarında %7.80, tatlı kayısı çekirdekleri yağlarında ise % 7.76 olarak tespit etmişlerdir. Pavlovic ve ark. (2018), soğuk pres kayısı çekirdeği yağında % FFA değerinin % 1.77, süperkritik ile ekstrakte edilen yağda ise % 1.88 olduğunu bildirmektedir.

Çalışmamızdaki numunelerin % FFA değerlerinin literatürdeki değerlere yakın olduğu görülmüştür. İstatistiksel olarak % FFA değerlerinde anlamlı düzeyde farklılar belirlenmiştir ($p<0.05$).

% FFA değerleri üzerine hammaddenin orjini, hasattan sonra bekleme süresi, depolama koşulları ve elde edilme proses yöntemlerinin etkili olduğu görülmektedir.

TGK Bitki Adı ie Anılan Yağlar Tebliği'nde çalışmamızda incelenen üzüm çekirdeği yağı dışındaki yağlar yer almadığı için, sadece üzüm çekirdeği yağı analiz değerleri tebliğ ile kıyaslanmıştır. Buna göre altı numuneden üçünün % FFA değeri (mg KOH / g yağ) limit dışında tespit edilmiştir.

Çizelge 1. Farklı markalardaki çörek otu, buğday rüşeymi, üzüm çekirdeği ve kayısı çekirdeği yağlarının % FFA değerleri (n:24)

	% FFA			
Numune	**Çörek Otu Yağı**	**Buğday Rüşeymi Yağı**	**Üzüm Çekirdeği Yağı**	**Kayısı Çekirdeği Yağı**
A	9.43 ± 0.01^{C}	1.68 ± 0.13^{B}	3.12 ± 0.03^{B}	4.39 ± 0.01^{B}
B	0.95 ± 0.08^{B}	0.95 ± 0.01^{C}	0.31 ± 0.04^{F}	1.17 ± 0.07^{D}
C	3.35 ± 0.04^{E}	1.78 ± 0.04^{B}	0.78 ± 0.01^{E}	2.87 ± 0.08^{C}
D	11.88 ± 0.22^{A}	1.71 ± 0.03^{B}	3.30 ± 0.10^{A}	11.85 ± 0.08^{A}
E	6.89 ± 0.12^{D}	0.56 ± 0.01^{D}	0.90 ± 0.03^{D}	1.09 ± 0.03^{D}
F	7.19 ± 0.29^{D}	1.94 ± 0.04^{A}	2.90 ± 0.04^{C}	4.24 ± 0.04^{B}
Ort.	**8.10**	**1.44**	**1.89**	**4.27**

Değerler ortalama±standart sapma şeklinde verilmiştir. Küçük harfler dört çeşit yağ arasındaki farkı; büyük harfler aynı yağın markalar arasındaki farkı göstermektedir ($p<0.05$).

Numunelere ait peroksit değerleri Çizelge 2'de verilmiştir. Çizelge 2 değerlendirildiğinde çörek otu yağında peroksit değerinin en düşük 5.08 meq O_2/kg yağ (C markası), en yüksek 46.34 meq O_2/kg yağ (E markası), ortalama değerin ise 24.30 meq O_2/kg yağ olduğu tespit edilmiştir. Sultan ve ark. (2009), çörek otu yağ karışımları üzerine yaptıkları çalışmada peroksit değerinin 5.7 meq O_2/kg yağ olduğunu bildirmektedir. Kiralan ve ark. (2014) ise, soğuk pres, soxhlet ekstraksiyon ve mikrodalga destekli ekstraksiyon yöntemi ile elde edilen çörek otu yağının peroksit değerlerini sırası ile 31.32 meq O_2/kg yağ, 25.23 meq O_2/kg yağ, 21.45 meq O_2/kg yağ olarak tespit etmişlerdir. Peroksit değeri üzerine sıcaklığın etkisi ile ilgili yapılan bir çalışmada, çörek otu yağı 3 hafta süresince 60°C sıcaklıktaki fırında bekletilmiş ve peroksit değeri başlangıç seviyesi 51 meq O_2/kg yağ iken, 64.5 meq O_2/kg yağ'a ulaşmıştır (Ramadan ve Mörsel, 2004). Mohammed ve ark. (2016) ise, soğuk pres ile çörek otu yağ eldesinde peroksit değerini 4.1 meq O_2/kg yağ bulmuşlardır.

Rüşeym yağının peroksit değerleri incelendiğinde, en düşük değerin 11.17 meq O_2/kg yağ (C markası), en yüksek değerin 44.32 meq O_2/kg yağ (F markası), ortalama değerin ise 21.42 meq O_2/ kg yağ olduğu belirlenmiştir. Mahmoud ve ark. (2015) rüşeym yağının peroksit değerini 16.35 meq O_2/kg yağ, Wang ve Johnson (2001) ise 20 meq O_2/kg yağ olduğunu bildirmektedir. Megahed (2011), Mısır orjinli buğdaydan elde edilen rüşeym yağlarını oda sıcaklığında 7 gün bekleterek peroksit değerlerini ölçmüş ve değerleri 1.71-19.48 meq O_2/kg yağ aralığında saptamıştır. Zou ve ark. (2018) çalışmalarında, kavrulmamış buğday rüşeymi yağında peroksit değerlerini, 0-110 meq O_2/kg yağ aralığında ve 180 °C'de 5, 10 ve 20 dk sürelerle kavrulmuş üç örnekte ise 0-140 meq O_2/kg yağ aralığında değiştiğini tespit etmiştir.

Üzüm çekirdeği yağında peroksit değerlerine bakıldığında, en düşük değer 6.06 meq O_2/kg yağ (A markası), en yüksek değer 27.81 meq O_2/kg yağ (F markası), ortalama değer ise 12.39 meq O_2/kg yağ olarak tespit edilmiştir. Üzüm çekirdeği yağının peroksit değeri ile ilgili yapılan diğer çalışmalarda El-Shami ve ark. (1992),8.5 meq O_2/kg yağ, Chander (2010) 13.5 meq O_2/kg yağ, Yousefi (2013) ise, farklı iki çeşit İran üzümünden elde edilen yağın peroksit değerlerini 9.30 ve 10.63 meq O_2/kg yağ olduğunu bildirmişlerdir.

Çalışmamızdaki numunelerin peroksit değerlerinin literatürdeki değerlere yakın olduğu tespit edilmiştir. İstatistiksel olarak yapılan değerlendirmede peroksit değerleri arasında anlamlı düzeyde farklılıklar belirlenmiştir ($p<0.05$). TGK Bitki Adı İle Anılan Yağlar Tebliği'nde çalışmamızda incelenen üzüm çekirdeği dışındaki yağlar yer almadığı için, sadece üzüm çekirdeği yağı analiz değerleri tebliğ ile kıyaslanmıştır. Buna göre altı numuneden ikisinin peroksit değeri (miliekivalen aktif oksijen/kg yağ) limit dışında tespit edilmiştir.

Kayısı çekirdeği yağının peroksit değerlerine bakıldığında en düşük değerin 1.1 meq O_2/kg yağ (A markası), en yüksek 97.79 meq O_2/kg yağ (E markası), ortalamanın ise 26.23 meq O_2/kg yağ olduğu Çizelge 2'de görülmektedir. Manzoor ve ark. (2012), Pakistan'da hekzan ekstraksiyonu ile elde edilen çekirdek yağlarında peroksit değerini 1.00-2.32 meq O_2/kg yağ arasında, Hussain ve ark. (2011) mekanik presleme ile elde edilen acı kayısı çekirdeği yağlarında 4.9 meq O_2/kg yağ, tatlı kayısı çekirdekleri yağlarında ise 5.0 meq O_2/kg yağ olarak tespit etmişlerdir. Pavlovic ve ark. (2018), soğuk pres kayısı çekirdeği yağında peroksit değerini 0.49 meq O_2/kg yağ, süperkritik ile ekstrakte edilen yağda ise 0.48 meq O_2/kg yağ olarak bildirmektedir. Durmaz (2008), Malatya orijinli farklı düzeylerde kavurma işlemine tabi tutularak hekzan ve petrol eteri karışımı ekstraksiyonuyla elde edilen yağlarının peroksit değerlerinin 103 meq O_2/kg yağ'a kadar ulaştığını belirlemiştir.

Çizelge 2. Farklı markalardaki çörek otu, buğday rüşeymi, üzüm çekirdeği ve kayısı çekirdeği yağlarının peroksit değerleri (PV) (n:24)

Numune	Çörek Otu Yağı	Buğday Rüşeymi Yağı	Üzüm Çekirdeği Yağı	Kayısı Çekirdeği Yağı
A	7.94 ± 0.28^{D}	17.74 ± 0.21^{CD}	6.06 ± 0.11^{D}	1.10 ± 0.14^{E}
B	14.28 ± 0.13^{C}	20.22 ± 0.30^{B}	8.88 ± 0.12^{C}	13.15 ± 0.31^{C}
C	5.08 ± 0.12^{D}	11.17 ± 1.11^{E}	6.27 ± 0.14^{D}	1.70 ± 0.13^{E}
D	36.36 ± 0.11^{B}	18.89 ± 0.01^{BC}	6.41 ± 0.42^{D}	5.10 ± 0.13^{D}
E	46.34 ± 5.29^{A}	16.18 ± 1.39^{D}	18.91 ± 0.23^{B}	97.79 ± 0.36^{A}
F	35.80 ± 0.61^{B}	44.32 ± 0.28^{A}	27.81 ± 0.42^{A}	38.55 ± 1.50^{B}
Ort.	**24.30**	**21.42**	**12.39**	**26.23**

Değerler ortalama±standart sapma şeklinde verilmiştir. Küçük harfler dört çeşit yağ arasındaki farkı; büyük harfler aynı yağın markalar arasındaki farkı göstermektedir ($p<0.05$).

Çörek otu yağı numunelerine ait iyot sayısı ve yağ asitleri kompozisyonu, Çizelge 3' te verilmiştir. Çizelge 3 incelendiğinde bir numune dışında (B markası) diğer tüm numunelerde en yüksek miktarda linoleik asit (ort. % 37.62), dört numunede omega-3 yağ asitlerinden Eikozapentaenoik Asit (**EPA**), bir numunede ise Dokozahekzaenoik Asit (**DHA**) tespit edilmiştir. Toplam doymuş yağ asitleri (**SFA**) en yüksek % 11.42 (E markası), en düşük % 7.14 (F markası), ortalama değerin ise % 9.26 olduğu saptanmıştır. Numunelerin tekli doymamış yağ içeriği (**MUFA**) için en yüksek % 42.78 (F markası), en düşük % 16.43(A markası) ve ortalama değerin % 27.94 olduğu, çoklu doymamış yağ içeriği (**PUFA**) için ise en yüksek % 48.81 (E markası), en düşük % 29.09 (B markası), ortalama değerin ise % 40.23 olduğu belirlenmiştir.

Çalışmalarda çörek otu yağının linoleik asit miktarının % 51.8-57.49 arasında, oleik asit miktarını % 23.95- 28.55 arasında ve linolenik asit miktarının ise % 0.25 olduğu bildirilmektedir. (Aftab ve ark., 2014; Kiralan ve ark., 2014). Diğer araştırmalardan farklı olarak numunelerimizin dört adedinde omega-3 yağ asitlerinden EPA, bir adedinde ise DHA tespit edilmiştir. SFA, MUFA ve PUFA değerlerine bakıldığında tüm numunelerin SFA değerleri, Kiralan ve ark (2014)'nın çalışmalarına yakın; PUFA değerleri, Aftab ve ark (2014)'nın çalışmalarına yakın; MUFA değerlerinin ise farklı olduğu görülmüştür.

Çalışmamızdaki çörek otu yağı numunelerinin iyot sayılarının 85.04 ile 106.7 arasında değiştiği tespit edilmiştir. Sultan ve ark. (2009), Pakistan cinsi çörek otundan elde edilen yağın iyot sayısının 112.32 olduğu, Üstün ve ark. (1998) ise Kütahya, Denizli ve Konya'da yetişen çörek otu yağının iyot sayısının sırası ile 116.63, 112.32 ve 122.13 olduğunu bildirmektedir. Mohammed ve ark. (2016), soğuk pres ekstraksiyonla çörek otu yağ eldesinde iyot sayısını 104.37 olarak tespit etmiştir.

Rüşeym yağı numunelerinin iyot sayısı ve yağ asitleri kompozisyonu, Çizelge 4'te verilmiştir. Çizelge 4 incelendiğinde, üç markada (A, C ve F) linoleik asit (ort. 36.29), en yüksek oranda çıkan yağ asididir. Diğer üç markada (B, D ve E) ise, oleik asit konsantrasyonu (ort. 34.18) yüksektir. Ayrıca, iki numunede **EPA** tespit edilmiştir. Örneklerin linolenik asit miktarı ise %1'in altında tespit edilmiştir. **SFA** değerlerinin en yüksek % 11.35 (F markası) ve en düşük % 6.83 (E markası) olarak tespit edilirken, ortalama değerin % 9.06 olduğu görülmüştür. Numunelerin **MUFA** içeriğinin en yüksek % 51.87 (D markası), en düşük % 22.64 (F markası) ve ortalama değerin % 36.52 olduğu; **PUFA** değerinin ise en yüksek % 54.87 (A markası), en düşük % 22.27 (E markası) ve ortalama değerin ise % 37.66 olduğu tespit edilmiştir.

Çizelge 3. Farklı markalardaki çörek otu yağlarının iyot sayıları ve yağ asitleri kompozisyonları (n:6)

Yağ Asitleri Kompozisyonu (%)	**A**	**B**	**C**	**D**	**E**	**F**	**Ort.**
C14:0	0.10	TE	0.07	TE	0.12	TE	**0.10**
C16:0	8.52	5.44	5.51	8.09	9.00	7.00	**7.26**
C16:1	0.15	0.16	TE	0.17	0.15	TE	**0.16**
C18:0	2.24	2.08	2.36	2.16	2.30	TE	**2.23**
C18:1	16.12	36.05	22.78	28.96	15.98	20.23	**23.35**
C18:2	40.38	27.69	41.92	40.03	46.36	29.34	**37.62**
C18:3 (cis-6,9,12)	0.15	0.19	0.17	0.19	0.15	0.32	**0.20**
C18:3 (cis-9,12,15)	0.22	0.43	0.15	0.54	0.25	0.39	**0.33**
C20:0	TE	0.25	TE	0.17	TE	0.14	**0.19**
C20:1	0.16	1.35	0.09	2.04	0.67	22.55	**4.48**
C20:2	1.72	0.23	0.53	1.55	1.99	0.98	**1.17**
C20:3	TE	0.28	0.37	0.13	TE	TE	**0.26**
C20:4	TE	0.17	TE	0.09	TE	0.32	**0.19**
C20:5	TE	0.10	1.14	0.06	0.06	TE	**0.34**
C22:6	TE	TE	TE	TE	TE	3.78	**3.78**
ΣSFA	10.86	7.77	7.94	10.42	11.42	7.14	**9.26**
ΣMUFA	16.43	37.56	22.87	31.17	16.80	42.78	**27.94**
ΣPUFA	42.47	29.09	43.28	42.59	48.81	35.13	**40.23**
İyot sayısı (g I_2/ 100 g yağ)	85.04	85.13	99.27	98.85	96.00	106.70	**95.17**

TE: Tespit edilmedi.

Literatürdeki bazı çalışmalara göre rüşeym yağının linoleik asit miktarı % 54.88- 59.7 arasında; oleik asit miktarı % 13.6-16.22; linolenik asit miktarı ise % 7.3-7.34 aralığındadır (Wang & Johnson, 2001; Özcan ve ark., 2013). Zou ve ark. (2018) ise, kavrulmamış rüşeym yağında SFA, MUFA ve PUFA değerlerini sırasıyla, % 17.39, % 16.35 ve % 65.17 saptamışlardır. SFA, MUFA ve PUFA değerlerine bakıldığında ise, analizlenen rüşeym yağlarının yağ asitleri kompozisyonu, literatür çalışmalarıyla karşılaştırıldığında farklılıklar görülmektedir.

Çizelge 4'e göre, rüşeym yağı numunelerinin iyot sayıları 84.03-121.98 aralığında değişmiştir. Arshad ve ark. (2008)'nın yaptıkları çalışmada, Pakistan orijinli rüşeym yağının iyot sayısını 107 olarak belirlemişlerdir. Mahmoud ve ark. (2015) ise Mısır orijinli buğday rüşeyminden elde edilen yağın iyot sayısını 115.47 olarak tespit etmişlerdir. Megahed (2011) ise çalışmasında, soxhelet yöntemiyle elde edilen rüşeym yağlarını 25-30 ^oC'de 7 gün boyunca bekletmiş ve 7. günün sonunda değeri 117.2 olarak bildirmiştir.

Üzüm çekirdeği yağı numunelerinin iyot sayısı ve yağ asitleri kompozisyonu, Çizelge 5'te verilmiştir. Çizelge 5 incelendiğinde bir numune dışında (E markası) diğer tüm numunelerde en yüksek miktarda linoleik asit (ort. % 38.67), beş numunede omega-3 yağ asitlerinden **EPA**, bir numunede ise **DHA** tespit edilmiştir. **SFA** değeri en yüksek % 11.86 (A markası), en düşük % 7.38 (C markası) ve ortalama değer % 8.79 olarak saptanmıştır. Numunelerin **MUFA** içeriği için en yüksek % 41.82 (E markası), en düşük % 22.68 (C markası) ve ortalama değerin % 30.36 olduğu; **PUFA** içeriği için ise en yüksek % 44.27 (F markası), en düşük % 30.76 (E markası) ve ortalama değerin % 40.67 olduğu belirlenmiştir.

Çalışmamızda iki adet numunede (E ve F kodlu) sırası ile % 0.98, % 0.15 oranında trans yağ asidi ve aynı numunelerde 18.91 ve 27.81 meq O_2/kg yağ değerlerinde peroksit sayısı tespit edilmiştir. Numunelerde trans yağ ve yüksek seviyede peroksit değeri tespit edilme nedenlerinin, tohumun orijininden, proses aşamasında yüksek sıcaklıklara maruz bırakılmasından ya da soğuk pres üzüm çekirdeği yağı içerisine tağşiş yapılarak, yüksek sıcaklıklarda deodorize edilmiş rafine yağ karıştırılmasından kaynaklanabileceği düşünülmektedir.

Çalışmalarda üzüm çekirdeği yağının linoleik asit miktarının % 49-63.33 arasında; oleik asit miktarının % 21.63-28.9 arasında ve linolenik asit miktarının ise % 0.35 olduğu bildirilmektedir (El-Shami ve ark., 1992; Baydar ve ark., 2007) Türk Gıda Kodeksi Bitki Adı ile Anılan Yağlar Tebliği Ek-3'e (TGK, 2020) göre, üzüm çekirdeği yağında linoleik asit % 58-78 ve oleik asit miktarı % 12-28

arasındadır. Diğer araştırmalardan ve TGK (2020)'den farklı olarak numunelerimizin beş adedinde omega-3 yağ asitlerinden EPA, bir adedinde ise DHA tespit edilmiştir.

Çizelge 4. Farklı markalardaki buğday rüşeymi yağlarının iyot sayıları ve yağ asitleri kompozisyonları (n:6)

Yağ Asitleri Kompozisyonu (%)	**A**	**B**	**C**	**D**	**E**	**F**	**Ort.**
C16:0	6.82	5.46	8.8	5.65	5.22	9.50	**6.91**
C16:1	TE	0.15	0.19	0.19	TE	TE	**0.18**
C18:0	3.02	2.39	1.42	1.90	1.61	1.85	**2.03**
C18:1	28.89	39.51	30.89	46.62	38.56	20.63	**34.18**
C18:2	53.64	34.82	40.14	25.73	20.96	42.43	**36.29**
C18:3 (cis-6,9,12)	0.25	0.25	0.30	0.94	TE	0.34	**0.42**
C18:3(cis-9,12,15)	0.25	0.65	0.29	1.09	0.89	0.32	**0.58**
C20:0	TE	0.28	TE	0.46	TE	TE	**0.37**
C20:1	0.78	2.93	1.23	5.06	4.15	2.01	**2.69**
C20:3	0.53	0.39	TE	0.30	TE	0.16	**0.35**
C20:4	TE	0.16	TE	0.34	0.42	TE	**0.31**
C20:5	0.20	0.16	TE	TE	TE	TE	**0.18**
ΣSFA	9.84	8.13	10.22	8.01	6.83	11.35	**9.06**
ΣMUFA	29.67	39.94	32.31	51.87	42.71	22.64	**36.52**
ΣPUFA	54.87	36.43	40.73	28.40	22.27	43.25	**37.66**
İyot sayısı (g I_2/100 g yağ)	121.98	84.03	93.50	99.86	97.10	89.00	**97.58**

TE: Tespit edilmedi.

Çalışmamızdaki üzüm çekirdeği yağı numunelerinin iyot sayısı değerlerinin Tebliğ'e uygun olmadığı tespit edilmiştir.

Kayısı çekirdeği yağlarının yağ asitleri kompozisyonu ve iyot sayıları Çizelge 6'da verilmiştir. Çizelge 6'ya göre, üç numunede (A, B ve D markaları) oleik asit en yüksek konsantrasyonda bulunan yağ asidi (ort. 41.36) iken, diğer üç numunede ise (C, E ve F markaları) linoleik asit miktarı (ort. 31.42) en yüksektir. Dört numunede ise (B, C, E ve F markaları) **EPA** tespit edilmiştir. Ayrıca, bir numunede (F markası) linoleik asitin trans izomeri saptanmıştır. Numunelerdeki linolenik asit miktarı ise % 1'in altında tespit edilmiştir. **SFA** değeri en yüksek % 10.29 (E markası), en düşük % 5.62 (D markası) ve ortalama değer ise % 7.78 olarak saptanmıştır. Numunelerin **MUFA** içeriği en yüksek % 59.29 (A markası), en düşük % 22.58 (F markası) ve ortalama değerin % 42.25 olduğu; **PUFA** içeriğinin ise en yüksek % 43.93 (F markası), en düşük % 21.15 (B markası) ve ortalama değerin % 32.03 olduğu tespit edilmiştir.

Pavlovic ve ark. (2018), soğuk pres ve süperkritik CO_2 ile ekstrakte edilen kayısı çekirdeği yağında oleik asit oranını % 57.33-68.69 olarak tespit etmişlerdir. C, E ve F marka yağlarda ise linoleik asidin miktarı diğer yağ asitlerine göre yüksektir. Aydemir (2003), Durmaz (2008) ve Hussain ve ark. (2011)'nın çalışmalarına göre, kayısı çekirdeği yağlarında oleik asit miktarı (% 63.81-68.69), diğer yağ asitlerinden belirgin şekilde yüksektir. Yapılan başka çalışmalarda ise kayısı çekirdeği yağında linoleik asit oranının % 21.66-30.33, linolenik asit oranın ise % 0.73-1.61 aralığında olduğu bildirilmiştir (Aydemir, 2003; Durmaz, 2008; Hussain ve ark., 2011; Pavlovic ve ark., 2018). Çalışmamız bu çalışmalarla karşılaştırıldığında, A markası dışında diğer yağlarda oleik asit miktarının oldukça düşük olduğu ve linoleik asit miktarının ise belirgin şekilde yüksek olduğu saptanmıştır. Ayrıca, diğer çalışmalardan farklı olarak dört numunede (B, C, E ve F markaları) EPA saptanmıştır. Pavlovic ve ark. (2018), sırasıyla SFA, MUFA ve PUFA değerlerini soğuk pres yağında, % 6.82, % 63.86, % 29.31 ve süperkritik ile ekstrakte edilen yağda ise % 7.57, % 58.45 ve % 33.98 olarak tespit etmişlerdir. Çalışmamızdaki MUFA değerleri, markalar arasında farklılık göstermekte olup, diğer çalışmalardaki değerlerden düşüktür. PUFA değerleri ise yine markalar arasında farklılık göstermiştir ve C, E ve F markalarında diğer çalışmalardaki değerlere göre oldukça yüksektir. Analizlenen kayısı çekirdeği yağının yağ asitleri kompozisyonu, literatür çalışmalarıyla karşılaştırıldığında büyük farklılıklar

görülmektedir. Bu farklılıkların ve F kodlu numunede trans yağ asidi tespit edilme nedeninin, uygun olmayan tohum ve proses şartlarının (depolama ve yüksek sıcaklık gibi) yanında, yağın içerisine tağşiş yapılarak, düşük kalitede rafine yağ karıştırılmış olma ihtimalinden kaynaklanabileceği düşünülmektedir.

Çizelge 5. Farklı markalardaki üzüm çekirdeği yağlarının iyot sayıları ve yağ asitleri kompozisyonları (n:6)

Yağ Asitleri Kompozisyonu (%)	**A**	**B**	**C**	**D**	**E**	**F**	**Ort.**
C16:0	7.84	5.04	4.78	6.23	4.72	5.86	**5.75**
C16:1	0.11	0.10	TE	0.16	TE	TE	**0.12**
C18:0	4.02	2.36	2.60	2.88	2.03	4.07	**2.99**
C18:1	27.03	27.81	22.34	30.24	38.12	18.80	**27.39**
C18:2	40.78	40.47	43.09	40.53	26.48	40.68	**38.67**
C18:2 (trans-9,12)	TE	TE	TE	TE	0.93	0.15	**0.54**
C18:3 (cis-6,9,12)	0.36	0.20	0.17	0.21	0.77	0.22	**0.32**
C18:3 (cis-9,12,15)	0.14	0.35	0.10	0.51	0.69	0.27	**0.34**
C20:0	TE	TE	TE	0.17	0.39	TE	**0.28**
C20:1	0.30	1.45	0.18	2.25	3.61	9.39	**2.86**
C20:2	0.21	TE	0.06	0.09	TE	TE	**0.12**
C20:3	TE	0.42	0.40	0.16	0.18	0.27	**0.29**
C20:4	TE	0.13	TE	0.21	0.38	0.34	**0.27**
C20:5	TE	0.16	0.14	0.07	0.07	0.10	**0.11**
C22:6	TE	TE	TE	TE	1.26	2.24	**1.75**
C24:1	TE	TE	TE	TE	0.09	TE	**0.09**
ΣSFA	11.86	7.4	7.38	9.28	6.89	9.93	**8.79**
ΣMUFA	27.44	29.36	22.68	32.65	41.82	28.19	**30.36**
ΣPUFA	41.49	41.73	43.96	41.78	30.76	44.27	**40.67**
İyot sayısı (g I_2/100 g yağ)	95.52	99.00	96.37	101.47	93.30	108.32	**99.00**

TE: Tespit edilmedi.

Çizelge 6'ya göre, farklı markalardaki kayısı çekirdeği yağlarının iyot sayıları 77.77-106 arasında değişmiştir. Markaların ortalaması 92.62'dir. Manzoor ve ark. (2012)'ın çalışmasında farklı türlerdeki Pakistan kayısı çekirdeklerinden sokselet yöntemiyle elde edilen yağların iyot sayıları 96.4-106.3 değerlerinin arasında değişmiş olduğu belirtilmiştir. Aydemir (2003)'in çalışmasında Malatya yöresi kayısılarından sokselet ekstraksiyonuyla elde edilen acı ve tatlı kayısı çekirdeği yağlarının iyot sayıları sırasıyla, 92.5 ve 101.2 olarak saptanmıştır. Acı ve tatlı kayısı çekirdeklerinde yapılan bir başka çalışmada her iki yağın iyot sayısının 95 olarak saptanmıştır (Hussain ve ark., 2011). Pavlovic ve ark. (2018), soğuk pres kayısı çekirdeği yağında iyot sayısını 103.45; süperkritik ile ekstrakte edilen yağda ise 102.98 olarak tespit etmişlerdir. Buna göre, iki numune (B ve D markaları) dışında diğer yağların iyot sayıları literatürdeki değerlerle örtüşmektedir.

İncelenen tüm yağların yağ asidi kompozisyonu değerleri arasındaki farklılıklarının, hammaddenin genetik, morfolojik, fizyolojik özellikleri ve yetiştirildiği ortamın ekolojik şartlarından kaynaklandığı düşünülmektedir. Özellikle, hammaddenin yetiştirildiği coğrafyanın, toprak özelliklerinin ve bakım şartlarının ürün özelliklerinde varyasyona sebep olabileceği belirtilmektedir (Altıkat ve Temiz, 2019). İyot sayısı değerlerindeki farklılıklar da, yağ asitleri bileşimindeki farklılıklardan kaynaklanmaktadır.

Çizelge 6. Farklı markalardaki kayısı çekirdeği yağlarının iyot sayıları ve yağ asitleri kompozisyonları (n:6)

Yağ Asitleri Kompozisyonu (%)	A	B	C	D	E	F	Ort.
C16:0	4.87	5.65	7.28	4.58	8.40	5.43	**6.04**
C16:1	0.58	0.35	0.26	0.56	TE	TE	**0.44**
C18:0	1.04	1.71	1.53	1.04	1.83	3.07	**1.70**
C18:1	58.93	44.00	34.26	55.34	34.18	21.46	**41.36**
C18:2 (cis-9,12)	22.96	19.96	37.56	22.80	42.61	42.63	**31.42**
C18:2 (trans-9,12)	TE	TE	TE	TE	TE	0.21	**0.21**
C18:3 (cis-6,9,12)	0.08	0.21	0.27	0.08	0.34	0.21	**0.20**
C18:3 (cis-9,12,15)	0.07	0.44	TE	TE	0.16	0.12	**0.20**
C20:0	TE	0.14	TE	TE	TE	TE	**0.14**
C20:1	0.08	1.77	0.37	TE	0.52	1.11	**0.77**
C20:2	TE	0.07	TE	0.07	TE	TE	**0.07**
C20:3	TE	0.17	0.11	TE	0.13	0.36	**0.19**
C20:4	TE	0.16	TE	TE	TE	TE	**0.16**
C20:5	TE	0.07	0.10	TE	0.13	0.36	**0.17**
C22:0	TE	TE	TE	TE	TE	0.05	**0.05**
ΣSFA	5.87	7.52	8.80	5.62	10.29	8.59	**7.78**
ΣMUFA	59.24	46.14	34.89	55.89	34.74	22.58	**42.25**
ΣPUFA	22.71	21.15	38.04	22.95	43.41	43.93	**32.03**
İyot sayısı (g I_2/100 g yağ)	90.46	77.77	96.5	87.81	106.00	97.15	**92.62**

TE: Tespit edilmedi.

4. Sonuç

Çalışmamızda altı marka, dört çeşit (çörek otu, rüşeym, üzüm çekirdeği ve kayısı çekirdeği yağı), toplam 24 adet soğuk pres yağın önemli kalite özelliklerinden % FFA ve peroksit değerleri (PV); önemli karakteristik özelliklerinden ise yağ asitleri kompozisyonları ve iyot sayıları incelenmiştir. Türk Gıda Kodeksi Bitki Adı ile Anılan Yağlar Tebliği'nde soğuk preslenmiş natürel yağ tanımı ile aspir, fındık, babassu, ayçiçek, hindistan cevizi, palm çekirdeği, palm çekirdeği olein, palm çekirdeği stearin, palm, palm olein, palm stearin, palm kernel, palm süperolein, pamuk, soya, susam, üzüm çekirdeği, kanola, yer fıstığı yağları yer almakta ve bu yağlara ait standart değerler belirtilmektedir. Oysa piyasada başta çörek otu, incir, kayısı, erik, karpuz, nar çekirdeği, rüşeym vb. Tebliğ'de yer almayan birçok soğuk pres yağ, "gıda takviyesi" olarak satılmaktadır. Çalışmamızda incelenen yağların sonuçlarından da görüldüğü gibi bu ürünlerin hem kalite hem de karakteristik özellikler çok değişken olduğu saptanmıştır. Özellikle kalite özelliklerinden asit ve peroksit değerleri gıda güvenliği ve sağlık açısından ciddi risk teşkil etmektedir. Karakteristik özellikler ise bu ürünlerde tağşiş yapıldığını gösterebilmektedir. Tüm bu nedenlerden dolayı piyasada satışa sunulan ve Tebliğ'de yer almayan soğuk pres yağ çeşitleri ile ilgili detaylı bir çalışma yapılması ve söz konusu ürün-standartlarının belirlenmesinin oldukça önemli olduğu düşünülmektedir.

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Research Article

Predicting Barley Harvest Time in Dryland Conditions Using Satellite Images

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Keywords
Barley farming,
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Satellite imagery.

Abstract: Barley has an important role in livestock feed. Therefore, an accurate estimation of harvesting time is necessary to minimize the loss in barley farming. The aim of this study is to determine barley harvest time using satellite images accurately. Field data were sampled from the farms in the Dezaj region of the west of Iran. In addition, satellite remote sensing technique was applied during barley growing season in 2019 using Landsat 8 images. The vegetation indexes were-used as input in the prediction model in this study. The results showed that satellite imaging has enough potential to predict the harvesting time of barley accurately. R-squared and RMSE values of the best-structured stepwise regression model in this study were 0.791 as well, and 1.34 respectively. This method can be beneficially employed by farm managers to have an accurate estimation of the most appropriate harvesting time and be able to manage the process, which is an important challenge for them.

Uydu Görüntülerini Kullanarak Kurak Arazi Koşullarında Arpa Hasat Zamanını Tahmin Etme

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Anahtar Kelimeler
Arpa yetiştiriciliği,
Hasat zamanı,
Uydu görüntüleri.

Öz: Arpanın hayvancılık yeminde önemli bir yeri vardır. Bu nedenle, arpa yetiştiriciliğinde kaybı en aza indirmek için hasat zamanının doğru tahmin edilmesi gerekmektedir. Bu çalışmanın amacı, uydu görüntüleri kullanılarak arpa hasat zamanını doğru bir şekilde belirlemektir. İran'ın batısında Dezaj bölgesindeki çiftliklerden tarla verileri örneklenmiştir. Ayrıca 2019 yılında arpa yetiştirme sezonunda Landsat 8 görüntüleri kullanılarak uydudan uzaktan algılama tekniği uygulanmıştır. Bitki örtüsü indeksleri bu çalışmada tahmin modelinde girdi olarak kullanılmıştır. Sonuçlar, uydu görüntülemenin arpanın hasat zamanını doğru bir şekilde tahmin etmek için yeterli potansiyele sahip olduğunu gösterdi. Bu çalışmada da en iyi yapılandırılmış aşamalı regresyon modelinin R kare ve RMSE değerleri sırasıyla 0.791 ve 1.34 idi. Bu yöntem, çiftlik yöneticileri tarafından en uygun hasat zamanının doğru bir şekilde tahmin edilmesi ve onlar için önemli bir zorluk olan süreci yönetebilmek için faydalı bir şekilde kullanılabilir.

1. Introduction

Crop production is a vital element for securing the survival of the human. Cereals have the most important role in the human food supply. Among the cereals, barley is cultivated in most parts of the world. Furthermore, it is more tolerant of environmental stresses such as drought, salinity than the cereal family, and today this product constitutes a significant percentage of feeding livestock. Currently, barley

plants in about 50 million hectares of the world's arable land. On the other hand, the highest area under barley cultivation in the world include European Union, Russia, Australia, Turkey, Ukraine, Canada, Kazakhstan, Iran and Morocco, respectively (FAO, 2017). This makes barley, one of the most important agricultural productions. Sustainable production of barley requires understanding the growth stages of barley (such as maturity and harvest time) and providing suitable machinery (cultivators, planters and harvesters) at these times (Anonymous, 2014). Therefore, there are some researches to estimate the growth stages of barley (Yin and Van Laar, 2005). The barley maturity stage is one of the most significant stages of barley growth. In general, barley maturity can be divided into two categories: morphological and technological maturity. At the technological maturity stage, the product is suitable for harvesting. The technological maturity stage is actually the harvest time and the quality and yield of barley is the maximum amount at this stage. Also, the growth stages of wheat and barley are similar together. Evers et al. (2010), used a model of wheat stages development combining aboveground, within the plant structure, assimilate distribution, plant structure, photosynthesis, and organ-level microclimate, organ growth and development. They used an experimental sigmoid relationship between leaf length and leaf mass for plant organ development calculation. The results showed that more efforts were necessary to modelling mechanistically other significant physiological processes such as nitrogen distribution and uptake, and leaf and tiller senescence. Other researchers (Gao et al., 2020, Canata et al., 2021, Mobe et al., 2021,) used some parameters such as weather temperature, soil moisture, etc. to predict barley growth stages. The disadvantage of these models is the unavailability of the above parameters for all farms. Therefore, it is needed to have an alternative or complementary method for these models. Harvest time (technological maturity) is an important factor in farm management. For example, harvest time has effects on the performance of the plants' rotation because delay in harvesting time could reduce the yield of the second crop in the plants' rotation. Sun et al. (2007) studied the effect of harvesting time in the rotation of winter wheat - maize. Results showed that each day of delay in barley harvesting (the first cultivated crop in the rotation) led to 0.6 % maize yield decrease (second cultivated crop). Remote sensing is fairly a new technique, which could help researchers to get more information about plants, periodically. Remote sensing, which concentrates on the images examination of the earth’s surface, has quickly evolved since the discovery of the infrared spectrum in the early 1800s (Campbell, 2002). The application of remotely sensed images leads to collect of reliable and timely data from crop performance (Lyle et al., 2013, Taghizadeh et al., 2019). Most vegetation indexes (VIs) incorporate reflectance in a few wavebands, which could be collected mainly by satellite broadband sensors. VIs have been used to determine the plant stage of development (Huete, 2012). Within the final decade, remote sensing has been very effective in farm administration decisions such as cultivation, fertilization and yield determination (Bao et al., 2008). Jongschaap and Schouten (2005) showed that using remote sensing, the wheat area could be appraised with more than 80% accuracy. They also reported good fitting; i.e. model based estimations of regional wheat production were in accord with agricultural statistics. Ren et al (2008) predicted wheat yield using MODIS-NDVI (Normalized Difference Vegetation Index) data in Shandong, China. They reported that the relative errors of the predicted yield were in the range of 4.62 -5.40 % and RMSE was 214.16 kg/ha. Song et al. (2016) evaluated the performance of the time series of Landsat 8 images to barley yield prediction. They used NDVI. Their results showed that there was good fitting (R2 =0.87) between this vegetation index and the yield of barley. Although satellite images were used in some agricultural applications, no research has yet been conducted on harvesting time prediction using Landsat 8. Therefore, the main aim of this research was to evaluate the proficiency of Landsat 8 satellite images to determine barley harvest time. Furthermore, developing a regression model for estimating barley harvest time is another purpose of this study.

2. Material and Methods

2.1. Field description

The collecting Method in this study was done in the Dezaj region (35°09′N, 47°91′E) in the west of Iran in 2019 (Figure 1). This region has a cold mountainous climate with an average annual rainfall of 444 mm and annual temperature changes from -38 to +35 ^{0}C. The predominant product of

this region is barley (Bahman cultivar). The growing season of wheat in this region is from mid-October to mid-July next year.

2.2. Field data

During field surveys before harvest season, 30 barley farms were selected from the study area for each year. The locations of farms were recorded using GPS (Garmin 62s). The required descriptive information of farms and the crop density of each farm were also recorded. The yield samplings were done (from the middle of June until harvesting day) using a 1m × 1m quadrate in the randomly selected points in each farm. The yield samplings were carried out by five random throws of the quadrate and choosing three crops in each throw. At each sampling, fifteen crops were sampled for each farm. As the plant densities were consistent in one farm, fifteen crops were sufficient for sampling. By measuring the grain mean weight of sampled crops in each farm and knowing crop density, the yield for each farm was calculated until harvest day. Yield samplings were performed with two days intervals and the yield of other days were obtained by interpolating. For each farm, the day with maximum yield was the best harvesting time.

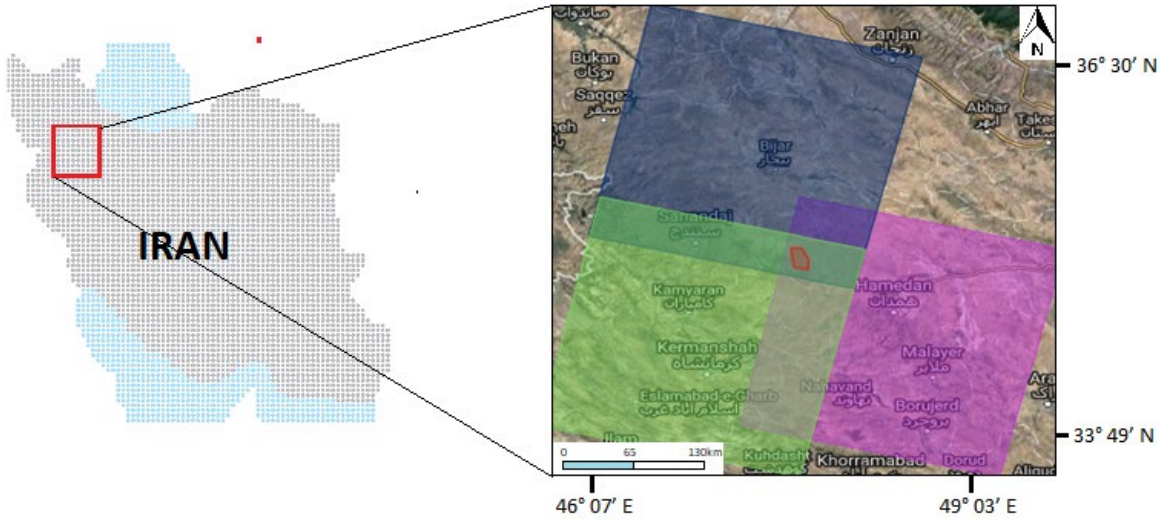

Figure 1. The study area is satellite imagery of Land.

2.3. Landsat 8 Images and spectral vegetation Indexes

Landsat 8 includes two sensors and eleven bands summarized in table 1 (Irons et al., 2012). Landsat gives the spatial determination and ceaseless record required to capture time histories and it is very useful for agricultural applications. In this study, the Landsat images of the study area were acquired according to the barley growing calendar. Seven cloud free images of the barley growing period were selected. Table 2 shows all images of the study area, from the tillering to ripening (maturity) of barley. FLAASH module/ ENVI was used for atmospheric correction. Also, the geometric correction was done for images. Then corrected images were used for the calculation of the VIs. These indices have made a simple and suitable approach for obtaining information from remote sensing data. In this study, we used four VIs as following:

1. Normalized Difference Vegetation Index (NDVI): NDVI is the most widely used index for remote sensing of vegetation in the past two decades. This index has been used in many applications, including the estimation of crop yields and above-ground dry biomass (Rouse et al., 1974; Tucker et al., 1986; Ren et al., 2008). NDVI is calculated by the following equation:

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})} \quad (1)$$

Where NIR and RED are spectral reflectances of Near Infrared and red bands.

Table 1. Description of Landsat 8 bands

Band Specifications	Wavelength (μm)
Band 1 — aerosol (30 m)	0.43–0.45
Band 2 — blue (30 m)	0.45–0.51
Band 3 — green (30 m)	0.53–0.59
Band 4 — red (30 m)	0.64–0.67
Band 5 — near infrared (30 m)	0.85–0.88
Band 6 — shortwave infrared (30 m)	1.57–1.65
Band 7 — shortwave infrared (30 m)	2.11–2.29
Band 8 — panchromatic (15 m)	0.50–0.68
Band 9 — cirrus (30 m)	1.36–1.38
Band 10 — thermal Infrared (100 m)	10.60–11.19
Band 11 — thermal Infrared (100 m)	11.50–12.51

2. Soil Adjusted Vegetation Index (SAVI): SAVI attempts to reduce the influence of the soil by assuming that most soil spectra follow the same soil line (Huete, 1998). The formula of SAVI is demonstrated in equation 2.

$$\mathrm{SAVI} = \frac{(1 + \mathrm{L})\ (\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED} + \mathrm{L})} \quad (2)$$

Where the constant L = 0.5 has been adjusted to account for first-order soil background variation.

3. Enhanced Vegetation Index (EVI): EVI is developed as a standard satellite vegetation product for the Terra and Aqua Moderate Resolution Imaging Spectroradiometers (MODIS). EVI provides improved sensitivity in high biomass regions while minimizing soil and atmosphere influences (Huete et al., 1997). The formula of EVI is demonstrated in equation (3).

$$\mathrm{EVI} = \frac{2.5\ (\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + 6 * \mathrm{RED} - 7.5 * \mathrm{Blue} + 1)} \quad (3)$$

Where Blue is the spectral reflectance of the blue band.

4. Normalized Difference Water Index (NDWI): NDWI is sensitive to changes in the liquid water content of vegetation canopies. NDWI is less sensitive to atmospheric effects than NDVI, (Gao, 1996). The formula of NDWI is demonstrated in equation 4.

$$\mathrm{NDWI} = \frac{(\mathrm{NIR} - \mathrm{SWIR})}{(\mathrm{NIR} + \mathrm{SWIR})} \quad (4)$$

Where SWIR is spectral reflectance of short wave infrared band.

The above mentioned spectral indices were calculated for farm pixels for all images from tillering to ripening stages.

2.4. Development of regression models for barley harvest date estimating

The stepwise regression method was used to determine affected growth stages using SPSS 16 software. Seven stepwise regression models of harvest date vs. vegetation indices were developed to find the relation between them for each barley growth stage. The models' inputs were spectral indices

and the best harvest date was the output of models. Field observation data were divided into two categories: 70% of data were used for model development and 30 % were used for validation of models.

3. Results and Discussion

3.1. Developing regression models at different growth stages of barley

As be seen in Table 3, the stages after flowering have the stronger ability to predict the harvesting date of barley. Moreover, table 3 shows the image coincide provided the best regression model with the dough stage (R^2 = 0.791; RMSE= 1.34). The spectral indices were used in this model were NDVI and NDWI. NDVI is one of the most extremely used indices. The range of NDVI values is between [-1, +1]. Based on phenology studies18 of the United States Geological Survey (USGS), the NDVI values are categorized as follows; the regions of sand or snow usually have very low NDVI values (e.g. 0.1 or less). Sparse vegetation as grasslands or senescing crops has moderate NDVI values (i.e. nearly 0.2 to 0.5). Dense vegetation such as tropical forests13 or crops at their peak growth stage may result in high NDVI values (about 0. 4 to 0.8). In this research, the NDVI is the only index, which has been entered in all models. Song et al. (2016), demonstrated that Landsat NDVI data could be used to predict the wheat yield. In their research, the booting stage of wheat was the best stage for yield prediction. Also, the results of Ren et al. (2008) research which used NDVI to estimate wheat regional yield showed that the best predicted yield data of winter wheat could be achieved nearly 40 days before harvest time (about booting stage). However, to predict barley harvest time in the Dezaj region, we found that about 15- 20 days ahead of harvest time (dough development stage) is the best time. The results of this research and mentioned researches showed that NDVI could be a good index for agricultural applications such as harvest time prediction and yield estimation. In previous studies, the NDVI index has been used to estimate the area of agricultural crops, plant yield and growth monitoring and determine the phenological stages of crops, which the results have been in accordance with our study (Shi et al., 2013; Zhang et al., 2013).

Table 1. The developed models at barley different growing stages

No	The growth stage	Developed model	R^2	RMSE
1	Tillering	Y=-2.30 NDWI+3.90 EVI+5.66 NDVI+176.22	0.135	3.51
2	Stem elongation	Y=5.11 NDWI+1.28 SAVI+8.33 NDVI+172.87	0.388	3.03
3	Booting	Y=85.2 NDWI+7.21 EVI2+3.78NDVI+175.33	0.376	3.01
4	Awn emergence	Y=4.54 NDWI+5.83 EVI+8.66 NDVI+174.55	0.441	2.91
5	Flowering	Y=65.55 NDWI+18.66 NDVI+173.29	0.599	2.18
6	Dough development	Y=83.26 NDWI+86.2 NDVI+168.53	1.34	0.791
7	Ripening	Y=148.32 NDVI+158.62	1.95	0.571

The results showed that NDWI could predict mature dates with an accuracy of 0.65. 3.2. Evaluation of the developed regression model for harvest time predicting In order to assess the predictive performance of the developed models, we used three models, which had the better estimations (the models of flowering, dough development and ripening stages). In this step, we used the 30% remained data for evaluation. Additionally, it can be concluded that the best time for barley harvest time prediction is after the best time for yield estimation. Furthermore, NDWI is an index, which is sensitive to changes in the liquid water content of vegetation canopies. That interacted with the incoming solar radiation (Gao, 1996). NDWI is less sensitive to atmospheric effects than NDVI. In addition, in various stages of barley growth, the amount of liquid water content changes. Therefore, there is a relationship between harvest day of barley and NDWI, and the most relationship was found at the dough development stage. Also, Studies have reported that NDWI is a good index for estimating the mature date of cereals (Meng et al., 2011; Meng et al., 2015; Mulianga et al., 2015).

Figures 2, 3 and 4 illustrate the performance of these models, in a scatter plot between predicted and observed harvest days. The R^2 and RMSE values of the developed model based on the dough development stage were achieved 0.812 and 1.40, respectively. In addition, as it can be seen in Figure 2, the image coincides with the dough development stage had the best predictive performance. The

performance of developed models at flowering (R2 = 0.557 and RMSE =2.51) and ripening (R2 = 0. 487 and RMSE = 2.84) stages were less than dough development stage. Therefore, it can be concluded that the suitable period for anticipated harvest time using satellite images for achieving the highest yield is the barley dough development stage.

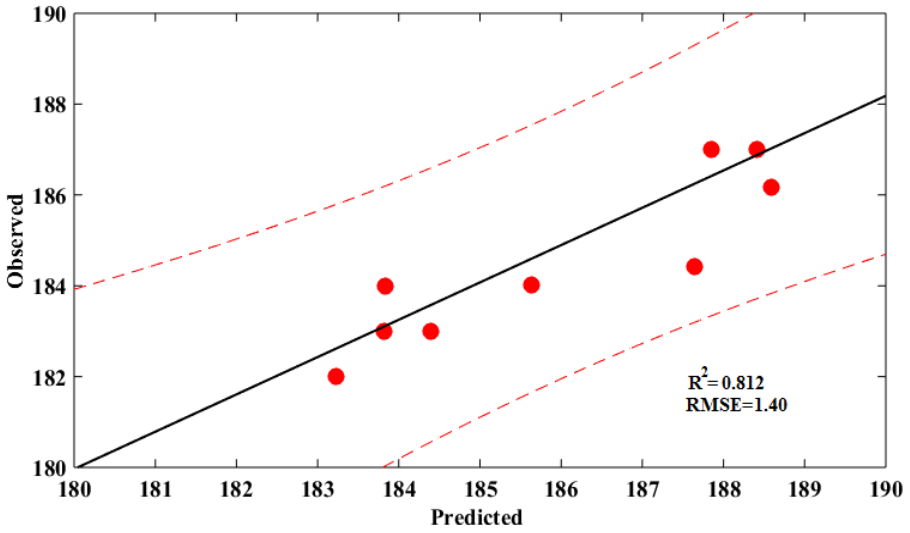

Figure 2. Scatter plot of predicted and observed harvest time for dough development stage (the boarder lines indicate confidence level of 0.01).

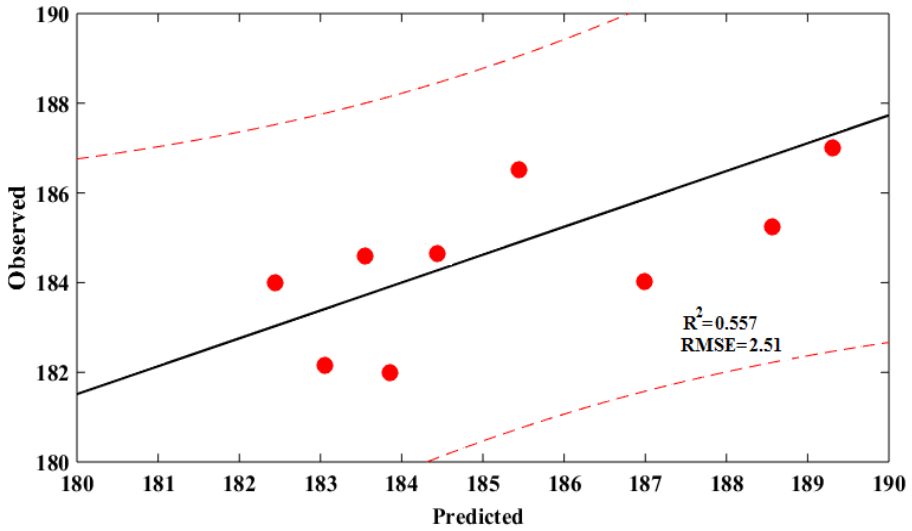

Figure 3. Scatter plot of predicted and observed harvest time for flowering stage (the boarder lines indicate confidence level of 0.01).

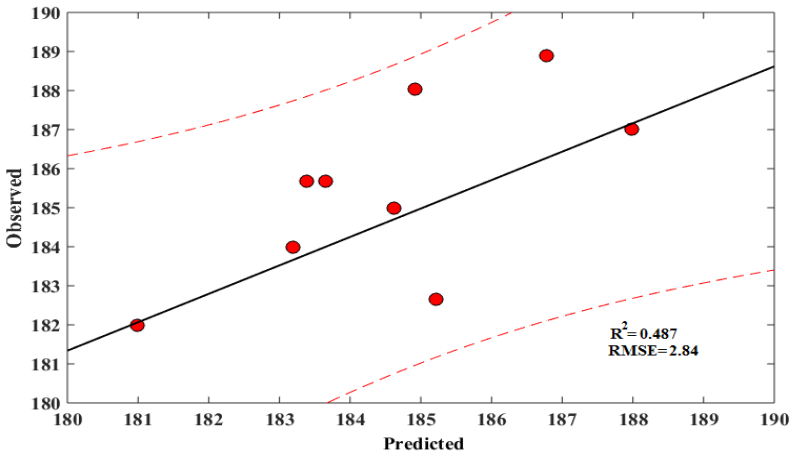

Figure 4. Scatter plot of predicted and observed harvest time for ripening stage (the border lines indicate confidence level of 0.01).

4. Conclusion

The objective of this study was to predict barley harvest time to reduce14 the yield gap (the difference between yield potential and the actual yield) using satellite images in the Dezaj region. The analyses of attained results showed Landsat satellite imagery is able to produce valuable information using spectral indexes. Regional estimation of harvest time has different important aspects including farm management, commercial politics and so on. Moreover, the knowledge of harvest time could help to crop harvest without decreasing yield. The advantage of remote sensing technologies and spectral indexes is their ability to continuous visit crops. However, many environmental factors such as the amount of clouds and atmospheric conditions could affect the estimations. It should be noted that NDVI and NDWI are important indexes in crop and vegetation studies. The best model to predict barley harvest time was extracted from indexes related to the barley dough development stage (R2 = 0.791; RMSE = 1.34). Therefore, Landsat 8 images could be used for harvest time prediction. This paper only demonstrates a primary research of crop harvesting time prediction using satellite imagery. To advance development the utilize of satellite remote sensing to accuracy harvest, the following researches are proposed: -The relationships between vegetation indexes and harvest time were influenced by satellite image procurement date, so the harvest time predicting models might be diverse when images on distinctive dates are utilized. Therefore, a general model could be developed using several years' data, which can actualize harvest time forecast with satellite images at diverse dates. integrating of crop models and satellite remote sensing based models could improve the predicting capability of these models. Therefore, a combination of these two categories of models is suggested for future researches.

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Research Article

Effects of Cuts and Different Phenological Stages on Antibacterial and Antioxidant Activities and Chemical Attributes of Garden Thyme (*Thymus vulgaris* L.) Essential Oil

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Garden thyme,
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Abstract: Garden thyme is an aromatic plant with various applications in the pharmaceutical, food, and hygienic-cosmetic industries around the world. In this research, field-cultivated plants were harvested in two cuts and three consecutive stages (pre-flowering, flowering, and post-flowering). The essential oil percentage and compositions were identified in the essential oil samples. The antibacterial activity of the essential oil was measured against *Escherichia coli* and *Staphylococcus aureus*. The antioxidant activity, total phenol and flavonoid contents, chain-breaking activity, and IC_{50} were recorded. The highest essential oil percentage (2.56%) was obtained from the pre-flowering stage. The results of GC/MS revealed that *p*-cymene, *γ*-terpinene, thymol, and carvacrol were the most important constituents of the studied essential oil. The lowest antibacterial activity was recorded by the second cut at the pre-flowering stage. The highest antibacterial activity against *E. coli* and *S. aureus* were recorded by the second cut during the flowering stage and the first cut during the flowering stage, respectively. The lowest MIC was 15.75 µg mL^{-1} related to the second cut during the flowering stage. The plants had the highest total phenol (16.64 mg GAE g^{-1} DM) and total flavonoid contents (2.88 mg QE g^{-1} DM) at the pre-flowering stage. The highest antioxidant activity (IC_{50} = 134.05 µg mL^{-1}) was observed at the pre-flowering stage. It can be said that phenological stages and cuts can affect essential oil antibacterial and antioxidant activities, as well as its chemical characteristics.

Kesimlerin ve Farklı Fenolojik Aşamaların Bahçe Kekiği (*Thymus vulgaris* L.) Uçucu Yağının Antibakteriyel ve Antioksidan Aktiviteleri ve Kimyasal Özellikleri Üzerine Etkileri

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Anahtar Kelimeler

Antibakteriyel aktivite,
Antioksidan aktivite,

Öz: Bahçe kekiği, dünya çapında ilaç, gıda ve hijyenik-kozmetik endüstrilerinde çeşitli uygulamalara sahip aromatik bir bitkidir. Bu araştırmada, tarlada yetiştirilen bitkiler iki kesimde ve birbirini takip eden üç aşamada (çiçeklenme öncesi, çiçeklenme ve çiçeklenme sonrası) hasat edilmiştir. Uçucu yağ örneklerinde uçucu yağ yüzdesi ve bileşimleri belirlendi. Uçucu yağın antibakteriyel aktivitesi *Escherichia coli* ve *Staphylococcus aureus*'a karşı ölçülmüştür. Antioksidan aktivite, toplam fenol ve flavonoid içerikleri, zincir kırma aktivitesi ve IC_{50} kaydedildi. En yüksek uçucu yağ yüzdesi (%2.56) çiçeklenme öncesi dönemden elde edilmiştir. GC/MS sonuçları, çalışılan uçucu yağın en önemli bileşenlerinin *p*-cymene, *γ*-terpinen, timol ve karvakrol olduğunu ortaya koydu. En düşük

Kesmek,
Esans,
Bahçe kekiği,
Fenolojik dönemler.

antibakteriyel aktivite, çiçeklenme öncesi aşamadaki ikinci kesimde kaydedilmiştir. E. coli ve S. aureus'a karşı en yüksek antibakteriyel aktivite, sırasıyla çiçeklenme döneminde ikinci kesimde ve çiçeklenme döneminde ilk kesimde kaydedilmiştir. En düşük MIC, çiçeklenme döneminde ikinci kesime bağlı olarak 15.75 µg mL^{-1} idi. Bitkiler, çiçeklenme öncesi aşamada en yüksek toplam fenol (16.64 mg GAE g^{-1} DM) ve toplam flavonoid içeriğine (2.88 mg QE g^{-1} DM) sahipti. En yüksek antioksidan aktivite (IC_{50} = 134.05 µg mL^{-1}) çiçeklenme öncesi aşamada gözlenmiştir. Fenolojik aşamaların ve kesimlerin uçucu yağın kimyasal özelliklerinin yanı sıra antibakteriyel ve antioksidan aktivitelerini de etkileyebileceği söylenebilir.

1. Introduction

Garden thyme (*Thymus vulgaris* L.) is a medicinal and aromatic plant species from the family Lamiaceae. The latest findings show that the essential oil of this plant species contains over 80 compounds, most of which have antioxidant and antimicrobial activities (Wesolowska & Jadczak, 2019). Phenol compounds like thymol (44-60%) and carvacrol (2.2-4.%) are among the main components of its essential oil (Pasqua et al., 2005).

The composition of the essential oil of aromatic plants is profoundly influenced by genetics, ecology, technology, cultivation techniques, harvesting methods, the storage conditions of the raw material, and processing methods. Thus, the wild and domesticated types of similar plant species can exhibit very different chemical components and characteristics (Miladi et al., 2013).

The results of a study in New Zealand on the effect of seasonal variations on the percentage and components of garden thyme essential oil revealed that the highest essential oil yield (22.8 L ha^{-1}) was obtained in December after the termination of the flowering period. The components were also very variable during the vegetative period. The highest contents of thymol and carvacrol (37%) were observed at the post-flowering stage in summer. As one of the most important components, *p*-cymene constituted 40-50% of the essential oil in winter and early spring, but it was reduced to 21% in January (McGimpsey et al., 1994). The constituents of the shoot essential oils of *T. kotschyanus* and *T. pubescens* were studied at the full flowering stage in Behshahr, Iran. The main components in the essential oil of *T. kotschyanus* were reported to include pulegone (18.7%), thymol (14.17%), 1,8-cineole (9%), piperitenone (6.3%), and carvacrol (37%). The essential oil of *T. pubescens* was found to mainly compose of 32.1% carvacrol, 19.1% thymol, 14.6% α -terpineol, and 6.1% p-cymene (Morteza-Semnani et al., 2006).

Escherichia coli is a common pathogenic bacterium in humans and animals that is mostly responsible for mild to severe diseases depending on the serotype. *E. coli* is transmitted by food and excretory pathways and has been isolated from various foodstuffs (Kordali et al., 2008). *Staphylococcus aureus* is the most common pathogen of skin infections (Bensouilah and Buck, 2006). Both bacteria are resistant to conventional synthetic antibiotics, complicating the treatment of the diseases caused by them. This inherent or acquired resistance, which has been shown in various pathogens, has so far been among the most important treatment problems. This has drawn the attention of researchers to alternative treatments, especially natural components that possess antibacterial properties. As such, the essential oil of medicinal and aromatic plant species has been proposed as a possible alternative (Kordali et al., 2008).

Various studies have reported the potential of using plant essential oils as a preservative in food industries against pathogenic and decaying microorganisms since they are more advocated by consumers owing to their natural compounds (Rojas-Gra et al., 2007). Although some main components of essential oils act similar to industrial antibiotics, they are very unlikely to be available as medication or food preservatives since a limited number of bacterial strains have been researched and even they have shown different sensitivities. Thus, to use these compounds as a medicine or food preservative, they need to be tested against a more diverse set of bacterial strains and species to prove their effectiveness (Fournomiti et al., 2015).

Few studies have addressed the effect of Shirazi thyme essential oil on preventing the toxicity of important bacteria in foodstuffs. In a study, for example, different rates of the essential oil of this plant species were applied to *Staphylococcus aureus* to check its impacts on the production of alpha-

hemolysin and enterotoxin C under in vitro conditions. The results revealed its inhibitory effect on its toxicity (Parsaeimehr et al., 2010).

Perpetual exposure to invasive factors results in the production of more free radicals, cell degradation, and in the long run, senescence and other organic disorders. Reactive oxygen species (ROS), nitrogen, and sulfur contain free radicals that cause various diseases including neural disorders, cancer, cardiovascular diseases, cataract, rheumatism, ulcer, and atherosclerosis. Antioxidants can neutralize free radicals and protect cell molecules including proteins, lipids, carbohydrates, and nucleic acids (Martins et al., 2015). These antioxidants are also used to preserve food quality for a longer time. Presently, there is a dispute on the use of synthetic antioxidants, so it is desirable to replace them with natural antioxidants (Delgado et al., 2014). Flavonoids are a group of pigments in plants that are responsible for the color of flowers and fruits and many of their biological properties, such as their antioxidant activities (Tripoli et al., 2007). Owing to its high thymol content, garden thyme has higher antioxidant activity than other thyme species so that its IC50 has been shown to be 59.159 μg mL^{-1} (Gedikoğlu et al., 2019).

In addition to assessing the antioxidant activity and other compounds in the essential oil of garden thyme, the present research aimed to measure the antibacterial activity of its leaf essential oil against *E. coli* and *S. aureus* during harvest at different phenological stages and at two cuts under the ecological conditions of Urmia, Iran.

2. Material and Methods

The seeds of garden thyme from the landrace of Deutsche Welle, Germany were sown in sowing trays on a substrate composed of perlite and peat moss under greenhouse conditions in February. For better acclimation, the seedlings were transferred to pots containing a mixture of soil, sand, and manure and were kept outdoors for one week. In mid-June, the seedlings were planted at the main farm in 2 × 3 m^2 plots spaced by 50 × 30 cm^2 in the research farm of the Faculty of Plant Production and Genetic Engineering, Department of Agriculture, Urmia University, Iran. The experiment was conducted as split plots based on a randomized complete block design with three replications. The main factor was assigned to harvest at different phenological stages (before, during, and after flowering) and the sub-plot to the cut (first and second cut). The plants were established in the first year and were harvested in the second year. After harvesting, the plant samples were dried at room temperature away from sunlight in 7 d. Then, they were refrigerated at 4 °C in paper pockets until the laboratory assays.

2.1. Essential oil distillation

The plant samples were separately distilled with a Clevenger for 3 h. Their essential oil was collected, and they were, then, measured and recorded in percentage (g/100gDW). After that, the essential oils were dried with water-free Na_2SO_4 (Sigma-Aldrich) and were stored in glass vials at 4°C.

2.2. Determination of essential oil components by GC/MS

The essential oil samples were examined by an Agilent 7890A gas chromatograph (US) equipped with an Agilent 5975C mass detector and the HP Chemstation software in Microsoft Windows, a split/splitless mode injector, and an HP-5 MS capillary column with a height of 30 m, an internal diameter of 0.25 mm, and a thickness of 0.25 mm (Agilent Co., US). The oven temperature was initially kept at 80 °C for 3 min, then increased to 180 °C at a rate of 8 °C min^{-1}, and kept at that temperature for 10 min. Helium was used as carrier gas. The flow rate of the carrier gas was 1 mL min^{-1} and the electron impact was 70 eV. The injection valve in the split mode had a ratio of 500:1 and a mass range for 40-500 mass bar^{-1}. To identify the components, the Wily 2007 and NIST 2005 mass references were used. The temperature of the injection valve was set at 250 °C. Data were analyzed by the Chemstation software package in Microsoft Windows.

2.3. Antibacterial activity

The antimicrobial susceptibility of the essential oil against *E. coli* and *S. aureus* were determined by the following two methods.

i. Broth microdilution to determine MIC and MBC
ii. Agar well diffusion

Distilled water was used as the solvent control and gentamicin (Sigma, US) was employed as the standard antibiotic. Each assay was performed in three replications.

2.3.1. Broth microdilution

The method is used to determine the minimum inhibitory concentration (MIC) or the maximum bactericidal concentration (MBC) of essential oils against bacteria. In summary, base-2 consecutive dilutions were prepared from the essential oils separately in round-bottom 96-well microplates (from dilutes 1:2 to 1:4096) containing the Mueller Hinton broth medium (Merc, Germany) and 5% dimethyl sulfoxide. Similar dilutions of distilled water, enrofloxacin, and dimethyl sulfoxide in the Mueller Hinton broth medium were prepared as the negative control, antibiotic control, and solvent control, respectively. It should be noted that the final volume of the wells had been adjusted at 180 µL until this stage. At the final step, 20 µL of the suspension of each bacterium equivalent to 0.5 McFarland standard (1-2 × 108 CFU mL^{-1}) was added to all wells. Also, in each row, one well was allocated to the culture medium control and one well to the bacteria growth control. After the bacteria were added, the microplates were placed in an oven in aerobic conditions at 37 °C for 24 h. To prepare the bacteria suspensions, 24 hours before preparing the foregoing dilutions, the bacteria were separately cultured in the TSB broth medium under aerobic conditions at 37 °C for 24 h. Then, the cultures were centrifuged at 2500 rpm at 4 °C for 15 min and the resulting sediment was suspended twice in a sterile physiological serum and its density was adjusted at 0.5 McFarland standard to be added to the wells (the final amount of bacteria inoculated into each group was 105 CFU/well).

To estimate MBC, 10 µL of the content of a well before and a well after the well in which MIC was observed was cultured linearly on an agar TSA medium.

2.3.2. Agar well diffusion

In the present study, the antibacterial activity of the essential oil was checked by the agar well diffusion method too for which plates with a diameter of 8 cm were first prepared from Mueller-Hinton agar culture and 6 mm wells were created with a sterile punch. After 24 h culture of the bacteria, a suspension was prepared similar to the previous method (0.5 McFarland) and linear culture was performed by a sterile swab on the plate. Finally, base-2 dilutions of essential oils (100, 200, 400 and 800 ppm) were prepared by the aforementioned method, 50 µL of each dilution was added into the wells, and the plates were placed in an oven under aerobic conditions at 37 °C for 24 h after which the diameter of the growth inhibition zone was measured with a ruler in mm (Qaiyami, 2007).

2.4. Antioxidant Activity

2.4.1. Measurement of DPPH radical scavenging percentage

The capability of essential oil in donating hydrogen atoms or electrons was measured by the extent of bleaching or reducing absorbance of purple DPPH solution in methanol (Brand-Williams et al., 1995). In this method, 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used as a stable radical composition and reagent for which 100 µL of different essential oil solutions (diluted to 1:500) was added to 2 mL of 0.004% DPPH in methanol. After 30 min of incubation at room temperature and in darkness, the absorbance of the samples was read against blank at 517 nm. The spectrophotometer was zeroed with methanol. DPPH free radical inhibition percentage was calculated by the following equation:

$$I\% = \frac{A_{blank} - A_{sample}}{A_{blank}} \times 100 \quad (1)$$

Then, to estimate IC50 (expressing the effective concentration of essential with the potency of 50% DPPH inhibition), five different rates of essential oil were prepared and after they were added to the DPPH solution similar to what described above, their absorbance was read with a spectrophotometer and was calculated by the diagram.

2.4.2. Measurement of total phenol content.

Total phenol was measured by Folin-Ciocalteu reagent using Oki et al. (2002)'s procedure. To this end, 1 mL of the Folin-Ciocalteu reagent (diluted to the ratio of 1:10) was added to 120 µL of essential oil solution (diluted to the ratio of 1:500). After 3 min, 0.3 mL of 2% sodium carbonate was added to the solution. The resulting solution was incubated at room temperature for 30 min and then, its absorbance was read at 750 nm with a spectrophotometer (Biowave, WPSA 2100, UK). The total phenol content was measured by using a standard gallic acid curve and expressed in mg gallic acid equivalent (GAE)/g dry matter (DM). The spectrophotometer was zeroed with methanol.

2.4.3. Measurement of total flavonoid content

The procedure described in Serra Bonvehí et al. (2001) was used to measure total flavonoid content. To this end, 260 µL of essential oil solution (diluted to 1:500) was mixed with 0.3 mL of 5% sodium nitrite and 3 mL of distilled water. After 5 min, 0.3 mL of 5% aluminium chloride was added. After 6 min, 2 mL of 1M sodium hydroxide solution was added to the solution and finally, the volume of the 10-mL volumetric flask containing the solution was adjusted with methanol. The absorbance was immediately read at 510 nm with a spectrophotometer against a control sample. The flavonoid content was calculated by the standard quercetin curve and expressed in quercetin equivalent (EC) per g DM.

2.4.4. Measurement of chain-breaking activity

Chain-breaking rate activity was measured using the DPPH reagent by Brand-Williams et al. (1995)'s procedure with slight modifications. The reaction rate was estimated by the following equation:

$$Abs^{-3} - Abs_0^{-3} = 03kt \quad (2)$$

in which *Abs* denotes absorbance over time, Abs_0 denotes absorbance at time 0, *t* denotes time in minutes, and k denotes chain-breaking rate.

2.5. Statistical Analysis

Data were statistically analyzed by the SAS software package. Means of the samples were compared by Duncan's test at the $P < 0.05$ level. The relationships between the recorded parameters were also checked by Pearson's test. MS-Excel was used to draw the graphs. All measurements were replicated three times and the values were reported as mean ± SD.

3. Results and Discussion

3.1. Essential oil percentage and compositions

Essential oil efficiency was found to be 40.20%, 1.2%, and 1.21% for the three phenological periods including pre-flowering, at flowering, and post-flowering in the first cut and 2.91%, 2.15%, and 1.76% for the three phenological periods in the second cut, respectively. Based on the results of the analysis of variance (ANOVA; Table 1), the main effect of the cut and phenological period was

significant ($P < 0.01$) on essential oil efficiency, but their interactive effect was revealed to be insignificant for this trait.

Table 1. The results of analysis of variance for the essential oil percentage based on a split-plot design over time

Sources of variations	df	Means of squares
		Essential oil percentage
Block	2	0.005^{ns}
Phenological stage	2	1.85^{**}
Error *a*	4	0.02
Cut	1	12.03^{**}
Phenological stage × cut	2	0.017^{ns}
Experimental error	6	0.03
Coefficients of variations (%)		8.21

ns, *, and ** show insignificance and significance at the $P < 0.05$ and $P < 0.01$ levels, respectively.

Essential oil efficiency was higher in the second cut (2.28%) than in the first (1.6%; Table 2). The highest essential oil efficiency (2.56%) was observed at the pre-flowering period, then it declined to 1.78% during flowering reaching its minimum value (1.49%) at the post-flowering period. It implies that as the plant approached maturity, its essential oil efficiency was decreased (Table 2). These findings are consistent with the results of other studies on garden thyme and other plants as to achieving the highest essential oil efficiency at the pre-flowering period. In a study on garden thyme, Salehi et al. (2014) found that the highest essential oil efficiency was 2.42% for the flower initiation period and as the plant approached the end of flowering, its essential oil percentage declined. A research on *Satureja sahendica* Bornm. revealed that the highest essential oil efficiency (3.30%) was at the early-flowering period and the lowest (1.65%) was at the late-flowering period among all phenological periods (Sefidkon & Akbari-nia, 2009). In a study on the hybrid *Thymus* × *citriodorus*, the highest and lowest essential oil was observed at the pre-flowering (2%) and post-flowering (1.3%) periods, respectively (Toncer et al., 2017). On the other hand, our findings are not consistent with the results of Zantar et al. (2015) on wild thyme, Ghasemi et al. (2016) on *Echinophora cinerea*, and Morshedloo et al. (2018) on *Origanum vulgare* subsp. *gracile*. They found that the studied plant species produced the highest essential oil percentage at the full flowering period. The inconsistency can be related to the differences in plant species and vegetative conditions.

Table 2. The comparison of means for the simple effects of phenological stage and cut on the recorded traits

Treatment	**Essential oil percentage**
Phenological stage	
Pre-flowering	2.56 ± 0.15 a
Flowering	1.78 ± 0.18 b
Post-flowering	1.49 ± 0.14 c
Cut	
First cut	1.60 ± 0.15 b
Second cut	2.28 ± 0.17 a

Means in each column with similar letter(s) did not differ statistically at the $P < 0.05$ level based on Duncan's test

The profile of the chemical compounds, which was determined by GC/MS, is presented in Table 3. The percentage of the compounds in the samples was determined based on the normalization of the curve peak and listed in order of their retention index on the HP-5MS column (Figure 1). A total of 25 compounds were detected of which 20 compounds were observed during and after flowering in the first cut and 19 compounds in the next cuts. The amount of oxygen-containing monoterpenes was higher in the first cut than in the second cut. With respect to the phenological periods, the highest value was 87.13% related to the harvest during flowering whereas the amount of hydrocarbonic monoterpenes was higher in the second cut than in the first cut and its highest amount (35.06%) among different phenological periods was related to the pre-flowering period.

Table 3. The chemical composition of the essential oils and the antibacterial activity of some constituents at different phenological stages. For the essential oil of *T. vulgaris*, the GC signal was observed and identified. The main components included p-cymene (3.37-18.04%), γ-terpinene (4.88-16.61%), thymol (43-63.18%), and carvacrol (4.73-17.84%).

No.	Components	RI	%						Antibacterial Activity	
			Cut1			Cut2				
			Pre-flowering stage	Flowering stage	Post-flowering stage	Pre-flowering stage	Flowering stage	Post-flowering stage	Species of bacteria	References
1	α -Thujen	927	0.55	-	0.40	0.84	0.82	0.76		
2	α -Pinene	931	0.55	-	0.51	0.56	0.55	0.51	*Campylobacter jejuni*	(Kovač et al.,2015)
3	1-Octen-3-ol	975	0.51	0.51	0.49	0.83	0.75	0.79		
4	β -Myrcene	989	1.05	-	0.91	1.18	1.08	1.00		
5	α -Terpinene	1015	1.70	0.38	1.15	2.04	1.35	1.13		
6	***P*-Cymene**	**1026**	**7.20**	**3.37**	**10.55**	**12.54**	**17.86**	**18.04**	*M. tuberculosis*	(Andrade et al., 2015)
7	Limonene	1028	0.42	-	0.37	0.46	0.44	-		
8	1,8-cineole	1032	-	0.46	0.89	0.59	0.48	0.54		
9	**γ -Terpinene**	**1060**	**13.78**	**4.88**	**7.55**	**16.61**	**10.60**	**8.46**	*S. aureus*	(Cristani et al., 2007)
10	Trans-sabinene hydrate	1068	0.60	0.63	0.68	0.7	0.76	0.57		
11	Linalool	1099	1.75	1.78	2.03	2.10	1.88	2.10	*Streptococcus mutans*	(Park et al.,2012)
12	Camphor	1148	-	-	-	-	0.43	-		
13	Borneol	1168	1.23	0.60	0.71	0.81	1.07	1.15		
14	Terpineol-4	1180	0.73	0.68	0.66	0.73	0.64	0.86		
15	α -Terpineol	1194	-	0.20	-	-	-	-	*E. coli&Staph. aureus*	(Cosentino et al.,1999)
16	Thymol, methyl ether	1235	-	1.23	0.68	1.12	-	1.05		
17	Carvacrol methyl ether	1245	0.88	1.13	0.75	0.89	0.62	0.86		
18	**Thymol**	**1295**	**55.14**	**62.12**	**63.18**	**51.10**	**43.00**	**44.41**	*E. coli&Staph. aureus*	(Kavoosi et al., 2013)
19	Borneol, acetate	1297	0.45	0.46	0.54	0.58	0.85	1.015		
20	**Carvacrol**	**1303**	**9.91**	**17.84**	**5.85**	**4.73**	**14.77**	**14.03**	*E. coli&Staph. aureus*	(Mahboubi& Kazempour.,2011)
21	Trans-caryophyllene	1425	1.84	2.45	1.64	1.27	1.57	1.54	*Staph. aureus*	(Dahham et al.,2015)
22	β-bisabolen	1509	-	0.23	-	-	-	-		
23	Delta-Cadinene	1527	-	0.33	-	-	-	-		
24	Caryophyllene oxide	1590	0.87	0.51	0.46	-	-	0.52		
25	α -cadinol	1645	0.38	0.22	-	-	-	-		
Monoterpene hydrocarbons			25.76	**9.14**	21.93	**35.06**	33.45	30.69		
Oxygenated monoterpenes			70.69	**87.13**	75.97	**63.35**	64.5	66.585		
Sesquiterpene hydrocarbons			1.84	**3.01**	1.64	**1.27**	1.57	1.54		
Oxygenated sesquiterpenes			1.25	0.73	0.46	-	-	0.52		
sum			**99.54**	**100.01**	**100**	**99.68**	**99.52**	**99.335**		

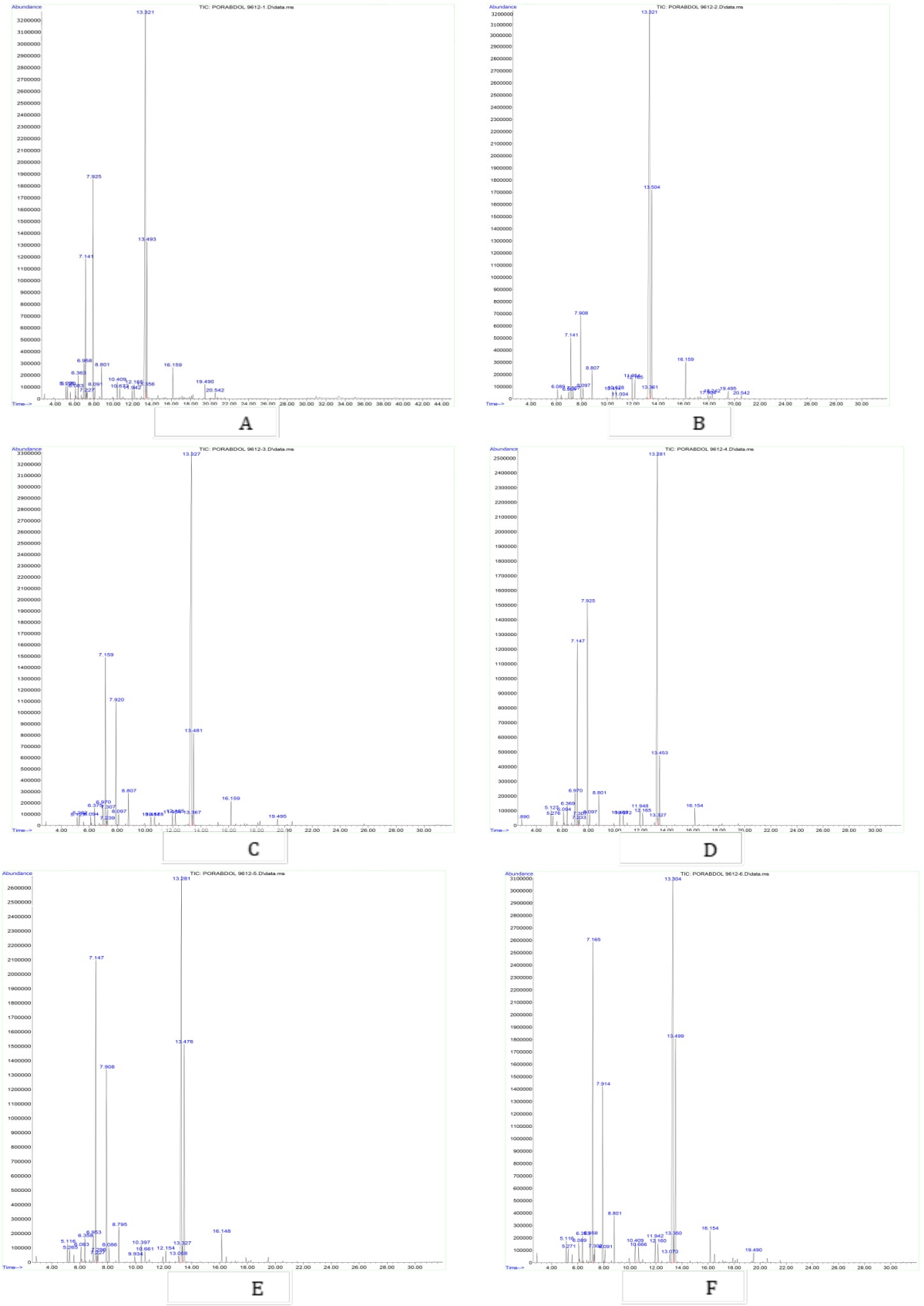

Figure 1. GC/MC chromatograms of *T. vulgaris* analyzed in GC/MC (Agilent, US) at the pre-flowering first cut (A), flowering first cut (B), post – flowering first cut (C), pre-flowering second cut (D), flowering second cut (E) and post – flowering second cut (F), using a capillary column (MS-5) attached to a mass detector.

The lowest amount of hydrocarbonic monoterpenes was obtained from the harvest during flowering in the second cut whilst these plants exhibited the highest amounts of oxygen-containing monoterpenes and sesquiterpenes too. The abundance of hydrocarbonic monoterpenes at the pre-flowering stage is reasonable since monoterpenes like c-terpinene and p-cymene are regarded as the biogenetic precursors of terpene phenol carvacrol (Casiglia et al., 2015). The main components of the essential oil were thymol (43-63.18%), *p*-cymene (3.37-18.04%), carvacrol (4.73-17.84%), and *γ*-terpinene (4.88-16.61%). The other components were observed in lower values in ranges smaller than 11.79-14.70%. The highest thymol content was related to the pre-flowering and post-flowering periods in the first cut, the highest *p*-cymene content to the post-flowering period in the second cut, the highest carvacrol content to the flowering period in the first cut, and the highest *γ*-terpinene to the pre-flowering period in the second cut. These results are partially in agreement with the results of Rota et al. (2008) who found that thymol, carvacrol, and *γ*-terpinene were the main components of the essential oil of *T. vulgaris*. However, our results are inconsistent with the results of Sartoratto et al. (2004) in their study on garden thyme in Brazil so that, according to their findings, geranyl was the most abundant component (21.8%), and *γ*-terpinene and thymol constituted 2.6% and 17.5% of the essential oil, respectively – much lower than our observations in the present study. This may point to the impact of geography or environment on the components of *T. vulgaris* essential oil. These differences can also be ascribed to the differences in chemotypes. On the other hand, a study on *Thymus* × *citriodorus* showed that the most abundant components on its essential oil were terpinolene, α-terpineol, linalool, bornyl acetate, and borneol (Toncer et al., 2017). Based on the results, it seems that the cut and phenological stage can influence the amount and type of essential oil components.

3.2. Antibacterial Activity

The results of ANOVA indicated that the interactive effect of cuts and phenological stage at harvest time was significant ($P < 0.01$) on the diameter of the zone of bacterial growth inhibition. Based on the comparison of means (Table 4), the highest diameter of the inhibition zone was the second cut during flowering (19.9 mm) for *E. coli* and the first cut during flowering (18.2 mm) for *S. aureus*. The results revealed that the plant had the lowest antibacterial activity among the studied essential oils before flowering at the second cut in which the diameter of the inhibition zone was 15.2 mm for *E. coli* and 13.2 mm for *S. aureus* (Table 4). Nedorostova et al. (2009) reported the antimicrobial activity of the essential oil of three plant species – *T. vulgaris*, *T. pulegioides*, and *T. serpyllum* – in the vapor phase against *E. coli* and *S. aureus*. In addition, a high level of antifungal activity has been reported for the essential oil of thyme isolated at the flowering stage (Saoud et al., 2013). The results indicate that the lowest MIC was 15.75 μg mL^{-1} related to the second cut during flowering and the highest was 125 μg mL^{-1} related to the second cut before flowering. These results are consistent with the findings as to the diameter of the growth inhibition zone.

Table 4. The antibacterial activity of the *T. vulgaris* essential oil at different phenological stages against *Staphylococcus aureus* and *Escherichia coli*. Gentamicin (Sigma, US) was used as the control medicine. The DMSO solvent (dimethyl sulfoxide) was 10% with no antibacterial activity.

Cut	Phenological stage	*S. aureus* ATCC 29213			*E. coli* ATCC35218		
		MIC (μg mL^{-1})	MBC (μg mL^{-1})	Inhibition zone (mm)	MIC (μg mL^{-1})	MBC (μg mL^{-1})	Inhibition zone (mm)
First	Pre-flowering	62.5	123	17.2 ± 0.06 b	62.5	125	16.3 ± 0.11 d
	Flowering	31.25	62.5	18.2 ± 0.17 a	31.25	62.5	19.4 ± 0.15 b
	Post-flowering	62.5	125	17.26 ± 0.2 b	125	250	17.2 ± 0.09 c
second	Pre-flowering	125	250	13.2 ± 0.11 d	125	250	15.2 ± 0.08 e
	Flowering	15.75	31.5	17.13 ± 0.08 b	15.75	31.5	19.9 ± 0.09 a
	Post-flowering	62.5	125	15.13 ± 0.15 c	62.5	125	16.4 ± 0.11 d
	Gentamycin	17.5	35	22	15	30	28

Means in each column with similar letter(s) did not differ statistically at the $P < 0.05$ level based on Duncan's test.

The antibacterial activity of carvacrol and p-cymene was examined against *Vibrio colerae*. Carvacrol showed a high inhibitory effect on *V. colerae* whereas p-cymene did not. Nonetheless, the presence of p-cymene reinforced the inhibitory activity of carvacrol when they were applied together. The synergy of p-cymene and carvacrol may justify their combined application to suppress *V. cholera* and other pathogens in foodstuffs (Mitropoulou et al., 2015). In another study on the antibacterial activities of various essential oils, including p-cymene, thymol, and carvacrol, against *Mycobacterium tuberculosis* and *M. bovis*, p-cymene showed the lowest antibacterial activity, but thymol and carvacrol were found to be the most active terpenes (Andrade-Ochoa et al., 2015). An interesting finding as to the relationship between the phytochemical analysis by GC and bioactivity on the bacteria of *Streptococcus mutans* showed that the bacteria was influenced by the high percentage of menthol in *M. arvensis* (over 70% of the total composition of the essential oil) and the high percentage of phenol monoterpenes such as carvacrol in *T. capitatus* (over 65% of the total composition of the essential oil) and thymol in *T. vulgaris* (over 25% of the total composition of the essential oil), which had a MIC of 8 μL mL^{-1} (Tardugno et al., 2018). The mechanism by which menthol and other phenolic isomers of thymol and carvacrol influence oral bacteria is associated with their performance in inducing disorder in membranes, which leads to cell leakage (Gursoy et al., 2009; Franz, 2010; Oyanagi et al., 2012; Freires et al., 2015; Kouidhi et al., 2015). Other components of essentials oils, e.g. α-pinene, γ-terpinene, linalool, α-terpineol, and trans-caryophyllene, have also been subject to extensive research (Table 3).

The results showed that the essential oil of garden thyme had an effective inhibitory impact on the growth of both tested bacteria (Figure 2). This finding corroborates similar reports as to the antibacterial activity of plant essential oils against Gram-positive and Gram-negative bacteria (Roldán et al., 2010; Soković et al., 2007). We observed that *E. coli* (a Gram-negative bacteria) was more sensitive to the antibacterial activity of the garden thyme essential oil than *S. aureus* (a Gram-positive bacteria). Fatma et al. (2014) report that despite the possession of an external layer composed of hydrophobic compounds around their cell wall, which acts as a barrier against permeability, the Gram-negative bacteria are usually more sensitive to the essential oil of *Thymus hirtus* sp. There is seemingly a relationship between the low antibacterial activity of thyme essential oil and the deficiency of oxygen-containing monoterpenes. Also, the low molecular weight of the essential oil compounds seems to allow them to penetrate across the internal membrane of Gram-negative bacteria (Pattnaik et al., 1997). The results of our screening prove the potential of the garden thyme essential oil to be used as an active ingredient in medications and food preservatives in the treatment of plant and animal disease and remove food-rotting microorganisms.

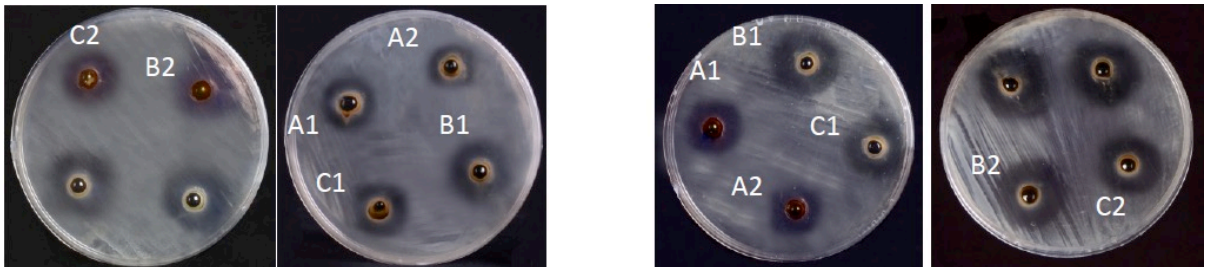

Figure 2. The inhibitory effect of the garden thyme essential oil on *Escherichia coli* and *Staphylococcus aureus* at different cuts and phenological stages: A = pre-flowering stage, B = flowering stage; C = post-flowering stage; 1 = first cut; 2 = second cut.

3.3. Antioxidant activity

The assay of the antioxidant activities of the *T. vulgaris* essential oil at a rate of 3.68 μg mL^{-1} provided the following results.

Based on the results of ANOVA (Table 5), the main effects of cut and phenological stage were significant ($P < 0.01$) on total phenol content, but their interaction was not. Among the phenological stages (Table 7), the highest total phenol content was obtained at the pre-flowering stage (16.64 mg GAE g^{-1} DM) and the lowest at the post-flowering stage (8.88 mg GAE g^{-1} DM).

Table 5. The results of analysis of variance for the antioxidant activities based on a split-plot design over time

Sources of variations	df	Means of squares				
		Total phenol	Total flavonoids	Chain-breaking	IC50	DPPH
Block	2	10.14^{*}	0.050^{ns}	4.26^{ns}	13.29^{ns}	7.95^{ns}
Phenological stage	2	90.30^{**}	2.47^{**}	2.75^{ns}	10856.44^{**}	31.62^{ns}
Error *a*	4	0.98	0.010	3.36	9.53	8.06
Cut	1	267.95^{**}	7.86^{**}	58.88^{**}	5739.85^{**}	0.19^{ns}
Phenological stage × cut	2	8.95^{ns}	0.27^{**}	27.63^{*}	718.78^{**}	74.16^{**}
Experimental error	6	4.30	0.012	3.68	16.16	6.32
Coefficients of variations (%)		16.24	5.06	10.51	2.30	6.80

ns, *, and ** show insignificance and significance at the $P < 0.05$ and $P < 0.01$ levels, respectively.

The total phenol content was higher in the second cut than in the first cut. Phenols are compounds that contain at least one hydroxyl (OH) group attached to an aromatic ring. They occur in aerial parts of the plants, e.g. flowers, leaves, seeds, fruits, stems, and also in their roots. Phenol compounds are interested in due to their appealing biological properties including antioxidant activities and free radical scavenging (Göçer et al., 2011). A research study on rosemary revealed that total phenol content was lower at the pre-flowering stage than at the fruit-bearing stage, which is inconsistent with our findings (Jordán et al., 2013).

The interaction of cut and phenological stage (Table 5) was significant for total flavonoids, IC50, and DPPH at the $P < 0.01$ level and for chain-breaking extent at the $P < 0.05$ level. Flavonoids are polyphenol compounds with a high distribution in plants and perform many functions. They may also be involved in chemical signalling, thereby contributing to physiological regulations and cell cycle inhibition (Galeotti et al., 2008). The comparison of means (Table 6) indicated that the total flavonoid content was lower in the first cut at different phenological stages and its highest value was related to the second cut at the pre-flowering stage (3.70 mg QE g^{-1} DM) and the lowest to the first cut at the post-flowering stage (1.21 mg QE g^{-1} DM). In separate studies on the alcoholic extract of garden thyme leaves, total flavonoid content was reported to be 8.56 mg QE g^{-1} DM (Nadia et al., 2013) and 36.6 mg QE g^{-1} DM (Köksal et al., 2017). The highest total flavonoid contents at the early-flowering stage were 14.94, 75.85, 8.4, and 36.87 mg QE g^{-1} DM for the extracts of *Agastache foeniculum*, *Lavandula foeniculum*, *Melissa officinalis*, and *Nepeta cataria*, respectively, which is consistent with our findings (Duda et al., 2015).

Table 6. The comparison of means for the interactive effects of phenological stage × cut on the studied traits

Phenological stage	Cut	Total flavonoid (mg QE g^{-1} DM)	Chain-breaking (%)	IC50 (μg mL^{-1})	DPPH inhibition (%)
Pre-flowering	First	2.07 ± 0.08 c	16.85 ± 2.34 c	193.37 ± 1.61 c	30.22 ± 3.07 b
	Second	3.70 ± 0.14 a	18.07 ± 1.09 bc	128.74 ± 0.98 d	38.55 ± 1.44 a
Flowering	First	1.28 ± 0.05 d	22.18 ± 0.65 a	196.51 ± 0.94 b	40.77 ± 0.69 a
	Second	2.77 ± 0.06 b	15.22 ± 0.40 c	145.54 ± 2.70 c	36.72 ± 1.39 a
Post-flowering	First	1.21 ± 0.02 d	21.11 ± 0.06 ab	241.67 ± 3.89 a	39.66 ± 0.53 a
	Second	2.05 ± 0.05 c	16 ± 0.275 c	196.12 ± 0.13 b	36 ± 0.34 a

Means in each column with similar letter(s) did not differ statistically at the $P < 0.05$ level based on Duncan's test.

The highest IC50 was observed in the first cut at the post-flowering period and the lowest in the first cut at the pre-flowering period (Table 6). This means that the antioxidant activity is higher in the first cut at the pre-flowering stage. A research study on *Echinophora cinerea* showed that the antioxidant activity was stronger at the pre-flowering stage than at the full-flowering stage (Ghasemi et al., 2016). The comparison of means showed that the first cut at the pre-flowering stage had the lowest DPPH, but it did not differ from the other treatments significantly. The highest chain-breaking activity was obtained from the first cut at the flowering stage and the lowest from the second cut at the flowering stage.

Table 7. The comparison of means for the simple effects of the phenological stage and cut on the studied traits

Treatment	Total phenol (mg GAE g^{-1} DM)	Total flavonoid (mg QE g^{-1} DM)	Chain-breaking (%)	IC50 (μg mL^{-1})
Phenological stage				
Pre-flowering	16.64 ± 2.14 a	2.89 ± 0.37 a	17.46 ± 1.88 a	134.05 ± 2.52 c
Flowering	12.76 ± 2.29 b	2.03 ± 0.34 b	18.70 ± 1.59 a	171.03 ± 11.47 b
Post-flowering	8.88 ± 1.17 c	1.63 ± 0.19 c	18.60 ± 1.15 a	218.90 ± 10.33 a
Cut				
First	8.9 ± 0.87 b	1.52 ± 0.14 b	20.04 ± 1.07 a	192.52 ± 14.85 a
Second	16.62 ± 1.64 a	2.84 ± 0.24 a	16.43 ± 0.55 b	156.80 ± 10.16 b

Means in each column with similar letter(s) did not differ statistically at the $P < 0.05$ level based on Duncan's test.

Phenol and total flavonoid contents were negatively correlated to the IC50 activity significantly ($P < 0.05$). A previous study on *T. vulgaris* (Sarikurkcu et al., 2008) revealed a close relationship between polyphenols and antioxidant activity, which can support the effectiveness of these compounds as free radical scavengers and antioxidants. Fatma et al. (2014) reported that total phenol and total flavonoid contents had a negative correlation with the DPPH assay whereas the positive correlation between a less-shown phenol compound ((+)-catechin hydrate) and the DPPH assay may support the role of trivial compounds in synergy with the main compounds in their antioxidant activity.

4. Conclusions

The results revealed the effectiveness of the thyme essential oil against the tested bacteria. All in all, the biochemical properties and the measurement of the antimicrobial activity showed that a higher percentage of aliphatic and oxygen-containing monoterpenes and mainly phenol monoterpenes such as thymol were responsible for the antioxidant activity of the studied essential oil. As well, the Gram-negative *E. coli* was more sensitive to the *T. vulgaris* essential oil than the Gram-positive *S. aureus*. The essential oil percentage was higher in the second cut than in the first cut. Also, the essential oil had stronger antioxidant activity in the second cut at the pre-flowering stage. Overall, it can be said that phenological stages and cuts can affect essential oil percentage, composition, and antioxidant and antimicrobial activities.

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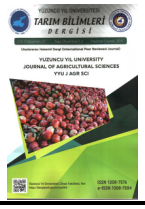

Research Article

Tolerance to Imazamox Herbicide Found after Screening of Advanced Generation Lentil Mutant Genotypes

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Imazamox tolerance.

Abstract: In Turkey, one of the essential grain legumes is lentil. It is usually perceived as a weak competitor with weeds. The research objective was to determine the tolerance of selected 145 mutagenized lentil genotypes at M5 generation to imazamox herbicide including 139 M5 lentil genotypes derived from Ethyl Methane Sulfonate (EMS) mutagenized seeds of cultivar Firat-87 and 6 control lentil cultivars were screened for imazamox herbicide tolerance. Experiments were carried out in the greenhouse and field. Herbicide was applied at 150% of the recommended dose of (100 ml/ha, or 40 g a.i/ha) imazamox when the plants were between 5 - 6 node stage. The response of the genotypes to the herbicide was evaluated by measuring the plant height as a sign of the growth and also by visual scoring of foliar damage with a 1 to 5 scale at 45 and 60 days after a spraying in the field experiment and at 30 and 60 days after a spraying in the greenhouse experiment. The genotypes were categorized based on their reactions to herbicides as highly tolerant, tolerant, moderately tolerant, sensitive, and highly sensitive. The results showed significant differences among the genotypes for tolerance to the herbicide. At 60 days after spray, most of the genotypes showed some of the recoveries in both experiments. Five genotypes (IMI-124, IMI-128, IMI-130, IMI-138, and IMI-139), displayed high herbicide tolerance in both experiments. The tolerant genotypes can be exploited in future breeding programs for improving herbicide tolerant lentil varieties.

İleri Generasyon Mercimek Mutant Genotiplerinin İmazamoks Herbisitine Toleranslarının Belirlenmesi

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Anahtar Kelimeler
Mercimek,
Etil metan sulfonat (EMS),
İmazamoks tolerans.

Öz: Yabancı otlara karşı rekabet gücü zayıf olan mercimek, Türkiye'de üretilen önemli yemeklik dane baklagillerdendir. Araştırma, Etil Metan Sülfonat (EMS) ile mutajenize edilen Fırat 87 çeşidinden M5 generasyonunda seçilen 139 mercimek mutant genotipleri ve 6 kontrol çeşitin imazamoks herbisite toleransını belirlemek amacıyla yürütülmüştür. Denemeler hem sera hem arazi şartlarında yapılmıştır. İmazamoks etken maddeli herbisit, bitkiler 5 - 6 boğumlu olduğu dönemde önerilen dozun (100 ml/ha veya 40 g a.i/ha) 1.5 katı (150 ml/ha) olarak uygulandı. Genotiplerin herbisite tepkisi, büyümenin bir işareti olarak bitki boyunun ölçülmesiyle ve ayrıca, bitki aksamında oluşan herbisit zararının görsel skorlanması (1= dayanıklı 5= % 100 ölü) yapılarak değerlendirildi. Ölçüm ve skorlamalar tarla denemelerinde ilaçlama yapıldıktan 45 ve 60 gün sonra, sera

denemelerinde ise 30 ve 60 gün sonra yapılmıştır. Genotiplerin herbisite karşı reaksiyonları; yüksek toleranslı, toleranslı, orta derecede toleranslı, hassas ve oldukça hassas olarak gruplandırıldı. Elde edilen sonuçlara göre, herbisite tolerans bakımından genotipler arasında önemli farklılıklar gözlenmiş olup ilaçlamadan 60 gün sonra yapılan değerlendirmelerde, hem tarla hem de sera denemelerinde genotiplerin çoğunda bir miktar iyileşmeler gözlenmiştir. Beş genotip (IMI-124, IMI-128, IMI-130, IMI-138 ve IMI-139), tarla ve sera denemelerinde herbisit toleransı en yüksek genotipler oalrak belirlenmiştir. Bu genotipler, imazamoks herbisite toleranslı mercimek çeşiti geliştirmek için ıslah programlarında kullanılabilir.

1. Introduction

Lentil (*Lens culinaris* Medik.) is a member of the Fabaceae family. It is grown as a winter crop in most parts of the world. Lentil can grow well in depleted soil, and a lack of rain and freezing conditions do not necessarily affect their growth. It has nutritional and health importance for humans because it contains a high percentage of vegetable protein (up to 30%) and is a good source of vitamins and other important nutrients, such as 0.5% phosphorus content. Furthermore, lentil brings good economic returns (Sarker, 2006). It is cultivated in most parts of the world and the countries with the greatest production are Canada, India, Australia and Turkey. Crushed crust from the processing of lentils is also used to feed cattle and poultry. Therefore, its cultivation brings secondary benefits such as animal feed and, via nitrogen fixation, increases the fertility of the land in which they are grown.

Lentil cultivation suffers from considerable annual variations in yield, and a clear decline has emerged over the last five years in Turkey due particularly to management problems, and susceptibility to various biotic and abiotic stresses (Figure. 1). The yield of current cultivars of lentil ranges between 1450 and 1950 kg/ha, but the yield can be considerably depressed due to poor weed management (Aktar et al., 2013). In Turkey, the lentil area harvested was 292 455 ha, production was 430 000 tonnes and yield was 1 470 Kg/ha, in 2017 (FAO, 2018).

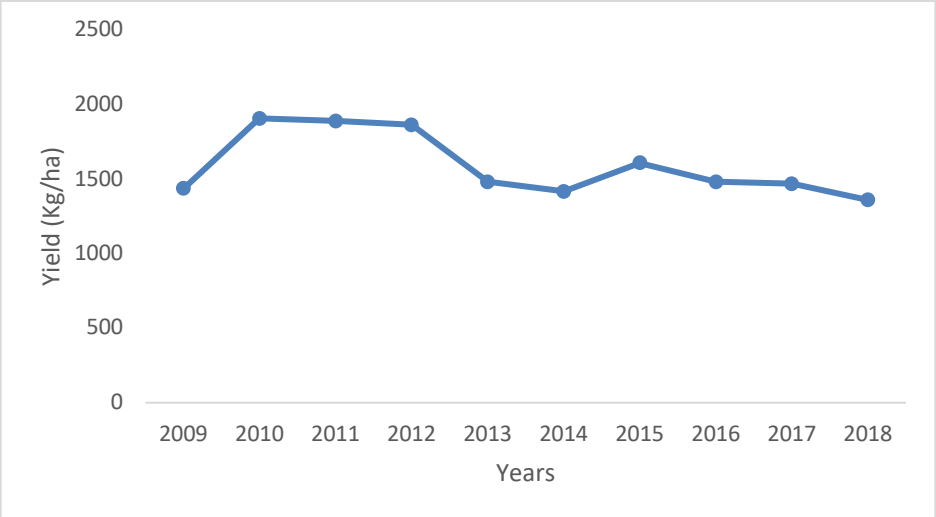

Figure 1.Variations in lentil yield in Turkey (FAO, 2018).

Weeds have a major impact on lentil production. Yield losses in lentil range between 20% and 80% because lentil is a poor weed competitor (Al Thahabi et al., 1994; Saxena and Wassimi 1980; Boerboom and Young, 1995; Brand et al., 2007). Many broadleaf species and annual grasses are in competition with lentils for water, nutrients, and sunlight, which affects lentil production and the quality of grain while also allowing diseases and other pests to thrive (Rizwan, 2015). Losses due to weed competition in the lentil yield are dependent on the level of weed infestation, and the types of weed species which are prevalent (Al-Thahabi et al., 1994; Yenish et al., 2009; Saxena and Wassimi 1980; Hattori, 1995).

In lentils, weeds are commonly controlled manually. However, hand weeding is impractical in the extensive production areas because is an expensive process and labour intensive (Baumgartner and Al-Khatib, 1999; Iler and Pauls,1993), and if delayed, the operation does not prevent the adverse effect of the weeds on crop yield. It is therefore necessary to use effective herbicides to decrease unwanted competition (Ashigh et al., 2009). As such, lentil genotypes with improved herbicide tolerance can offer more suitability for the use of broad-spectrum post-emergence herbicides which are required by farmers. In light of this information, lentil varieties with improved herbicide tolerance which can offer greater flexibility for the use of broad-spectrum post-emergence herbicides are required by farmers.

The IMI class of herbicides, including imazethapyr, imazamox and imazapic, provides a broad spectrum of weed control activity, adjustability in the timing of application, low usage rates, and low mammalian toxicity. Other advantages of using IMI herbicides include low environmental damage, control of broadleaf weeds and a low herbicide dose per hectare (Weed Science Society of America 2007). Furthermore, IMI-tolerant genotypes have been identified in many species, which has enabled the development of several tolerant crops (Ashigh et al., 2009). At present, IMI herbicides are used on non-pulse crops such as barley, spring wheat, sunflower, oats, oilseed mustard, canola and alfalfa and pulse crops including lentil, field pea, soybean and dry bean (Saskatchewan Ministry of Agriculture 2013).

There is the possibility of finding highly tolerant genotypes by the screening of a large number of genotypes to exploit natural differences or screening of genotypes created through induced mutations (Toker et al., 2012). Other studies have reported the creation of herbicide-tolerant mutants by selection from spontaneous mutation (Bernasconi, 1995; Tan, 2005). Herbicide tolerant mutant plants have been discovered in many crops like lentil (Sharma, 2017), wheat (Newhouse, 1992) and maize (Anderson, 1989; Newhouse, 1992). In particular, many studies have found that in many crops, the mutations were efficient in the creation of genotypes tolerant to herbicide (Tan et al., 2005; Rizwan et al., 2017; Ndungu, 2009; Malkawi, 2003; Sharma et al., 2018; Chant 2004; Bernasconi et al., 1995; Beckie at al., 2006).

Seed mutagenesis followed by herbicide selective pressure has been utilized widely to develop crop resistance to herbicides (Mulwa and Mwanza, 2006). This technique obtains a wide array of advantages for farmers of enhanced economical weed control and improves economic returns. Enhanced economical weed control are advantage to farmers from the technique of seed mutagenesis. Plant -tolerance to herbicides has been developed by the widespread utilization of seed mutagenesis followed by herbicide selective pressure. The selected- mutations can be evaluated for herbicide resistance. Because most herbicide-resistant mutants have been created via chemical mutagenesis, this process was understood to be a significant source of producing genetic variability.

Among chemical mutagens, ethyl methanesulfonate (EMS) is the most popular method for obtained an effective method (Rizwan et al., 2017; Tan et al., 2005). EMS generally causes little nucleotide changes or small point mutations within the genome, as compared to other chemical and physical mutagens that cause huge changes such as the disappearance of the large part of the genome that causes significant changes and can also destroy the characteristics of the cultivar (Weil and Monde, 2007).

This study aims to explore the potential of EMS induced mutation to generate lentil genotypes that are tolerant of the imidazolinone herbicide that could be included in plant breeding programs.

2. Material and Methods

2.1. Material

The present study was conducted at Harran University, Faculty of Agriculture Experiment Station field and greenhouse facilities in the 2017-2018 growing season. A total of 145 genotypes including 139 genotypes of EMS mutagenized seeds of cultivar Firat-87 and 6 lentil cultivars used as imidazolinone sensitive controls (Firat-87, Cagil and 4 Canadian cultivars with the unknown name) were screened against imazamox herbicide tolerance in the experiment. The protocol for ethyl methanesulfonate (EMS) mutation has been described by Bukun and Kahraman, 2013.

EMS mutated Firat 87 genotypes were selected at M2 generations based on healthy appearance after two doses of imazamox spray in the field and were advanced to M6 generation using single seed descent (SSD) to obtain homozygosity and also to generate enough seed for the experiment.

A commercial herbicide of imazamox was used in the experiment. The herbicide is registered for use on Clearfield Sunflower cultivars with a recommended dose of 1250 ml/ha (50 g a.i/ha) in Turkey. Currently, there is no imidazolinone herbicide registered for use in lentil in Turkey but imidazolinone herbicides have been used on Clearfield lentil cultivars grown in Canada with a recommended application dose of 40 g a.i/ha. Based on this information, it was decided to apply with an extra 50% of the recommended dose of imazamox (1500 ml/ha, e.g 60 g a.i/ha) to determine the tolerant genotypes. Any genotype that survived at this dose of herbicide would be considered tolerant to the herbicide. A shoulder-mounted hand operated knapsack sprayer was used to spray agents the herbicide by100 L/ha of water during cooler hours of the day when there was slow or no wind.

Two experiments were carried out both in the greenhouse and in the field in a randomized complete block design (RCBD) with three replications. Since the aim of the experiment was to determine genetic resistance to the herbicide, seed yield was not evaluated, and the experiments were not carried out at the usual planting time of lentil. About 30 seeds from each genotype were planted in 1 m rows with 20 cm of row spacing in the field experiment. For the greenhouse experiment, 10 seeds from each genotype were planted in a 50 cm row length with a 20 cm of row spacing.

The imazamox herbicide was applied when the plants had grown between 5 - 6 nodes in size. A 1 to 5 scale was used to evaluate the damage caused by the herbicide as proposed in chickpea [(Gaur et al., 2013), (Table 1)]. The damage was scored in the whole row. The damage response of lentil genotypes against imazamox herbicide in the field experiment was observed after 45 and 60 days after spraying (DAS), or after 30 and 60 DAS for the greenhouse experiment.

Table 1. The scale used for categorizing plants for their reaction against herbicides (Gaur et al., 2013)

Damages	**Reaction**
Highly tolerant	Very good genotype growth with no chlorosis/burning/narrowing of leaves
Tolerant	Good genotype growth with a lıtle chlorosis /narrowing/burning of leaves
Moderately	moderate genotype growth with medium chlorosis/narrowing/burning of leaves,
Sensitive	Weak growth genotype growth with severe chlorosis /narrowing/burning of leaves
Highly sensitive	Very Weak growth genotype with complete chlorosis/narrowing/burning leading to mortality of most plants

In addition to the susceptibility score, plant height was measured immediately before spray (BS). Resistance to the herbicide was observed by measuring plant height as a sign of post-treatment growth after 15 and 45 DAS for the field experiment, or after 30 and 60 DAS for the greenhouse experiment of the spray. Stalling or stunting of plant growth was considered as susceptibility to the herbicide, while regular normal growth of any genotype was considered as resistance to the herbicide.

2.1. Statistical Analysis

Statistical analysis of the data was performed with Microsoft Excel and Genstat v12 and involved analysis of variance (ANOVA) to test for differences in plant height between genotypes at each measured timepoint in the field and greenhouse experiments. Histograms were constructed to show the frequency distribution of plant height and plant damage reaction scales. The dynamic development of plant height in each response category was assessed by comparing mean plant height across timepoints and using ANOVA to test the significance of differences between each category and the interaction between category and time point. The relationship between plant height and tolerance scores was assessed with least squares difference (LSD) tests of plant height in each category.

3. Results

3.1. Plant damage reaction scale

Based on the visual scoring at 45 DAS and classification, the herbicide tolerance score of the genotypes ranged from 1 to 5 in the field experiment. Out of 139 genotypes tested, one genotype (IMI-128) was scored as highly tolerant, 4 genotypes as tolerant (IMI-124, IMI-130, IMI-138 and IMI-139), 9 genotypes as moderately tolerant, 7 genotypes as sensitive, and the rest of the genotypes (124) were

highly sensitive (Table. 2) shows the results of variance analysis. The response of the genotypes for imazamox at 60 DAS indicated some differences in the herbicide tolerance scores among the genotypes with some recovery observed in plants possibly due to late rains in the field. Based on the second visual scoring at 60 DAS (Figure 2), it was observed that 3 genotypes (IMI-124, IMI-128, IMI-130) were highly tolerant, 7 genotypes (IMI- 125, IMI -132, IMI- 135, IMI- 136, IMI- 137, IMI- 138, IMI- 139), were tolerant, 8 genotypes were moderately tolerant, 19 sensitive, and the rest of the genotypes (108) were highly sensitive (Table 3).

The herbicide tolerance score of the genotypes in the greenhouse at 30 DAS ranged from 1.3 to 5.0. No genotype was scored as highly tolerant, 4 genotypes (IMI-128, IMI- 129, IMI- 130 and IMI-138) were tolerant, 11 genotypes were moderately tolerant, 4 genotypes were sensitive and the rest of the 126 genotypes were highly sensitive (Table 3). Similar to the field results, the second visual scoring at 60 DAS recorded that some genotypes showed recovery. According to the second visual scoring, it was observed that 2 genotypes (IMI-129, and IMI-130) were highly tolerant, 5 genotypes (IMI- 123, IMI- 124, IMI- 128, IMI- 138, IMI- 139) were tolerant, 10 genotypes were moderate tolerant, one genotype was sensitive, and the rest of the genotypes (127) were highly sensitive. (Table 3 and Figure 3).

For the control genotypes, little tolerance was observed against imazamox herbicide in field and greenhouse experiments. All these genotypes were highly sensitive and sensitive, except a Canadian genotype (CL-Lentil-4) that was moderately tolerant at first and second observation in the field and greenhouse experiments.

The ANOVA test (Table. 2) showed significant differences between field and greenhouse experiments. Most of the differences between field and greenhouse experiments were among sensitive and highly sensitive genotypes (Figure 4).

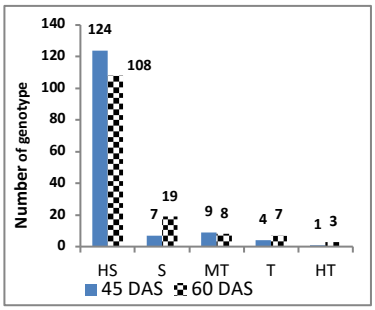

Figure 2. Frequency distribution of lentil genotypes for imazamox herbicide on a 1-5 scale in the field experiment.

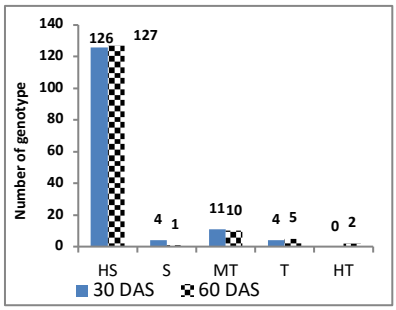

Figure 3. Frequency distribution of lentil genotypes for imazamox herbicide on a 1-5 scale in the greenhouse experiment.

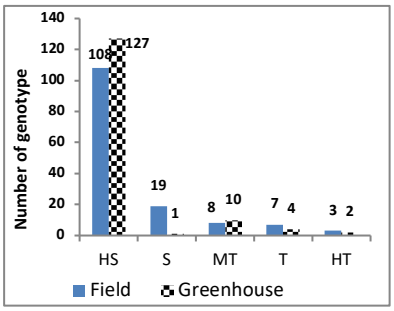

Figure 4. Frequency distribution of lentil genotypes for imazamox herbicide on 1-5 scale in field and greenhouse experiments, 60 DAS.

HS: Highly sensitive, S: sensitive, M: Moderately tolerant, T: Tolerant, HT: Highly tolerant.

Table. 2. Analysis of variance for scales according to location, genotype and replication in the field and greenhouse experiments

Source	DF	Sum of Squares	F Ratio	Prob > F
Location	1	139.58	395.01	<0.001*
Replication	2	3.87	5.48	0.043*
Genotype	144	1011.99	19.89	<0. 001*

Asterisks indicate significant ANOVA results.

3.2. Plant height

Visual symptoms started appearing on plants from about 15 DAS, where the imazamox herbicide killed the growing tips of the branches and affected the vegetative growth of the highly sensitive and sensitive genotypes. A high level of injuries on various plant parts was observed in highly sensitive genotypes that led to the death of many plants. According to the analysis of variance for plant

height, there were highly significant differences between the height of treated genotypes in the field and greenhouse experiments ($p<0.001$) at each timepoint (Tables 4 & 5).

Plant height in the field experiment at BS ranged from 2.33 to 5.70 cm (IMI-75and IMI-20, Figure 5). Plant height in the field at 15 DAS ranged from 0.00 (plants were dead) to 7.67 cm (IMI-68, IMI-127 Figure 6), while plant height in the field at 45 DAS ranged from 2.67 to 26.33 cm (IMI-86 and IMI-128, Figure 7), with only a few genotypes growing taller than 20 cm.

Plant height in the greenhouse experiment at BS was 7.33 to 12.00 cm (IMI-65 and IMI-141) (Figure 8), while at 30 DAS plant height ranged between 0.00 (plants were dead) for many highly sensitive and sensitive genotypes to 17.00 cm (IMI-123, and IMI-130, Figure. 9), and at 60 DAS, the range was 0.00 cm to 27.67 cm (CL-Lentil-4, Figure 10). Only a few tolerant and highly tolerant genotypes had plant heights greater than 15 and 20 cm at 30 and 60 DAS, respectively (Figure. 9 & 10).

The results indicated that all control genotypes showed low tolerance responses for plant height against imazamox herbicide, except CL-Lentil-4 that showed a high tolerance response for plant height against imazamox herbicide in both field and greenhouse experiments (Figures 11 & 12, Table 3).

Table7 indicates no significant differences for plant height between the field and the glasshouse, confirming that relative plant height per genotype is consistent across environments.

The correlation for plant height between each consecutive timepoint showed a significant increase between BS and 15 DAS, also a highly significant increase was between 15 DAS and 45 DAS in the field experiment, while in greenhouse no significant change between BS and 30 DAS was seen because strongly growing plants could still be herbicide sensitive, but a highly significant increase was seen between 30 DAS and 60 DAS because the tolerance continues across these timepoints (Table.6).

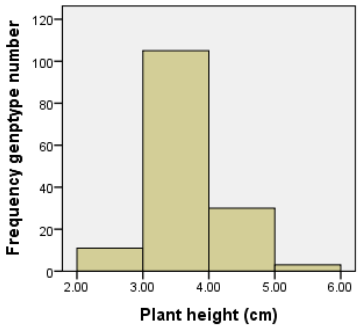

Figure. 5. Frequency distribution for plant height in field experiment before spray.

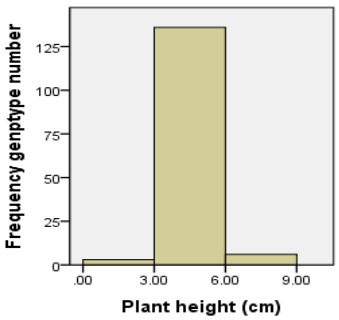

Figure.6.Frequency distribution for plant height in field experiment 15 DAS.

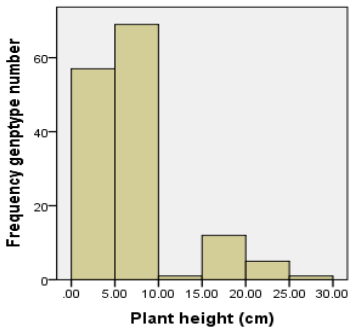

Figure 7. Frequency distribution for plant height in field experiment, 45 DAS.

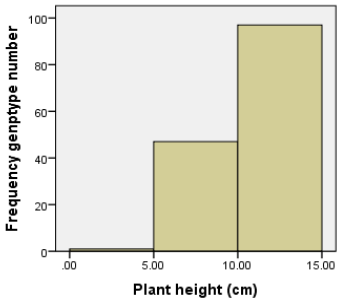

Figure 8. Frequency distribution for plant height in greenhouse experiment before spray.

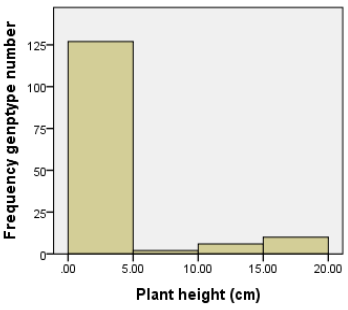

Figure 9. Frequency distribution for plant height in greenhouse experiment 30 DAS.

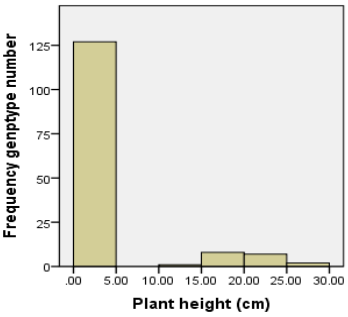

Figure 10. Frequency distribution o for plant height in greenhouse experiment 60 DAS.

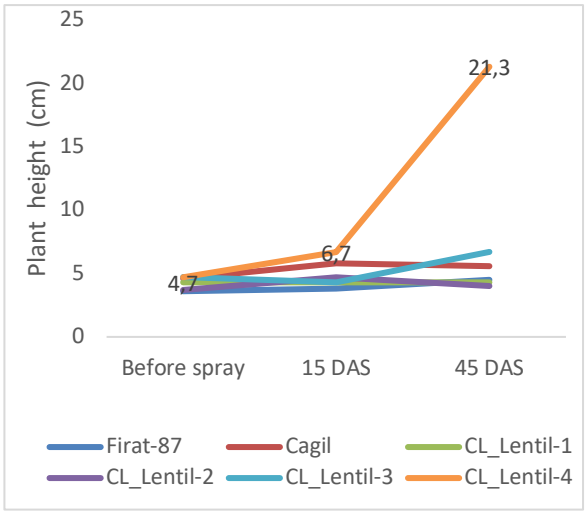

Figure 11. Response of plant height for control genotypes against imazamox herbicide in the field experiment.

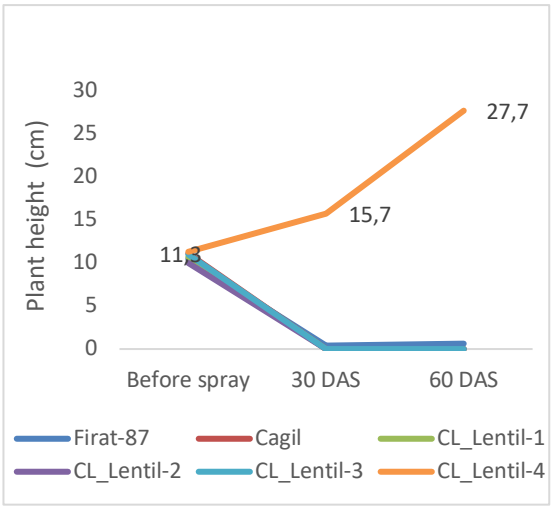

Figure 12. Response of plant height for control genotypes against imazamox herbicide in the greenhouse experiment.

Table 3. Damage scale and plant height responses of tolerant lentil genotypes and controls for imazamox herbicide in field and greenhouse experiments at different timepoints

Genotype		**1-5 (scale)**			**Plant height (cm)**						
		Field		Greenhouse	Field				Greenhouse		
		45 DAS	60 DAS	30 DAS	60 DAS	BS	15 DAS	45 DAS	BS	30 DAS	60 DAS
Firat-87	Control	HS	HS	HS	HS	3.60	3.80	4.50	10.50	0.40	0.60
Cagil	Control	HS	HS	HS	HS	4.60	5.80	5.60	11.10	0.00	0.00
CL_Lentil-1	Control	HS	HS	HS	HS	4.30	4.30	4.30	10.70	0.00	0.00
CL_Lentil-2	Control	HS	HS	HS	HS	3.70	4.70	4.00	10.00	0.00	0.00
CL_Lentil-3	Control	HS	HS	HS	HS	4.70	4.30	6.70	11.00	0.00	0.00
CL_Lentil-4	Control	MT	MT	MT	MT	4.70	6.70	21.30	11.30	15.70	27.70
IMI-123	M5	MT	MT	MT	T	3.30	5.30	15.70	11.70	17.00	21.70
IMI-124	M5	T	HT	MT	T	3.70	5.70	19.00	10.70	16.70	22.30
IMI-125	M5	MT	T	MT	MT	3.30	5.30	18.30	11.30	8.30	18.00
IMI-128	M5	HT	HT	T	T	3.70	6.70	26.30	10.30	16.30	21.30
IMI-129	M5	MT	MT	T	HT	3.00	5.00	20.70	9.70	16.70	25.00
IMI-130	M5	T	HT	T	HT	4.30	7.70	23.00	9.70	17.00	24.00
IMI-132	M5	MT	T	MT	MT	2.33	4.33	17.33	9.00	12.67	16.67
IMI-135	M5	MT	T	MT	MT	3.00	5.00	18.30	10.30	13.70	18.30
IMI-136	M5	MT	T	MT	MT	3.00	5.00	19.30	9.30	15.00	19.30
IMI-137	M5	MT	T	MT	MT	3.70	5.30	19.70	11.30	15.30	20.00
IMI-138	M5	T	T	T	T	3.30	6.00	23.00	10.70	15.30	22.30
IMI-139	M5	T	T	MT	T	3.30	5.70	21.70	11.00	16.00	21.70

BS: Before spray, DAS: Days after spray, HS: Highly sensitive, S: sensitive, M: Moderately tolerant, T: Tolerant, HT: Highly tolerant.

Table 4. Analysis of variance for plant height according to genotype and replication in the field experiment

Source of variation		BS			15 DAS			45 DAS		
	DF	MS	F	F pr.	MS	F	F pr.	MS	F	F pr.
Genotypes	144	0.89	1.34	<0.001**	2.45	2.23	<0.001*	75.94	16.59	<0. 001**
Replications	2	11.57	18.21	<0.001**	44.17	40.21	<0.001*	293.24	64.07	<0. 001**

Table 5. Analysis of variance for plant height according to genotype and replication in the greenhouse experiment

Source of variation	DF	BS MS	F	F pr.	30 DAS MS	F	F pr.	60 DAS MS	F	F pr.
Genotypes	144	2.83	2.40	<0.001**	71.40	43.44	<0.001**	140.02	38.80	<0.001**
Replications	2	25.27	21.52	<0.001**	2.30	1.823	0.16	7.63	2.13	0.12

Table 6. The correlation for plant height between each consecutive time point in the field and greenhouse experiments

Field experiment				Greenhouse experiment			
Correlations	**BS1**	**15 DAS**	**45 DAS**	**Correlations**	**BS2**	**30 DAS**	**60 DAS**
Bs1	1	0.146*	0.17*	**Bs2**	1	0.11	0.08
15 DAS		1	**0.57****	**30 DAS**		1	**0.98****
45 DAS			1	**60 DAS**			1

*Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level.

Table 7. Analysis of variance for plant height according to the location on, genotype, and replication in the field and greenhouse experiment

Source	DF	Sum of Squares	F Ratio	Prob > F
Location	1	4.72	0.25	0.62
Replication	2	436.46	11.48	<0.001**
Genotype	144	21307.72	7.79	<0.001**

3.3. The dynamic development of plant height in each response category against imazamox herbicide

Analysis of variance for the interaction between category and timepoint showed highly significant differences ($p<0.001$) in plant height for response categories, timepoint, and category × timepoint interaction in the greenhouse and the field experiments (Table. 8). These are due to differences in the response of these categories against imazamox herbicide in field and greenhouse experiments. Also, Table. 9 indicates significant differences between response categories for plant height in the field and greenhouse experiments, except between tolerant and moderately tolerant in field and between highly tolerant and tolerant in the greenhouse.

Figure 13 shows the dynamic development of average plant height by time for each imazamox damage response category in the field experiment. Firstly, before spray, the average plant height for all categories was about 4 cm. Secondly, at 15 DAS, some differences between categories were observed, that the average plant height for highly tolerant and tolerant categories was mostly 6.67 cm, moderately tolerant category was 5.30 cm, while the sensitive and highly sensitive categories were about 4.00 cm. Thirdly, at 45 DAS, large differences between categories were observed, where the average of plant height for; highly tolerant, tolerant, moderately tolerant, sensitive, and highly sensitive categories were respectively; 24.11, 22.33, 18.70, 8.50, and 5.12 cm.

Also, Figure 14 indicates large differences in average plant height of genotypes in each response category against imazamox herbicide in the greenhouse experiment at 30 and 60 DAS. The average plant height before spray for all categories was about 10 cm. While at 30 DAS, the average of plant height in each category; highly tolerant, tolerant, moderately tolerant, sensitive, and highly sensitive, was respectively; 16.83, 15.38, 13.17, 5.33, and zero cm. Finally, at 60 DAS, the average plant height for each respective category was; 24.50, 21.10, 18.70, 12.67, and zero cm.

Table 8. Analysis of variance for the interaction between category and timepoint in the field and greenhouse experiment

Source	DF	Field experiment			Greenhouse experiment		
		Sum of Squares	F Ratio	Prob >F	Sum of Squares	F Ratio	Prob > F
Category	4	1357.04	274.48	<0.001**	6606.41	1748.90	<0. 001**
Timepoint	2	2617.18	1058.71	<0.001**	279.02	147.73	<0. 001**
Category× Timepoint	8	1874.90	189.61	<0.001**	3471.4	459.49	<0. 001**

Table 9. Significant differences between categories for plant height, in-field and greenhouse experiment

	Category	Field experiment		Greenhouse experiment	
		LSD group	Mean plant height (cm) /category	LSD group	Mean plant height (cm) /category
1	Highly tolerant	A	11.09	A	17.00
2	Tolerant	B	9.35	A	16.33
3	Moderately tolerant	B	8.79	B	14.37
4	Sensitive	C	4.95	C	9.33
5	Highly sensitive	D	4.11	D	3.35

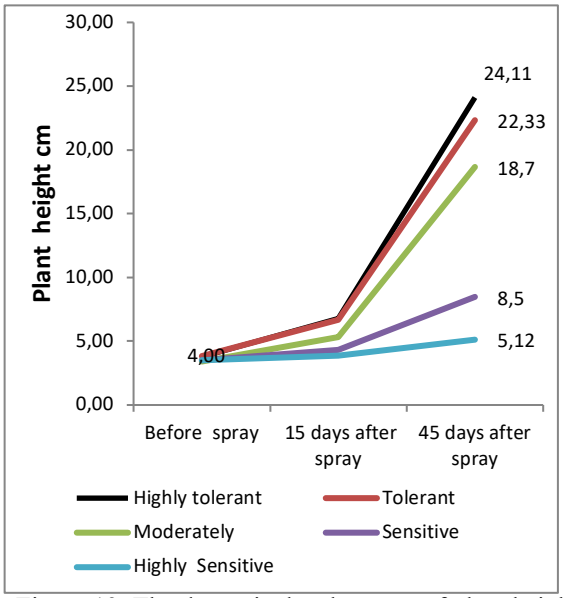

Figure 13. The dynamic development of plant height in each category against imazamox herbicide in the field experiment.

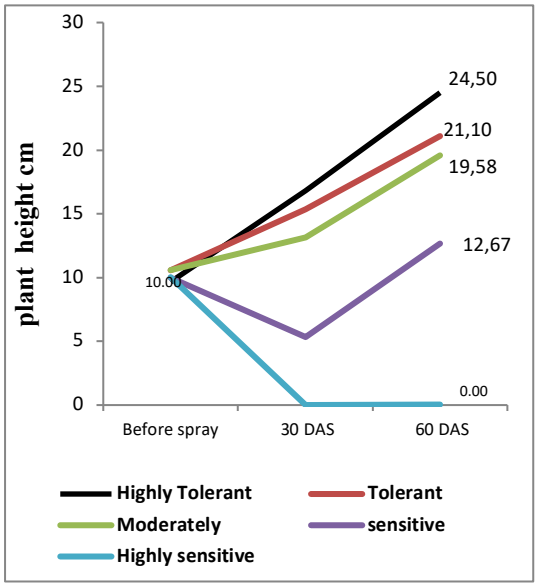

Figure 14. The dynamic development of plant height in each category against imazamox herbicide in the greenhouse experiment.

4. Discussion and Conclusion

Lentils are a weak competitor of weeds and their sensitivity to herbicides is a major hurdle for large scale production. It is crucial to control the sensitivity of lentil to herbicides because the selection of herbicides targeting only weeds is difficult to achieve. Due to the limited responsiveness of leguminous crops to transformation, scientists have instead tried seed mutagenesis to develop imidazolinone resistant crops, with many mutagens being used with seeds in different crops, including physical (gamma irradiation) and chemical (ethyl methanesulfonate, N-nitroso-N-methylurea, ethylnitrosourea and sodium azide) treatments. For example, Malkawi et al., (2003) treated lentil cultivars with gamma radiation to develop tolerance against chlorsulfuron herbicide. In the present study, chemical mutagen EMS (ethyl methane sulfonate) was used to create variability in the genotypes.

The resulting lentil genotypes were evaluated for enhanced tolerance against imidazolinone herbicide. The screening and selection of imidazolinone herbicide resistant mutants is a necessary first step for further plant breeding efforts.

In the present study, the EMS mutagenized lentil genotypes showed a range of different responses against imazamox herbicide measured on a 1-5 scale and as plant height in both field and greenhouse experiments. Differences in induced mutations of these genotypes is a likely reason for the observed variability intolerance as evidenced by the consistent results across replicates, experiments and timepoints. In earlier studies, the classification of tested lentil genotypes into different categories revealed considerable genetic variations in tolerance to imazethapyr herbicide, such as in lentil (Sharma et al., 2018; Rizwan et al., 2017), chickpea (Gaur et al., 2013; Chaturvedi et al., 2014) and ryegrass (Preston and Powles 2002). Our findings are consistent with that of Taran et al., (2010) who showed the existence of a significant range of natural differences for resistance to the IMI class of herbicides (imazethapyr and imazamox) in chickpea (Taran et al., 2010) and field pea (Hanson and Thill 2001). A possible explanation for the different levels of resistance in different varieties might be the different levels of resistance in different genotypes which can be attributed to differential metabolic degradation rates (Sharma et al., 2018).

This study indicated that EMS is an efficient tool to develop herbicide-resistant genotypes in lentil. In particular, the second visual scoring revealed that some genotypes showed symptoms of recovery in the field experiment and greenhouse experiment. A similar study performed by Sharma et al. (2018) screening 180 lentil genotypes for tolerance against imazethapyr herbicide by visual scoring to determine the resistance at 14 and 45 DAS indicated that some lentil genotypes showed recovery in the second visual scoring. This result corroborates our findings that some mutant genotypes can show recovery after herbicide spray.

Lentil genotypes showed a range of different responses against imazamox herbicide in both field experiments and greenhouse experiments. The field and greenhouse experiments had contrasting environments (i.e the greenhouse was protected from the rain while the field was not). The change in the category of a few genotypes between field and greenhouse experiments appears to be due to environmental conditions such as late rains in the field experiment, which might have reduced the efficacy of the herbicide. The limited difference in genotypes' relative imazomox tolerance were observed between the field and greenhouse experiments, indicating that these differences were under genetic control. The significant genetic differences determined in these lentil genotypes for imazamox herbicide resistance will encourage further study efforts towards the development of herbicide-tolerant varieties.

Five genotypes (IMI-124, IMI-128, IMI-130, IMI-138, and IMI-139), were observed to have a high tolerance response for imazamox herbicide in the field and greenhouse experiments. These genotypes can be used in future breeding programs for creating herbicide-resistant lentil varieties. Based on the second visual scoring, some studied genotypes showed some recovery in both locations. The herbicide-tolerant genotypes that have been examined in this study would be helpful in genetic and physiological studies aimed at determining the molecular mechanisms of imazamox herbicide tolerance. .3.2000Greater knowledge about the mechanisms of imazamox herbicide tolerance could facilitate future progress in the development of herbicide tolerant lentil cultivars.

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Research Article

Influence of Groundnut Waste as Substrate and Host Plant on Inoculum Production of Endophytic Mycorrhiza for Large Scale Agricultural Application

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Arbuscular mycorrhizal fungi,
Groundnut waste,
Root colonization

Abstract: A pot culture experiment was conducted to study the effect of soil amendment with different forms of groundnut waste on spore population and root infection of indigenous Arbuscular Mycorrhizal fungal species i.e. *Glomus mosseae* under polyhouse conditions. Two angiospermic plant species viz. sorghum and sesame were also examined for mycorrhization potential in the study. Observations were made for percent root colonization, spore density of AM fungi and the effectiveness of AM fungi on the shoot and root biomass of both host plants. The results indicated that AM fungal spore population and colonization levels were substantially enhanced by the application of compost groundnut waste as a substrate over dry groundnut waste. Among growth parameters, plant height, root length and plant biomass were recorded more in sorghum than sesame. On the whole, mycorrhization was reported the highest with 75 g/pot concentration of waste. Also, sorghum appeared to be a better host than sesame.

Büyük Ölçekli Tarımsal Uygulama İçin Endofiz Mikorrhizasının İnokülum Üretimi Üzerinde Substrat ve Konak Bitki Olarak Yer Fıstığı Atıklarının Etkisi

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Anahtar Kelimeler

Arbuscular mikorzal funguslar,
Groundnut atıkları,
Kök kolonizasyonu

Öz: Farklı yerfıstığı atığı formları ile ıslah edilen toprakların, sera koşullarında yerli Arbuscular Mycorrhizal Fungus türlerinin, yani *Glomus mosseae*'nin spor popülasyonu ve kök enfeksiyonu üzerindeki etkisini incelemek için bir saksı kültürü deneyi yapılmıştır. İki anjiyospermik bitki türü olan sorghum ve susam bitkileri de çalışmada mikoriza potansiyeli açısından incelenmiştir. Her iki konukçu bitkinin sürgün ve kök biyokütlesi üzerinde yüzde kök kolonizasyonu, AM funguslarının spor yoğunluğunu ve AM funguslarının etkinliğini tespit etmek için gözlemler yapılmıştır. Sonuçlar, kuru yerfıstığı atığı üzerine bir substrat olarak kompost yerfıstığı atığının uygulanmasıyla AM fungus spor popülasyonunun ve kolonizasyon seviyelerinin önemli ölçüde arttığını göstermiştir. Büyüme parametreleri arasından bitki boyu, kök uzunluğu ve bitki biyokütlesi sorgum bitkisinde susama göre daha fazla kaydedilmiştir. Genel olarak, en yüksek mikorizamiktarı 75 g/saksı atık konsantrasyonunda tespit edildi. Ayrıca, sorgum bitkisinin susam bitkisinden daha iyi bir konukçu olduğu görülmüştür.

1. Introduction

The productive improvement of plants through regular use of synthetic fertilizer is the most common habit among farmers because nutrient availability is an important yield determining factor. But the huge application of synthetic fertilizers leads to degradation of long term soil fertility, pollution and increased disease susceptibility in the plant (Eman et al., 2008). The use of soil microbes as bio-fertilizer with respect to sustainable agriculture is becoming increasingly urgent since the apposite management of these microbes could potentially decrease the dependency on synthetic fertilizers. Among different soil microbes used as biofertilizer, AM fungi (AMF) are most common due to their ubiquitous distribution and forming a symbiosis with the roots of nearly 80 percent of the plant community, played an important role in the restoration of soil fertility (Pacheco et al., 2021). These arbuscular mycorrhizal fungi are widely known to improve plant growth through stimulating nutritional uptake, water absorption, made infected plants healthier and tolerant to drought, salinity and pathogen attack by activation of different kinds of alleviating processes associated with stresses (Sharma et al., 2017; Kumar et al., 2020). To achieve the benefits, the main approach adopted is the introduction of AMF propagules i.e. rhizospheric soil having AMF spores and colonized root fragments into destined soil. Unfortunately, the obligate symbiotic nature of AMF does not let them flourish in pure cultures, distant from their host plants making it challenging to produce large scale AMF inoculums. Except for its nature, demand for pathogen-free inoculum with an increased shelf life is another factor that limits its application at the commercial level. In spite of the availability of different kinds of techniques intentionally meant for inoculum production of AM fungi, the traditional pot-culture method is one of the most commonly followed methods where the AMF spores are usually maintained and multiplied in combination with suitable host plant roots (Kadian et al., 2019).

Groundnut is the second most nutritious legume in the world after soya-bean known for its diverse uses including oil production, human consumption as food and also animal consumption in the forms like hay, silage and cake. Approximately, 97% of the global area is used for groundnut cultivation mainly in developing countries and that contributes 94% of groundnut production (Prasad et al., 2009). One tone of groundnut yield produces approximately 35-40 kg shell waste, left after the extraction of groundnut seed from its pod. This is the abundant lingo-cellulosic waste product that has a very slow degradation rate under natural conditions (Zheng et al., 2013; Musekiwa et al., 2020). However, lingo-cellulosic agricultural wastes after crop harvest the usually left in unused form or burned which elevate the level of greenhouse gases in the atmosphere (Guzmán et al., 2015). Thus, new technologies have been adopted to maximise the use of agricultural waste products for meaningful purposes like integration of small fractions in animal feed, used in pulp production, bio-ethanol production and wastewater treatment. These wastes in their original or compost form and in definite proportion could be applied to the soil deliberately to assess their consequence on fauna and flora. Several workers have introduced waste substrates in addition to the soil-sand mixture to promote the AM fungal growth earlier (Tanwar et al., 2013; Kadian et al., 2018). In this series of investigations, groundnut wastes or groundnut shell waste may be a useful substrate as it contains cellulose (35.7%), hemicelluloses (18.7%), lignin (30.2%) and has total nitrogen 0.87%, total phosphorus content 1.87%, total potassium 1.19%, organic carbon 30.0% and C/N ratio 34.5 (Torkashvand et al., 2015; Ramgopal et al., 2016).

Keeping in view, the concept of sustainability, obligate biotrophic nature and importance of AM fungi, production of agricultural waste and demand for AM inoculum, a systematic investigation was undertaken to assess the mass production of *Glomus mosseae* using sorghum and sesame as hosts and different form of groundnut waste as substrate. Moreover, the lack of external application of synthetic fertilizers to the soil and published reports concerning the use of groundnut waste as substrate for mass production of AM fungal inoculum made it different from earlier studies.

2. Material and Methods

2.1. Study site and soil characterstics

The experiment was performed under polyhouse conditions at the Botany Department, Kurukshetra University, Kurukshetra, Haryana, from September 2018 to January 2019. Soil used in this

experiment consisted of sand 64.2%, clay 3.90 %, silt 21.81%, pH 6.8 ±0, EC 0.25 dS m^{-1}, organic carbon 0.40%, nitrogen 0.042%, phosphorous 0.017% and potassium 220 kg ha^{-1}.

2.2. Experimental design

The experiment was a 4×2×2 factorial in a completely randomized design employing two types of hosts (sesame and sorghum) and four concentrations (without substrate (control), 50, 75, 100 g pot^{-1})) of each substrate (groundnut waste used in dry and compost form). Five replicates were maintained for each treatment. The experiment was carried out in a polyhouse, where humidity was approximately 55-70% and temperature 25±30 °C. The light was provided by cool white fluorescent lamps (8000 lux) under a 16-h photoperiod. The polyhouse received natural sunlight also.

2.3. Selection of AM fungi, hosts and substrates

The rhizospheric soil samples of *Cymbopogon citratus* were examined for a dominant strain of AM fungi i.e. *Glomus mosseae* and further spores used for the preparation of starter inoculum. The identification of AM spores was done by using the identification manual of Schenck and Perez (1990). Two host plants namely sesame and sorghum (member of Pedaliaceae and Poaceae family respectively) were screened for each substrate. Dry and compost forms of groundnut waste were selected for mass multiplication of *G. mosseae*. Groundnut waste was collected from the university market, the first sun-dried, grounded to make fine powder and used as dry form, and for the second form collected waste subjected for further decomposition (placed in jute bags and buried under soil for 3 months). Both forms of substrates were autoclaved at 121 ºC for 2 hr and then utilized in different concentrations with soil: sand (3:1) in pots for mass production of the AM fungi in polyhouse.

2.4. Preparation of Starter inoculums

The starter culture of the selected AM fungal spores was multiplied with sorghum as a host using the soil funnel technique of Menge and Timmer (1982). In this technique, earthen funnels (Chillams) were filled with sterilized sand: soil mixture (1:3), inoculated with selected AM spores and then disinfected seeds of sorghum were sown for 30 days. The inoculum thus produced was further subjected for the multiplication of AM fungi first under big earthen pots for 60 days. The inoculum produced in earthen pots was examined for root colonization and spore count by methods suggested by Gerdemann and Nicolson (1963) and Philips and Hayman (1970) respectively, and then used as starter inoculums for further study.

2.5. Experimental setup

Top soil for this experiment was collected from Botanical Garden Kurukshetra University, Kurukshetra. Initially, the soil was air-dried, pulverized and then sieved through a 2 mm sieve. The soil was then mixed with the sand to form a soil: sand ratio 3:1 and further sterilized in an autoclave at 121 ºC for two consecutive days at 15 lb pressure for 15 minutes. Different concentrations of each substrate (without substrate-0, 50, 75 and 100 g pot^{-1}) were mixed thoroughly with soil: sand mixture to make a final volume of 1 kg which was then added to earthen pots (15×15 cm). To each pot, 10% i.e. 100 g of selected AM inoculum consisting of chopped AM colonized root pieces of sorghum along with soil containing 200-250 AM spores 100 g^{-1} was added. Healthy seeds of sorghum and sesame after surface sterilization with 0.5% sodium hypochlorite for 10 min and subsequent washing with double distilled water were sown in each pot above the layer of inoculum further covered with a layer of sterilized soil mixture. Plants were watered regularly to maintain the moisture content of soil and 100 mL pot^{-1} of Hoagland's solution (without KH_2PO_4) were poured into each pot at 15-day intervals.

2.6. Harvest and analysis

Plants were manually uprooted after 90 days of planting to measure plant height and root length. The plants were cleaned in running tap water and then separated into roots and shoots to note down their

fresh weight, placed in an oven to dry at 70 °C and then weighted for dry weight. The rhizosphere soil and fresh root samples were assessed for mycorrhization.

2.7. Statistical analysis

The experimental data were subjected to analysis of variance and means were separated with the least significant difference test using the IBM Statistical Package for Social Sciences [IBM SPSS, ver. 25, Chicago (IL), USA].

3. Results

The data analysis related to inoculum productions of *G. mosseae* shows significant variations in AM spore number and root colonization in relation to the type of host, substrate forms and their different concentrations used for mass multiplication. When sorghum was used as a host, the mycorrhization was enhanced with an increase in substrate concentration as maximum spore count (103.6±18.97), 65.88% increase in spore number as compared to control and percent root colonization (66.77±6.840%) was recovered with a dry substrate concentration of 100 g (Table 1). Control plant (without substrate) was reported with the least mycorrhization. However, an increase in concentrations of the dry form of groundnut substrate was also found to be stimulatory in the case of sesame as a host plant and observed maximum spore number (89.09±34.91) plus percent increase i.e. (72.36%) and root colonization (65.94±20.31%) with substrate concentration of 75 g. The least mycorrhization status was observed in the control treatment which had no substrate (Table 3). Similarly, morphological parameters of host plants were also influenced by substrate concentration indirectly through mycorrhization. It was found that the sorghum plants having 100 g dry groundnut substrate concentration had improved shoot fresh(03.67±0.856 g) and dry weight (1.116±0.035 g), root length (19.55±2.715 cm), root fresh (2.170±0.771 g) and dry weight (1.20±0.047 g) except shoot height i.e. (45.83±06.75 cm) with substrate concentration of 50g (Table 2). So, a positive influence of mycorrhization was observed for maximum growth parameters in the sorghum plant. In the case of sesame, plant height (40.09±11.53 cm) was recorded highest at 50g dry groundnut substrate concentration. Other parameters like shoot fresh weight (2.336±0.221 g) dry weight (1.096±0.215 g), root length (14.59±5.859 cm), root fresh weight (1.356±0.357 g) and dry weight (1.030±0.105 g) were reached a maximum level at 75 g dry groundnut substrate concentration (Table 4).

When compost form of groundnut waste was used as substrate and sorghum as the host plant, maximum spore count (125.1±30.91), as well as AM root colonization (72.30±12.80%) were observed with 75 g concentration. On comparing spore count and root colonization with the control plant, percent increase was recorded maximum with 75 g per pot concentration of compost waste When sesame plants were used as hosts with compost groundnut substrate, root colonization (67.57±14.00%) and spore count (92.76±12.94) were recorded highest at 75 g concentration of substrate (Table 1). Data analysis studies clearly showed that the root colonization positively influenced the morphological parameters of sorghum like plant height (55.13±03.73 cm), shoot fresh (03.86±0.630 g) and dry weight (1.256±0.659 g), root length (25.21±4.775 cm) and root fresh (3.466±1.098 g) and dry weight (1.36±0.015 g) (Table 2). Shoot height (50.26±3.689 cm), fresh weight (4.180±0.096 g) and dry weight (1.270±0.151 g) were recorded maximum at a substrate concentration of 75 g in the dicot plant as the host. In the same way, root length (20.86±2.540 cm), root fresh weight (1.856±0.281 g) and dry weight (1.006±0.081 g) were reported maximum with 75 g concentration of compost form of groundnut substrate in sesame as host (Table 4). When sorghum and sesame were used as host with dry and compost form of groundnut substrate at a concentration of 75 g was found best for mass multiplication of *G. mosseae*.

The data analysis related to inoculum productions of *G. mosseae* shows significant variations in AM spore number and root colonization in relation to the type of host, substrate forms and their different concentrations used for mass multiplication. When sorghum was used as the host, the mycorrhization was enhanced with an increase in substrate concentration as maximum spore count (103.6±18.97) and percent root colonization (66.77±6.840%) was recovered with a dry substrate concentration of 100 g (Table 1). Control plant (without substrate) was reported with the least mycorrhization. However, the increase in concentrations of the dry form of groundnut substrate was also found to be stimulatory in the case of sesame as the host plant and observed maximum spore number (89.09±34.91) and root

colonization (65.94±20.31%) with substrate concentration of 75 g. The least mycorrhization status was observed in the control treatment which had no substrate (Table 3). Similarly, morphological parameters of host plants were also influenced by substrate concentration indirectly through mycorrhization. It was found that the sorghum plants having 100 g dry groundnut substrate concentration had improved shoot fresh(03.67±0.856 g) and dry weight (1.116±0.035 g), root length (19.55±2.715 cm), root fresh (2.170±0.771 g) and dry weight (1.20±0.047 g) except shoot height i.e. (45.83±06.75 cm) with substrate concentration of 50 g (Table 2). So, a positive influence of mycorrhization was observed for maximum growth parameters in sorghum plant. In the case of sesame, plant height (40.09±11.53 cm) was recorded highest at 50 g dry groundnut substrate concentration. Other parameters like shoot fresh weight (2.336±0.221 g) dry weight (1.096±0.215 g), root length (14.59±5.859 cm), root fresh weight (1.356±0.357 g) and dry weight (1.030±0.105 g) were reached a maximum level at 75 g dry groundnut substrate concentration (Table 4).

Table 1. Influence of groundnut waste as substrates (dry and compost) and their different concentrations on mycorrhization status associated with host plant (sorghum) used for mass multiplication of *G. mosseae*

Form of groundnut waste as Substrate	Concentration of substrate (g pot^{-1})	AM spore number/100 g of soil	Percent increase in AM spore number	AM root colonization (%)	Percent increase in root colonization	Pattern of colonization		
						Mycelium	Vesicles	Arbuscules
Dry	Control	35.34±2.103^{cd}	-	35.34±2.101^{bc}	-	+	+	-
	50	60.85±11.31^{bc}	41.92	60.85±10.34^{a}	41.92	+	-	+
	75	103.6±18.97^{a}	65.88	66.37±5.024^{a}	46.75	+	++	++
	100	103.3±13.97^{a}	65.78	66.27±6.840^{a}	46.67	++	+	+
Compost	Control	44.01±8.342^{d}	---	22.24±6.604^{c}	---	+	+	-
	50	64.51±1.610^{cd}	31.77	70.97±26.34^{ab}	68.66	+	+	+
	75	125.1±30.91^{ab}	64.82	72.30±12.80^{a}	69.10	+	++	+
	100	109.6±28.24^{ab}	59.84	70.10±11.41^{a}	68.27	+++	+	+
	L.S.D (P≤0.05)	30.682		21.518				
	ANOVA F(7,16)	9.153		4.703				
	Substrate type	5.071		2.599				
	Substrate conc.	19.505		9.710				
	S type ×S conc	0.163		0.398				

Each value is mean of five replicates, ±: standard deviation, S: substrate, AM: Arbuscular mycorrhizae, - : absent, + : scanty, ++ : moderate, +++ : abundant, means followed by same letter/s within a column are not significantly at P≤0.05 level (least significant difference test).

When compost form of groundnut waste was used as substrate and sorghum as the host plant, maximum spore count (125.1±30.91), as well as AM root colonization (72.30±12.80%) were observed with 75g concentration. When sesame plants were used as hosts with compost groundnut substrate, root colonization (67.57±14.00%) and spore count (92.76±12.94) were recorded highest at 75 g concentration of substrate (Table 1 and 3). Data analysis studies clearly showed that the root colonization positively influenced the morphological parameters of sorghum like plant height (55.13±03.73 cm), shoot fresh (03.86±0.630 g) and dry weight (1.256±0.659 g), root length (25.21±4.775 cm) and root fresh (3.466±1.098 g) and dry weight (1.36±0.015 g) (Table 2). Shoot height (50.26±3.689 cm), fresh weight (4.180±0.096 g) and dry weight (1.270±0.151 g) were recorded maximum at a substrate concentration of 75 g in the dicot plant as the host. In the same way, root length (20.86±2.540 cm), root fresh weight (1.856±0.281 g) and dry weight (1.006±0.081 g) were reported maximum with 75 g concentration of compost form of groundnut substrate in sesame as host (Table 4). When sorghum and sesame were used as the host with dry and compost form of groundnut substrate at a concentration of 75 g was found best for mass multiplication of *G. mosseae*.

Table 2. Influence of groundnut waste as substrates (dry and compost) and their different concentrations on growth parameters of the host plant (sorghum) used for mass multiplication of *G. mosseae*

Form of groundnut waste as Substrate	Concentration of substrate (g pot^{-1})	Plant Height (cm)	Shoot weight (g)		Root Length (cm)	Root weight (g)	
			Fresh	Dry		Fresh	Dry
Dry	Control	31.36±05.44^{d}	02.30±1.093^{bc}	0.690±0.336^{a}	11.93±2.481^{bc}	1.020±0.070^{d}	0.71±0.347^{b}
	50	45.83±06.75^{bcd}	02.86±0.546^{abc}	0.933±0.085^{a}	13.74±2.014^{bc}	1.133±0.159^{cd}	0.97±0.052^{ab}
	75	39.44±09.21^{cd}	03.04±0.605^{abc}	1.016±0.070^{a}	14.33±0.813^{b}	1.340±0.357^{cd}	1.09±0.128^{a}
	100	42.35±14.84^{cd}	03.67±0.856^{ab}	1.116±0.035^{a}	19.55±2.715^{a}	2.170±0.771^{bc}	1.20±0.047^{a}
Compost	Control	25.22±02.31^{d}	02.21±1.037^{c}	0.816±0.515^{a}	6.686±3.18^{c}	1.066±0.654^{d}	0.26±0.045^{c}
	50	42.49±12.38^{abc}	02.28±0.088^{abc}	1.032±0.660^{a}	18.43±2.068^{a}	2.356±0.453^{ab}	0.77±0.163^{ab}
	75	50.43±06.44^{ab}	03.86±0.630^{a}	1.256±0.659^{a}	25.21±4.775^{a}	3.466±1.098^{a}	1.36±0.015^{ab}
	100	55.13±03.73^{a}	03.06±0.895^{abc}	1.120±0.617^{a}	11.69±2.938^{bc}	2.096±0.330^{ab}	0.63±0.295^{ab}
	L.S.D (P≤0.05)	14.926	1.351	0.093	4.898	1.006	0.311
	ANOVA F(7,16)	5.799	2.140	0.514	6.946	6.162	6.471
	Substrate type	15.083	0.547	0.493	0.559	13.754	5.251
	Substrate conc.	6.609	4.608	1.027	13.358	8.351	12.400
	S type ×S conc	1.894	0.202	0.008	2.662	1.443	0.949

Each value is mean of five replicates, ±: standard deviation, S: substrate, AM: Arbuscular mycorrhizae, means followed by same letter/s within a column are not significantly different at P≤ 0.05 (least significant difference test).

Table 3. Influence of groundnut waste as substrates (dry and compost) and their different concentrations on mycorrhization status associated with host plant (sesame) used for mass multiplication of *G. mosseae*

Form of groundnut waste as Substrate	Concentration of substrate (g pot^{-1})	AM spore number/100g of soil	Percent increase in AM spore number	AM root colonization (%)	Percent increase in root colonization	Pattern of colonization		
						Mycelium	Vesicles	Arbuscules
Dry	Control	24.62±11.01^{d}	-	40.73±15.66^{abc}	-	+	-	+
	50	53.52±22.40^{bcd}	53.99	52.45±13.73^{ab}	22.34	+	+	+
	75	89.09±34.91^{a}	72.36	65.94±20.31^{a}	38.23	+	-	-
	100	70.96±12.50^{ab}	65.30	54.01±13.42^{ab}	24.58	+	+	+
Compost	Control	37.11±7.010^{cd}	-	43.99±16.61^{c}	-	+	+	+
	50	56.02±10.50^{bcd}	33.75	55.89±1.879^{bc}	21.29	+	+	-
	75	92.76±12.94^{abc}	59.99	67.57±14.00^{ab}	34.89	+	+	+
	100	71.04±13.92^{abc}	47.76	58.07±10.87^{ab}	24.24	+	+	+
	L.S.D (P≤0.05)	30.723		23.187				
	ANOVA F(7,16)	4.099		3.097				
	Substrate type	0.820		3.431				
	Substrate conc.	8.513		5.488				
	S type ×S conc	0.780		0.595				

Each value is mean of five replicates, ±: standard deviation, S: substrate, AM: Arbuscular mycorrhizae, -: absent, +: scanty, ++: moderate, +++: abundant, means followed by the same letter/s within a column are not significantly different at P≤0.05 level (least significant difference test).

Table 4. Influence of groundnut waste as substrates (dry and compost) and their different concentrations on growth parameters of host plant (sesame) used for mass multiplication of *G. mosseae*

Form of groundnut waste as substrate	Concentration of substrate (g pot^{-1})	Plant Height (cm)	Shoot weight (g)		Root Length (cm)	Root weight (g)	
			Fresh	Dry		Fresh	Dry
Dry	Control	14.82±3.436^{c}	0.980±0.776^{c}	0.483±0.176^{c}	5.333±0.881^{e}	0.646±0.368^{d}	0.350±0.026^{c}
	50	40.09±11.53^{a}	2.190±0.105^{ab}	1.046±0.171^{ab}	10.93±1.427^{d}	1.093±0.109^{cd}	0.836±0.050^{ab}
	75	36.21±14.62^{ab}	2.336±0.221^{ab}	1.096±0.215^{ab}	14.59±5.859^{bcd}	1.356±0.357^{abc}	1.030±0.105^{a}
	100	31.73±4.075^{ab}	2.090±0.103^{abc}	1.030±0.401^{ab}	13.81±2.450^{cd}	1.216±0.061^{bc}	0.963±0.300^{a}
Compost	Control	23.19±1.875^{bc}	1.250±0.538^{bc}	0.446±0.125^{c}	4.53±1.532^{e}	0.623±0.188^{d}	0.373±0.109^{c}
	50	31.11±3.116^{ab}	2.156±1.005^{ab}	0.740±0.105^{bc}	20.23±1.700^{ab}	1.383±0.149^{abc}	0.679±0.105^{b}
	75	50.26±3.689^{a}	4.180±0.096^{a}	1.270±0.151^{a}	20.86±2.540^{a}	1.856±0.281^{a}	1.006±0.081^{ab}
	100	37.23±2.701^{a}	3.536±1.041^{ab}	0.968±0.055^{ab}	19.49±2.020^{abc}	1.846±0.550^{ab}	0.920±0.135^{ab}
	L.S.D (P≤0.05)	12.385	1.072	0.347	4.698	0.520	0.240
	ANOVA F(7,16)	5.535	2.901	5.035	15.222	6.935	10.801
	Substrate type	2.957	4.982	0.426	12.179	6.757	4.268
	Substrate conc.	9.462	4.192	10.558	27.569	12.566	23.155
	S type ×S conc	2.468	0.918	1.050	3.890	1.363	0.624

Each value is mean of five replicates, ±: standard deviation, S: substrate, AM: Arbuscular mycorrhizae, means followed by same letter/s within a column are not significantly different at P≤0.05 level (least significant difference test).

4. Discussion and Conclusion

The two host plants used for the experiment are found selective for the mycorrhizal association. Sorghum was reported to be the best host as compared to sesame. The mycorrhization of *G. mosseae* was recorded highest in sorghum host amended with compost form of groundnut waste at the concentration of 75 g pot^{-1}. Variation in root types, root architecture, nutrient status and hormone production in relation to the rhizospheric environment might be the causative factors behind host susceptibility for mycorrhization (Rajkumar et al., 2012). Moreover, growth conditions like the type of soil, moisture, pH, fertility, temperature and light condition, microbial interaction and ability of plants to acclimatize are also accountable for variation in the degree of root colonization in two hosts (Kumar et al., 2021).

The root colonization is directly controlled by the growth of the roots while, the addition of decomposed substrates increased the nutrient availability and improved porosity of the soil which are favourable conditions for the growth of developing root and thus increased availability to host roots for more sporulation as well as root colonization (Coelho et al., 2014). An increase in spore number and root colonization by AMF with sorghum plant has been reported by Kadian et al. (2018).

The variable responses are also corresponding to the availability of nutrients in used substrates with different hosts. After decomposition, groundnut waste has been reported to contain more nutrients like total nitrogen 2.76 %, total potassium -1.48 %, while total phosphorus content -0.67 %, organic carbon 27.1 %, C/N ratio 9.8 are reduced than the unused form of organic wastes (Torkashvand et al., 2015). Many studies confirmed the positive influence of compost waste as substrates on AMF sporulation (Agnihotri et al., 2021). The application of these organic wastes was found to be stimulatory for sporulation as well as root colonization in both the trap hosts and increased in addition to wastes as compared to the control which consisted of soil sand mixture. The positive impact of substrates on mycorrhization status was supported by increased water holding capacity, soil aeration, nutrient uptake, space for spreading of roots due to the addition of wastes thus more surface area for colonization and nutrient absorption (Kadian et al., 2019). Moreover, the availability of high nitrogen and low phosphorus content has been observed to promote symbiosis (Ingraffia et al., 2021). On the other hand, the soil mixture deficient in nitrogen promotes competition among the host plants and the fungi for nitrogen. This affects the mycorrhizal sporulation as well as root colonization in a negative way. The mycorrhizal fungi led to improved phosphorus content of inoculated plants under adequate levels of nitrogen in the soil (Puschel et al., 2016; Bawadekji et al., 2016).

With sorghum as host, spore number of *G. mosseae* and root colonization was found highest at 75 g pot^{-1} concentration of groundnut waste and lowered at other concentrations. Similarly, the spore

number of *G. mosseae* was observed maximum in sesame host supplemented with the same concentration of groundnut waste. This increment in mycorrhization might be due to high cellulose and hemicellulose content in groundnut waste that supports the findings of Tanwar et al. (2013), who also observed that the rate of mycorrhization is directly related to the cellulose content of substrates. In control without substrate, the mycorrhization status was lesser due to decreased aeration and more mechanical stress imposed on roots which favours decreased root colonization (Kadian et al., 2019).

In this mass multiplication experiment, the concentrations of the substrate which tends to increased colonization also observed to increase above plant parts and biomass of host plants because the AM fungi improved the uptake of mineral nutrients and water by increasing the surface area for absorption through the hyphal networks which extend beyond the nutrient-depleted zone of the soil. A similar positive relation between mycorrhization and above plant part biomass of host has been noted by many investigators (Mangla et al., 2012; Sharma et al., 2015; Sharma et al., 2021). Moreover, the occurrence of vesicles and arbuscules in mycorrhizal roots were found to be related to the biomass of the host as the plants had more arbuscules and vesicles in the infected roots had improved morphology and biomass.

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Araştırma Makalesi (Research Article)

Şanlıurfa'da Yetiştirilen Bazı Nar (*Punica granatum* L.) Çeşitlerinin Fenolik Bileşenleri ve Antioksidan Aktivitelerinin Belirlenmesi**

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Anahtar Kelimeler

Antioksidan aktivite,
Antosiyanin
Flavonoid,
Nar

Öz: Bu araştırmada Şanlıurfa'nın Merkez, Bozova, Harran ve Suruç ilçelerinden temin edilen Hicaznar, Katırbaşı, Devedişi, Suruç ve Suruç Karası nar çeşitlerinin meyve suyu ve çekirdeklerindeki toplam fenolik madde, toplam flavonoid, toplam antosiyanin miktarı ve antioksidan aktiviteleri incelenmiştir. Çalışma sonucunda; nar çeşitlerinden alınan meyve suyundaki toplam fenolik madde miktarının 26.60-40.43 µg GAE g^{-1} arasında, toplam flavonoid miktarının 572.66-1150.83 µg QE g^{-1} arasında, toplam antioksidan kapasitenin % 89.47-96.38 arasında, toplam antosiyanin miktarının 0.84-24.12 mg siyanidin 3-glikozit l^{-1} arasında, çekirdeklerindeki toplam fenolik madde miktarının 95.39-146.44 µg GAE g^{-1} arasında, toplam flavonoid miktarının 983.57-1830.18 µg QE g^{-1} arasında, toplam antioksidan kapasitenin % 7.76-26.64 arasında, toplam antosiyanin miktarının 0.19-3.51 mg siyanidin 3-glikozit l^{-1} arasında olduğu tespit edilmiştir. Tüm çeşitler içinde en yüksek toplam fenolik madde miktarı ve toplam flavonoid miktarı çekirdek örneklerinde, toplam antioksidan kapasitesi ve toplam antosiyanin miktarı ise meyve suyu örneklerinde ölçülmüştür. Araştırmadan elde edilen sonuçlar ışığında, nar çeşitlerinin meyve suyu ve çekirdeklerinin zengin fitokimyasal içeriğe sahip olduğu ve insan sağlığı üzerine faydalı fenolik bileşenleri yüksek miktarda içerdikleri görülmüştür.

Determination of the Phenolic Contents and Antioxidant Activities of Some Pomegranate (*Punica granatum* L.) Cultivars Grown in Şanlıurfa

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Keywords

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Anthocyanin
Flavonoid,
Pomegranate.

Abstract: In this research; total phenolic content, total flavonoid content, total anthocyanin content and antioxidant activities in fruit juices and seeds of Hicaznar, Katırbaşı, Devedişi, Suruç and Suruç Karası pomegranate cultivars obtained from the Central, Bozova, Harran and Suruç districts of Şanlıurfa were investigated. As a result of the study, the total amount of phenolic substance in the juice taken from pomegranate varieties is between 26.60-40.43 µg GAE g^{-1}, the total amount of flavonoids is between 572.66-1150.83 µg QE g^{-1}, the total antioxidant capacity is between 89.47-96.38%, the total anthocyanin amount is between 0.84-24.12 mg cyanidin 3-glycoside L^{-1} between, the total amount of phenolic substance in the seeds is between 95.39-146.44 µg GAE g^{-1}, the total amount of flavonoids is between 983.57-1830.18 µg QE g^{-1}, the total antioxidant capacity is between 7.76-26.64%, the total amount of anthocyanin is 0.19-3.51 mg cyanidin 3-glycoside L^{-1} ıt was found to be between. The highest total

phenolic content and total flavonoid content among all cultivars were measured in seed samples, and total antioxidant capacity and total anthocyanin content in fruit juice samples. In the light of the results obtained from the research, it was seen that the juice and seeds of pomegranate varieties have rich phytochemical content and contain high amounts of phenolic components beneficial for human health.

**Bu makale, Emine DURSUN'un "Bazı Nar (*Punica granatum* L.) Çeşitlerinin Pomolojik Özellikleri, Fenolik Bileşenleri ve Antioksidan Aktivitelerinin Belirlenmesi" başlıklı yüksek lisans tezinden üretilmiştir.

1. Giriş

Nar (*Punica granatum* L.), Punicaceae familyasına ait subtropik ve tropik iklim kuşağında yetiştirilen bir meyve türüdür. Eski çağların önemli meyve türlerinden birisi olan narın tarihçesinin günümüzden 7 bin yıl öncesine kadar uzandığı ifade edilmektedir. Mezopotamya'da M.Ö. 2500 yıllarına ait yazıtlarda, bu meyve türünden bahsedildiği bildirilmektedir (Kaygısız, 2009).

Nar potasyum, demir ve C vitamini bakımından zengin bir meyvedir. Narın çeşitli kısımlarından tanen, pektin, yağ, sitrik asit, sirke, hayvan yemi, boya, mürekkep ve çeşitli ilaç hammaddeleri elde edilmektedir (İkinci, 2007; Şimşek ve İkinci, 2017). Nar, taze olarak tüketilebildiği gibi meyve suyu, meyve suyu konsantresi, reçel, şarap ve likör işlenebilen, çeşitli gıdalara renk verici ve tatlandırıcı olarak da kullanılabilmektedir. Nar içeriğindeki sağlık üzerine olumlu etkiler sağlayan bileşenler sayesinde uzun yıllardan beri halk arasında uygulanan geleneksel tedavi yöntemlerinde kullanılan bir meyvedir. Uzun yıllar süren bilimsel çalışmalar, narın insan vücudunu pozitif olarak etkileyen besin içerikleri ile yüklenmiş olduğunu ortaya çıkarmıştır (Şimşek ve İkinci, 2017).

Narın çeşitli ürünlere işlenmesinde önemli olan parametrelerin başında şeker, asitlik ve fenolik bileşikler gelmektedir. Vücutta serbest radikal oluşumunu önleyerek kanser ve kalp damar hastalıklarını önlemede bu fenolik bileşiklerin büyük bir etkisinin olduğu bildirilmektedir. Çeşitli çalışmalarda, antioksidan, bağışıklık artırıcı ve anti-kanserojenik özellikleri nedeniyle nar meyvesinin bitkisel bir tedavi edici olarak uygulanabileceği bildirilmiştir. Özütlerinde görülen benzersiz antimikrobiyal ve antioksidan etkileri nedeniyle bilim insanları narı kanser önleyici ajanlar olarak kullanma arayışına girmiştir (Gölükcü ve ark., 2011; Karimi ve Nowrozy, 2017).

Nar meyvesi temel olarak kabuk, çekirdek, tane ve beyaz zar olmak üzere 4 ana bölümden oluşmaktadır. Narın taneleri, meyvenin % 52'sini oluşturmakta ve tanelerin ise % 78'i meyve eti, % 22'si çekirdekten oluşmaktadır. Meyve suyu ise % 84.5 oranında su ve buna ek olarak önemli miktarlarda suda çözünür kuru madde, fenolikler, antosiyaninler, askorbik asit, protein ve şeker içermektedir (Fadavi ve ark., 2005; Kulkarni ve Aradyha, 2005).

Narın suyunun yanı sıra çekirdeği ve kabuğunun da birçok fenolik bileşeni barındırdığı, bu bileşenlerin meyve suyuna önemli miktarda geçebildiği bildirilmiştir. Nar suyunun delfinidin, siyanidin, pelargonidin, ellajik asit, ellagatinler ve punikalajinden dolayı yüksek antioksidan kapasitesiye sahip olduğu bilinmektedir. Nar suyunda kumarik asit, klorojenik asit, ferulik asit, gallik asit, ellajik asit, protokateşik asit ve kafeik asit en çok bulunan fenolik asitlerdir. Nar çekirdeği önemli düzeyde palmitik asit, stearik, linoleik, linolenik ve oleik gibi yağ asitlerini, kabuk ise luteolin, kuersetin ve gallik asit gibi tanen flavonlarını içermektedir. Ayrıca; antimikrobiyal, antikanserojen, antiparasitik ve antiviral gibi özelliklere sahip olması nedeniyle, gelecek yıllarda bu meyveye olan ilginin daha da artacağı ifade edilmiştir (Singh ve ark., 2008; İlbey ve ark., 2009; Gündoğdu ve ark., 2010; Kelebek ve Canbaş, 2010; Nizamlıoğlu ve ark., 2010; Fischer ve ark., 2011; Karaca, 2011; Mizrahi ve ark., 2014; Ahmadiankia, 2019; Guerrero-Solano ve ark., 2020).

Nar meyvesinin kimyasal kompozisyonu yetiştirilme bölgesine, iklimine, çeşidine, dikim uygulamasına ve depolama koşullarındaki değişikliklere göre farklılık gösterir. Kimyasal kompozisyonuna bağlı olarak nar suları taze tüketim, sanayi üretimi veya tıbbi amaçlar için kullanılmaktadır. Yapılan çalışmalarda nar tanelerinde fizikokimyasal ve fonksiyonel parametreler açısından nar çeşitleri arasında önemli farklılıklar olduğu bulunmuştur. Nar; yüksek toplam polifenol içeriği, antioksidan aktivite, ham lif ve mineraller açısından da fonksiyonel gıda olarak kullanılabilmektedir (Martos ve ark., 2010; Marmol ve ark., 2017).

Bu çalışmada, Şanlıurfa'da yaygın olarak yetiştirilen 'Hicaznar', 'Katırbaşı', 'Devedişi', 'Suruç' ve 'Suruç Karası' nar çeşitlerinin fizikokimyasal özelliklerinin ortaya konulması amaçlanmıştır. Araştırma kapsamında, nar çeşitlerine ait meyve suyu ve çekirdek örneklerinin toplam fenolik madde miktarı, toplam flavonoid miktarı, toplam antioksidan kapasitesi, toplam antosiyanin miktarı ve fenolik bileşik dağılımı belirlenmiş ve bu özellikleri karşılaştırılmıştır.

2. Materyal ve Yöntem

2.1. Materyal

Araştırma kapsamında materyal olarak, Şanlıurfa'nın Bozova ve Merkez ilçelerinden temin edilen Hicaznar, Harran ilçesinden temin edilen Hicaznar, Katırbaşı ve Devedişi, Suruç ilçesinden temin edilen Suruç ve Suruç Karası çeşitleri kullanılmıştır.

Nar meyveleri 10-21 Ekim 2018 tarihleri arasında hasat edilmiştir. Meyveler paslanmaz çelik bıçakla 2-4 parçaya ayrılarak, dane dokusuna zarar vermeyecek şekilde elle danelenmiştir. Meyve örneklerinden alınan 200'er gram dane örneklerinin katı meyve sıkacağı (Pro 120, Moulinex, Fransa) ile suyu çıkarılmış, çıkarılan sular kaba filtre kâğıdından geçirilmiş ve nar suyu örnekleri kimyasal analizler yapılıncaya kadar -18°C'de muhafaza edilmiştir. Daha sonra ayırılan çekirdek örneklerinin Soxhlet ekstraksiyon cihazı ile ekstraktları hazırlanmıştır.

2.2. Yöntem

2.2.1. Fizikokimyasal analizler

Araştırma kapsamında, Harran Üniversitesi Merkezi Laboratuvarı'nda meyve suyu ve çekirdek örneklerinin toplam fenolik madde miktarı, toplam flavonoid miktarı, toplam antioksidan kapasitesi ve toplam antosiyanin miktarı belirlenmiştir.

2.2.1.1. Toplam fenolik madde miktarı

Nar suyu örneklerinin toplam fenolik madde miktarı Singleton ve Rossi (1965) tarafından geliştirilen metot esas alınarak gerçekleştirilmiştir. Bitkisel materyallerden alınan ekstraktlar, Folin & Ciocalteau reaktifi 1:9 olacak şekilde saf su ile uygun oranlarda seyreltilmiştir. 0.4 ml seyreltilen ekstrakt üzerine 0.1 N 2 ml Folin-Ciocalteau ve 1.6 ml % 7.5 Na_2CO_3 çözeltisi eklenip; vortekslenmiştir. Oda sıcaklığında 1 saat karanlık ortamda bekletilen karışımların, Shimadzu UV-1700 UV-Vis spektrofotometre ile 765 nm'de absorbans değerleri okunmuştur. Toplam fenolik madde miktarı, standartlardan elde edilen kalibrasyon grafiği (R^2=0.99) yardımıyla hesaplanarak, sonuçlar µg GAE g^{-1} olarak verilmiştir.

2.2.1.2. Toplam flavonoid miktarı

Toplam flavonoid madde miktarı Zhinsen ve ark. (1999) tarafından önerilen yöntemle belirlenmiştir. Nar suyu örneklerinin toplam flavonoid madde miktarı µg QE g^{-1} olarak spektrofotometrede [Shimadzu UV-1700 UV-Vis spektrofotometre, Japonya] absorbansın 510 nm'de ölçülmesiyle tespit edilmiştir.

2.2.1.3. Toplam antioksidan kapasitesi

Antioksidan kapasitenin bir ifadesi olan DPPH radikalini indirgeme aktivitesi (antiradikal aktivite, % ARA) Brand-Williams ve ark. (1995)'na göre belirlenmiştir. Analize başlanmadan önce DPPH radikali hazırlanmıştır. 0.008 g DPPH radikali amberli ve alüminyum ile kaplı şişeye alınmıştır. Üzerine 150 ml çözücü (etanol) eklenmiştir. 1 gün karanlık ortamda çalkalanmış ve süre sonunda 50 ml daha çözücü eklenmiştir. Daha sonra her bir bitkisel materyalin ekstraktları saf su ile 10 kat seyreltilmiştir. Ekstraktlardan 0.1, 0.2 ve 0.3 ml alınarak, tüpler içerisine eklenmiştir. Her tüpe toplam 3 ml olacak şekilde çözücü eklenmiştir. Üzerine 1 ml DPPH radikali eklenerek, vorteks ile karıştırılıp,

oda sıcaklığında karanlıkta 30 dakika bekletilmiştir. 30 dakika sonunda Shimadzu UV-1700 UV-Vis spektrofotometre ile 517 nm'de absorbans değerleri okunmuştur. Ekstraktların antioksidan kapasitesinin bir ölçüsü olan % ARA değerleri aşağıdaki formüle göre hesaplanmıştır (1).

$$\% ARA = [\, Ak - \left(\frac{\text{Ak}}{\text{Aö}}\right)] \times 100 \quad (1)$$

Ak: Kontrolün absorbansı
Aö: Örneğin absorbansı

2.2.1.4. Toplam antosiyanin miktarı analizi

Toplam antosiyanin miktarı içerikleri Giusti ve Wrolstad (2001) tarafından belirtilen pH-diferansiyel metoduna göre belirlenmiştir. 0.025 M KCl tamponu [pH 1.0] ve 0.4 M CH_3COONa tamponu içerisinde inkubasyona tabi tutulan örneklerin absorbansları spektorfotometrede [Shimadzu UV-1700 UV-Vis spektrofotometre, Japonya] 520 ve 700 nm'de ölçülmüş ve absorbans değerleri A [absorbans değeri]=[A_{520nm}-A_{700nm}] pH 1.0- [A_{520nm}-A_{700nm}] pH 4.5 formülüyle bulunmuştur. Örneklerin elde edilen absorbans değerleri aşağıda verilen eşitlik kullanılarak hesaplanmış ve toplam antosiyanin miktarı mg siyanidin 3-glikozit 100 ml^{-1} olarak hesaplanmıştır (2).

Toplam antosiyanin miktarı = $(A*MW*DF*10^3)/ \varepsilon*1$ (2)
MW: Siyanidin-3-glikozidin molekül ağırlığı = 449.2 g mol^{-1}
DF: Seyreltme faktörü
ε: Siyanidin-3-glikozidin molar absorpsiyon katsayısı = 26.900

2.3. İstatiksel Analizler

Araştırma, tesadüf parselleri deneme planında üç tekerrürlü ve her tekerrürde 5 meyve olacak şekilde yürütülmüştür. Analizlerinde, her örnek için iki paralel okuma yapılmıştır. İstatistiksel analizlerde elde edilen sonuçlar ortalama ± standart sapma şeklinde ifade edilmiştir.

3. Bulgular ve Tartışma

3.1. Toplam fenolik madde miktarı

Şanlıurfa'da yaygın olarak yetiştirilen nar çeşitlerine ait meyve suyu ve çekirdek örneklerindeki toplam fenolik madde miktarları Çizelge 1 ile Şekil 1'de verilmiştir.

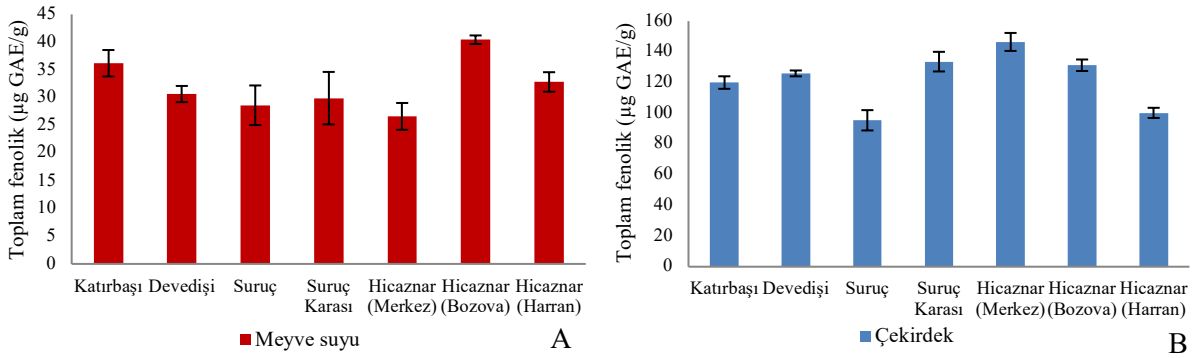
Araştırmada incelenen nar çeşitlerinin meyve sularında toplam fenolik madde miktarı 26.60-40.43 µg GAE g^{-1} arasında değişim göstermiştir. Bozova ilçesinde yetiştirilen Hicaznar (Bozova) çeşidi en yüksek fenolik madde miktarı ile diğer örneklerden önemli düzeyde farklılık göstermiştir (Çizelge 1 ve Şekil 1). Nar çeşitlerinin çekirdeklerindeki toplam fenolik madde miktarı bakımından 146.44 µg GAE g^{-1} ile Hicaznar (Merkez) en yüksek toplam fenolik madde miktarına sahip olduğu belirlenmiştir. Hicaznar (Merkez) çeşidini, Suruç Karası (133.60 µg GAE g^{-1}) ve Hicaznar (Bozova) (131.25 µg GAE g^{-1}) çeşitleri takip etmiştir (Çizelge 1 ve Şekil 1).

Yapılan analiz sonuçlarına göre nar çekirdeklerindeki toplam fenolik madde miktarının, meyve sularındaki miktardan daha yüksek olduğu saptanmıştır (Çizelge 1 ve Şekil 1). Özgen ve ark. (2008), ülkemizde yetiştirilen 6 nar çeşidine ait meyve suların toplam fenolik madde miktarının 1245-2076 mg GAE l^{-1} arasında; Sarkhosh ve ark. (2009), İran'da yetiştirilen 21 farklı nar genotipine ait çekirdeklerin toplam fenolik madde miktarının 50.73-103.83 mg GAE 100 g^{-1} arasında; İzol (2012), Siirt'in Şirvan ilçesinde yetiştirilen bazı nar çeşit ve genotiplerinin danelerinde toplam fenolik madde miktarının 820.98-1303.60 mg GAE l^{-1} arasında; Salgado ve ark. (2012), nar çekirdeğinin toplam fenolik madde miktarının 62.0 mg GAE g^{-1} olduğunu; Akhavan ve ark. (2015), İran'da yetiştirilen 10 farklı nar çeşidinde danelerden elde edilen ekstraktların toplam fenolik madde miktarının 220-1267 mg GAE l^{-1} arasında, bütün meyvelerden elde edilen ekstraktların toplam fenolik madde miktarının 943-2931 mg GAE l^{-1} arasında; Okumuş (2016), Wonderful ve Hicaznar çeşitlerine ait suların toplam fenolik madde

miktarının 1156.67-1428.1 mg GAE l^{-1} arasında, çekirdeklerin toplam fenolik madde miktarının 43.71-54.66 mg GAE g^{-1} arasında; Ambigaipalan ve ark. (2017), toplam fenolik madde miktarının çekirdek ekstraktlarında (3.39 mg GAE g^{-1}), meyve suyu ekstraktlarından (1.03 mg GAE g^{-1}) yaklaşık üç kat fazla olduğunu; Özden (2018), Şanlıurfa'da yetiştirilen 3 nar çeşidinde toplam fenolik madde miktarının dane ekstraktlarında 728.88-906.66 mg GAE kg^{-1} arasında ve çekirdek ekstraktlarında 4733.33-6511.11 mg GAE kg^{-1} arasında olduğunu bildirmişlerdir.

Çizelge 1. Nar çeşitlerinin meyve suyu ve çekirdek örneklerindeki toplam fenolik madde ve toplam flavonoid miktarı

	Toplam fenolik madde miktarı (µg GAE g^{-1})		Toplam flavonoid miktarı (µg QE g^{-1})	
Çeşitler	Meyve suyu	Çekirdek	Meyve suyu	Çekirdek
Katırbaşı	36.19 ± 2.38	119.97 ± 4.08	872.75 ± 99.90	1830.18 ± 75.37
Devedişi	30.63 ± 1.46	125.94 ± 1.91	627.03 ±59.09	1573.44 ± 213.73
Suruç	28.61 ± 3.57	95.39 ± 6.62	572.66 ± 44.15	1040.01 ± 6.19
Suruç Karası	29.89 ± 4.73	133.60 ± 6.39	868.62 ± 28.68	983.57 ± 69.63
Hicaznar (Merkez)	26.60 ± 2.42	146.44 ± 5.86	1132.24 ± 140.69	1636.08 ± 92.44
Hicaznar (Bozova)	40.43 ± 0.77	131.25 ± 3.75	1150.83 ± 19.18	1597.53 ± 29.27
Hicaznar (Harran)	32.81 ± 1.76	100.21 ± 3.31	1026.93 ± 56.37	1161.84 ± 51.37



Şekil 1. Nar çeşitlerinin toplam fenolik madde miktarları (A: meyve suyu, B: çekirdek).

İncelenen nar çeşitlerinin meyve suyu ve çekirdek örneklerinin toplam fenolik madde miktarı, literatürdeki çalışmalarda da tespit edildiği gibi, meyve suyu örneklerinin toplam fenolik madde miktarından yaklaşık 3-4 kat daha yüksek olduğu saptanmıştır. Bu sonuç nar çekirdeğinin önemli bir gıda kaynağı olduğunu göstermektedir. Çalışmamızda elde edilen sonuçlar ile literatürdeki çalışma sonuçları kısmen benzerlik göstermektedir. Verilerdeki farklılıkların çeşit, olgunluk, yetişme bölgesi, presleme basıncı, örneklerin ekstrakte edildiği çözücü, kullanılan standart çözelti ve sonuçların farklı birimlerde değerlendirilmesi gibi nedenlerden kaynaklandığı düşünülmektedir.

3.2. Toplam flavonoid miktarı

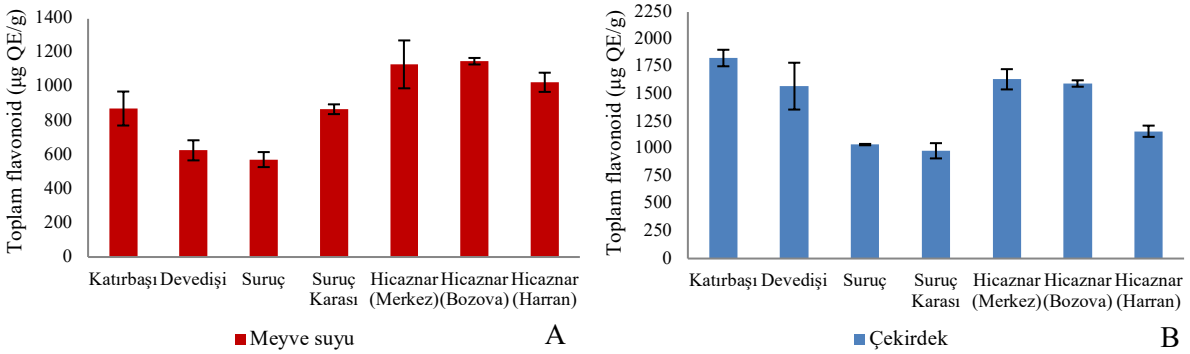
Çeşitlere ait meyve suyu örneklerinin toplam flavonoid miktarları 572.66-1150.83 µg QE g^{-1} aralığında belirlenmiştir (Çizelge 1 ve Şekil 2). Toplam flavonoid miktarı bakımından Hicaznar (Bozova) çeşidini, Hicaznar (Merkez) (1132.24 µg QE g^{-1}) ve Hicaznar (Harran) (1026.93 µg QE g^{-1}) çeşitleri izlemiştir. En düşük flavonoid miktarı ise 572.66 µg QE g^{-1} ile Suruç çeşidinde tespit edilmiştir.

Çekirdek örneklerinin toplam flavonoid miktarı karşılaştırıldığında, en yüksek değer Katırbaşı çeşidinde 1830.18 µg QE g^{-1}, en düşük değer ise Suruç Karası çeşidinde 983.57 µg QE g^{-1} olarak tespit edilmiştir (Çizelge 1 ve Şekil 2). Toplam flavonoid miktarı bakımından Katırbaşı çeşidini, Hicaznar (Merkez) (1636.08 µg QE g^{-1}), Hicaznar (Bozova) (1597.53 µg QE g^{-1}) ve Devedişi (1573.44 µg QE g^{-1}) çeşitleri takip etmiştir. Yapılan analiz sonuçlarına göre nar çekirdeklerindeki toplam flavonoid miktarının, meyve sularındaki miktardan daha yüksek olduğu saptanmıştır.

Karadeniz ve ark. (2005), nar suyunun toplam flavonoid miktarının 459 mg QE kg^{-1}; Fawole ve ark. (2012), Güney Afrika'da yetiştirilen 3 nar çeşidinde toplam flavonoid miktarının 46.38-72.28 mg

100 ml^{-1} arasında; Turgut ve Seydim (2013), bazı nar çeşit ve genotiplerinde toplam flavonoid miktarının 5.898-19.438 mg QE 100 ml^{-1} arasında; Li ve ark. (2015), Çin'de yetiştirilen 10 nar çeşidinin dane ekstraktlarında toplam flavonoid miktarının 0.045-0.335 QE mg ml^{-1} arasında; Özden (2018), Şanlıurfa'da yetiştirilen 3 nar çeşidinde toplam flavonoid miktarının dane ekstraktlarında 458.33-559.21 mg QE kg^{-1}, çekirdek ekstraktlarında 1677.63-3076.75 mg QE kg^{-1} arasında olduğunu ve çekirdek ekstraktlarının toplam flavonoid miktarının, dane ekstraktlarından daha yüksek olduğunu bildirmişlerdir.

Çalışmamızda elde edilen bulgular, diğer araştırıcıların bulgularıyla kısmen örtüşmektedir. Özden (2018)'in çekirdek ekstraktlarının toplam flavonoid miktarının dane ekstraktlarından daha yüksek olduğu bulgusu, araştırma sonuçlarımız ile paralellik göstermektedir.



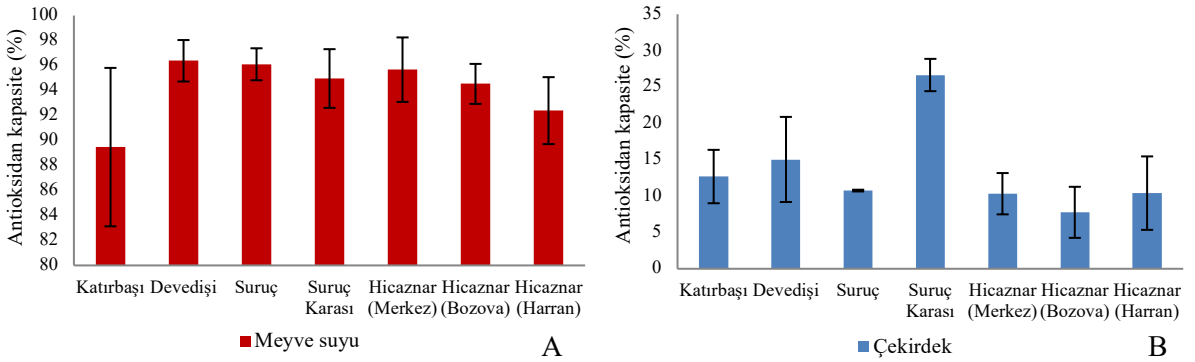
Şekil 2. Nar çeşitlerinin toplam flavonoid miktarları (A: meyve suyu, B: çekirdek).

3.3. Toplam antioksidan kapasitesi

Nar çeşitlerine ait meyve suyu ve çekirdek örneklerinde toplam antioksidan kapasiteleri Çizelge 2 ile Şekil 3'te verilmiştir.

Çizelge 2. Nar çeşitlerinin meyve suyu ve çekirdek örneklerindeki toplam antioksidan kapasite ve toplam antosiyanin miktarı

	Toplam antioksidan kapasite (%)		Toplam antosiyanin miktarı (mg siyanidin 3-glikozit l^{-1})	
Çeşitler	Meyve suyu	Çekirdek	Meyve suyu	Çekirdek
Katırbaşı	89.47 ± 6.34	12.68 ± 3.67	0.92 ± 0.34	0.71 ± 0.64
Devedişi	96.38 ± 1.66	15.03 ± 5.85	1.79 ± 0.26	1.18 ± 0.64
Suruç	96.10 ± 1.28	10.75 ± 0.12	0.84 ± 0.74	0.19 ± 0.12
Suruç Karası	94.96 ± 2.35	26.64 ± 2.22	1.02 ± 0.42	0.91 ± 0.50
Hicaznar (Merkez)	95.67 ± 2.58	10.32 ± 2.84	20.27 ± 1.04	2.58 ± 2.25
Hicaznar (Bozova)	94.53 ± 1.60	7.76 ± 3.51	24.12 ± 1.73	1.45 ± 1.27
Hicaznar (Harran)	92.39 ± 2.68	10.40 ± 5.05	14.62 ± 1.03	3.51 ± 0.35



Şekil 3. Nar çeşitlerinin DPPH metodu ile antioksidan aktivite tayini (A: meyve suyu, B: çekirdek).

Nar çeşitlerine ait meyve sularındaki toplam antioksidan kapasite bakımından en yüksek değer % 96.38 ile Devedişi çeşidinde ve en düşük değer ise Katırbaşı çeşidinde % 89.47 olarak tespit edilmiştir (Çizelge 2 ve Şekil 3). Toplam antioksidan kapasitesi bakımından Devedişi çeşidini, Suruç (% 96.10) ve Hicaznar (Merkez) (% 95.67) çeşitleri takip etmiştir.

Nar çeşitlerinin çekirdek örneklerindeki toplam antioksidan kapasite karşılaştırıldığında; en yüksek değer % 26.64 ile Suruç Karası çeşidinde ve en düşük değer Hicaznar (Bozova) çeşidinde % 7.76 olarak tespit edilmiştir (Çizelge 2 ve Şekil 3). Toplam antioksidan kapasitesi bakımından Suruç Karası çeşidini, Devedişi (% 15.03) ve Katırbaşı (% 12.68) çeşitleri izlemiştir.

Yapılan analiz sonuçlarına göre, tüm çeşitlerde en yüksek toplam antioksidan kapasite meyve suyu örneklerinde ölçülmüştür (Çizelge 2 ve Şekil 3). Surveswaran ve ark. (2007), nar çekirdeğinin antioksidan kapasitesini 3.53 mmol TE 100 g^{-1}; Özgen ve ark. (2008), 6 farklı nar çeşidinin antioksidan kapasitesinin 0.56-0.770 mmol TE 100 ml^{-1} arasında; Mousavinejad ve ark. (2009), İran'da yetiştirilen farklı çeşitlere ait nar sularının antioksidan kapasitesini DPPH metodu ile % 18.60-42.80 arasında; Tezcan ve ark. (2009), ticari nar sularının antioksidan kapasitesini DPPH metodu ile % 10.37-67.46 arasında; Tehranifar ve ark. (2010), İran'da yetiştirilen 20 nar çeşidinde antioksidan kapasitesini DPPH metodu ile % 15.59-40.72 arasında; Karaca (2011), taze sıkılmış nar suyunda antioksidan kapasitesini DPPH metodu ile % 79.6-86.2 arasında; Zaouay ve ark. (2012), Tunus'ta yetiştirilen 13 farklı çeşide ait nar sularının antioksidan kapasitesini DPPH metodu ile 9.57-21.07 mmol TE l^{-1} arasında; Turgut ve Seydim (2013), bazı nar çeşit ve genotiplerinin antioksidan kapasitesinin 1.004-1.641 mmol TE 100 ml^{-1} arasında; Karaaslan ve ark. (2014), Türkiye'de yetiştirilen 4 farklı nar çeşidinin antioksidan kapasitesinin 267.3-381.2 mg TE 100 g^{-1} arasında; Kaur ve ark. (2014), Hindistan'da 6 farklı nar çeşidinin antioksidan kapasitesinin DPPH metodu ile 8.98-15.47 µmol TE/g arasında; Abbasoğlu (2016), Şanlıurfa'da 3 nar çeşidinin antioksidan kapasitesini DPPH metodu ile 4.70-19.42 mM TE l^{-1} arasında; Okumuş (2016), Wonderful ve Hicaznar çeşitlerinin antioksidan kapasitesini DPPH metodu ile nar sularında 7.40-7.58 mmol TE l^{-1}, nar çekirdeklerinde 0.25-0.29 mmol TE g^{-1} arasında; Özden (2018), Şanlıurfa'da 3 nar çeşidinde dane ekstraktlarının toplam antioksidan kapasitelerinin, çekirdek ekstraktlarından daha yüksek olduğunu bildirmişlerdir.

Çalışmamızda meyve suyu örneklerinin toplam antioksidan kapasitelerinin, çekirdek örneklerinden daha yüksek olması literatür sonuçlarıyla uyumludur. Ayrıca araştırmamızda meyve suyu ve çekirdek örneklerinden elde edilen antioksidan kapasitesi değerlerinin, literatürde saptanan değerlerden daha yüksek olduğu da görülmüştür.

3.4. Toplam antosiyanin miktarı

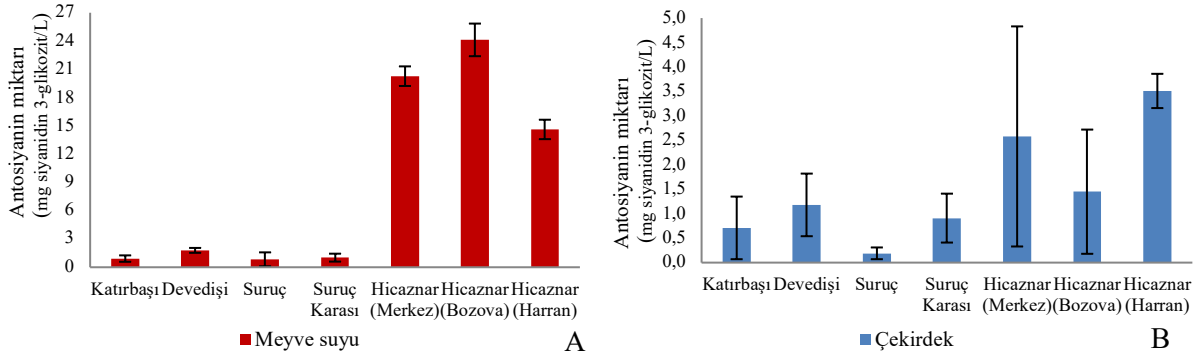
Nar çeşitlerine ait meyve suyu ve çekirdek örneklerinde toplam antosiyanin miktarı Çizelge 2 ile Şekil 4'te verilmiştir. Araştırmada incelenen çeşitlerin meyve sularındaki toplam antosiyanin miktarı 0.84 (Suruç) mg siyanidin 3-glikozit l^{-1} ile 24.12 mg siyanidin 3-glikozit l^{-1} (Hicaznar (Bozova)) arasında değişkenlik göstermiştir. Toplam antosiyanin miktarı bakımından Hicaznar (Bozova) çeşidini, Hicaznar (Merkez) (20.27 mg siyanidin 3-glikozit l^{-1}) ve Hicaznar (Harran) (14.62 mg siyanidin 3-glikozit l^{-1}) çeşitleri takip etmiştir.

Çekirdek örneklerindeki toplam antosiyanin miktarı karşılaştırıldığında, en yüksek değer Hicaznar (Harran) çeşidinde 3.51 mg siyanidin 3-glikozit l^{-1} ve en düşük değer ise Suruç çeşidinde 0.19 mg siyanidin 3-glikozit l^{-1} olarak tespit edilmiştir (Çizelge 2 ve Şekil 4). Toplam antosiyanin miktarı bakımından Hicaznar (Harran) çeşidini, Hicaznar (Merkez) (2.58 mg siyanidin 3-glikozit l^{-1}) ve Hicaznar (Bozova) (1.45 mg siyanidin 3-glikozit l^{-1}) çeşitleri izlemiştir. Analiz sonuçlarına göre, tüm çeşitlerde en yüksek toplam antosiyanin miktarı meyve suyu örneklerinde ölçülmüştür (Çizelge 2 ve Şekil 4).

Nar çeşit ve genotiplerinde toplam antosiyanin miktarının tespit edildiği diğer çalışmalar incelendiğinde; Özgen ve ark. (2008), Akdeniz Bölgesi'nde yetiştirilen 6 farklı nar çeşidinde toplam antosiyanin miktarının 0.61-21.9 mg 100 ml^{-1} arasında; Çam ve ark. (2009), ülkemizde yetiştirilen 10 farklı nar çeşidinde toplam antosiyanin miktarının 8.1-36.9 mg 100 ml^{-1} arasında; Tehranifar ve ark. (2010), İran'da yetiştirilen 20 farklı nar çeşidinde toplam antosiyanin miktarının 5.56-30.11 mg 100 g^{-1} arasında; Sepulveda ve ark. (2010), Şili'de yetiştirilen 8 nar genotipinde toplam antosiyanin miktarının 16.8-132.8 mg siyanidin 3-glikozit 100 ml^{-1} arasında; İzol (2012), Siirt'in Şirvan ilçesinde yetiştirilen bazı nar çeşit ve genotiplerinin danelerinde toplam antosiyanin miktarının 27.16-171.86 mg siyanidin

3-glikozit kg^{-1} arasında; Fawole ve ark. (2012), Güney Afrika'da yetiştirilen 3 nar çeşidinde toplam antosiyanin miktarının 16.53-26.93 mg 100 ml^{-1} arasında; Turgut ve Seydim (2013), bazı nar çeşit ve genotiplerinde toplam antosiyanin miktarının 9.892-34.616 mg siyanidin 3-glikozit 100 ml^{-1} arasında; Abbasoğlu (2016), Şanlıurfa'da 3 nar çeşidinde toplam antosiyanin miktarının 2.07-67.84 mg siyanidin 3-glikozit l^{-1} arasında; Okatan ve ark. (2018), Bitlis'in merkez bölgesinde yetişen nar genotiplerinde toplam antosiyanin miktarının 55.37-156.03 mg siyanidin 3-glikozit l^{-1} arasında; Özden (2018), Şanlıurfa'da 3 nar çeşidinde toplam antosiyanin miktarının nar danelerinde 46.58-347 mg siyanidin 3-glikozit kg^{-1}, nar çekirdeklerinde 54.93-68.29 mg siyanidin 3-glikozit kg^{-1} arasında; Özkan ve ark. (2018), Zivzik narında toplam antosiyanin miktarının 16.3-21.7 mg siyanidin-3-glikozit 100 g^{-1} arasında değişiklik gösterdiğini bildirmişlerdir.

Toplam antosiyanin miktarı açısından elde etmiş olduğumuz değerler, diğer araştırıcıların bulgularıyla kısmen uyumlu bulunmaktadır. Dane renkleri pembe ve açık pembe olan Devedişi, Katırbaşı, Suruç ve Suruç Karası çeşitlerinin meyve suyu ve çekirdek örneklerinin toplam antosiyanin miktarı, dane rengi kırmızı olan Hicaznar çeşitlerinden daha düşük saptanmıştır.



Şekil 4. Nar çeşitlerinin toplam antosiyanin miktarı (A: meyve suyu, B: çekirdek).

4. Sonuç

Araştırma sonucunda; çalışmada kullanılan nar çeşitlerinden alınan meyve örneklerinin analiz edilmesi sonucunda hem çeşitlerin birbiri arasında hem de meyvelerden alınan meyve suyu ve çekirdek özlerinin birbiri ile kıyaslanması bakımından toplam fenolik madde miktarı, toplam flavonoid miktarı, toplam antioksidan kapasite ve toplam antosiyanin miktarları değişkenlik göstermiştir. Araştırmada incelenen tüm nar çeşitlerinde fenolik madde ve toplam flavonoid miktarının çekirdeklerde daha fazla olduğu, buna karşılık toplam antioksidan kapasitesi ve toplam antosiyanin miktarının ise meyve suyu örneklerinde daha yüksek düzeyde olduğu saptanmıştır.

Araştırmadan elde edilen sonuçlar ışığında, nar çeşitlerinin meyve suyu ve çekirdeklerinin toplam fenolik madde miktarı, toplam flavonoid miktarı, toplam antioksidan kapasitesi, toplam antosiyanin miktarı ve sağlık açısından faydalı fenolik bileşenleri yüksek miktarda içerdikleri görülmüştür. Sofralık tüketim ve meyve suyu endüstrisinde kullanımının yanında, özellikle albenisi olmayan ve bu yüzden yetiştiriciler tarafından tercih edilmeyen Suruç Karası çeşidinin, çekirdeklerindeki oldukça yüksek fenolik madde ve antioksidan kapasite nedeniyle fonksiyonel ürün olarak da endüstriyel kullanımının yaygınlaştırılması önerilmektedir.

Nar yetiştiriciliği için uygun ekolojik koşullara sahip olan bölgemizde üreticilerin nar yetiştiriciliği konusunda bilinçlendirilmesi ve yetiştiriciliğinin yaygınlaştırılmasının bölge ve ülke ekonomisine de önemli bir katkı sağlayacağı düşünülmektedir.

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Research Article (Araştırma Makalesi)

Efficacy Detection of Low-Cost Hall Effect Sensor for a LabVIEW-Based Agricultural Gaussmeter

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LabVIEW,
Magnetic field,
Microcontroller.

Abstract: Developing technology enables more accurate and efficient measurement with the help of low-cost sensors. Therefore, in this study, a gaussmeter that can be used for agricultural purposes was developed using a low-cost microcontroller development card. The developed low-cost gaussmeter includes an inexpensive magnetic field sensor, a microcontroller development card, and LabVIEW software. Magnetic field measurements, based on the optimization of the microcontroller-based gaussmeter, were developed with the HAL503 Hall Effect sensor with the help of LabVIEW software. A high regression was observed between the values obtained from the device and the results found from the calculations made using theoretical magnetic field formulas and the measured values. It was observed that it works with an average accuracy of 99.6% for 3 different thickness magnets. According to the developed measuring device results of 6, 8, and 10 magnets sizes, R^2 values were evaluated as 99.8%, 99.7%, and 99.3%, respectively.

LabVIEW Tabanlı Tarımsal Amaçlı bir Gaussmetre için Düşük Maliyetli Hall Etkisi Duyargasının Etkinlik Tespiti

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Anahtar Kelimeler
Gaussmetre,
Hall etkisi duyargası,
LabVIEW.
Manyetik alan,
Mikrodenetleyici,

Öz: Gelişen teknoloji düşük maliyetli duyargalar yardımıyla daha doğru ve verimli ölçüm yapılmasını sağlamaktadır. Bu nedenle bu çalışmada, düşük maliyetli tarımsal amaçlı kullanılabilecek bir gaussmetre geliştirilmiştir. Geliştirilen düşük maliyetli gaussmetre, bir manyetik alan duyargası, bir mikrodenetleyici geliştirme kartı ve LabVIEW yazılımından oluşmaktadır. Manyetik alan ölçümleri LabVIEW yazılımı yardımıyla HAL503 Hall Effect duyargası ile geliştirilen mikrodenetleyici tabanlı gaussmetrenin optimizasyonuna dayalı olarak yapılmıştır. Cihazdan elde edilen değerler ile teorik manyetik alan formülleri kullanılarak yapılan hesaplamalardan bulunan değerler arasında yüksek bir regresyon gözlenmiştir. HAL503 hall etkisi duyargası kullanılarak yapılan bu çalışmada, 3 farklı kalınlıktaki mıknatıs için cihazın ortalama %99.6 hassasiyetle çalıştığı görülmüştür. 6, 8 ve 10 mıknatıs boyutunda, geliştirilen ölçüm cihazı R^2 değerleri sırasıyla %99.8, %99.7 ve % 99.3 olarak hesaplanmıştır.

1. Introduction

The first magnetometer was invented by Carl Friedrich Gauss in 1833 with the ability to measure magnetic density. There have been notable developments in the Hall Effect, which is still widely used for magnetic field measurements in the 19th century (Khan et al., 2017). Sensors used for magnetic field measurements play an important role in many areas. For example, space researches (Can and Topal, 2015), agricultural and aquaculture enhancement, water treatment (Lin and Yotvat, 1990), agricultural machinery, and military systems are well-known applications (Nowicki and Szewczyk, 2013; Nowicki and Szewczyk, 2019). Agricultural production and irrigation magnetic field studies provide important progress in agriculture sector.

Lin and Yotvat (1990) reported an increase in water efficiency in both crop and livestock production at magnetically treated water. In another study, Amaya et al. (1996) and Podlesny et al. (2004) showed the acceleration of plant growth, especially the seed germination and emergence rate, through optimal external electromagnetic fields. Podlesny et al. (2004) investigated and observed significant beneficial effects on germination, emergence, and seed yield by exposing the pod seeds to varying magnetic forces before planting. After the use of magnetic treatment, a more regular plant occurred and 2-3 days before the control process was observed. The magnetic field effect has also been found to be effective when consuming plants with nutrients. Some studies show that strawberries and tomatoes are increasingly flowering, early in life, and total fruit output by applying magnetic fields (Esitken and Turan, 2004; Danilov et al., 1993). Duarte Diaz et al. (1997) have observed an increase in the intake of food in magnetic processing. In the literature, the root growth of different plant species is influenced by magnetic field applications (Belyavskaya, 2001; Belyavskaya, 2004; Muraji et al., 1992; Muraji et al., 1998; Turker et al., 2007). Maize (*Zea mays*) root growth increase was shown by Muraji et al. (1992) in the form of exposure to 5 mT magnetically grown seedlings at an alternative frequency of 40-160 Hz. Also magnetic field application improve yield and plant growth in cucumber, as well as an iron chelate (Ahmadi et al., 2020). Additionally, the magnetic field is known to reduce stress in seedlings caused by heat. For 40 minutes, the effect of heat stress on cress seedlings (*Lepidium sativum*) was reduced by exposure to a highly low-frequency magnetic field (50 Hz, 100T).

Hall effect refers to the phenomenon in which a potential difference develops in a conductor that carries current in a magnetic field. This fact was discovered by Edwin Hall in 1879 (Hall, 1879). It is believed that gaussmeter and electronic integrated flux meters are the most used devices for measuring magnetic flux density (Seely, 1997). To ensure the proper use of magnetic measuring instruments, it is necessary to understand the application methods of these tools (Murphy, 1999). Measuring the magnetic field using the Hall Effect sensors is only one of these application methods (Blagojevic et al., 2004; Logofatu et al., 1997), and gaussmeter are used for this purpose. The use of gaussmeter's for magnetic parameters and properties of materials is a result of particle movement in the electric field. Besides, different types of electricity in AC and DC can be measured using an industrial gaussmeter with a Hall-effect sensor. When the sensor is near a magnetic field, it creates voltage differences according to the strength of the magnetic field. However, they are costly as industrial measuring instruments. Hall sensors, AMR sensors, GMR - STD sensors, FLUXGATE sensors, and some other devices use magnetic field measurements (Ripka and Janosek, 2010). Also, different development cards such as Arduino, ARM, Raspberry Pi can be used for this purpose (Khan et al., 2017). In the literature, Prasad et al. (2014) stated that a low-cost development card-based device can be used to conduct various experiments on magnetism in the physics laboratories. There are many Hall generators known today (Randjelovic et al., 1999; Popovic, 1991). However, the noise impact of hall sensors limits their use (Popovic et al., 2001). The hall effect plane is important in magnetic fields measured using the Hall sensor (Morvic and Betko, 2005; Goldberg and Davis, 1954; Schott et al., 2000). The sensor used in this study is the HAL503 linear Hall Effect sensor. The principle of operation of the sensor used is that when the current is kept constant, the voltage changes linearly according to the magnetic field (Badaroglu et al., 2008). Magnetic sensors are solid-state devices that are becoming more and more popular because they can be used in many different types of applications such as sensing position, velocity, or directional movement (Khan et al., 2017).

In this research, considering the literature, the efficacy of a microcontroller and LabVIEW-based gaussmeter has been studied with the help of HAL503 magnetic field sensor that works based on

magnetic field theory for effectiveness detection because of the future low-cost magnetic field applications in agriculture.

2. Material and Method

2.1. Material

The main subject of the adjustment is the development of an effective system in the LabVIEW environment that can measure the magnetic field values of three different thickness neodymium magnets in gauss and millitesla levels under controlled laboratory conditions with low-cost parts (Figure 1).

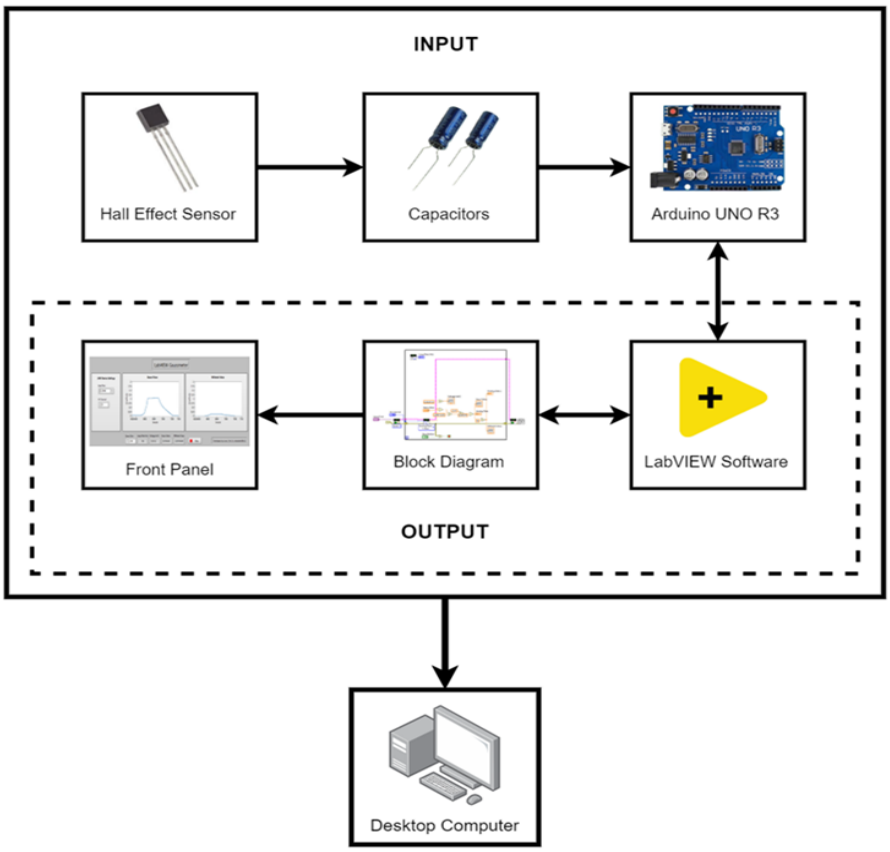


Figure 1. Flow chart of LabVIEW-based gaussmeter software.

For this purpose, the voltage of the HAL503 magnetic field sensor, which received the analog 0 pin signal of the Arduino UNO R3 microcontroller development card, is stabilized using two 16V 100uF capacitors (Figure 3 - 5). Arduino Uno R3 can be operated via USB and communicates with LabVIEW software via Serial Port (COM) (D'Ausilio, 2012). Sensor values obtained through Arduino matching LabVIEW software, that are calculated in the block diagram of the LabVIEW software and the signals processed in the graphics and measurement boxes created in the front panel (66Hz) are given instantly (Figure 9 - 10). LabVIEW, which can interfere with the front panel and block diagram in these computer operations, can provide the user a comfortable reading on the front panel (Figure 1).

2.1.1. Magnetic Field Generation

The most powerful permanent magnets currently available are neodymium magnets, which were developed in 1982 by General Motors and Sumitomo Special Metals. Many applications of modern products that include powerful permanent magnets, such as motors in cordless drills, hard disk drives, and magnetic fasteners, have been taken over by them. Rare Earth magnets (also known as Neodymium

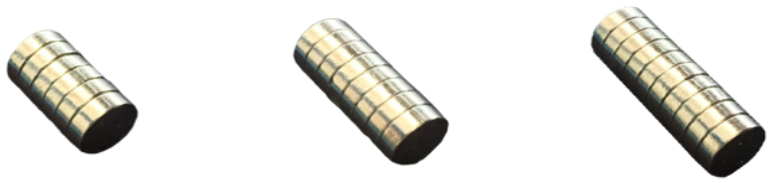
magnets) are 5–7 times stronger than Ferrite magnets and are the most cost-effective. Higher values, from N35 to N52, indicate stronger magnets. The magnetic field was created by layering various thicknesses of N35 neodymium magnets (Table 1).

Table 1. Features of N35 neodymium magnets that are used in the application

Grade	Residual magnetism		Coercive and field strength				Energy product		Max. operational temp.
	Br		bHc		iHc		(BxH)max.)		
	Gauss(G)	Tesla (T)	kOe	kA/m	kOe	kA/m	MGOe	kJ/m^3	°C
N35	11700-12100	1.17-1.21	10.8-11.5	860-915	≥12	≥955	33-35	263-279	≤80

Br: Remanence, bHc: coercive field force, iHc: demagnetized field strength, BxH: maximum energy product, N35: Type of neodymium magnet.

Three different neodymium magnets group were used for the measurements. 6, 8, and 10 magnets which have 10 mm diameter and 3 mm thickness were used respectively (Figure 2). In this way, at different thickness levels, different magnetic fields were obtained from N35 neodymium magnets. Additionally, with the N35 neodymium magnets, three different magnetic fields created for 25 different distance levels change 1 mm between the measurements 10 mm to 35 mm.



(a) (b) (c)

Figure 2. 6 neodymium magnets (a), 8 neodymium magnets (b) and 10 neodymium magnets(c).

Neodymium magnets are generally more powerful than normal magnets. However, neodymium magnets cost more due to the more expensive materials needed to manufacture them: they require a mixture of iron, neodymium, and boron to magnetize via exposure to a powerful magnetic field. Normal and neodymium magnets each have different benefits. Neodymium magnets are metal magnets, and they are colored in silver, like most other metals. The neodymium magnet is extremely strong, with magnetic strengths between N24 and N55, with N55 being the strongest manufactured.

2.1.2. Arduino UNO R3

There are a lot of different development boards in the markets. However, Arduino UNO R3 is the widely used one between them (Figure 3). It has enough capability and technical properties for this low-cost measurement device development process. The board is easily connected with LabVIEW software by using the LINX firmware. In this development process, an analog input of the board was used for getting the voltage values. Also, it was used for the measurement of gauss values. For this aim, the software was developed in the LabVIEW platform.

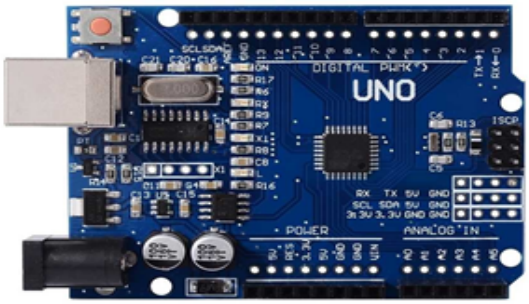


Figure 3. Arduino UNO R3 microcontroller board front view.

The Arduino development card uses an ATmega328 embedded microcontroller from Atmel, which has 6 analog inputs with 10-bit resolution, and a USB (Universal Serial Bus) connection.

2.1.3. HAL503 Hall Effect Sensor

The HAL503 is the sensor for the Hall effect that monitors very little magnetic density changes, very small changes in the Hall effect controls. HAL503 hall effect sensor contains the Vcc, ground, and Vdd terminals (Figure 4). They are magnetically driven mirrors for mechanical phenomena like motion sensors, gear tooth sensors, and detectors of proximity. As sensitive electromagnet monitoring systems, the performance of the system can be effectively measured by negligible loading of systems, while providing insulation from contaminated and noisy environments. Each integrated Hall Effect circuit comprises a Hall sensor element, the linear amplifier, and the output stage for the emitter follower. The Hall cell and amplifier in one chip minimizes problems with the processing of small analog signals. For most applications, three-pack styles deliver a magnetically optimized pack. The 'UA' packet suffix is an ultra-mini SIP three-pin.

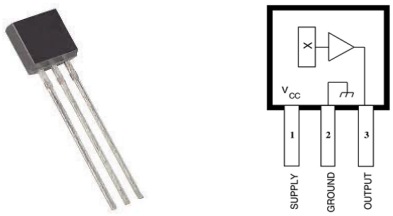


Figure 4. HAL503 Hall effect sensor and pinout.

For continuous operation, the sensor is evaluated within -40°C to +170°C. It has a high sensitivity. It can function up to 10 kHz and dynamic magnetic fields in static magnetic fields. Becoming suitable for multi-poles and rotational speed measurements, the HAL503 hall effect sensing sensors and operating range allow for this application. The HAL503 Hall Effect Sensor absolute maximum values can be seen in Table 2.

Table 2. Absolute maximum ratings of HAL503 Hall Effect Sensor

Absolute Maximum Ratings	**Specification**
Supply Voltage (Vcc)	3.8V to 24V
Magnetic Flux Density	B Unlimited
Operating Temperature Range (T_A)	-40°C to +170°C
Switching Type	Latching

2.1.4. Capacitors

A capacitor is a component that stores potential energy in an electric field between the passive two-electrical terminal (Figure 5). The effect of a capacitor was called capacitance. While some capacitance exists between any two electrical conductors in proximity to a circuit, a capacitor is an electrical component that was designed to add capacitance to a circuit. The capacitor was initially known as a condenser (Anonymous, 2018). In this magnetic field measurement system, two capacitors (100 µF) were used to control the current.

Figure 5. 16V 100µF capacitors.

In the research, the hall effect sensor's output was connected to the A0 pin of the Arduino, which communicates with the computer via a USB (Universal Serial Bus), and thus the voltage data sent to the Arduino was processed through the LabVIEW program (Figure 6-7).

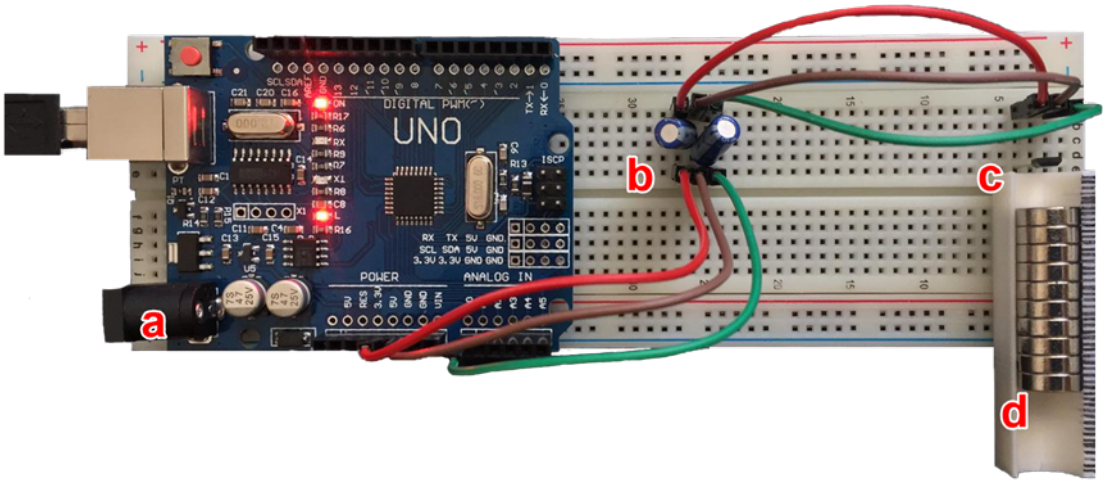


Figure 6. Arduino UNO R3 (a), capacitors (b), hall effect sensor (c), and 10 magnets (d).

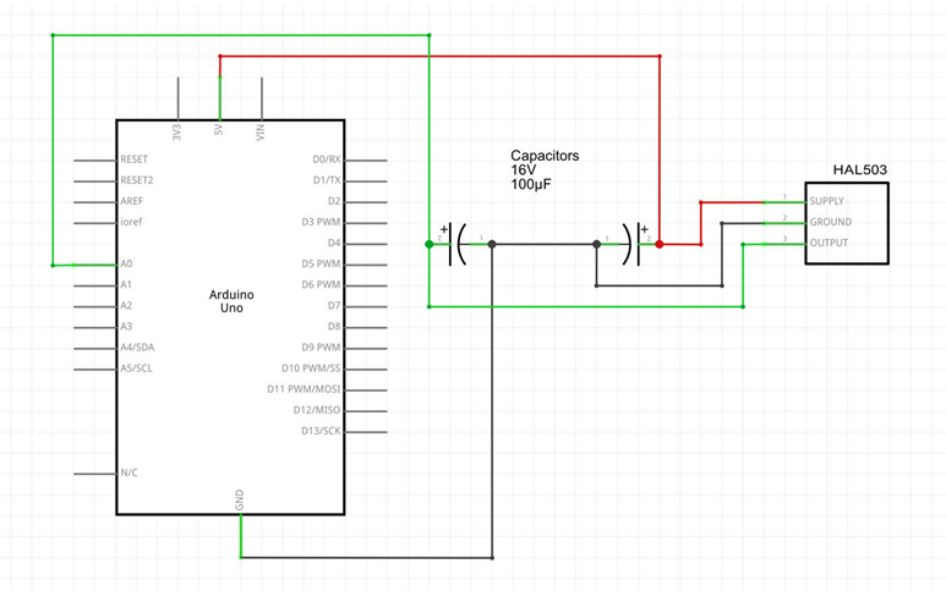


Figure 7. Schematics diagram of the magnetic field measurement system.

2.2. Methods

2.2.1. Magnetic Field Measurement

It is used to calculate the magnetic field force in gauss, near a disc or cylinder-shaped neodymium magnet in the magnetic field calculation. Important points in the magnetic field calculation;

1. Magnet material,
2. Remanence (Br),
3. Magnet shape,
4. Diameter,
5. Thickness (the direction of magnetization).

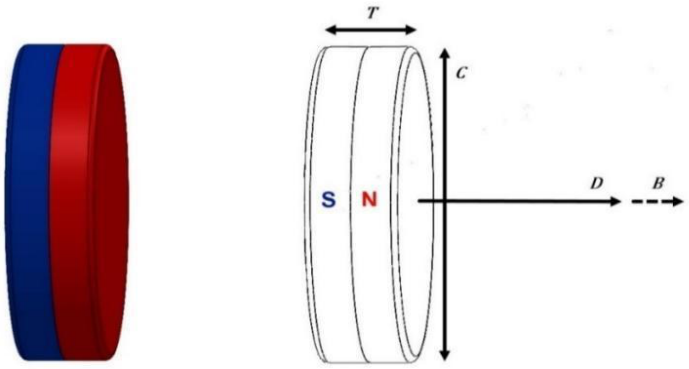


Figure 8. Size and distance parameters for cylinder-shaped magnets (Thickness T, Diameters C, Distance D, Magnetic field B).

The Magnetic Field (gauss) can be evaluated at different levels, in the research, diameter, thickness, and distance values was entered on the K&J Magnetics site to evaluate the magnetic field values online (Anonymous, 2021). The magnetic field calculation is generally done the following formula:

$$B = \frac{B_r}{2}\left(\frac{T+x}{\sqrt{R^2+(T+x)^2}} - \frac{x}{\sqrt{R^2+x^2}}\right) \quad (1)$$

In this formula (Coramık and Ege, 2018);
B: Magnetic field (10 Gauss (G)=1 Militesla (mT))
X: Distance,
R: Magnet diameter,
T: Thickness,
B_r: Remanence (Figure 8).

2.2.2. LabVIEW based Gaussmeter Software

There are a lot of scientific softwares like MATLAB, L takes, etc. Between these platforms, LabVIEW is a useful development platform. Because of this reason, LabVIEW platform was chosen for the Arduino-based low-cost gaussmeter software development platform. The connection between the Arduino and LabVIEW platform was made with the help of LINX firmware. Arduino was connected to the computer by using a USB port. Results of this connection Windows operating system created a com port for precise communication. This part can be selected by using the front panel of the LabVIEW gaussmeter (Figure 9). The Hall-effect sensor can be connected with different analog channels of the development board because the board has different channels for the connection of different sensors. As a result of this condition, channel selection properties were added to the front panel of the Arduino gaussmeter. A chart was placed in the front panel to see the differences of gauss value during one minute period. For the calibration of the low-cost gaussmeter control, input was also added. Instant loop rate and gauss values can be seen as decimal numbers from the front panel. Also, a gauge tool was placed to better understand the gauss differences visually. The measurement process can be stopped by using the stop button on the front panel of the developed software.

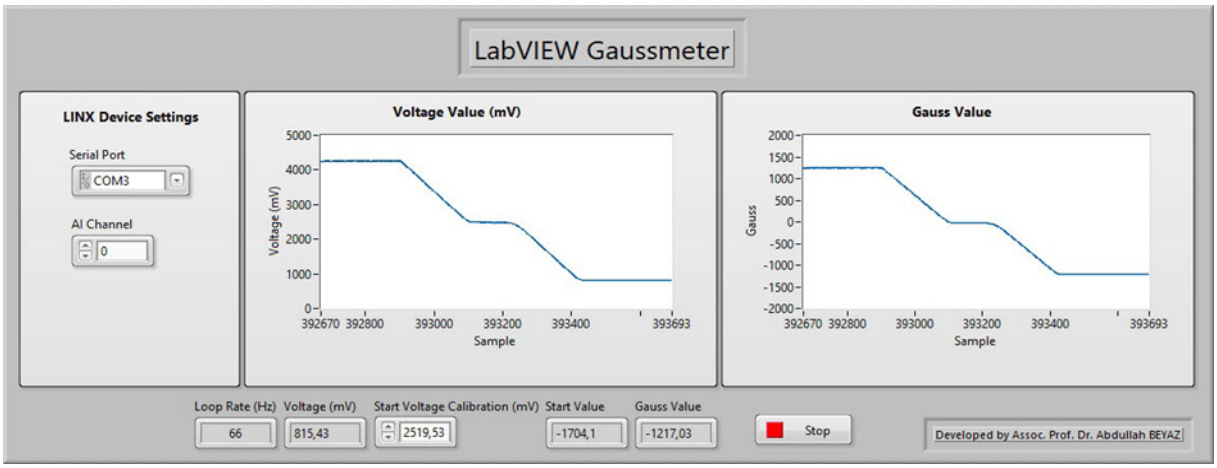


Figure 9. The front panel with measurement LabVIEW Gaussmeter.

Arduino has six ADC channels that any one or all of them can be used as inputs for analog voltage. The Arduino UNO R3 ADC has a 10-bit resolution, so it means that the integer values change between 0 to 1023. This also means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023 (Khan et al., 2017). For every integer value corresponding to 5/1024= 4.9 mV (0.0049 V) per unit. The default reference if 5 volts and resolution are 10 bit we get 5/1024 = 4.9 mV for every one increment that is counted. The sensor calibration was done by using an online theoric gauss calculator for getting the gauss values according to the type of grade, diameter, and thickness of the magnet and distance. Then the 0 gauss output of the sensor is 2500 mV. To get 2500 mV output also we need to subtract the 2519,53 mV value first to hold a 0 V read at the 0 Gauss field in the block diagram of the developed software (Figure 10).

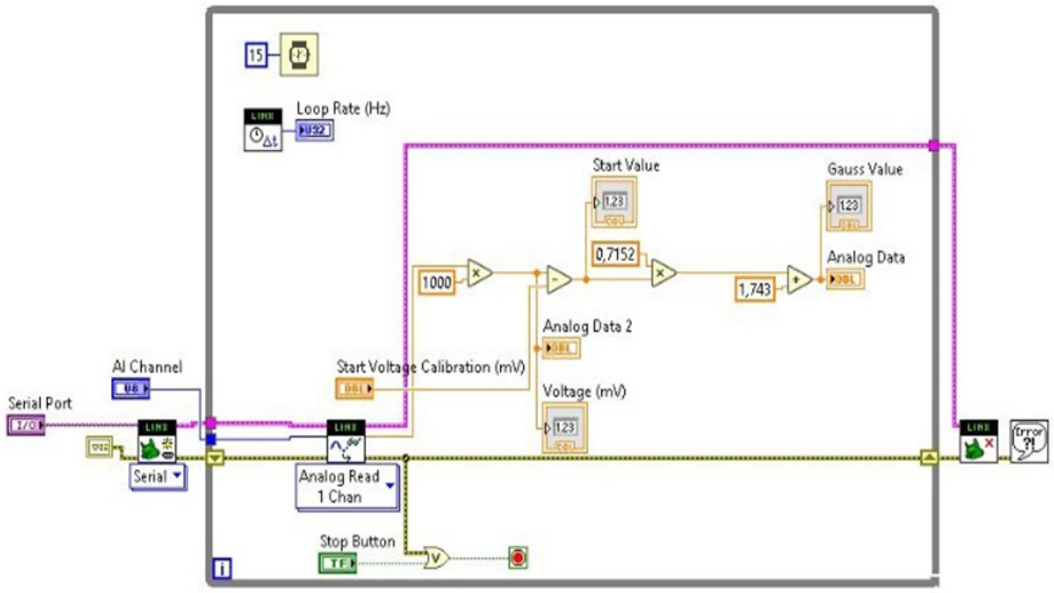


Figure 10. Block diagram of LabVIEW Gaussmeter.

3.Result and Discussion

The regression coefficient and estimation equation for Calculated Gauss Value – LabVIEW Gauss Value (Gauss) can be seen in Figure 11.

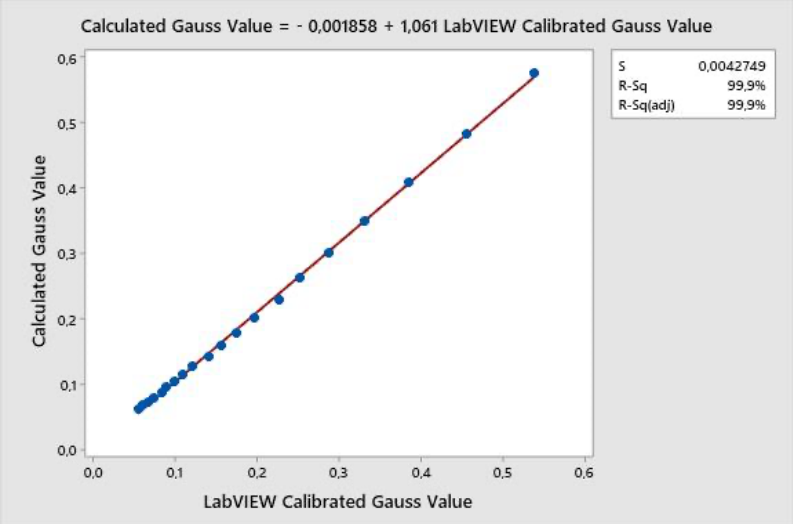


Figure 11. Calculated Gauss Value – LabVIEW Calibrated Gauss Value regression and estimation equation.

Also, regression coefficient and estimation equation for Calculated Gauss Value – LabVIEW Calibrated Gauss Value (Gauss) can be seen in Figure 12.

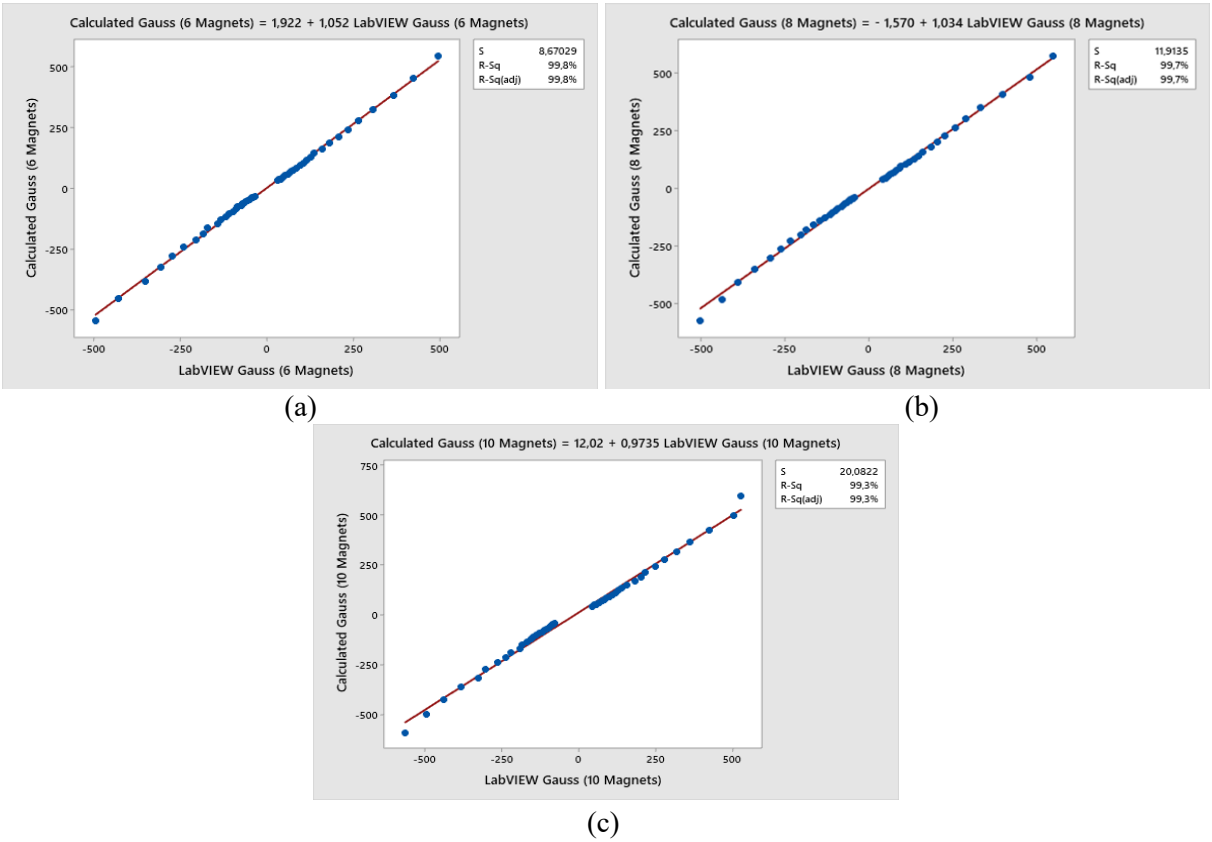


Figure 12. 6 Magnets (a), 8 Magnets (b), and 10 Magnets (c) Calculated Gauss Value – LabVIEW Gauss (Gauss) regressions and estimation equations.

Haned and Missous (2003) express that the Hall effect sensor measures efficiently at 1μT using DC techniques and 100 nT using AC techniques at low-level magnetic fields. Also, the measurement results show that the LabVIEW-based low-cost gaussmeter which was developed with the help of LabVIEW software is working efficiently. The measurement system has the capability of calibration for different industrial gaussmeter corrections. It means that the system can be easily calibrated by using the calibration control part of the front panel. According to Puaypung and Rakkapao, (2018) magnetic field measurement research measurements can display about a 0.6% difference between the experimental and theoretical magnitudes of the magnetic fields. In their experiment, they simply obtained a linear relationship between the magnetic field (B) and the applied current (I) as B = 33.24I mT with R^2 = 0.99. Also, Oy et al. (2015) claim that the gaussmeter which is developed by them can be used more economically than if the measurement can be made between +1000 G (0.1 T) and -1000 G (-0.1 T). In their research, their gaussmeter gave %100 regression with a limited number of measurements (9 readings) at the measurements that had been done between +1000 G (0.1 T) and -1000 G (-0.1 T). On the contrary of the research of Oy et al. (2015), in this research, the post-calibration regression calculations of the values taken from three different thickness neodymium (NdFeB) magnets were 99.8% for 6 magnets, 99.7% for 8 magnets, and 99.3% for 10 magnets from 50 readings for each magnet group, totally 150 readings were done. In the measurements made with 3 different thickness magnets for the calibrated device, it was observed that the gauss measurement in the LabVIEW program operated with an average accuracy of 99.6% between -500 G (-50 mT) and +500 G (+50 mT).

4.Conclusion

The developed system has been provided to be efficient and economical in laboratory applications to be performed by students, scientists, and experts, compared with the gauss meters that are more expensive and wide measurement range. Using this system, which is easy to use and measure the data and also calibrate, it has been ensured that measurements for various agricultural activities can

be made accurately and effectively. Also, the choice of ADC is important in terms of the precision of the measurements. Therefore, its performance has been taken into consideration when selecting ADC (Analog Digital Converter). Measurement accuracy can be increased by using higher-resolution ADC and more sensitive sensors (Oy et al., 2015). Since the developed system works through a computer, it works properly in indoor cultivation, factories, and industrial built-in spaces. A laptop is required for instant measurements of the system in agricultural land and breeding places. In order to provide flexibility to the user in terms of mobility and portability, the system can be re-coded for mobile use and used with instant telephone measurements in the field.

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Araştırma Makalesi (Research Article)

Capsicum chinense Türüne Ait Biber Popülasyonunun SSR Molekülerleri ile Karakterizasyonu

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Anahtar Kelimeler

Capsicum chinense,
Karakterizasyon,
SSR,
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Öz: Genetik kaynaklarının karakterizasyonu ve çeşitlilik düzeylerinin belirlenmesinde morfolojik tanımlayıcılar ve moleküler analiz yöntemlerinden yararlanılmaktadır. *Capsicum chinense* biber türü; meyve özellikleri yönünden yüksek düzeyde varyasyon göstermektedir. Bu çalışmada, *Capsicum chinense* türüne ait biber genetik kaynaklarının (83 genotip) SSR yöntemine göre moleküler karakterizasyonu ile tür içerisindeki mevcut popülasyondaki varyasyon düzeyi ve genetik çeşitlilik düzeylerinin saptanması amaçlanmıştır. Moleküler analizler sonucunda, incelenen 14 SSR primerinden toplam 115 bant elde edilmiştir. Yapılan değerlendirme sonucunda, bantların 66 tanesinin polimorfik (% 57.4) ve 49 tanesinin ise monomorfik (% 42.6) olduğu belirlenmiştir. *Capsicum chinense* türüne ait biber genotipleri, SSR markörleri ile yapılan moleküler analizler sonucunda Ağırlık atanmamış komşu birleştirme yöntemine göre üç farklı heterojen genetik gruba ayrılmıştır. Ayrıca, *C. chinense* türüne ait biber genotipleri arasında genetik uzaklık değerlerinin 0.15-0.75 arasında değiştiği bulunmuştur. Bu çalışma sonucunda karakterizasyonu yapılmış olan *C. chinense* türüne ait biber genotiplerinde halen seleksiyon ıslahı çalışmalarına devam edilmektedir.

Molecular Characterization of *Capsicum chinense* Populations with SSR markers

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Capsicum chinense,
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Genetic diversity.

Abstract: Morphological descriptors and molecular analysis methods were used to identify plant genetic resources and determine genetic diversity levels. *Capsicum chinense* has a high variation in terms of fruit traits. In this study, it was aimed to identify the plant characteristics of 83 *Capsicum chinense* genotypes and to determine genetic diversity levels in the existing population within the species by SSR method. As a result of molecular analysis of genotypes of *Capsicum chinense* species, a total of 115 bands were obtained from 14 SSR markers. As a result of the evaluation, 66 of the bands were polymorphic (57.4%) and 49 were monomorphic (42.6%). As a result of analyses made with SSR markers in *Capsicum chinense* genotypes, it was divided into 3 heterotic main groups according to the Unweighted Neighbor-Joining method. Genetic distance values of *C. chinense* genotypes were found to vary between 0.15-0.75. It is planned to continue selection breeding studies in *C. chinense* genotypes, which have characterization with this study.

1. Giriş

Biber bitkisi, *Solanaceae* familyası içerisinde yer alan 98 cinsten birisi olan *Capsicum* cinsine aittir (Greenleaf, 1986; Eshbaugh, 2012). Günümüzde *Capsicum* cinsi içerisinde sadece beş tür (*C. annuum* L., *C. baccatum* L. var. *pendulum*, *C. chinense* Jacq., *C. frutescens* L. ve *C. pubescens* Ruiz & Pav.) kültüre alınmıştır (Eshbaugh, 2012; Barboza ve ark., 2019). Bu türler, üç farklı gen merkezinde yaygın olarak rastlanan yabani türlerden zaman içerisinde ortaya çıkan değişimler sonucunda meydana gelmişlerdir. *C. chinense* ve *C. frutescens* türlerinin gen merkezi, Amazon Havzası olarak kabul edilmektedir (Ramchiary ve ark., 2014).

Biberin orijini, Orta Amerika'dır. Brezilya'da en çok yetiştirilen ve tüketilen acı biber türü, *C. chinense'*dir. *C. chinense* Jacq türü 2n = 2x = 24 genom yapısına sahip olup, 2017 yılında referans genomu yayımlanmıştır. Biber ıslahında özellikle biyotik ve abiyotik stres dayanıklılık/toleransının genetik alt yapısını ve allel çeşitliliğinin birincil kaynağı olarak çeşit ıslah programlarında kullanılmaktadır. (Qin ve ark., 2014; Kim ve ark., 2017). *Capsicum chinense* Jacq. bitki karakterleri; meyve şekli, rengi ve büyüklüğü bakımında yüksek düzeyde çeşitlilik göstermektedir (Bharath ve ark., 2013). Bu tür, Orta ve Güney Amerika ülkelerinde ve Asya'da Çin ve Japonya'da oldukça fazla yayılış göstermektedir (Eshbaugh, 2012). Günümüzde kültüre alınan formlarının yanı sıra geçit formlarda bulunmaktadır. Bu nedenle *C. chinense* türü; meyve şekli, meyve rengi, meyve büyüklükleri ve acılık seviyeleri yönünden yüksek oranda fenotipik çeşitlilik göstermektedir (Moscone ve ark., 2007).

Genetik kaynaklar, yeni çeşitlerin geliştirilmesinde ve çeşit ıslah programlarının oluşturulmasında bitki ıslahçılarının en büyük yardımcısıdır (Balkaya ve Yanmaz, 2001; Karaağaç ve Balkaya, 2017). Ayrıca bu genetik materyaller yetiştirildikleri farklı ekolojilere adaptasyon yetenekleri, hastalık ve zararlılara karşı dayanıklılık göstermeleri ve istenen birçok kalite özelliğine sahip olmaları nedeniyle de çeşit ıslahı programları için eşsiz nitelikte değerli kaynaklardır (Hawkes, 1983). Islahçılar son yıllarda genetik çeşitlilikten yararlanarak, adaptasyon, verim, kalite, hastalık ve zararlılara dayanıklılık yönünden istenilen özelliklere sahip bitki çeşitlerini seçme veya çeşit geliştirme yolunda önemli düzeyde başarılar elde etmişlerdir (Karaağaç ve Balkaya, 2017). Ortiz ve Delgado (1990), farklı tohum gen bankalarında (UNA, Peru; CATIE, Kosta Rika; INIA, Meksika ve CIRF, Meksika) bulunan *Capsicum* cinsinin kültürü yapılan beş farklı biber türünde, morfolojik özellikler yönünden incelemeler yapmışlar ve *C. annuum* L., *C. chinense* Jacq., *C. frutescens* L., *C. pubescens* ve *C. baccatum* L. türüne ait biber genotiplerini çeşit ıslahı çalışmalarında kullanılmak üzere gruplandırmışlardır.

Biber yetiştiriciliği yapılan ülkelerde zaman içerisinde yüksek düzeyde zengin bir genetik çeşitlilik oluşmuş ve bunun sonucunda birçok farklı niteliklere sahip yeni çeşitler meydana gelmiştir. Çeşitli yollarla bir bölgeye gelen bitkisel gen kaynakları, bulunduğu bölgeye zamanla adapte olmakta ve çevre faktörlerinin de etkisiyle zamanla genetik yapısında belirgin fenotipik açılmalar meydana gelmektedir (Karaağaç, 2006). Biberde yabancı tozlanma oranı, çeşitlere göre % 9-32 oranları arasında değişmektedir (Bayraktar, 1970). Biber tohum üretiminde izolasyon tekniklerine uyulmadığı takdirde yüksek oranda genetik açılmalar meydana gelebilmektedir (Karaağaç ve Balkaya, 2010).

Bitki genetik çeşitlilik düzeylerinin belirlenmesine yönelik çalışmalarda, genetik farklılıkların tam ve doğru olarak ortaya konulmasında hem morfolojik tanımlayıcılar hem de moleküler analiz yöntemlerinden yararlanılmaktadır (Geleta ve ark., 2005). *Capsicum* türleri, birçok araştırıcı tarafından morfolojik tanımlayıcılar, sitogenetik analizler ve moleküler markörler kullanılarak ayrıntılı olarak incelenmiştir (Conicella ve ark., 1990; Lefebvre ve ark., 1993, 2001; Zewdie ve Zeven, 1997; Geleta ve ark., 2004). Bu çalışmalarda, *Capsicum* cinsi içerisinde bitkisel özelliklerle ilgili 290'nın üzerinde genin bulunduğu bildirilmiştir. Bu genlerin kalıtım mekanizmaları ile ilgili çalışmalar halen devam etmektedir (Buso ve ark., 2003).

Tarla ve sera denemeleri ile yapılan morfolojik çeşit tanımlama çalışmaları hem uzun zaman almakta hem de bazı morfolojik karakterlerin kalıtım derecesinin düşük olması nedeniyle çevre koşullarından kolaylıkla etkilenmekte, dolayısıyla genotipik özellikleri ile fenotipik özellikleri arasında zamanla belirgin farklılıklar oluşabilmektedir. Bunun sonucunda bazen kesin sonuçlara ulaşılamamaktadır (Okumuş ve Balkaya, 2007; Karaağaç ve Balkaya, 2010). Bu sorunun üstesinden gelmek ve ıslahçının daha doğru ve kesin teşhislere ulaşabilmesi için günümüzde modern biyoteknolojik yöntemlerden yararlanılmaktadır. Son yıllarda birçok farklı moleküler markör tekniği geliştirilmiştir. Bunlardan bazıları; RFLP (Restriction Fragment Length Polymorphism), RAPD (Random Amplified Polymorphic DNAs), AFLP (Amplified Fragment Length Polymorphisms), SSR (Simple Sequence

Repeats) ve SNP (Single Nucleotide Polymorphism) teknikleridir. (Röder ve ark., 1995; Geleta ve ark., 2005; Şensoy ve Şahin, 2012; Erdinc ve ark., 2017).

Capsicum chinense Jacq. genomunun genetik haritalarının oluşturulması, genoma spesifik markörlerin geliştirilmesi ve markör verilerinin biber türleri arasında transfer edilebilirlikleri ile karşılaştırmalı haritalama çalışmaları gerçekleştirilmiştir (Kim ve ark., 2017; Uncu 2019; Qin ve ark., 2014; Park ve ark., 2019; Zhu ve ark., 2019). Birçok bilimsel çalışmada; *C. chinense* gen kaynaklarında farklı moleküler markör sistemleri kullanılarak genotipler arasında genetik çeşitliliğin belirlenmesi, popülasyon yapısı analizleri ile karakterize edilmiştir. Özellikle AFLP, SNP ve SSR markör sistemlerinin *C. chinense* türüne ait gen kaynaklarının karakterizasyonunda çoklukla kullanıldığı bilinmektedir. (Baruah ve ark., 2019; Baba ve ark., 2016; Zhang ve ark., 2016; Moreira ve ark., 2018). *C. chinense* gen kaynaklarının karakterizasyonuna önemli bir örnek Latin Amerika coğrafyasından elde edilen 112 adet *C. chinense* genotipinin SSR markörleri kullanılarak genetik çeşitlilik ve popülasyon yapısının analiz edildiği çalışmadır (Moses ve ark., 2014).

Kromozomların üzerinde genlerin bulunduğu özel kısımlar için fazla oranda allel üretebilmesi, tekrarlanabilir olması, aynı türe dahil olan çeşitler ile aynı cinse dahil türler arasında aktarımın sağlanabilmesi ve ülkelerin veri tabanlarının kıyaslanmasına izin vermesi gibi oldukça önemli avantajlara sahip olması nedeni ile SSR tekniği, bitki türlerinin tanımlanmasında önceki DNA primerlerin kullanıldığı tekniklere (RFLP, RAPD, AFLP vb.) göre daha yaygın kullanılmaktadır (Acunalp, 2012). Araştırıcılar, SSR yönteminin sağladığı bu avantajlardan dolayı farklı bitki tür ve çeşitlerinde oldukça başarılı bir şekilde uygulanabildiğini bildirmişlerdir (Röder ve ark., 1995; Geleta ve ark., 2005).

Bu çalışma ile Amerika Tarım Bakanlığı Tohum Gen Bankasında kayıtlı bulunan *C. chinense* türüne ait dünya koleksiyonunun SSR markörleri kullanılarak karakterize edilmesi, genotipler arasındaki genetik uzaklıkların belirlenmesi ve birbirleriyle olan akrabalık ilişkilerinin ayrıntılı olarak belirlenmesi amaçlanmıştır.

2. Materyal ve Yöntem

Araştırma, 2019 yılında Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, Tarımsal Biyoteknoloji Bölümü'nde ve Necmettin Erbakan Üniversitesi Fen Fakültesi Moleküler Biyoloji ve Genetik Bölümü'nde koordineli olarak yürütülmüştür. Bitkisel materyal olarak Amerika Tarım Bakanlığı Tohum Gen Bankasından (USDA-ARS-National Plant Germplasm System NPGS) temin edilen *Capsicum chinense* türüne ait 83 biber genotipi kullanılmıştır (Çizelge 1). *C. chinense* genotiplerinde genetik materyallerde bir generasyon kendileme yapılmıştır. *C. chinense* türüne ait biber fideleri, Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü sıcaklık kontrollü sera ünitesinde yetiştirilmiştir. Daha sonra 4-5 gerçek yaprağa ulaşan fideler deneme arazisine 50 x 50 cm sıra arası ve sıra üzeri mesafe ile dikilmiştir. Arazide dikimi yapılmış genç biber yapraklarından her bir populasyonu temsil edecek şeklide bitkilerden bulk şeklinde örnekler alınarak laboratuvara getirilmiş ve DNA izolasyonu yapılıncaya kadar -80°C'de derin dondurucuda muhafaza edilmiştir.

2.1. Moleküler Karakterizasyon

Bitkisel genetik materyalde DNA izolasyonu, 14.01.2019 tarihinde ZR Plant/Seed DNA MiniPrep kit kullanılarak gerçekleştirilmiştir. İzolasyonu gerçekleştirilen DNA'ların kalitesi ve miktarları NanoDrop spektrofotometre'de ölçülmüştür. Bitkisel materyallerden izole edilen DNA'lar seyreltildikten sonra sentetik olarak hazırlanmış SSR primerleri ve tüm reaksiyon komponentleri eklenerek Polimeraz Zincir Reaksiyonu Sıcaklık Döngü cihazı (PCR thermal cycler) içerisine yerleştirilmiştir. Çalışmada kullanılan SSR markörleri, literatürde biberde daha önce farklı popülasyonlarda başarıyla uygulanan markörlerdir (Çizelge 2) (Lee ve ark., 2004; Lee ve ark., 2005; Yi ve ark., 2006). PCR uygulaması, 0.2 ml'lik mikro tüplerde 25 µl' lik (Buffer 2 µl, $MgCl_2$ 1.5 µl, Taq polimeraz enzimi 0.25 µl, dNTP karışımı 0.2 mM, Primer F 0.75 µl, Primer R 0.75 µl, DNA 1 µl, ddH_2O) toplam reaksiyon hacminde gerçekleştirilmiştir. PCR cihazında PCR ürünleri ilk olarak DNA denatürasyonu için, 94 °C'de 10 dakika; 94 °C'de 30 saniye (35 döngü), 55 °C'de 30 saniye (primerlere

göre bu sıcaklık dereceleri değişiklik gösterebilmektedir) primer sıcaklıkları ve uzama için 72 °C'de 45 saniye, son aşamada ise uzama 72 °C'de 10 dakika olarak ayarlanmıştır. Daha sonrasında, PCR ürünleri görüntüleneceği zamana kadar -20 °C'de bekletilmiştir.

Çizelge 1. *C. chinense* türüne ait gen havuzunda yer alan biber genotiplerinin aksesyon numaraları ve orijinleri

Çalışma Kodu	Aksesyon Numarası	Orijin	Genotip Kodu	Aksesyon Numarası	Orijin
CC1	PI 159223 01	ABD	CC39-2	PI 281430 01	Bolivya
CC2	PI 213916 01	Bolivya	CC39-3	PI 281430 01	Bolivya
CC3	PI 215736 01	Peru	CC39-4	PI 281430 01	Bolivya
CC4	PI 244667 01	Hindistan	CC40-1	PI 315013 01	Peru
CC5	PI 257085 01	Kolombiya	CC40-2	PI 315013 01	Peru
CC6	PI 257129 01	Kolombiya	CC40-3	PI 315013 01	Peru
CC7	PI 257145 01	Peru	CC40-4	PI 315013 01	Peru
CC8	PI 260470 01	Peru	CC47	PI 238053 01	Meksika
CC9	PI 260485 02	Bolivya	CC50	PI 497976 01	Filipinler
CC10	PI 260486 01	Bolivya	CC51	PI 241669 01	ABD
CC11	PI 260508 01	Peru	CC51-3	PI 241669 01	ABD
CC13	PI 281393 01	Meksika	CC52	PI 653747 01	Venezuela
CC14	PI 281417 01	Filipinler	CC54	PI 653677 02	Peru
CC16	PI 281435 01	ABD	CC55	PI 653676 02	Peru
CC17	PI 281440 01	Venezuela	CC56	PI 645487 03	Hindistan
CC18	PI 315019 01	Peru	CC57	PI 257068 01	Kosta Rika
CC19	PI 315023 02	Peru	CC59	PI 639655 02	Kosta Rika
CC20	PI 322721 01	Hindistan	CC60	PI 645555 01	Meksika
CC21	PI 406725 01	Kosta Rika	CC61	PI 593925 02	Bolivya
CC22	PI 438532 01	Belize	CC62	PI 585253 04	Güney Kore
CC23	PI 438636 02	Meksika	CC63	PI 241668 01	Ekvator
CC24	PI 439416 01	Bolivya	CC65	PI 257064 01	Ispanya
CC25	PI 439432 01	G. Kore	CC66	Grif 9261 01	Kosta Rika
CC26	PI 585278 02	Ekvator	CC68	PI 439419 01	Meksika
CC27	PI 257158 01	Peru	CC69-1	PI 257126 01	Kolombiya
CC28	PI 666562 01	Meksika	CC69-2	PI 257126 01	Kolombiya
CC-29	PI 260491 01	ABD	CC69-3	PI 257126 01	Kolombiya
CC29-1	PI 260491 01	ABD	CC69-4	PI 257126 01	Kolombiya
CC-30	PI 666561 01	Bolivya	CC72	PI 441635 01	Brezilya
CC31	PI 438635 01	Peru	CC72-4	PI 441635 01	Brezilya
CC33	PI 439467 01	Hindistan	CC76	PI 260465 02	Arjantin
CC34	PI 653746 02	Kolombiya	CC78	Grif 9193 02	Kolombiya
CC35	Grif 9308 01	Kolombiya	CC79	PI 666547 01	Guatemala
CC36	PI 639657 04	Peru	CC82-1	PI 260477 01	Peru
CC37	PI 485593 01	Peru	CC82-2	PI 260477 01	Peru
CC38	PI 209028 01	Bolivya	CC82-3	PI 260477 01	Peru
CC38-2	PI 209028 01	Bolivya	CC82-4	PI 260477 01	Peru
CC39-1	PI 281430 01	Bolivya			

PCR reaksiyonları sonucu *C. chinense* genotiplerine ait DNA örneklerinden; çoğaltılmış olan SSR markörleri Qiaxcel Fragment Analyzer (Qiagen Sample&Assay Technologies) kapiler elektroforez sistem ile Qiaxcel DNA High Resolution Kiti, QX DNA Size Marker 25–500 bp, v2.0 (Qiagen) boy standardı ve QX Alignment Marker 15 bp/600 bp (Qiagen) hizalama standardı kullanılarak OM800 yürütme ve ayırma programı ile yüksek çözünürlükte polimorfik allellerin belirlenmesi için yürütülmüş ve QIAxcel ScreenGel Software (Qiagen) yazılımı kullanılarak görüntülenerek manuel olarak skorlanmıştır.

Çizelge 2. PCR çalışmalarında kullanılan SSR primerleri ve baz dizinleri

Markör ismi	İleri primer (5′ → 3′)	Geri primer (5′ → 3′)
EPMS-596	CTCGTGCCGTATTTCTGTCA	AAGGGCGTGTTTGGTATGAA
EPMS-600	ATGGGTACGTGTTTGGGGTA	ACTTTATTCCTCGTGCCGAA
EPMS-601	AAATTGAGAACATCGGTGCC	TAAAGAAAGAGCCTCGTGCC
EPMS-603	GCGGTTCCCTATTTGAAGAA	ATAGGGGGAATTGGGTTCC
EPMS-628	TGCTCCTTAAGACTGGCACC	GGGTTCGGCTCTGTTATTGA
EPMS-629	GCTCGAGGGAGAGAGACTGT	GGTCATATGTTTCCATGGGC
EPMS-642	CAACTTCGCGTTATTGTCCA	AGGGCGGACAAAGAAGATTT
EPMS-643	CCAAGATCAACTCTTACGCTAT	CCCCTCAAGAATTCCCTCCAT
EPMS-648	TGTAAAATAAAATAAGGCTAA	CAAGAAAGTGTGCCCCAAAT
EPMS-649	AAGGGTTCTCGAGGAAATGC	TCAATCCCAAAACCATGTGA
EPMS-650	CATGGGTGAGGGTACATGGT	AGAGGGAAGGGTTATTTGCC
EPMS-654	TTCCACTCTTCGAAGCACCT	GGTAGGGTTTAACACCGCCT
EPMS-658	CCTTGAGTAGGCGCACAAAT	TTCCTCATTGCTTTTCCCAC
EPMS-670	TCACAAAGATGGAGAAGGGAA	CAATCACTGTCACTGCTACTGCT
EPMS-683	AAATGGATCCCAACAACCAA	GGAGTTGAAAACGGTGGAGA
EPMS-697	ATGTCGCTCGCAATTTCACT	CGTAGGGAGGAGCGATAGAG
EPMS-704	GGTCCTCTGATTGGCAACAT	GACCTGAAATTGGAGCAAACA
EPMS-705	TCAACTAGATCCACCACGCA	TAACCCGTTGCTCACACTCA
EPMS-725	TTGAATCGTTGAAGCCCATT	ATCTGAAGCTGGGCTCCTTT
EPMS-745	GTTGTTGGGTGGTACTTGGG	GGAAGATCTCAAATGGGTCG
EPMS-747	CATTGGACGGTTGGTTCTCT	TGGAATTGGAACTTCAAGCA
EPMS-755	CGCTCGCTACCCTTTCATTA	AATTTCGGAAGGGCAAAGAT
EPMS-762	CGGCGAGATATGGACTTGAT	CCCACGTTATACCATCCAGG
EPMS-773	CGAGCAACTCCCTCTTATCG	TCGAATAGCACGCACGTTAG
EPMS-923	CAAAACCAAATAGGTCCCCC	CGCGCAATAATTCAATATCG

2.2. *C. chinense* Popülasyonunda Genetik Çeşitlilik Düzeyinin Belirlenmesi

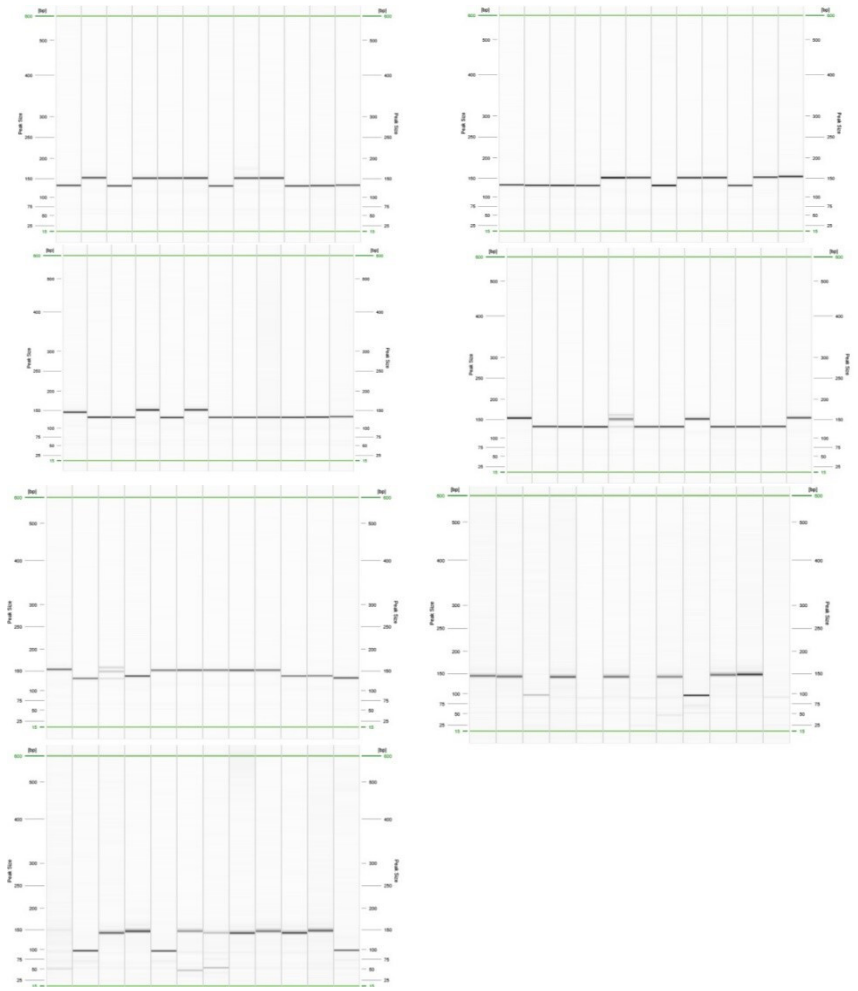
Genotiplere ait SSR markör allelleri mevcut (1) veya yok (0) ve kayıp veri (9) olarak skorlanmıştır. Bu veriler, Nei'nin genetik benzerlik indeksinin (The Nei index of genetic similarity) hesaplanmasında kullanılmıştır (Nei, 1973). Polimorfik markör verileri moleküler genetik çeşitliliği analiz etmek için DARwin 6 (http://darwin.cirad.fr) bilgisayar programı kullanılarak analiz edilmiştir. Markör skorlama verileri benzememezlik hesabı, her bir genotip arasında Dice katsayısı ile hesaplanmıştır. Ağırlık atanmamış komşu birleştirme yöntemi kullanılarak bir genetik çeşitlilik ağacı çizilmiştir. Ayrıca yine aynı yazılım kullanılarak genotiplere ait allel verisi Temel Koordinat Analizi (PCoA) yapılmıştır. Mantel testi benzememezlik hesabı ile çizilen çeşitlilik ağacının arasındaki korelasyonu test etmek üzere gerçekleştirilmiştir.

3. Bulgular ve Tartışma

Çalışmada, toplam 83 *C. chinense* biber genotipi SSR yöntemi ile 25 adet markör kullanılarak incelenmiştir. Markörlerden 11 tanesinden tekrarlanabilir kalitede amplifikasyon elde edilememiştir. Amplifikasyonu oluşturan 14 markörden, toplam 115 bant elde edilmiştir. Yapılan değerlendirme sonucunda, bantların 66 tanesinin polimorfik (% 57.4) ve 49 tanesinin ise monomorfik (% 42.6) yapıda olduğu belirlenmiştir (Çizelge 3, Şekil 1). Çalışma kapsamında tespit edilen markör başına düşen polimorfizim yüzdesi, Baruah ve ark. (2019) ve Zhang ve ark. (2016) yaptıkları çalışmalar ile benzerlik göstermektedir.

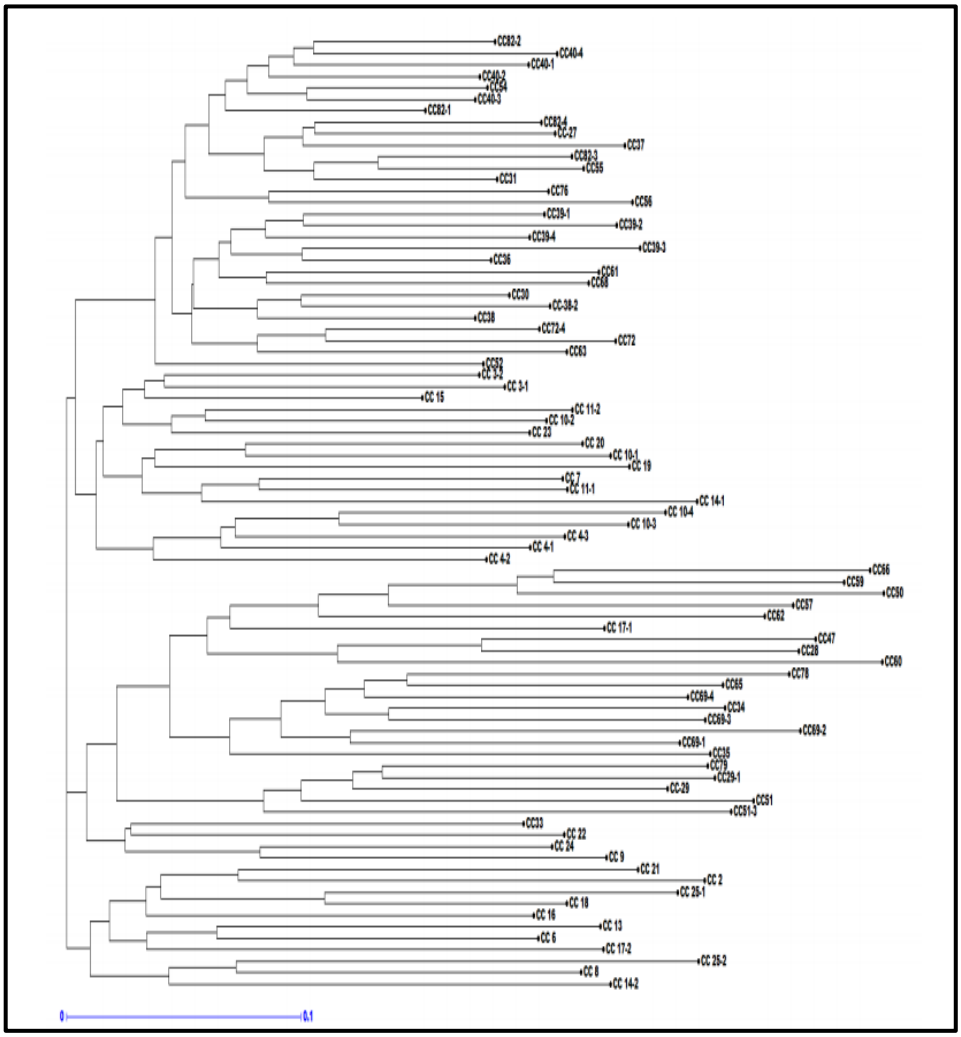
Çizelge 3. *Capsicum chinense* türüne ait biber popülasyonunda SSR analizi sonucunda 14 markörden elde edilen bantların sayısı ve dağılışları

Markör Adı	Toplam Bant Sayısı	Polimorfik Bant Sayısı (Allel)	Monomorfik Bant Sayısı	Alel Büyüklükleri (bç)
EPMS-596	5	3	2	114-138
EPMS-600	8	4	4	98-142
EPMS-601	7	6	1	166-193
EPMS-603	9	5	4	112-204
EPMS-628	11	7	4	160-196
EPMS-649	7	4	3	137-219
EPMS-650	9	4	5	119-182
EPMS-705	9	2	7	144-157
EPMS-725	7	5	2	123-177
EPMS-745	5	3	2	119-163
EPMS-747	7	6	1	120-163
EPMS-755	8	2	6	119-136
EPMS-762	9	7	2	117-159
EPMS-773	14	8	6	124-182
Toplam	115	66	49	



Şekil 1. *C. chinense* türüne ait biber genotiplerinde EPMS-773 SSR markörü ile elde edilen bantların Qiaxcel Fragment Analyzer yürütmesinin QIAxcel ScreenGel Software görünümü.

Araştırma sonucunda incelenen *C. chinense* türüne ait biber genotipleri arasında DARwin 6 programı ile *C. chinense* türüne ait biber genotiplerinin genetik uzaklık değerleri hesaplanmıştır. *Capsicum chinense* türüne ait tüm genotipler arasında genetik uzaklık değerlerinin, 0.15-0.75 arasında olduğu tespit edilmiştir. Elde edilen sonuçlara göre en düşük genetik uzaklık değeri CC54 ve CC40-3 genotipleri arasında 0.15 ve en yüksek genetik uzaklık değeri ise CC79 ve CC2 genotipleri arasında 0.75 olarak bulunmuştur. Araştırma kapsamında kullanılan *C. chinense* türüne ait biber gen kaynaklarının ortalama genetik uzaklığı 0.44 olarak hesaplanmıştır. Çalışma kapsamında hesaplanan ortalama uzaklık değeri, incelenen gen havuzunun yüksek bir genetik çeşitliliği barındıran bir genetik alt yapıdan geldiğini işaret etmektedir. Bu durum hem çalışılan türün karakteri hem de dünya gen koleksiyonunu temsil eden bir genetik havuzun kullanılmasının sonucudur. Kullanılan gen havuzu, tür içeresinde bulunabilecek olası her lokus için potansiyel tüm allelleri taşıma ihtimaline sahip eşsiz bir gen koleksiyonu niteliğindedir. Araştırma kapsamasında kullanılan gen havuzuna benzer özelliklere sahip gen kaynaklarının karakterizasyonu çalışmalarında elde edilen genetik uzaklık verilerine benzer ve doğrular nitelikte sonuçlar elde edilmiştir (Baba ve ark., 2016; Zhang ve ark., 2016; Moreira ve ark., 2018; Baruah ve ark., 2019). Moleküler karakterizasyon sonucunda toplam 83 genotipten elde edilen polimorfik bantlardan hesaplanan benzerlik oranları kullanılarak oluşturulan dendrogram, Şekil 2'de verilmiştir.



Şekil 2. Ağırlık atanmamış komşu birleştirme yöntemi (Unweighted Neighbor-Joining [NJ]) metodu ile oluşturulmuş *C. chinense* türüne ait biber genotipleri arasındaki genetik ilişkileri gösteren dendrogram.

Uzaklık matrisi ile genetik benzerlikler (NJ) arasındaki korelasyon Mantel test ile belirlenmiştir (r = 0.92). Genetik uzaklık matrisi verileri ile dendrogram birlikte değerlendirildiğinde sonuçların uyumlu olduğu görülmektedir. Dendrogram incelendiğinde *C. chinense* türüne ait biber genotiplerinin 3 ana grup içerisinde kümelendikleri belirlenmiştir (Çizelge 4). Moses ve ark. (2014) tarafından Latin Amerika kökenli bir *C. Chinense* genotip koleksiyonunun moleküler genetik çeşitliliğinin incelendiği çalışma sonuçları, bu çalışma ile benzer şekilde genotiplerin üç grupta toplandığını göstermektedir.

Çizelge 4. *C. chinense* biber popülasyonlarının küme analizi sonucunda elde edilen grup ve alt grupların dağılışı

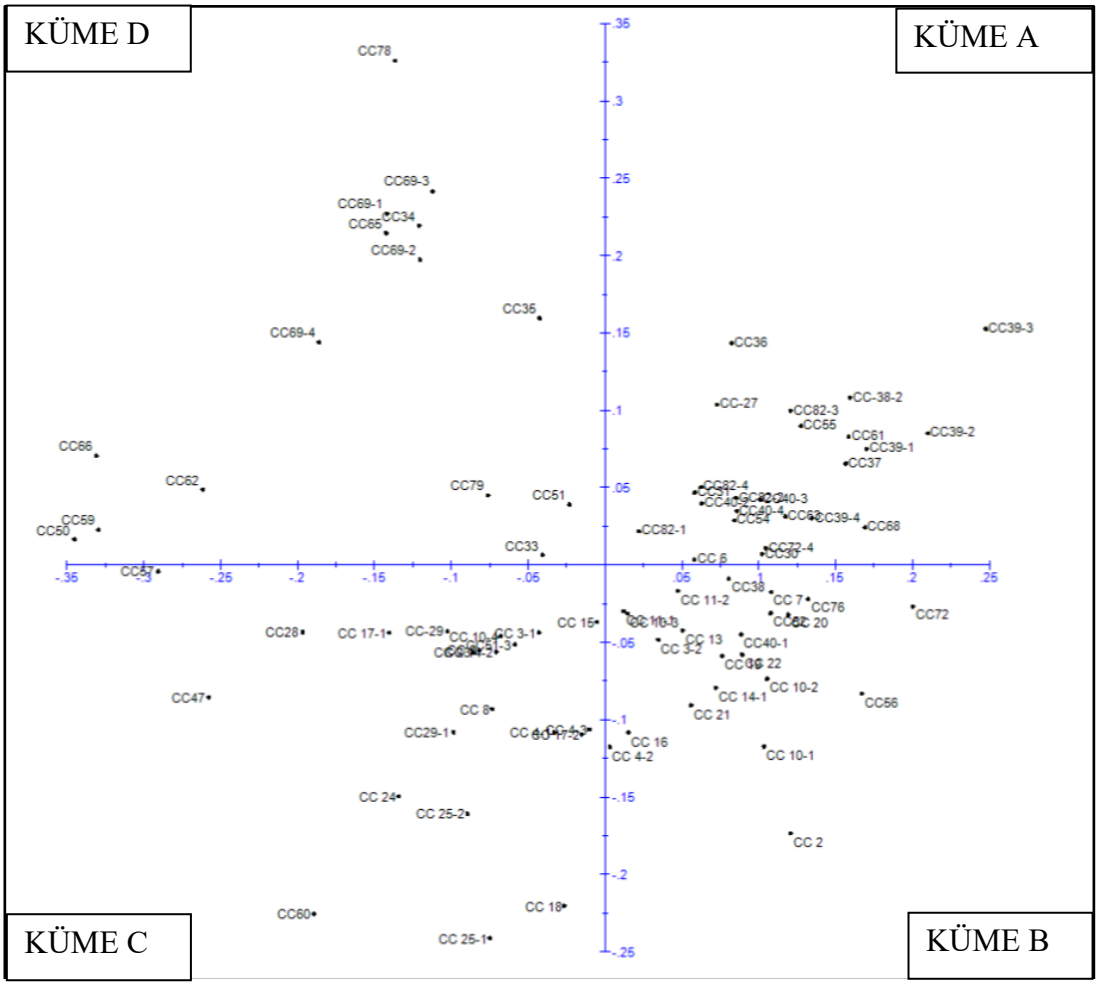
Grup	Alt Grup	Genotipler	Toplam Genotip Sayısı
A	5	CC82-2, CC40-4, CC40-1, CC40-2, CC54, CC40-3, CC82-1, CC82-4, CC27, CC37, CC82-3, CC55, CC31, CC76, CC56, CC39-1, CC39-2, CC39-4, CC39-3, CC36, CC61, CC68, CC30, CC38-2, CC38, CC72-4, CC72, CC63, CC52, CC3-2, CC3-1, CC15, CC11-2, CC10-2, CC23, CC20, CC10-1, CC19, CC7, CC11-1, CC14-1, CC10-4, CC10-3, CC4-3, CC4-1, CC4-2	46
B	4	CC66, CC59, CC50, CC57, CC62, CC17-1, CC47, CC28, CC60, CC78, CC65, CC69-4, CC34, CC69-3, CC69-2, CC69-1, CC35, CC79, CC29-1, CC29, CC51, CC51-3, CC33, CC22, CC24, CC9	26
C	3	CC21, CC2, CC25-1, CC18, CC16, CC13, CC6, CC17-2, CC25-2, CC8, CC14-2	11
Toplam	12		83

Dendrogramda Grup A içerisinde, 5 alt grubun yer aldığı belirlenmiştir. En fazla biber genotipi (46 genotip) Grup A içerisinde bulunmuştur. Grup A'dan sonra en fazla alt grup, Grup B'de belirlenmiştir. Dendrogram incelendiğinde, Grup C'nin 3 alt gruba ayrıldığı ancak en az sayıda biber genotiplerinin kümelendiği grup olduğu bulunmuştur. Bu grup içerisinde yer alan genotiplerin Grup A ve Grup B'ye göre daha uzak genetik uzaklığa sahip oldukları belirlenmiştir.

C.chinense türüne ait biber gen havuzunun 3 farklı heterotik grup oluşturması nedeniyle gelecekte heterosis ıslahında yeni biber çeşitlerin geliştirilmesinde yararlanma potansiyeli bulunmaktadır. Ayrıca, araştırma sonucunda farklı alt gruplar içerisinde yer alan biber genotiplerinde var olan genetik çeşitliliği büyük oranda temsil eden çekirdek koleksiyonların oluşturulması da planlanmaktadır. Böylece benzer genotiplerin çeşit ıslah programları içerisinde duplikasyonları önlenmiş olacaktır.

Araştırma sonucunda, elde edilen moleküler benzerlik oranları ile daha önceden başka bir çalışmada tespit edilmiş olan morfolojik yönden benzerlik oranları arasında direkt bir ilişkisinin olmadığı ortaya çıkmıştır. Bu nedenle *C. chinense* türüne ait biber genotiplerinde hem morfolojik özellikler hem de moleküler analiz sonuçlarına göre tek başına genotiplerin orijinleri ile ilişkilendirilmesi mümkün olmamıştır. Bu durum, *C. chinense* türünde çalışmalar yürüten Baba ve ark. (2016) ve Moreira ve ark. (2018)'nın sonuçları ile de benzerlik göstermiştir.

Temel Koordinat Analizi (PCoA) sonucunda biber genotipleri 4 ana grup içerisinde kümelenmiştir (Şekil 3). Temel Koordinat Analizi sonucunda oluşan kümelerde yer alan genotiplerin dağılışı ile dendrogram grupları içerisinde oluşan kümelenmeler çoğunlukla uyum sağlamıştır. PCoA analizi genel olarak bu çalışmada *C. chinense* türüne ait biber popülasyonlarında SSR markörleriyle dünyanın farklı yerlerinden toplanmış olan *C. chinense* biber genotipleri arasındaki coğrafi bir kümelenmeyi ortaya çıkarmıştır. PCoA, ölçülen değişkenler açısından popülasyonlara ait genotipler arasındaki benzerlikleri bir koordinat üzerinde göstermiştir (Şekil 3).



Şekil 3. *Capsicum chinense* türüne ait biber genotiplerinin PCoA (Temel Koordinat Analizi) grafiği.

4. Sonuç

C. chinense türü, *Capsicum* cinsi içerisinde yer alan en önemli biber türlerinden birisidir. Günümüzde kültüre alınan formlarla birlikte yabani ve geçit formları da bulunmaktadır. Bu nedenle, *C. chinense* türü içerisinde yer alan biber genotipleri; meyve şekli, meyve rengi, meyve büyüklükleri ve acılık seviyeleri yönünden yüksek düzeyde genetik çeşitlilik göstermektedir. Birçok araştırıcı, *C. chinense* türünün biyotik ve abiyotik stres koşullarına dayanıklılık yönünden önemli bir genetik kaynak olduğunu bildirmişlerdir (Hawkes, 1983; Yoon ve ark., 2006; Fonseca ve ark., 2008). Bu araştırma sonucunda, *C. chinense* türüne ait biber popülasyonunda moleküler analizlerde 14 SSR markörlerinden toplam 115 bant elde edilmiştir. Ağırlık atanmamış komşu birleştirme yöntemine göre biber genotipleri, 3 ana gruba ayrılmıştır. Farklı uzunluklarda dendrogram grupları, *C. chinense* türüne ait biber genotiplerinin genetik farklılıklarının oldukça yüksek düzeyde olduğunu göstermiştir.

Bu araştırma, *C. chinense* biber çeşit ıslahında türe ait başlangıç popülasyonunun moleküler yöntemler ile ayrıntılı olarak tanımlanmasını kapsayan çeşit ıslah programının başlangıç aşamasını oluşturmaktadır. Önümüzdeki yıllarda popülasyon içerisinden seleksiyon ıslahı ile seçilecek üstün nitelikli genetik materyallerin farklı ıslah amaçları doğrultusunda değerlendirilmesi planlanmaktadır.

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Araştırma Makalesi (Research Article)

Macar Fiğinin (*Vicia pannonica* Crantz) Farklı Ekim Zamanlarına Göre Verim, Kalite ve Besin Elementleri İçeriklerinin Değişimi

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Macar Fiği,
Verim

Öz: Bu çalışma, Macar fiğinin farklı ekim zamanlarına göre verim, kalite ve besin elementleri içerikleri açısından gösterdiği farklılıkları ortaya koymak amacıyla 2014-2015 ve 2015-2016 yıllarında Bingöl ili ekolojik koşullarında yürütülmüştür. Araştırmada Eylül ayının ikinci yarısından başlamak üzere 10 günlük aralıklarla 4 ekim zamanı seçilmiştir. Bitki boyu, yeşil ot verimi, kuru ot verimi açısından birinci ekim zamanlarının en yüksek değerleri verdiği, ham protein oranlarının ise ekim zamanları açısından istatistiksel olarak bir farklılık göstermediği görülmüştür. En düşük asit deterjan lif (ADF) ve nötral deterjan lif (NDF) oranları ile en yüksek sindirilebilir kuru madde ve nispi yem değerlerinin de birinci ekim zamanından elde edildiği belirlenmiştir. Besin elementleri açısından ise Ca, Mg ve K açısından ekim zamanları arasında bir fark olmadığı ve ekim zamanı geciktikçe P oranında ise azalmalar olduğu görülmüştür. Bingöl ve benzeri ekolojik koşullara sahip karasal bölgelerde, Macar fiği ekiminin, Eylül ayının ikinci yarısından itibaren mümkün olduğunca erken yapılmasının verim ve kalite açısından avantajlı olduğu sonucuna varılmıştır.

Changes in Yield, Quality and Nutrient Content of Hungarian Vetch (*Vicia pannonica* Crantz) in Different Sowing Times

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Abstract: This study was conducted in 2014-2015 and 2015-2016 under Bingöl ecological conditions to determine the yield, quality, and nutrient content differences of Hungarian vetch, which sowing different times. In the research, starting from the second half of September, 4 sowing times were chosen at 10-day intervals. It was found that the first sowing time had the highest value in terms of plant height, forage yield, and dry matter yield, whereas crude protein ratios did not show a statistically significant difference in terms of sowing times. Also, it was determined that the lowest acid detergent fiber (ADF) and neutral detergent fiber (NDF) ratios, and the highest digestible dry matter and relative feed values were obtained from the first sowing time. It was observed that there was no difference between the planting times in terms of Ca, Mg, and K elements and the P ratio decreased when sowing time was delayed. It has been concluded that Hungarian vetch cultivation in the second half of September is advantageous in terms of yield and quality in Bingöl and similar terrestrial regions with similar ecological conditions.

1. Giriş

Baklagiller familyasından olan fiğ cinsi (*Vicia* L.), yeryüzünde yaklaşık 150 farklı türe sahiptir (Maxted, 1995). Türkiye'de ise 66 adet fiğ türünün bulunduğu bildirilmektedir (Basbag ve ark., 2013). Macar Fiği (*Vicia pannonica*), fiğ türleri arasında yagın olarak bilinen ve hayvan besleme amacıyla kullanılan, değerli bir yem bitkisidir (Erdoğdu ve ark., 2016). Macar fiği, çoğu fiğ türlerine göre soğuğa daha dayanıklı bir yapıya sahip olmasının yanısıra kıraç koşullarda ve ağır killi topraklarda daha yüksek verim sağlamaktadır (Hashalıcı ve ark., 2017). Ayrıca deniz seviyesinden 2200 m yüksekliğe kadar olan habitatlarda büyüyebilmetedir (Maxted, 1995). Dolayısıyla Türkiye'nin başta Orta ve Doğu Anadolu bölgeleri olmak üzere tüm bölgelerinde hem ana ürün hem de ikinci ürün olarak rahatlıkla tarımı yapılabilmektedir (Açıkgöz, 2013). Macar fiği yanlız olarak yetiştirilebildiği gibi orta derecede yatık bir yapıya sahip olması nedeniyle, yatmayı önlemek amacıyla tahıllarla birlikte karışık olarak ta ekilebilmektedir (Gülümser ve ark., 2017).

Yem bitkilerinin besleme değerlerinin belirlenmesinde yaygın olarak NDF, ADF ve ham protein içerikleri kullanılmaktadır (Üke et al., 2017) ve bu klalite kriterleri açısından Macar fiği genotiplerinin yüksek yem kalitesine sahip olduğu birçok araştırmacı tarafından bildirilmiştr (Lamei ve ark., 2011; Ilieva ve Naidenova, 2016; Kaplan ve ark., 2019). Baklagillerin yeşil ve kuru otlarının protein, vitamin ve mineral madde içerikleri açısından zengin olduğu ve Macar fiğinin kalite açısından yaygın fiğden biraz daha yüksek değerlere sahip olduğu da bildrilmiştir (Vasiljevic ve ark., 2009).

Macar fiğinin verim, kalite ve besin elementleri içerikleri ile ilgili olarak bir çok çalışma yürütülmüştür. Sayar ve ark. (2012), Mardin ili Kızıltepe koşullarında 12 Macar fiği genotipi ile yürüttükleri çalışmada bitki boyunu 52.3-63.1 cm, yeşil ot verimini 1227-2336 kg/da ve kuru ot verimini 295-575 kg/da arasında tespit etmişlerdir. Kayseri kıraç koşullarında beş Macar fiği çeşidi yürütülen bir çalışmada bitki boyu 48.8-76.3 cm, yeşil ot verimi 1160-2600 kg/da, kuru ot verimi 393-782 kg/da, ham protein oranı % 16.0-18.6, ADF oranı % 30.0-37.1 ve NDF oranı % 39.1-46.8 aralığında tespit edilmiştir (Hashalıcı ve ark., 2017). Bingöl koşullarında Kaplan ve ark. (2019) tarafından yürütülen çalışmada bitki boyu 90.2-105.2 cm, yeşil ot verimi 1429-1963 kg/da, kuru ot verimi 298-380 kg/da, ham protein oranı % 15.5-20.9, ADF oranı % 34.3-40.7, NDF oranı % 46.3-50.0, sindirilebilir kuru madde oranı % 57.2-57.4 ve nispi yem değeri ise 106-124 aralığında tespit edilmiştir.

İranda fiğlerin kimyasal kompozisyonunun belirlenmesi amacıyla yürütülen çalışmada Macar fiğinin ham protein oranı % 22.6, ADF oranı % 25.3, NDF oranı % 31.2, Ca 13.4 g/kg, P 1.01 g/kg, K 28.6 g/kg, sindirilebilir kuru madde oranı % 70.3 ve nispi yem değeri ise 209 olarak tespit edilmiştir (Badrzadeh ve ark. 2008). Sırbistanda yürütülen bir çalışmada Macar fiğinin bitki boyu 65-93 cm, yeşil ot verimi 16.5-48.7 mg/ha ve kuru ot verimi 4.0-12.0 mg/ha olarak tespit edilmiştir (Mihailovic ve ark., 2009). İran'ın soğuk bölgeleri için kullanılabilecek uygun kışlık bitki türünün belirlenmesi amacıyla yürütülen iki yıllık çalışmada Macar fiğinin yeşil ot verimi 20.38 t/ha, kuru ot verimi 5.49 t/ha ve ham protein verimi 897.1 kg/ha olarak tespit edilmiştir. Çalışma sonucunda İranın soğuk bölgeleri için Macar fiği tavsiye edilmiştir (Lamei ve ark. 2011). Bulgaristanda 21 Macar fiği genotipinin incelendiği çalışmada ham protein oranı % 21.12, Ca oranı % 1.35 ve P oranı % 0.34 olarak tespit edilmiştir (Ilieva and Naidenova, 2016). Romanyada yürütülen bir çalışmada ekim zamanı ve azot gübrelemesinin kışlık bezelye ve Macar fiğinin kuru madde verimi üzerine etkisi araştırılmıştır. Çalışmada Macar fiği için ideal ekim zamanının 20-30 Eylül tarihleri olduğu ve bu zamanda yapılan ekimlerden en yüksek verim alındığı (7.71 t/ha) bildirilmiştir (Dragomir ve ark., 2007).

Çalışmanın yürütüldüğü Bingöl ilinin ekolojik koşulları, Macar fiği üretimi için büyük bir potansiyele sahiptir (Çaçan ve Yılmaz, 2015). Bingöl'de yeşil ot üretimi amacıyla 3700 dekarlık alanda yalın ekimi yapılan Macar fiğinden 2 269 kg/da verim elde edilmektedir. Bingöl ilinde Macar fiğinin yeşil ot verimi hem Türkiye'deki ortalamasından (1 421 kg/da) hem de Elazığ (1 200 kg/da), Malatya (1 649 kg/da) ve Diyarbakır (1 494 kg/da) gibi çevre illerin ortalamasından daha yüksektir (TUİK, 2019). Bingöl ilinde iklim özelliklerinin uygunluğu, özellikle yıllık düşen toplam yağışın (886.7 mm) hem Türkiye hem de çevre illerin yağış miktarından yüksek olması, Macar fiğinden yüksek verim elde edilmesini sağlamaktadır.

Türkiye'de Macar fiği ekimi, Eylül başından Kasım ayına kadar olan süre içerisinde yani sonbaharda yapıldığı takdirde daha yüksek verim alınabilmektedir (Taş, 2011). Macar fiğinin Doğu Anadolu Bölgesinde sonbaharda ekimi yapılabilmesine karşın, sonbahar ayları içerisindeki uygun ekim zamanı bilinmemektedir. Bingöl ve benzer ekolojiye sahip olan Doğu Anadolu illerinde sonhahar

aylarında Macar fiği için ideal ekim zamanının belirlenmesi durumunda, birim alandan verim ve kalitesi yüksek ürün elde edilmesi sağlanacaktır. Uygun ekim zamanının belirlenmesi sayesinde artacak verim ve kalitenin, Macar fiğinden yetiştiriciliğinin de yaygınlaşmasına katkı sağlayacağı ön görülmektedir.

Macar fiğinin farklı ekim zamanlarına göre verim, kalite, sindirilebilirlik ve besin elementleri açısından gösterdiği farklılıkları tespit etmek ve bu özellikler doğrultusunda ideal ekim zamanını belirlemek amacıyla bu çalışma yürütülmüştür.

2. Materyal ve Yöntem

Bitkisel materyal olarak, Macar fiğinin (*Vicia pannonica* Crantz) Tarım İl Müdürlüğünden temin edilen Ağrı popülasyonu kullanılmıştır. Bu popülasyonun verim ve kalite açısından yüksek değerlere sahip olduğu Kaplan ve ark. (2019) tarafından ortaya konulmuştur. Araştırma, Bingöl il merkezine 15 km uzaklıkta ve ortalama rakımı 1092 m olan Bingöl Üniversitesi Tarımsal Uygulama ve Araştırma alanında (Kuzey enlemi 38.81589^{o} ile 40.53866^{o} Doğu boylamı) yürütülmüştür.

2.1. Araştırma Alanının İklim Verileri

Bu çalışma 2014-2015 ve 2015-2016 yetiştirme dönemlerinde yürütülmüştür. Bingöl İl Meteoroloji Müdürlüğü'nün araştırmanın yürütüldüğü ayların uzun yıllar içerisindeki (2000-2015) verileri incelendiğinde (MGM, 2020), araştırma süresince tespit edilen ortalama sıcaklık değerlerinin uzun yıllar ortalamasının (7.9 °C) üzerinde, toplam yağış miktarının uzun yıllar ortalamasının (886.7 mm) altında ve nispi nem oranının ise uzun yıllar ortalamasına (% 62.6) yakın olduğu görülmüştür (Çizelge 1).

2.2. Araştırma Alanının Toprak Özellikleri

Bingöl Üniversitesi Ziraat Fakültesinde yapılan toprak analizi sonuçları, Sezen (1995) ve Zengin (2012) referans alınarak değerlendirilmiştir. Araştırma alanının toprak yapısının tınlı (% 43.3), hafif asidik pH'lı (6.37), az kireçli (% 0.15) ve tuzsuz (% 0.0066) olduğu belirlenmiştir. Toprağın organik madde (% 1.26), K (24.5 kg/da) ve P (7.90 kg/da) miktarlarının da yetersiz olduğu belirlenmiştir.

Çizelge 1. Bingöl iline ait 2014-2015, 2015-2016 ve uzun yıllar (2000-2015) aylık iklim verileri

Aylar	Ortalama sıcaklık (°C)			Toplam yağış (mm)			Nispi nem (%)		
	2014-2015	2015-2016	Uzun Yıllar	2014-2015	2015-2016	Uzun Yıllar	2014-2015	2015-2016	Uzun Yıllar
Eylül	21.3	23.4	21.3	63.7	0.8	16.4	36.2	30.2	42.2
Ekim	13.7	14.3	14.2	87.3	220.9	70.3	62.3	68.3	58.9
Kasım	6.3	14.4	6.5	99.0	18.9	91.8	64.3	56.4	64.7
Aralık	4.6	1.3	0.2	63.2	46.2	121.8	75.7	58.6	70.7
Ocak	-1.8	-2.8	-2.5	148.2	235.1	154.0	74.7	75.3	73.3
Şubat	1.9	2.4	-0.9	115.8	86.3	137.7	73.8	73.7	72.2
Mart	5.4	7.0	4.9	154.4	125.5	124.1	65.9	60.4	64.2
Nisan	10.9	13.9	10.9	66.7	45.5	103.8	58.7	48.4	61.2
Mayıs	16.6	16.3	16.2	21.2	62.2	66.8	52.0	57.4	55.8
Toplam/Ort.	8.8	10.0	7.9	819.5	841.4	886.7	62.6	58.7	62.6

2.3. Metot

Çalışmanın yürütüldüğü yetiştirme sezonlarındaki ekim ve hasat tarihleri Çizelge 2'de sunulmuştur.

Çizelge 2. Macar fiğinin 2014-2015 ve 2015-2016 yıllarına ait ekim ve hasat tarihleri

	2014-2015 yetiştirme sezonu		2015-2016 yetiştirme sezonu	
Ekim zamanları	Ekim tarihi	Hasat tarihi	Ekim tarihi	Hasat tarihi
E_1 (Birinci ekim)	19.09.2014	11.05.2015	17.09.2015	10.05.2016
E_2 (İkinci ekim)	30.09.2014	11.05.2015	29.09.2015	10.05.2016
E_3 (Üçüncü ekim)	11.10.2014	18.05.2015	09.10.2015	17.05.2016
E_4 (Dördüncü ekim)	21.20.2014	18.05.2015	20.10.2015	17.05.2016

Çalışmanın yürütülmesi sırasında karışıklık yaşanmaması için ekim zamanlarının tarihlerini kullanmak yerine ilk ekimden başlamak üzere sırasıyla birinci, ikinci, üçüncü ve dördüncü ekim zamanları kavramları kullanılmıştır. Denemenin ekimi, parsel uzunluğu 5 m, her parsele 6 sıra ve 20 cm sıra arası olacak şekilde 10 kg/da tohumluk kullanılarak yapılmıştır. Ekim yapıldıktan sonra saf madde üzerinden 4 kg/da azot (N) ve 10 kg /da P gübresi uygulanmıştır.

Hasat, parsellerin % 50 çiçeklenme döneminde ve parsellerin sağ ve solundan 0.5 m, alt ve üstünden birer sıra kenar tesiri alındıktan sonra 3.2 m^2'lik alanda yapılmıştır. Yeşil ot verimini hesaplamak amacıyla parsellerden biçilen ot tartılarak elde edilen değer dekara dönüştürülmüştür. Dekara kuru ot verimi ise parsellerden alınan 500 g yeşil otun, 70 °C'de 48 saat kurutulup tartılmasıyla hesaplanmıştır. Ham protein (HP), asit deterjan fiber (ADF), nötral deterjan fiber (NDF), Kalsiyum (Ca), Magnezyum (Mg), Fosfor (P) ve Potasyum (K) oranları birçok araştırmacı tarafından aktif bir şekilde kullanılan NIRS (Near Infrared Reflektans Spektroskopisi - Foss Model 6500) cihazı ile belirlenmiştir (Başaran ve ark., 2011; Basbag ve ark., 2018; Gülümser ve ark., 2020). Analiz sonuçları kullanılarak, Macar fiği otunun HP verimi, sindirilebilir kuru madde (SKM=88.9-(0.779 x ADF)) oranı ve nispi yem değerleri (NYD=SKM x KMT (120/NDF)/1.29) hesaplanmıştır (Rohweder ve ark., 1978; Morrison, 2003).

2.4. İstatistiksel Model ve Analiz

Çalışma, tesadüf blokları deneme desenine göre üç tekerrürlü olacak şekilde yürütülmüştür. Çalışma sonucunda elde edilen verilere, JMP istatistik programı (JMP Sas Institute, 2002) yardımıyla varyans analizi uygulanmıştır. Grupların ortalamaları ise LSD (% 5) testi ile karşılaştırılmıştır.

3. Bulgular

3.1. Macar fiğinin farklı ekim zamanlarına ait verim ve kalite özellikleri

Çizelge 3'te farklı zamanlarda ekilen Macar fiğinin verim (yeşil ot, kuru ot ve bitki boyu) ve kalite (HP, ADF, NDF, SKM ve NYD) özellikleri sunulmuştur.

Farklı ekim zamanlarının yeşil ot verimi, kuru ot verimi ve bitki boyu üzerinde oluşturduğu farkın istatistiksel olarak önemli olduğu tespit edilmiştir ($P<0.01$). Yeşil ot verimi, kuru ot verimi ve bitki boyu açısından yıl ve yıl x zaman interaksiyonun ise istatistiksel olarak önemsiz olduğu görülmüştür. En yüksek yeşil ot verimi (1 514 kg/da) ve kuru ot verimi (446 kg/da) birinci ekim zamanından elde edilmiştir. Yeşil ot ve kuru ot verimlerinin birinci ekim zamanından sonra azaldığı ve en düşük yeşil ot verimi (512 kg/da) ve kuru ot veriminin (138 kg/da) dördüncü ekim zamanından elde edildiği görülmüştür. En yüksek bitki boyu (93.3 cm) birinci ekim zamanından elde edilmiştir. Ikinci ekim zamanında istatistiksel olarak en yüksek değeri veren birinci ekim zamanı ile aynı grupta yer almıştır. En düşük bitki boyu da (50.8 cm) dördüncü ekim zamanından elde edilmiştir.

Ekim zamanları geciktikte, Macar fiğinden elde edilen HP oranları da azalmıştır. Ancak iki yılın ortalaması olarak elde edilen HP oranları, ekim zamanları ve yıllar açısından istatistiksel olarak bir farklılığa yol açmamıştır. HP oranı, yıl x ekim zamanı interaksiyonu açısından önemli bulunmuştur. En yüksek HP oranı, birinci yılın birinci ekim zamanından elde edilirken (% 24.2), bunu istatistiksel olarak aynı grupta yer alan birinci yılın ikinci ve üçüncü ekim zamanları ile ikinci yılın birinci ekim zamanı

izlemiştir. En düşük HP oranları ise istatistiksel olarak aynı grupta olan birinci yılın dördüncü ekim zamanı ile ikinci yılın ikinci, üçüncü ve dördüncü ekim zamanlarından elde edilmiştir.

Çizelge 3. Macar fiğinin farklı ekim zamanlarına ait verim ve kalite özellikleri

	Yeşil ot verimi (kg/da)			**Kuru ot verimi (kg/da)**		
Ekim zamanı	2015	2016	Ortalama	2015	2016	Ortalama
E_1	1534	1495	1514 a	461	432	446 a
E_2	1266	1319	1292 b	352	369	361 b
E_3	1161	1166	1164 b	309	341	325 c
E_4	567	457	512 c	150	126	138 d
Ortalama	1132	1109	1121	318	317	317
LSD (% 5)	Zaman (Z): 149.45**	Yıl (Y): ---	Z x Y: ---	Zaman (Z): 29.48**	Yıl (Y): ---	Z x Y: ---
	CV:% 10.66, **: p<0.01			CV: % 7.50, **: p<0.01		
	Bitki boyu (%)			**Ham protein oranı (%)**		
Ekim zamanı	2015	2016	Ortalama	2015	2016	Ortalama
E_1	98.0	88.7	93.3 a	24.2 a	22.3 ab	23.2
E_2	86.3	81.2	83.8 ab	22.0 ab	21.3 b	21.6
E_3	77.5	80.3	78.9 b	22.1 ab	20.0 b	21.0
E_4	48.3	53.3	50.8 c	20.0 b	20.2 b	20.1
Ortalama	77.5	75.9	76.7	22.1	20.9	21.5
LSD (% 5)	Zaman (Z): 10.47**	Yıl (Y): ---	Z x Y: ---	Zaman (Z): ---	Yıl (Y): ---	Z x Y: 2.37**
	CV:% 11.02, **: p<0.01			CV:% 6.29, **: p<0.01		
	ADF (%)			**NDF (%)**		
Ekim zamanı	2015	2016	Ortalama	2015	2016	Ortalama
E_1	25.7	24.8	25.2 c	33.7	34.3	34.0 b
E_2	28.2	28.6	28.4 b	33.7	36.6	35.2 b
E_3	30.5	26.5	28.5 b	36.4	36.4	36.4 ab
E_4	32.9	30.8	31.9 a	38.7	38.3	38.5 a
Ortalama	29.3 A	27.7 B	28.5	35.6	36.4	36.0
LSD (% 5)	Zaman (Z): 2.02**	Yıl (Y): 1.43*	Z x Y: ---	Zaman (Z): 2.54*	Yıl (Y): ---	Z x Y: ---
	CV:% 5.74, *: p<0.05, **: p<0.01			CV: % 5.69, *: p<0.05		
	SKM (%)			**NYD**		
Ekim zamanı	2015	2016	Ortalama	2015	2016	Ortalama
E_1	68.9	69.6	69.2 a	191	190	190 a
E_2	67.0	66.6	66.8 b	186	170	178 ab
E_3	65.2	68.3	66.7 b	167	174	170 b
E_4	63.3	64.9	64.1 c	152	158	155 c
Ortalama	66.1 B	67.3 A	66.7	174	173	173
LSD (% 5)	Zaman (Z): 1.58**	Yıl (Y): 1.11*	Z x Y: ---	Zaman (Z): 14.02**	Yıl (Y): ---	Z x Y: ---
	CV:% 1.91, *: p<0.05, **: p<0.01			CV: % 6.53, **: p<0.01		

ADF oranı ekim zamanı ve yıllar, NDF oranı ise sadece ekim zamanları açısından istatistiksel olarak farklılık gösterdiği görülmüştür. En düşük ADF oranı birinci ekim (% 25.2) zamanından, en düşük NDF oranı ise birinci (% 34.0) ve ikinci (% 35.2) ekim zamanlarından elde edilmiştir. En yüksek ADF oranı dördüncü ekim zamanından, en yüksek NDF oranı ise istatistiksel olarak aynı grupta olan üçüncü ve dördüncü ekim zamanlarından elde edilmiştir. Ayrıca ikinci yıl edilen ADF oranının, birinci yıl edilen ADF oranından daha düşük olduğu tespit edilmiştir.

SKM oranı ekim zamanı ve yıllar, NYD ise sadece ekim zamanları açısından istatistiksel olarak önemli bulunmuştur. En yüksek SKM oranı (% 69.2) birinci ekim zamanından, en düşük SKM oranı ise dördüncü (% 64.1) ekim zamanından elde edilmiştir. En yüksek NYD istatistiksel olarak aynı grupta yer alan birinci (190) ve ikinci (178) ekim zamanlarından elde edilirken, en düşük NYD dördüncü ekim zamanından (155) elde edildiği görülmüştür.

3.2. Macar fiğinin farklı ekim zamanlarına ait besin elementleri içerikleri

Macar fiğinin faklı ekim zamanlarına ait besin elementleri içerikleri Çizelge 4'te verilmiştir. Besin elementleri içerikleri Ca, Mg ve K için ekim zamanları, yıllar ve ekim zamanı x yıl interaksiyonu açısından istatistiksel önemli bulunmamıştır. Sadece P'un ekim zamanları açısından istatistiksel olarak önem arz ettiği, en yüksek P oranlarının aynı grupta yer alan birinci ve ikinci ekim zamanlarından elde edildiği, en düşük P oranlarının da üçüncü ve dördüncü ekim zamanlarından elde edildiği görülmüştür.

Çizelge 4. Macar fiğinin farklı ekim zamanlarına ait besin elementleri içerikleri

	Ca (%)			**Mg (%)**		
Ekim zamanı	**2015**	**2016**	**Ortalama**	**2015**	**2016**	**Ortalama**
E_1	1.52	1.51	1.51	0.32	0.31	0.32
E_2	1.54	1.54	1.54	0.34	0.34	0.34
E_3	1.57	1.58	1.58	0.34	0.33	0.33
E_4	1.68	1.68	1.68	0.34	0.34	0.34
Ortalama	1.58	1.58	1.58	0.34	0.33	0.33
LSD (% 5)	Zaman (Z): ---	Yıl (Y): ---	Z x Y: ---	Zaman (Z): ---	Yıl (Y): ---	Z x Y: ---
	CV:% 6.25			CV: % 4.29		
	P (%)			**K (%)**		
Ekim zamanı	**2015**	**2016**	**Ortalama**	**2015**	**2016**	**Ortalama**
E_1	0.39	0.37	0.38 ab	2.05	1.95	2.00
E_2	0.39	0.39	0.39 a	2.34	2.34	2.34
E_3	0.36	0.37	0.36 b	2.21	2.07	2.14
E_4	0.36	0.36	0.36 b	1.98	1.98	1.98
Ortalama	0.38	0.37	0.37	2.15	2.09	2.12
LSD (% 5)	Zaman (Z): 0.02**	Yıl (Y): ---	Z x Y: ---	Zaman (Z): ---	Yıl (Y): ---	Z x Y: ---
	CV:% 4.14, **: p<0.01			CV: % 12.02		

4. Tartışma ve Sonuç

Macar fiğinin iki yıllık ekim zamanları ve yıl ortalaması olarak yeşil ot verimi 1121 kg/da, kuru ot verimi ise 317 kg/da olarak tespit edilmiştir. Ekim zamanı ilerledikçe elde edilen yeşil ve kuru ot verimlerinde düşüş görülmüştür. Yüzüncü Yıl Üniversitesi Ziraat Fakültesi deneme alanında yürütülen bir çalışmada, Macar fiği ve tüylü fiğin farklı ekim zamanlarının verim üzerindeki etkisinin incelendiği ve Van için ideal ekim zamanının belirlenmeye çalışıldığı çalışmada; Macar fiğinin ekimi 20 Eylül, 10 Ekim ve 30 Ekim tarihlerinde yapılmıştır. Çalışmada elde edilen ortalama 910 kg/da yeşil ot verimi, 304 kg/da kuru ot verimi ile ekim zamanı geciktikçe verimin düştüğünün belirlenmesi ve ideal ekim zamanının Van ili için Eylül ayı olarak tavsiye edilmesi, bu çalışmadan elde edilen sonuçları destekler niteliktedir (Turna ve Ertuş, 2017). Isparta ekolojik koşullarında yürütülen ve Macar fiği, tüylü fiğ yaygın fiğin farklı ekim zamanları ile hasat zamanlarının verim ve kalite özelliklerine olan etkisinin incelendiği çalışmada 5 Ekim, 20 Ekim ve 5 Kasım tarihleri ekim zamanları olarak belirlenmiştir. Macar fiğinden ortalama 416 kg/da kuru ot veriminin alınması ve ekim zamanı geciktikçe verimde görülen düşüşlerin istatistiksel olarak anlamlı olması, bu çalışmadan elde edilen bulgular ile paralellik göstermektedir (Güzeloğulları ve Albayrak, 2017). Romanya'da yürütülen bir çalışmada da farklı gübre uygulamaları ile Macar fiğinin 10 Eylül, 20 Eylül ve 30 Eylül olacak şekilde ekim zamanlarının verim

üzerindeki etkileri incelenmiştir. 6.80-7.71 t/ha Kuru ot veriminin elde edildiği 20-30 Eylül tarihleri Macar fiği için ideal ekim zamanı olarak tespit edilmesi (Dragomir ve ark., 2007), mevcut çalışma bulgularını desteklemektedir.

Çalışmada Macar fiğinin bitki boyu 50.8-93.3 cm aralığında ve ortalaması 76.7 cm olarak tespit edilmiş ve geç yapılan biçimlerde daha düşük bitki boyları elde edilmiştir. Sırbistan koşullarında Mihailovic ve ark. (2009) tarafınan yürütülen bir çalışmada Macar fiği popülasyonlarında bitki boyunun 65-93 cm, Kayseri ekolojik koşullarında beş farklı Macar fiği çeşidinin bitki boyunun 55.8-66.6 cm (Hashalıcı ve ark., 2017) ve Kırklareli koşullarında bazı Macar fiği genotiplerinin farklı biçim zamanlarının verim ve kalite üzerine etkisinin incelendiği çalışmada bitki boyunun 84.4-91.3 cm (Tenikecier ve ark., 2020) aralığında tespit edilmesi, mevcut çalışma bulgularını desteklemektedir.

Farklı zamanlarda ekilen Macar fiğinde ham protein oranları % 20.1-23.2 aralığında ve ortalama % 20.1 olarak tespit edilmiştir. Badrzadeh ve ark. (2008), İran koşullarında Macar fiğinde HP oranını % 22.6, Güzeloğulları ve Albayrak (2016) Macar fiğinde HP oranını biçim zamanlarına göre değişmekle birlikte ortalama % 20.7, Ilieva ve Naidenova (2016) Bulgaristan koşullarında Macar fiğinde HP oranını % 21.2, Budak (2017) Iğdır koşullarında Macar fiğinde HP oranını % 18.8-20.0 ve Kaplan ve ark. (2019) Bingöl koşullarında aynı Macar fiği popülasyonunda HP oranını % 20.9 olarak tespit etmeleri, mevcut bulguları desteklemektedir. Ancak, Macar fiğinde Celen ve ark. (2005)'ının % 17.4, Hashalıcı ve ark. (2017)'ının % 16.0-18.6, Şentürk (2019)'ün % 10.6-16.3 ve Tenikecier ve ark. (2020)'ının % 15.8-17.2 olarak tespit ettikleri HP oranları, mevcut çalışma bulgularından farklı olduğu görülmüştür. Bu farklılığın muhtemel nedeni hasat zamanları arasındaki farklıklardır. Bazı çalışmalarda tam çiçeklenme döneminde, bazı çalışmalarda ise % 50 çiçeklenme döneminde hasat yapılması, diğer koşulların eşdeğer olması durumunda bile farklılığa sebebiyet verebilmektedir.

Farklı ekim zamanlarına göre değişmekle birlikte, mevcut çalışmada Macar fiğinin ADF oranı % 25.2-31.9, NDF oranı % 34.0-38.5, ADF oranı yardımıyla hesaplanan sindirilebilir kuru madde oranı % 54.1-69.2 ve nispi yem değeri de 155-190 arasında değişim gösterdiği tespit edilmiştir. Bu çalışmadan elde edilen sonuçların, İran koşullarında Macar fiğinden elde edilen % 25.3 ADF oranı, % 31.2 NDF oranı, % 70.3 SKM oranı ve 209 nispi yem değeri (Badrzadeh ve ark., 2008), Tokat koşullarında saf ekilen Macar fiğinden elde edilen % 29.2 ADF ve % 66.2 SKM oranları (Kılıçalp ve ark., 2020) ile Güzeloğulları ve Albayrak (2016) tarafından Isparta koşullarında farklı ekim ve hasat zamanlarında Macar fiğinden elde edilen ortalama % 30.4 ADF ve % 36.5 NDF oranları ile benzerlik göstermektedir. ADF ve NDF oranları bitki hücre çeperini oluşturan bileşikler olup, genel itibariyle bitkilerin erken dönemlerinde oranları daha düşük, geç dönemlerinde ise daha yüksek olmaktadır. Dolayısıyla farklı çalışmalarda hasadın farklı dönemlerde yapılması, ADF ve NDF oranlarının farklı çıkması üzerinde en çok etkili olan faktör olarak ortaya çıkmaktadır. Bu nedenledir ki Hashalıcı ve ark. (2017) tarafından Kayseri koşullarında Macar fiği çeşitlerinde tespit edilen ADF (% 32.0-35.4) ve NDF oranları (% 40.6-45.2), Kaplan ve ark. (2019) tarafından Bingöl koşullarında Macar fiği genotiplerinde tespit eilen ADF (% 34.3-40.7), NDF (% 46.4-50.0), SKM (% 57.2-62.2) oranları ve nispi yem değeri (106.7-124.7), yine Bingöl koşullarında Bayar ve Çaçan (2019) tarafından hasat zamanlarında farklılık göstermek üzere tespit edilen ortalama ADF (% 36.5), NDF (% 42.8), SKM (% 60.5) ve nispi yem değeri (133.7) ile Tenikecier ve ark. (2020) tarafından Kırklareli koşullarında Macar fiği genotiplerinde tespit edilen ADF (% 31.7-33.9) ve NDF oranları (% 44.7-47.1), bu çalışmadan elde edilen sonuçlardan bir miktar farklılık göstermiştir.

Macar fiğinin ekim zamanlarına göre değişmekle birlikte Ca oranı % 1.51-1.68, Mg oranı % 0.32-0.34, P oranı % 0.36-0.39 ve K oranı % 1.98-2.34 arasında değişim göstermiştir. Van ilinde bazı fiğ türlerinin besin içeriklerinin belirlenmesi amacıyla yürütülen bir çalışmada Macar fiğinin P oranı % 0.62, K oranı % 1.86 ve Mg oranı % 0.38 olarak tespit edilmiştir (Çelen ve ark., 2005). İran koşullarında bazı fiğ türlerinin kimyasal kompozisyonunun belirlendiği çalışmada Macar fiğinin Ca içeriği % 1.34 ve K içeriği % 2.86 olarak tespit edilmiştir (Badrzadeh ve ark., 2008). Bulgaristan'da 21 Macar fiği genotipinin incelendiği çalışmada Ca oranı % 1.35 ve P oranı % 0.34 olarak elde edilmiştir (Ilieva ve Naidenova, 2016). Tekirdağ ve Kırklareli olmak üzere iki lokayonda bazı Macar fiği genotiplerinin adaptasyon yeteneklerinin belirlenmesi amacıyla yürütülen çalışmada K içeriği % 1.97-2.53 ve Ca içeriği % 0.92-1.13 arasında tespit edilmiştir (Şentürk, 2019). Bu çalışmalardan elde edilen bulguların, mevcut çalışmadan elde edilen bulgular ile benzerlik gösterdiği görülmektedir.

Sonuç olarak, Eylül ayının ikinci yarısından başlayarak 10 günlük aralıklarla yapılan ekimlerden elde edilen veriler karşılaştırıldığında; en yüksek yeşil ot ve kuru ot verimi ile bitki boyu değerlerinin

birinci ekim zamanından elde edildiği görülmektedir. Birinci ekim zamanında yapılan ekimlerden elde edilen yeşil ve kuru ot verimlerinin (1514 kg/da, 446 kg/da), dördüncü ekim zamanında yapılan ekimlerden elde edilen yeşil ve kuru ot verimlerinin (512 kg/da, 138 kg/da) yaklaşık üç katı daha yüksek olduğu görülmüştür. Eylül ayı ortasında yapılacak ekimin, Ekim ayı sonunda yapılacak ekime göre yeşil ot verimi açısından % 295, kuru ot veriminin ise % 323 oranında daha avantajlı olduğu tespit edilmiştir. Eylül ayının ikinci yarısında yapılacak Macar fiği ekimlerinden, birim alandan daha fazla ürün elde edilmektedir.

Ekim zamanının geciktirilmesi ile Macar fiği otunun kalitesinin de düştüğü görülmektedir. HP oranları ekim zamanına göre istatiksel olarak bir farklılık göstermemiştir. Ancak en düşük ADF ve NDF oranları ile en yüksek SKM oranı ve NYD'nin de genel olarak Eylül ayının ikinci yarısında yapılan ekimlerden elde edildiği görülmüştür. Ca, K ve Mg elementlerinin oranları ekim zamanları arasında istatiksel olarak farklılık göstermezken, P elementi oranı ise birinci ve ikinci ekimlerde diğer ekim zamanlarına göre daha fazla bulunmuştur. Eylül ayının ikinci yarısında yapılacak Macar fiği ekimlerinden, birim alandan daha kaliteli ürün elde edildiği görülmektedir.

Eylül ayının ikinci yarısında yapılacak ekimlerin, bölge çiftçileri için hem verim hem de kalite açısından daha karlı olacağı tespit edilmiştir. Dolayısıyla iki yıl yürütülen bu çalışma neticesinde, Bingöl ili ve benzer ekolojik koşullara sahip bölgelerde ot üretimi amacıyla yapılacak Macar fiği ekimi için uygun ekim zamanının Eylül ayının ikinci yarısı olduğu kanaatine varılmıştır.

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Research Article

Evaluation of the Beypınarı Land Consolidation Project of Erzurum Province in Terms of Quantitative Features

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Land fragmentation,
In-field services.

Abstract: This study was carried out to evaluate the efficiency of the Erzurum-Beypınarı land consolidation project. In the study, primary data were obtained from agricultural enterprises through a survey and secondary data from State Hydraulic Works. The minimum number of questionnaires was determined as 20, taking into account the finite population and a 10% safety margin. Quantitative data of the consolidation project were obtained with the help of the NetCAD program. According to the results obtained from the research, the consolidation rate in the research area was 67.9%. The average parcel size, which was 13.33 decares before consolidation, increased to 28.04 decares after consolidation. The water supply and water usage rates were 55.1% and 17.4%, respectively, between 2000-2012, and these values increased to 100% and 26.8% after consolidation. The ratio of shapeless parcels was 66.8% before Beypınarı consolidation, this value decreased to 15.4% after consolidation. With the consolidation, the length of the in-field road increased 2.67 times, and the rate of parcels directly connected to the road increased from 52% to 100%. Shareholders' sharing of agricultural lands before consolidation efforts resulted in the emergence of new businesses. However, the number of active agricultural enterprises has decreased. When agricultural active enterprises are considered, it has been observed that the number of parcels per enterprise, which was 16.11, decreased to 5.16 after consolidation. The fact that the Beypınarı project area borders the Erzurum Airport and the Kars-Erzincan ring road has transformed the agricultural lands into an attraction center, but made them disposed to misuse. From the research, it was concluded that land consolidation projects are beneficial in terms of quantitative features, but the multiplier effect can be increased by investigating them socially and economically.

Erzurum İli Beypınarı Arazi Toplulaştırma Projesinin Niceliksel Özellikler Açısından Değerlendirilmesi

Makale Bilgileri

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Anahtar Kelimeler

Sürdürülebilirlik,

Öz: Bu çalışma Erzurum-Beypınarı arazi toplulaştırma projesinin etkinliğini değerlendirmek için yapılmıştır. Çalışmada, birincil veriler tarım işletmelerinden anket yoluyla ve ikincil veriler Devlet Su İşleri'nden alınmıştır. En az anket sayısı, sonlu popülasyon ve % 10 güvenlik payı dikkate alınarak 20 olarak tespit edilmiştir. Toplulaştırma projesine ait niceliksel veriler NetCAD programı yardımı ile elde edilmiştir. Araştırmadan elde edilen sonuçlara göre araştırma alanında toplulaştırma oranı % 67.9 olarak gerçekleşmiştir. Toplulaştırma öncesinde 13.33 dekar olan ortalama parsel büyüklüğü toplulaştırma sonrasında 28.04 dekara yükselmiştir. Su sağlama ve su kullanma oranları 2000-2012 yılları

Kırsal gelişim,
Arazi toplulaştırma,
Kırsal altyapı,
Arazi parçalılığı,
Tarla içi geliştirme hizmetleri.

arasında sırasıyla % 55.1 ve % 17.4 olarak gerçekleşmiş olup, toplulaştırmadan sonra bu değerler % 100 ve % 26.8'e çıkmıştır. Beypınarı toplulaştırmasından önce şekilsiz parsellerin oranı % 66.8 iken, toplulaştırma sonrası bu değer % 15.4'e düşmüştür. Toplulaştırma ile birlikte tarla içi yol uzunluğu 2.67 kat artmış, doğrudan yola bağlı parsel oranı % 52'den % 100'e çıkmıştır. Toplulaştırma çalışmaları öncesinde hissedarların tarım arazilerini paylaşması yeni işletmelerin ortaya çıkmasına neden olmuştur. Ancak tarımsal aktif işletme sayısı azalmıştır. Tarımsal aktif işletme dikkate alındığında, 16.11 adet olan işletme başına düşen parsel sayısının toplulaştırma sonrası 5.16'ya düştüğü gözlenmiştir. Beypınarı proje alanının Erzurum Havaalanı ve Kars-Erzincan çevre yoluna sınır olması tarım arazilerini çekim merkezine dönüştürmüş, ancak amaç dışı kullanıma açık duruma getirmiştir. Kırsal göçün önlenememesi ise tarım arazilerinin etkin kullanılmamasına neden olmaktadır. Araştırmadan, arazi toplulaştırma projelerinin nicel özellikler açısından yararlı olduğu, ancak sosyal ve ekonomik yönden araştırılması ile çarpan etkisinin artırılabileceği sonucu çıkarılmıştır.

1. Introduction

Land consolidation is to join the farmlands to irrigation network and the road taking into consideration ecological requirements and combine the lands of the same enterprise that located in different directions and places compared to the village center, and in suitable shape geometrically in terms of agricultural processing (Arici and Akkaya Aslan, 2014). With land consolidation, parcels are rearranged and a positive parcel transformation is achieved. This situation facilitates the management of agricultural enterprises; it also directly affects the rural development processes. There are many studies on this subject in Turkey and the world. These studies are related to obtaining more efficiency from a unit area with land consolidation studies (Çelebi, 2010; Çakmak and Eminoğlu, 2013; Sönmezyıldız and Çakmak, 2013; Arslan and Değirmenci, 2016; Dağdelen et al., 2017), allowing the use of modern production techniques (Peker and Dağdelen, 2016; Değirmenci et al., 2017), making public and the other investments cheaper (Uçar and Kara, 2006; Kumbasaroğlu and Dağdemir, 2007; Akkaya et al., 2017; Asiama et al., 2018; Buday et al., 2018; Kirmikil and Aydus, 2018), and building social peace among the people who benefit from these services. (Demetriou et al., 2012; Kirmikil and Arici, 2013; Kosoe et al., 2020). In other words, these studies explain that land consolidation plays a major role in the effective and sustainable use of agricultural land.

Reducing the number of parcels per agricultural enterprise, increasing the average parcel area, ensuring that each parcel benefits from irrigation, drainage, and road network, ensuring effective use of irrigation water, and arranging the parcels in a manner suitable for mechanization are the quantitative objectives (visible, measurable) of land consolidation projects (Arici and Akkaya Aslan, 2014; Choumert, and Phelinas, 2015; Kuslu and Ertem, 2019). Although land consolidation efforts in Turkey have started about 60 years ago, this type of project is quite new in Erzurum province. It is aimed to assess Beypınarı Land Consolidation Project in terms of the acquisitions and changes quantitatively.

2. Materials and Methods

2.1. Study area

In Erzurum, the first compulsory consolidation decision was taken in the 13 village settlements in the Erzurum Plain within the Kuzgun Dam irrigation area with Cabinet Decree No. 7103 in 2004. Erzurum province Beypınarı rural settlement is also included in this scope (Figure 1). The consolidation project was started in 2010 and was completed at the end of 2012. Beypınarı is located between 39° 99′ north latitude and 41° 15′ east longitude, 9.5 km from Aziziye District and 16.1 km from Erzurum city center. Migration is experienced in a residential area. According to TURKSTAT (2020) data, the population of Beypınarı was 736 in 1965, 749 in 1975, 630 in 2000, and 417 as of the beginning of 2020. The altitude of Beypınarı is 1770 m and its total area is 16.416 km^2. In terms of soil properties, it is seen that it has I, II, and III grade farmlands with a depth of 90 cm alluvial and fine-textured soils (Canbolat et al., 1999). The average land slope varies between 0-2% and has a flat and nearly flat topography (Kuşlu and Yağanoğlu, 2007). The average of some meteorological data for long years

(1981-2018) in the study area is 5.2 °C for temperature, -1.8 °C for the lowest temperature, 12.2 °C for the highest temperature, and 404.9 mm for precipitation (TSMS, 2021).

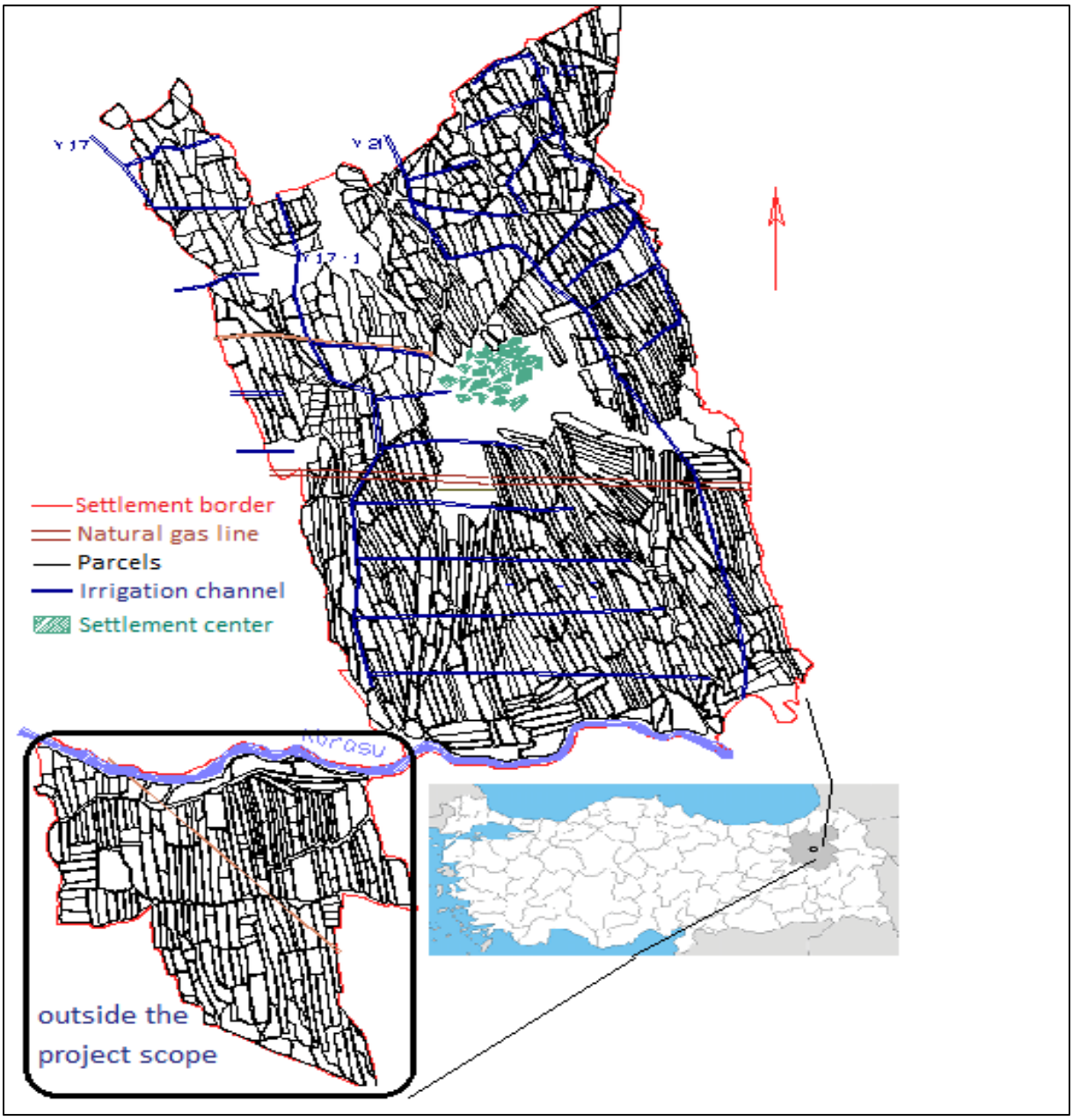

Figure1. Parcel status of Beypınarı before land consolidation (Kuslu, 2004).

2.2. Methods

Primary data on the research area were obtained from the questionnaires applied to the agricultural enterprises in the Beypınarı project area. While determining the minimum number of enterprises to conduct the study, the following equation developed for finite populations was used for the simple random sampling method, since the population subject to the study is finite and the variance is limited (Çiçek and Erkan, 1996):

$$n = \frac{N\sigma^2}{(N-1)D^2 + \sigma^2} \quad (1)$$

In the equation, n is sample unit number, N is population unit number, σ2 is population variance, and D is the possible error value. As a result of the calculations, 17 enterprises were found for the survey. Considering the data security margin, 20 enterprises were considered in the evaluation in the study.

The secondary data of the study were taken from the records of the VIII. Regional Directorate of State Hydraulic Works, Land Consolidation, and On-Farm Development Services Branch Directorate. The NetCAD program was used in drawing the maps.

In the study, the efficiency of Erzurum-Beypınarı consolidation was determined quantitatively by some criteria. These are number of enterprise rate (ENR), consolidation rate (LCR), parcel area change (PA), number of parcels per enterprise (NPE), water supply (WSR) and use (WUR) rates, road efficiency (RE), connecting road rate (CRR), and parcel shape criteria.

$$ENR = \frac{ENB}{ENA} x100 \quad (2)$$

$$LCR = \frac{PNB - PNA}{PNB} x100 \quad (3)$$

$$PA = \frac{PAB - PAA}{PAB} x100 \quad (4)$$

$$NPE = \frac{NPEB - NPEA}{NPEB} x100 \quad (5)$$

$$WSR = \frac{IL}{PrA} x100 \quad (6)$$

$$WUR = \frac{AICL}{IL} x100 \quad (7)$$

$$RE = \frac{RLB}{RLA} x100 \quad (8)$$

$$CRR = \frac{PCR}{PNA} x100 \quad (9)$$

In these equations, ENB; the number of enterprises before land consolidation (pcs), ENA; the number of enterprises after land consolidation (pcs), PNB; the number of parcels before land consolidation (pcs), PNA; the number of parcels after land consolidation (pcs), PAB; parcel area before land consolidation (da), PAA; parcel area after land consolidation (da), PrA; Project area (da), NPEB; the number of parcels per enterprise before land consolidation (pcs), NPEA; the number of parcels per enterprise after land consolidation (pcs), IL; irrigated land (da), AICL; active irrigated cultivated land (da), RLB; road length before land consolidation (km), RLA; road length after land consolidation (km), PCR; the number of parcels directly connected to the road (pcs).

One of the goals of land consolidation is to arrange the parcels in regular geometric shapes. In the research area, the parcels were grouped in three ways as quadrangular-shaped parcels with an acceptable aspect ratio (1/3-1/7), trapezoid-shaped parcels with at least two sides parallel to each other, and shapeless parcels, and the parcel shape was evaluated status before and after consolidation.

3. Results

The parcel status of the Beypınarı before and after the consolidation is given in Figure 1 and Figure 2.

Figure 2. Parceling status of Beypınarı after land consolidation.

The number of enterprises engaged in active agricultural activities in the Beypınarı settlement is 73, and the total number of enterprises registered in agricultural lands is 298. The LCR and NPE values for the Beypınarı project are given in Table 1. The number of parcels in the Beypınarı settlement, which was 1176 before consolidation, decreased to 377, and the consolidation rate was realized as 67.9%. The number of parcels per enterprise decreased both based on agricultural active enterprises and the basis of total enterprises.

Table 1. Land consolidation ratio (LCR) and number of parcels per enterprise (NPE) values for agricultural active and total enterprises

	PNB (pcs)	**LCR (%)**	**NPE***	**NPE****
Before land consolidation	1176	67.9	16.11	3.95
After land consolidation	377		5.16	1.27

* Enterprises currently engaged in agricultural activity, ** Including enterprises that do not reside in Beypınarı and do not engage in agricultural activities.

Information on the size distribution of the parcels and the change parcel area in the study area are given in Table 2. As can be seen from Table 2, the number of parcels according to their sizes is the highest in the I. group land class before and after consolidation. However, after consolidation, there was a decrease in small parcel groups (I. and II. groups) and an increase in other parcel groups. In all of the plots, there was an area increase of 110.35%.

Table 2. Parcel situation before and after land consolidation and average parcel size

	Number of parcel (pcs)				Rates (%)				Average parcel area (da)	PA (%)
Groups	I	II	III	IV	I	II	III	IV		
Before land consolidation	1016	135	16	9	86.4	11.4	1.4	0.8	13.33	110.35
After land consolidation	161	108	61	47	42.7	28.6	16.2	12.5	28.04	

I. group: <15 da, II. group: 16-30 da, III. group: 31-55 da, IV. group: >55 da.

The data obtained for water use (WPR, WUR) efficiency and indicators are given in Table 3. As can be shown from Table 3, the water supply rate has reached 100% with the consolidation project. While the water usage rate was 17.4% before consolidation, this value increased to 26.8% after consolidation.

Table 3. Water use indicators in the research area

	Before land consolidation (2000-2012 years) average	After land consolidation (2013-2019 years) average
Irrigated land (da)	8641.4	15672.7
Active irrigated cultivated land (da)	1505.4	4195.9
Project area(da)	15672.7	15672.7
WPR (%)	55.1	100
WUR (%)	17.4	26.8

The calculated indicators for the road network in the research area are shown in Table 4. The road length, which was 12801 km before consolidation, increased by 34235 km. With land consolidation, road efficiency (the proportion of parcels directly connected to the road) has risen from 52% to 100%.

Table 4. Beypınarı land consolidation project road network efficiency

	Road length (km)	Indicator	PCR	Number of total parcel (pcs)	RE (%)
Before land consolidation	12801	2.674	612	1176	52
After land consolidation	34235		377	377	100

The effect of the Beypınarı consolidation project on the parcel shape and the change that occurred is shown in Table 5. While the rate of shapeless parcels was 66.8% before land consolidation in the research area, this rate decreased to 14.0% after consolidation. The proportion of rectangular parcels increased from 15.4% to 69.0%.

Table 5. Parcel shape distribution of the Beypınarı

Shape group	Before land consolidation (pcs)	Rate (%)	After land consolidation (pcs)	Rate (%)
Quadrangular	181	15.4	260	69.0
Trapezoid	210	17.8	64	17.0
Shapeless	785	66.8	53	14.0

4. Discussion and Conclusion

Rural infrastructure defects such as increased fragmentation, fragmentation of parcels, road inadequacy, loss of time cause delays in planting time and prevent parcels from benefiting from infrastructure facilities (Latruffe and Piet, 2014; Yucer et al., 2016; Kuslu, 2019; Sardar et al., 2019; Ağızan et al., 2020; FAO, 2020; Kuzu and Değirmenci, 2020). At the end of all these, the desired product increase cannot be achieved. For the Beypınarı project, the number of enterprise change (ENR) values was determined as 87.13%. The ENR indicator should have been 100%. In the Beypınarı project, the reason why this ratio is below 100% has been investigated. The main reason for this situation is that the shareholders, who are not engaged in agriculture and do not reside in the Beypınarı, get their shares of lands in cadastral studies (Demirel and Şenol, 2019; Karakayacı, 2019). The fact that the project area borders the Erzurum Airport, which was put into service in 2005, and the Kars-Erzincan ring road are the most important factors. In this way, new enterprises have been created. The fact that the criterion is smaller than 100% indicates that new businesses are set up. Other indicators also need to be evaluated together with ENR.

The consolidation rate is the most known and widely used indicator of project success. As the consolidation rate increases, enterprises management becomes appropriate and the efficiency of land consolidation increases and the activity extends over time. The consolidation ratio of the study area has been calculated as 67.9% (Table 1). The average consolidation ratio in the land consolidation project in Turkey is 42.4% (Sönmezyıldız and Çakmak, 2018). The consolidation ratio of the Beypınarı project appears to be above the average of Turkey. In the enterprises whose main occupation is agriculture, the number of parcels per enterprise decreased from 16.11 to 5.16 after the project (Table 1).

Decreasing the number of parcels belonging to an enterprise increases the parcel size. As can be seen in Table 2, the average parcel size has increased from 13.33 decares to 28.04 decares with the consolidation project. The rate of change has been 110.35%. With the consolidation of Beypınarı, the share of the I. group lands (< 15 da) in total parcels, which was 86.4% before, decreased to 42.7%, while the other groups increased. This shows that consolidation is effective in reducing the number of small size parcels.

Beypınarı irrigation project was carried out with the irrigation of Kuzgun Dam (2002), but the consolidation project was completed at the end of 2012. Since the entire project area was opened to irrigation after the land consolidation project, the WSR value was 100% (Table 3). The water usage rate in the region was 19.63% on average between 2000 and 2019. The lowest water use rate was 13.8% in 2002, the highest water use rate was 33.15% in 2013, during the vegetation period after the completion of the consolidation project. But, the increase did not continue in the following years. The WUR values were realized as 28.3% in 2014, 24.53% in 2016, and 18.54% in 2019. If the irrigation rate is less than 30%, it indicates that the irrigation rate is "weak" (Çakmak and Eminoğlu, 2013). When the reasons for this are investigated, it has been determined that most of the Beypınarı lands are not cultivated, and the rural migration that previously existed has accelerated (Kuslu, 2009;). A similar situation is valid for other countries, and new approaches are needed for land consolidation studies (Akkaya et al., 2018; Büyüktaş et al., 2018; Muchova et al., 2018; Sardar et al., 2020).

One of the aims of land consolidation projects is to provide roads for all parcels. With the land consolidation project in the study area, it was ensured that all parcels benefit from the road network. The

indicator was found as 2.67 and the value greater than one indicates that the road activity is successful (Table 4).

The increase in the number of rectangular and square parcels is one of the indicators of effective consolidation. Before the Beypınarı consolidation, the ratio of quadrangular parcels was 15.4%, after consolidation, this rate increased to 69.0%. Considering that the effect of the parcel shapes on the mechanization tendency is a known fact, it can be concluded that the Beypınarı consolidation project is quite successful in this regard.

Beypınarı Land Consolidation Project has achieved most of its quantitative targets. As a result of the project, the total number of parcels and the number of parcels per enterprise has decreased. However, the average parcel area and the rate of utilization from irrigation drainage and road networks increased. A noticeable improvement in the geometric shapes of the parcels has been observed with the consolidation. However, the goal of increasing irrigation efficiency, one of the most important goals of land consolidation projects, has been insufficient. It has been concluded that the increase of this efficiency is not related to quantitative gains (increasing the irrigation-drainage network), but is closely related to the uncontrolled rural migration of the population engaged in agriculture in Beypınarı.

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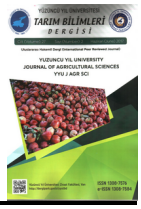

Araştırma Makalesi (Research Article)

Bazı Armut Çeşitlerinin (*Pyrus comminus* L.) Vejetatif Gelişimi Üzerine Su Stresinin Etkisi

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Anahtar Kelimeler

Armut,
Su stresi,
Bitki gelişimi,
Sürgün gelişimi.

Öz: Ülkemizde son yıllarda armut üretim alanları artmış ve yetiştiricilikte farklı gelişim özelliklerine sahip anaç ve yeni çeşitler de kullanılmaya başlanmıştır. Bundan dolayı yeni anaçlar ve çeşitlerin su stresine karşı gösterdikleri tepkilerin belirlenmesine gereksinim duyulmaktadır. Bu amaçlar yürütülen çalışmada OHFx333 anacı üzerine aşılı Deveci, Ankara ve Margarita armut çeşitlerine ait 1 yaşlı fidanlar kullanılmıştır. Deneme Eğirdir Meyvecilik Araştırma Enstitüsü Müdürlüğü'nde yürütülmüştür. Denemede kullanılan saksı harcı 1:1:0.5 oranlarında tınlı toprak:torf:hayvan gübresi karışımından oluşmuştur. Karışım, ağırlıkları bilinen 18 litrelik saksılara eşit miktarlarda konulmuş ve 1 yaşlı armut ağaçlarının dikimi yapılmıştır. Denemede her bir çeşit için 3 farklı sulama konusu yer almıştır. Konular; D_0: her sulamada eksilen nemin saksı tarla kapasitesine getirilmesi, D_1: D_0 uygulamasında saksılara verilen suyun % 50'sinin verilmesi, D_2: D_0 uygulamasında saksılara verilen suyun % 25'inin verilmesi şeklinde oluşturulmuştur. Bitki boyu, bitki ağırlığı, kök ağırlığı, sürgün uzunluğu ve sürgün çapı gelişimleri stres düzeylerinin yoğunluğuna bağlı olarak olumsuz etkilenmiştir. Vejetatif ölçüm sonuçlarına göre OHFx333 anacına aşılı Margarita çeşidinin su stresinden en az etkilenen çeşit olduğu belirlenmiştir.

Effects of Water Stress on Vegetative Development of Some Pear Varieties (*Pyrus comminus* L.)

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Keywords
Pear,
Water stress,
Plant growth,
Shoot development.

Abstract: Pear production areas have been increasing in the last years and rootstocks and new varieties which have different growing characteristics are being used. Therefore, their responses to water stress must be determined. For this purpose, one-year-old Deveci, Ankara, and Margarita pear varieties grafted on OHFx333 rootstock were used in this study. This experiment was conducted at Fruit Research Institute, MAREM, Eğirdir-Isparta, Turkey. The potted mixture used in the study consisted of 1:1:0.5 ratio of soil:peat:manure. The mixture was put into pots having 18 liter volume as equal amounts and one year old pear trees was planted. There were three different water stress treatments in the study for each variety/rootstock combination. The treatments were; D_0: the soil was fully irrigated to reach field capacity in each irrigation; D_1: 50% of D_0; D_2: 25% of D_0, severe stress. Plant height, plant weight, root weight, shoot length, and shoot diameter were affected negatively depending to stress level intensity. According to the results of measurement, it was determined that Margarita variety grafted onto OHFx333 rootstock was least affected by water stress.

1. Giriş

Son yıllarda olumsuz etkilerini daha çok hissettiren küresel iklim değişikliğinin en önemli sonuçlarından birisi, belki de en önemlisi, su kaynakları üzerindeki olumsuz etkileridir. Araştırmacılar yağışların sabit olduğu kabul edildiği durumda bile, küresel ısınmaya bağlı olarak yüzey akışlarının %30 dolayında azalacağını bildirmişlerdir (Önder ve Önder, 2007). Bu konuda son dönemde yapılan araştırmalar, suyun diğer kullanım alanları olan endüstriyel ve evsel kullanım alanlarında su kullanım oranlarının artacağını ve tarımsal sulamada kullanılan su oranının azalacağını bildirmektedir (Coşkun, 2008). Diğer bir deyişle, kullanılabilir su kaynakları miktarının azalmaya başladığı günümüzde, tarımsal üretimi yapılan bitki türlerinin yakın zamanda su azlığı ile karşılaşma ihtimali yüksektir.

Kullanılabilir su kaynakları miktarı sadece tarımsal üretim için değil diğer sektörler için de gün geçtikçe azalmaktadır. Bu nedenle suyu kullanırken çok daha dikkatli olunmalıdır. Tarımsal üretimde kullanılan suyun miktarı çok olduğu için kuraklık stresi ile ilgili çalışmalar daha da önem kazanmaktadır (FAO, 2011). Su kıtlığının artması bitkisel üretim için ciddi bir çevresel kısıtlamadır (Farooq ve ark., 2009).

Meyveler tarımsal üretimin yanında insan sağlığı için de önemlidir. Armut elmadan sonra yaygın olarak yetiştirilen bir meyvedir. 2018 yılı üretim rakamlarına göre toplam armut üretimi 23.852.421 ton olarak gerçeklemiştir. Türkiye armut üretiminde 519.451 ton/yıl ile 5. Sırada yer almaktadır (FAO, 2020). Son yıllarda meyve yetiştiriciliğinde farklı anaçlar ve yeni çeşitler kullanılmaya başlanılmıştır. Armut yetiştiriciliğinde de farklı gelişme gücüne sahip anaçlar ve çeşitler kullanılmaktadır. Armut ağaçları büyüme ve gelişmeleri için suya ihtiyaç duyarlar. Bu nedenle, anaçlar ve çeşitler arasında su stresi ilişkisi konusunda gerekli araştırmaların yapılmasına ihtiyaç vardır. OHxF 333 armut yetiştiriciliğinde yaygın kullanılan anaçlardan biridir (Hepaksoy, 2019). Bundan dolayı bu çalışmada bu anaç tercih edilmiştir.

Armut yetiştiriciliğinde ticari sürdürülebilirliğin sağlanmasında su en önemli faktördür. Son yıllarda, Türkiye gibi kuraklık tehdidi altındaki ülkeler kuraklık stresi ile su stresi ile ilgili çalışmalar ivme kazanmıştır. Meyve ağaçlarının kuraklığa tepkisini sadece anaçlar değil çeşitler de etkileyebilir.

Bir bitkinin kuraklığa dayanıklılığı sadece kök sisteminin genişliği ile ilgili değil, aynı zamanda büyüme ve gelişme gücü, dal yapısı ve yaprak özellikleri ile de ilgilidir. Ancak, bitkiler kuraklık stresinin üstesinden sadece toprak nem koşullarından kaynaklanan kök gelişimi ve emiş gücü farklılıkları ile gelemezler. Ağacın aşı noktasının üstündeki gövde, sürgün gibi organlar da su stresiyle başa çıkmada önemli rol oynarlar (Eriş, 2007). O nedenle anaçlara ek olarak çeşitler-kuraklık arasındaki ilişkiler de araştırılmalıdır.

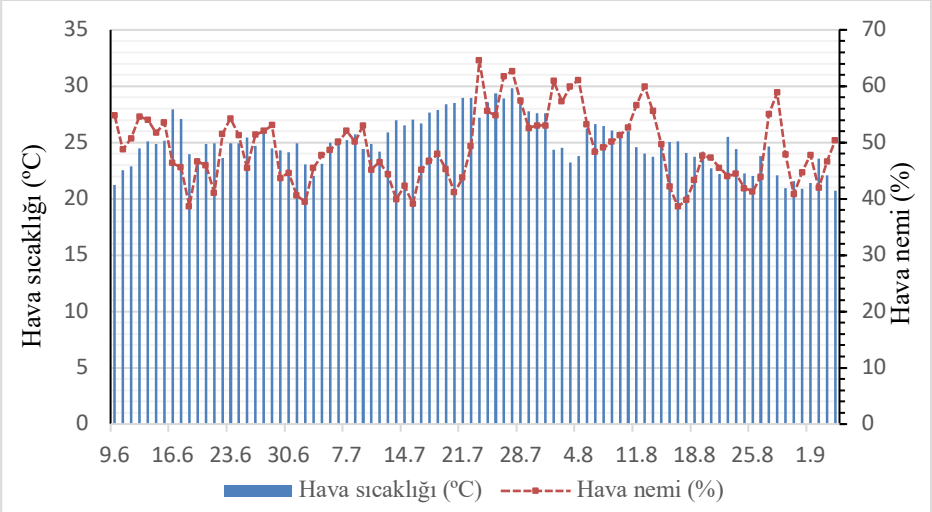
Bu çalışmada OHxF 333 anacı üzerine aşılı Deveci, Ankara ve Margarita armut çeşitlerinin farklı su stresi seviyelerine tepkilerini belirlemek amaçlanmıştır.

2. Materyal ve Yöntem

2.1. Deneme alanı ve bitkisel materyal

Bu çalışma Meyvecilik Araştırma Enstitüsü (Eğirdir,Isparta) deneme alanında bulunan yarı açık (ısıtmasız) seralarda 2017 yılında yürütülmüştür. Denemede, OHxF 333 anacına aşılı 1 yaşlı Deveci (*Pyrus Comminus L.* "Deveci"), Ankara (*Pyrus comminus L.* "Ankara") ve Margarita (*Pyrus comminus L.* "Margarita") çeşitleri kullanılmıştır. Ankara ve Deveci armut çeşitlerinin kullanılmasının sebebi; Türkiye'de armut yetiştiriciliğinde yüksek oranda kullanılmasıdır (Özaydın ve Özçelik, 2014; Sakaldaş ve Gündoğdu, 2016). Margarita ise bu çeşitlere göre yeni ve armut yetiştiriciliğinde ümitvar bir çeşit olduğu için seçilmiştir.

Ağaçlar Nisan ayı başında saksılara dikilmiştir. Deneme başlamadan önce dikim için benzer gelişme gücüne sahip ağaçların seçilmesine dikkat edilmiştir. Deneme konularının haricinde, saksı harcının tarla kapasitesini belirlemek için, içinde saksı harcı olan 5 adet bitkisiz saksı hazırlanmıştır. Saksıların tümü, yağmurun etkisinden korunmak için üstü şeffaf plastik ile kaplı, yan kenarları açık olan yarı açık plastik sera içerisine konmuştur. Yarı açık sera içerisinde deneme alanına ait hava sıcaklığı ve nem değerlerini kaydetmek için Hobo cihazı kullanılmıştır. Deneme süresince kaydedilen hava sıcaklığı ve nem değerleri Şekil 1'de gösterilmiştir.



Şekil 1. Denemenin yürütüldüğü alana ait hava sıcaklığı ve hava nemi değerleri.

2.2. Denemede kullanılan sulama suyu ve saksı harcı

Denemede kullanılan saksı harcı 1:1:0.5 oranlarında torf:tınlı toprak:hayvan gübresinin karışımından oluşmuştur. Karışım, ağırlıkları bilinen 18 litrelik saksılara eşit miktarlarda konulmuş ve 1 yaşlı armut ağaçlarının dikimi yapılmıştır. Meyvecilik Araştırma Enstitüsü arazisi içinde bulunan sulama kuyusundan sağlanan su ile sulama yapılmıştır. Sulama suyu, ABD Tuzluluk Laboratuvarı Grafik Sistemine göre C_2S_1 sınıfında (tuzluluk: 0.310 dS/m, SAR:1.04) (USSL 1954) olup sulama için elverişlidir.

2.3. Deneme konuları, sulama suyu ve bitki su tüketiminin belirlenmesi

Deneme başlamadan önce, her bir saksıya uygulanacak sulama suyu miktarını belirlemek için saksı içindeki harç karışımlarına ait tarla kapasitesi değeri belirlenmiştir. Bunun için deneme kurulmadan önce içine dikim yapılmayan ve harç bulunan 5 adet saksıya yavaş yavaş su eklenmiş, bu işlem sızma olana kadar devam etmiştir. Sızma işlemi sona erdikten sonra saksılara yavaş yavaş su ekleme işi birkaç kez daha tekrarlanmıştır. Daha sonra alüminyum folyo ile buharlaşmayı önlemek için saksıların üzeri örtülmüştür. Bu işlemden 48 saat sonra saksıların ortalaması alınarak tarla kapasitesi değeri belirlenmiştir. Bu değere saksı ağırlıkları ve her bir çeşide ait fidanların dikim sırasındaki ağırlıkları eklenerek, bulunan değer her bir saksıya ait tarla kapasitesi olarak kaydedilmiştir.

Denemede sulama aralığı 4 gün olarak belirlenmiş, her sulamada her saksı tarla kapasitesine getirilene kadar sulama suyu uygulanmıştır. Deneme 3 Temmuz 2017 tarihinde başlanmış, dikimden deneme başlangıç tarihine kadar her saksıdaki ağaçlar tarla kapasitesine getirilene kadar sulama yapılmıştır. Stres uygulamalarına 11 Eylül 2017 tarihinde son verilmiş, stres uygulamaları 70 gün sürmüştür.

Denemede her bir çeşit için 3 farklı sulama konusu yer almıştır. Konular; D_0: her bir sulamada saksı harcında eksilen nemin saksı tarla kapasitesine gelene kadar sulanması, D_1: 1. D_0 konusunda saksılara uygulanan su miktarının %50'sinin verilmesi, D_2: D_0 konusunda saksılara uygulanan su miktarının %25'inin verilmesi şeklinde oluşturulmuştur. D_0 konusundaki saksılar her sulama öncesi tartılmış, eksilen su 2 l hacimli bir mezür (50 ml hassas) yardımıyla saksılara verilmiş, D_0 konusundaki her bir saksıya ait mevcut nem miktarı tarla kapasitesine getirilene kadar sulama yapılmıştır. D_0 konusunda yer alan saksılara uygulanan su miktarlarının ortalaması alınmış, diğer konulara uygulanan su miktarları için bu ortalama değerler dikkate alınmıştır. Her bir saksının altında bulunan tabağa su sızması durumunda bu su tekrar saksı içerisine eklenmiştir.

Her bir konuya ait toplam sulama suyu miktarının belirlenmesi için her sulamada uygulanan su miktarları toplanmış ve l/bitki cinsinden hesaplanmıştır. Su stresi uygulamalarının başladığı 3 Temmuz tarihine kadar tüm konularda yer alan saksılardaki eksik nem tarla kapasitesine gelene kadar su uygulanmıştır. Uygulanan bu miktarlar bitki su tüketimi hesaplamalarında dikkate alınmıştır.

Su stresi uygulamalarının başladıktan sonra 10 günlük dönemler halinde hesaplanan bitki su tüketimi için Eşitlik (1) kullanılmıştır (Pouyafard, 2013).

$$ET_{10\ gün} = T_1 + I - T_2 \quad (1)$$

Eşitlikte;

$ET_{10gün}$= 10 günlük bitki su tüketimi (gr),
T_1 = Bir önceki tartım değeri (gr),
I = İki ölçüm arasında sulama ile uygulanan su miktarı (gr),
T_2 = Son ölçümdeki tartım değeri (gr)

Hesaplanan bitki su tüketimi değerleri ağırlık cinsinden bulunmuş, sonrasında hacme çevrilerek l/bitki cinsinden verilmiştir.

2.4. Vejetatif Ölçümler

Farklı su stresi düzeylerinin ağaçların gelişimine etkilerini belirlemek amacıyla tüm vejetatif ölçümler her tekerrürde seçilen 1 adet fidanda yapılmıştır.

Bitki boyu: Her ağaç için aşı noktasından fidanın en üst noktasına kadar olan mesafe şerit metre ile ölçülmüştür. Ağaçların gelişim dönemi süresince 4 Temmuz, 20 Temmuz, 3 Ağustos ve 11 Eylül olmak üzere 4 defa ölçüm yapılmıştır.

Bitki ve kök ağırlıkları: Deneme sonunda, ölçüm yapılacak ağaçlar söküldükten ve kök sistemlerindeki topraklar temizlendikten sonra 0.1 g hassasiyetli terazide ağırlıkları tartılarak bitki ağırlığı değerleri belirlenmiştir. Daha sonra kök boğazının hemen üzerinden kökler kesilmiş ve tartım yapılarak kök ağırlıkları belirlenmiştir.

Sürgün uzunluğu: Stres konularının uygulanmaya başladığı tarihten itibaren 4 Temmuz, 3 Ağustos ve 11 Eylül tarihlerinde olmak üzere deneme süresince 3 defa ölçüm yapılmıştır. Ölçümler için, her tekerrürden bir fidan seçilmiş, fidanda tüm sürgünlerin gövdeye bağlandığı yerden en uç noktasına kadar olan mesafe ölçülmüştür. Ölçümler şerit metre ile cm cinsinden yapılmıştır.

Sürgün çapı: Stres konularının uygulanmaya başladığı tarihten itibaren 4 Temmuz, 3 Ağustos ve 11 Eylül tarihlerinde olmak üzere deneme süresince 3 defa ölçüm yapılmıştır. Ölçümlerde sürgün uzunluğu ölçümü için seçilen fidanlar kullanılmış, sürgün çapı ölçümü için sürgünlerin gövdeye bağlandığı yerden itibaren 5. cm'de ölçümler yapılmıştır. Ölçümlerde dijital kumpas kullanılmış, mm cinsinden ölçümler gerçekleştirilmiştir.

2.5. Deneme deseni ve istatistiksel analiz

Deneme Tesadüf Parsellerinde Faktöriyel Deneme Desenine göre düzenlenmiştir. Denemede her konuda 3 tekerrür, her tekerrürde ise 3'er adet fidan olacak şekilde planlama yapılmıştır.

Denemeden elde edilen veriler JUMP istatistik paket programı kullanılarak varyans analizine tabi tutulmuş, uygulamalar arasındaki farklılıklar LSD çoklu karşılaştırma testine göre değerlendirilmiştir.

Metin içerisinde çeşit/anaç kombinasyonlarından bahsedilirken; Deveci/OHxF 333 çeşit/anaç kombinasyonu "Deveci", Ankara/OHxF 333 çeşit/anaç kombinasyonu "Ankara" ve Margarita/OHxF 333 çeşit/anaç kombinasyonu ise "Margarita" olarak isimleri kullanılmıştır.

3. Bulgular ve Tartışma

3.1. Bitki su tüketimi

Her bir çeşit için konulara ait bitki su tüketimi değerleri Çizelge 1'de gösterilmiştir. En yüksek su tüketimi Deveci çeşidinden (46.9 l) elde edilirken, Ankara ve Margarita çeşitlerine ait değerler birbirine yakın olmuştur (sırasıyla 42.4 l ve 42.0 l). Çeşitlerin gelişim gücünün ve vejetatif gelişimlerinin farklı olması su tüketimi değerlerini etkilemiştir (Küçükyumuk ve ark., 2015a). Uygulanan sulama suyu miktarı azaldıkça ağaçların su tüketimi değerleri tüm çeşitlerde azalmıştır. Armutta yapılan çalışmalarda

da uygulanan sulama suyu miktarına göre bitki su tüketimi azalmıştır (Kang ve ark., 2002; Gençoğlan ve Gençoğlan, 2018).

Çizelge 1. Konulara ait bitki su tüketimi değerleri (l/ağaç)

Çeşitler	**Uygulamalar**		
	D_0	D_1	D_2
Deveci	46.9	30.5	23.2
Ankara	42.4	27.3	20.3
Margarita	42.0	26.9	21.0

3.2. Bitki boyu

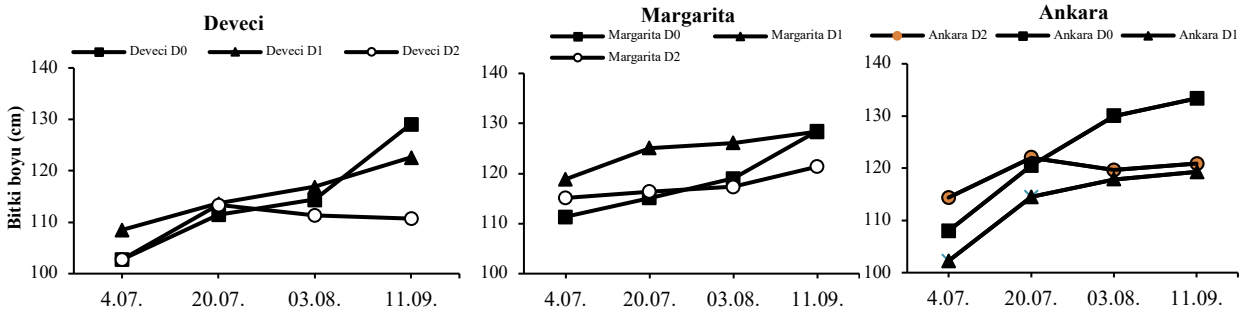
Çeşitlerin bitki boyu gelişimleri farklı olmuştur (Çizelge 2). Çeşitler kendi içerisinde uygulamaların etkisi dikkate alınarak incelendiğinde, su stresi uygulamalarının istatistiksel olarak % 1 (Deveci ve Ankara çeşitleri) ve % 5 düzeyinde (Margarita çeşidi) önemli olduğu görülmüştür. Her bir çeşit için istatistiksel olarak 2 farklı grup olmuştur. Deveci ve Margarita çeşitlerinde D_1 (% 50 su kısıtı) konusunda yer alan fidanların boyları kontrol konusundaki fidanlarla aynı grupta yer almıştır. Ankara çeşidinde ise % 50 (D_1) ve % 75 (D_2) su kısıtı konularının bitki boyu üzerindeki etkileri aynı olmuştur. Konular kendi arasında değerlendirildiğinde, aynı konularda yer alan çeşitlerde ise sadece % 75 su kısıntısının yapıldığı konuda (D_2) istatistiksel olarak farklılık olmuş, diğer uygulamalar için çeşitler arasında fark oluşmamıştır. En düşük bitki boyu değeri 110.8 cm ile D_2 konusunda Deveci çeşidinden elde edilmiştir. Ankara ve Margarita çeşitleri aynı grupta yer almıştır.

Dikim sırasında tüm fidanlarda eşit uzunlukta tepe kesimi yapıldığı için deneme başlangıç boyları birbirine yakındır. Bundan dolayı uygulamaların bitki boyuna etkileri net görülebilmiştir. Bitki boyundaki en yüksek artış değerleri, su kısıtı olmayan konular arasında Deveci ve Ankara çeşitlerinden (% 25,7 ve % 23.5) elde edilmiştir. % 75 su kısıtı uygulanan (D_2) konular arasında en düşük bitki boyu artış değerleri % 5.4 ve % 5.7 ile sırasıyla Margarita ve Ankara çeşitlerinden elde edilmiştir. Genç meyve ağaçlarında yapılan su stresi çalışmalarında su kısıtının bitki boyunu azalttığı bildirilmiştir (Kaya, 2012; Reddy ve ark., 2004; Gür ve Şan, 2017).

Çizelge 2. Armut çeşitlerine ait bitki boyları

Çeşitler	**Bitki boyu (cm)**		
	D_0	D_1	D_2
Deveci	129.1 A***öd*	122.6 A*öd*	110.8 Bb*
Ankara	133.4 A**	109.3 B	120.9 Ba
Margarita	128.5 A*	128.4 A	121.4 Ba

Büyük harfler uygulamalar arası farklılıkları, küçük harfler ise çeşitler arası farklılıkları gösterir.
**Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.01$).
*Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.05$).
öd önemli değil.



Şekil 2. Bitki boyunun dönemsel değişimi ve artış oranları (kutucuklarda gösterilen).

3.3. Bitki Ağırlıkları

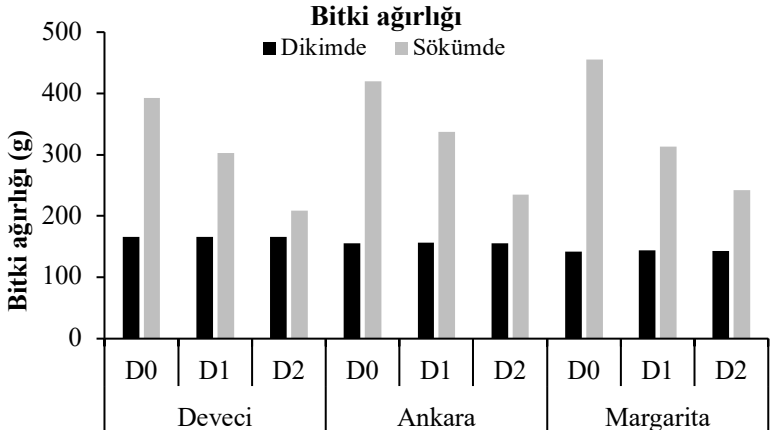
Su stresi uygulamalarının bitki ağırlığı değerlerine etkisini net olarak belirleyebilmek için deneme kurulma aşamasında tüm fidanlar aynı noktadan tepe kesimi yapılarak tartılmış, ağırlık değerleri birbirine yakın olan fidanlar seçilmiştir (Şekil 3). Çeşitler kendi içerisinde değerlendirildiğinde, her uygulama istatistiksel olarak farklı grupta yer almıştır (Çizelge 3).

Uygulamalar dikkate alındığında, Ankara çeşidi her iki su stresi konusunda da ilk grupta yer almış, Deveci çeşidi her iki su stresi uygulamasında da 2. grupta yer almıştır. Artış oranlarına göre, tüm konularda en düşük değerler Deveci çeşidinden elde edilmiştir.

Çizelge 3. Bitki ağırlığı ölçüm sonuçları ve artış oranları

Çeşitler		**Bitki ağırlığı (g)**		
		D_0	D_1	D_2
Deveci		392.5 A***öd*	302.5 Bb*	208.8 Cb**
	Artış oranı (%)	136.1	82.2	26.1
Ankara		420.0 A**	337.5 Ba	235.0 Ca
	Artış oranı (%)	169.9	115.4	50.6
Margarita		455.0 A**	313.8 Bb	242.5 Ca
	Artış oranı (%)	220.4	118.2	69.0

Büyük harfler uygulamalar arası farklılıkları, küçük harfler ise çeşitler arası farklılıkları gösterir.
**Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.01$).
öd önemli değil.



Şekil 3. Dikimde ve sökümde bitki ağırlıkları.

3.4. Kök Ağırlıkları

Su stresi uygulamalarının kök ağırlığı değerlerine etkisini net olarak belirleyebilmek için deneme kurulma aşamasında dikimden önce tüm fidanlarda eşit oranda kök budaması yapılmıştır. Çeşitler kendi arasında uygulamalar dikkate alınarak değerlendirildiğinde, kök ağırlığı değerleri üzerinde su kısıtı uygulamalarının etkisi istatistiksel olarak önemli bulunmuştur ($p<0.01$ ve $p<0.05$). % 50 su kısıtının (D_2) Deveci ve Ankara çeşitlerinde kök gelişimini azaltıcı olumsuz bir etki yapmadığı belirlenmiştir (Çizelge 4). Su stresi uygulanmayan konular ile % 50 su kısıtı konuları bu çeşitlerde istatistiksel olarak aynı grupta yer almıştır. Margarita çeşidinde ise % 50 ve % 75 su kısıtı konuları (D_2 ve D_3) istatistiksel olarak aynı grupta yer almıştır.

Her bir uygulama kendi arasında çeşitler dikkate alınarak değerlendirildiğinde ise, her iki su kısıtı uygulamasında (D_1 ve D_2) Ankara çeşidi en yüksek kök gelişimi gösteren çeşit olmuştur. OHFx333 anacı üzerine aşılı Deveci ve Ankara çeşitlerinin erken yaşlarda bile orta derecede şiddetli su stresi durumunda (% 50 su kısıtı-D_2 konusu) kök ağırlıklarını artırma özelliklerine sahip oldukları belirlenmiştir. Bu sonuç, arazi koşullarında bu çeşide ait ağaçların etkili kök bölgelerinde suyun azalması durumunda kök gelişimini artırarak daha geniş bir alanda suya ulaşabileceğini gösterir.

Çizelge 4. Kök ağırlığı ölçüm sonuçları

Çeşitler	Kök ağırlığı (g)		
	D_0	D_1	D_2
Deveci	37.5 A***öd*	40.0 Aab*	12.5 Bb*
Ankara	45.0 A*	52.5 Aa	22.5 Ba
Margarita	52.5 A**	27.5 Bb	17.5 Bab

Büyük harfler uygulamalar arası farklılıkları, küçük harfler ise çeşitler arası farklılıkları gösterir.
**Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.01$).
*Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.05$).
öd önemli değil.

Farklı oranlarda uygulanan su stresi uygulamaları çeşitlere göre değişen oranlarda olsa da bitki ve kök ağırlığını etkilemiştir. Kurak koşulların oluştuğu ilk dönemlerde, bitki daha fazla suya ulaşabilmek için kök gelişimini tetikler (Öztürk, 2015). Bu durum Deveci ve Ankara çeşitlerinde belirlenmiş, % 50 su kısıtında bu çeşitlere ait kökler suyu bulmak amacıyla kontrol konusuna göre daha fazla gelişim göstermişlerdir. Buna karşın, kurak koşulların bitkide hasara yol açabilecek kadar şiddetli olması durumunda kök gelişimi yavaşlar veya durur (Farooq ve ark., 2009; Kamiloğlu ve ark., 2014, Öztürk, 2015).) Su stresi vejetatif gelişim üzerinde de olumsuz etkiye sahiptir, hücre büyümesi ve bölünmesi üzerinde olumsuz etki oluşturarak vejetatif gelişmeyi (bitki boyu, kök gelişimi vb.) engeller (Robinson ve Barrit, 1990; Kaynaş ve ark., 1997; Eriş ve ark., 1998; Özyurt, 2011).

3.5. Sürgün Uzunluğu ve Çapı

Su stresi uygulamalarının sürgün uzunluğuna etkisi istatistiksel olarak önemli bulunmuş ($p<0.01$ ve $p<0.05$), sürgün uzunluğu su stresi uygulamalarından olumsuz etkilenmiştir, kısıt miktarı arttıkça sürgün gelişimi azalmıştır (Çizelge 5). Sürgün uzunluğu değerlerine göre çeşitler kendi içerisinde uygulamalar dikkate alınarak değerlendirildiğinde Margarita çeşidinde % 50 ve % 25 su kısıtının aynı etkiye sahip olduğu görülmüştür.

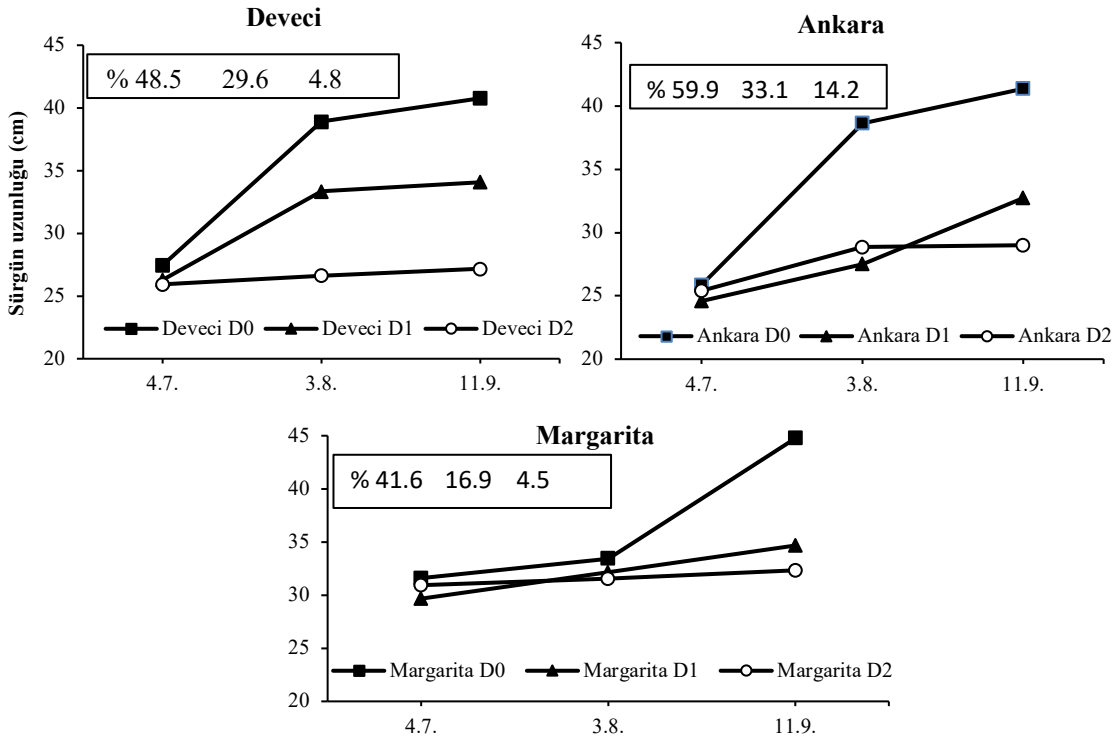
Her bir uygulama kendi arasında çeşitler dikkate alınarak değerlendirildiğinde, su stresi uygulanmayan konulardan (D_0) her üç çeşit için birbirine yakın sürgün gelişimi değerleri elde edilmiştir. D_0 ve D_1 konularında çeşitler arasında istatistiksel olarak farklılık bulunmadığı % 75 su kısıtının uygulandığı konuda ise (D_2) Deveci ve Ankara çeşitlerine ait sürgün uzunluğu değerlerinin aynı grupta yer aldığı görülmüştür.

Su stresi uygulamalarının başladığı tarihten itibaren 3 farklı tarihte (4 Temmuz, 3Ağustos ve 11 Eylül) sürgün uzunlukları ölçülmüş, dönem süresince yapılan ölçümler ve artış oranları Şekil 4'te verilmiştir. Buna göre en yüksek artış oranı su stresi uygulanmayan konularda % 59.9 ile Ankara çeşidinden elde edilmiştir. Tüm konularda en yüksek sürgün uzunluğu değerleri Ankara çeşidinden elde edilmiştir. Su kısıtı miktarı arttıkça sürgün gelişimi azalmıştır. En düşük artış oranları D_2 konusunda Deveci ve Margarita çeşitlerinde belirlenmiştir (sırasıyla % 4,8 ve % 4.5). Dönem boyunca yapılan ölçümler incelendiğinde D_2 konusunda adı geçen çeşitlerde sürgün gelişiminin daha durağan olduğu görülmüştür. Sürgün uzunluğu değerleri, su stresi uygulanmaya başladıktan 30 gün sonra (4 Ağustos) daha etkili olmuş, D_1 ve D_2 konularındaki ağaçlarda sürgün gelişimi yavaşlamıştır. Bu sonuç, yetişme ortamında elverişli su miktarının azalmasıyla da ilgilidir (Küçükyumuk ve ark., 2015b).

Çizelge 5. Denemeden elde edilen sürgün uzunluğu değerleri

Çeşitler	Sürgün uzunluğu (cm)		
	D_0	D_1	D_2
Deveci	41.9 A***öd*	34.0 AB*öd*	27.2 Bb*
Ankara	41.4 A*	32.4 AB	28.9 Bb
Margarita	44.8 A**	34.8 B	32.7 Ba

Büyük harfler uygulamalar arası farklılıkları, küçük harfler ise çeşitler arası farklılıkları gösterir.
**Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.01$).
*Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.05$).
öd önemli değil.



Şekil 4. Sürgün uzunluğunun dönemsel değişimi ve artış oranları (kutucuklarda gösterilen).

Su stresi uygulamalarının sürgün çapı gelişimine etkisi sürgün uzunluğuna benzer olmuş, istatistiksel olarak önemli bulunmuştur ($p<0.01$ ve $p<0.05$). Çeşitlere kendi içerisinde uygulamaların etkisi dikkate alındığında, her bir farklı su stres düzeyinin istatistiksel olarak etkisine göre farklı gruplarda yer aldığı belirlenmiştir. Bu sonuç, etkili kök bölgesinde toprak nemi seviyesinde azalma olduğu durumlarda, su eksikliğinin sürgün çapı üzerinde etkili olduğunu gösterir. Her bir uygulama için çeşitler değerlendirildiğinde, Margarita çeşidinin su stresi uygulamalarında en yüksek değerleri verdiği belirlenmiştir.

Sürgün çapı artış oranları su stresi olmayan konularda birbirine yakın değerler göstermiştir. % 50 su kısıtı uygulanan konularda sürgün çapı su stresi uygulamalarından 30 gün sonra daha durağan bir gelişme göstermiştir. Tüm çeşitler için D_2 stres uygulamasında yer alan ağaçlara ait sürgün çapı değerleri azalma göstermiştir. Bu değer Deveci ve Ankara çeşitlerinde en fazla olmuştur (sırasıyla % -9.6 ve % -9.3). Sharma ve Sharma (2008) ve Bolat ve ark. (2014) armutta su stresinin sürgün çapında azalmaya neden olduğunu bildirmişlerdir.

Çizelge 6. Denemeden elde edilen sürgün çapı değerleri

Çeşitler	Sürgün çapı (mm)		
	D_0	D_1	D_2
Deveci	6.54 A***öd*	4.73 Bb*	3.97 Cb**
Ankara	6.84 A**	5.35 Bab	4.34 Cb
Margarita	7.04 A**	5.93 Ba	4.84 Ca

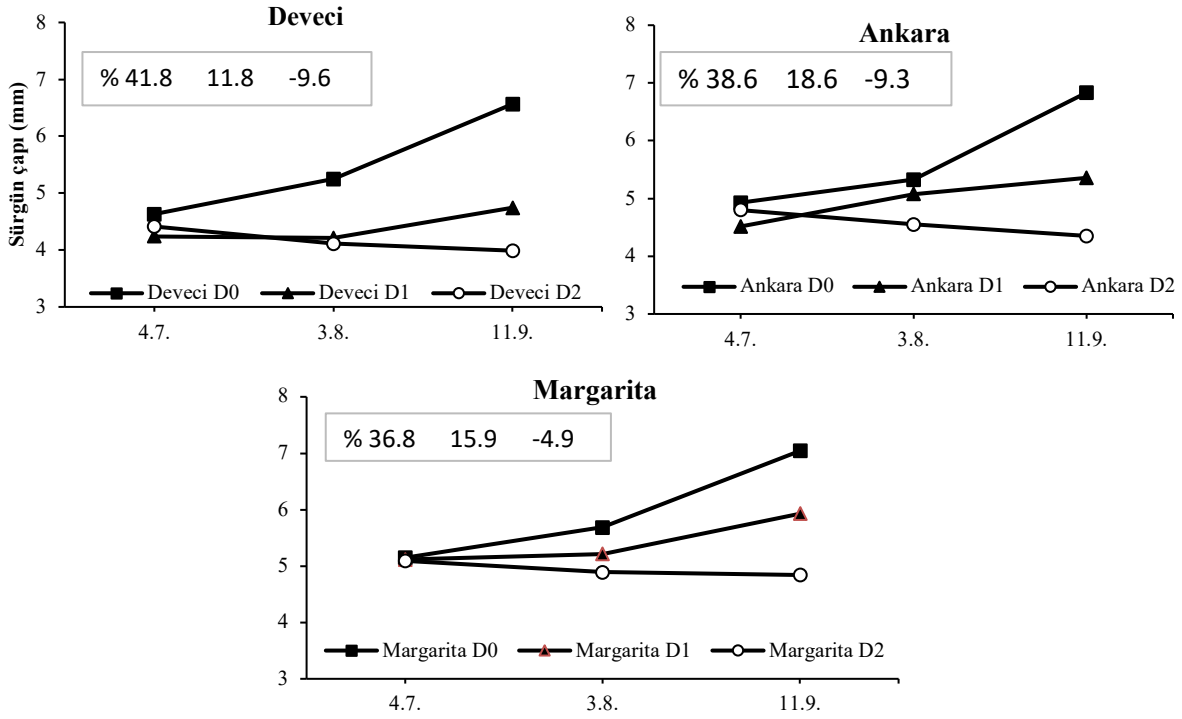
Büyük harfler uygulamalar arası farklılıkları, küçük harfler ise çeşitler arası farklılıkları gösterir.
**Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.01$).
*Aynı sütunda ve aynı satırda farklı harflerle gösterilen ortalamalar arası fark önemlidir ($p<0.05$).
öd önemli değil.

Sivritepe ve ark. (2008), Correa-Tedesco ve ark. (2010) ve Bolat ve ark. (2014) su stresi uygulamalarının meyve ağaçlarında sürgün gelişimini azalttığını bildirmiştir.

Bitkinin yetişme dönemi boyunca, etkili kök bölgesi olarak adlandırılan bölgede bitki tarafından alınabilen elverişli nem miktarının azaldığı durumlarda köklerin su alımı azalır. Su stresi sonunda bitki hücrelerinde hücre su potansiyelinin azalması, turgor basıncının azalması vb. birtakım olaylar meydana

gelir. Bu olayların sonucu olarak bitkilerde büyüme hızı yavaşlar ve vejetatif gelişim olumsuz etkilenir (Kocaçalışkan 2005).

Armutun da içinde bulunduğu ılıman iklim meyve türleri dikim yılından itibaren yoğun vejetatif gelişim gösterirler. Bu nedenle bu çalışmada vejetatif gelişim parametreleri dikkate alınmıştır. Etkili kök bölgesinde toprak neminin azalmasıyla birlikte bitki gelişimlerinde azalmalar gözlenmiştir. Farklı oranlarda yapılan su stresi uygulamaları sadece bir parametreyi değil genç meyve ağaçlarının tüm vejetatif gelişiminde etkili olmuştur. Buradan çıkacak sonuç; su stresi tek bir organı ya da parametreyi değil, ağacın tamamını etkilemiştir. Yani suyun bitkiye girdiği köklerden itibaren suyun ulaştığı en uç noktasına kadar su stresi etkili olmuştur.



Şekil 5. Sürgün çapının dönemsel değişimi ve artış oranları (kutucuklarda gösterilen).

Bu tip çalışmalarda amaç; su stresinin etkilerini belirlemek, anaç ve çeşitler arasında en az etkilenen kombinasyonu tespit etmek, bunları armut yetiştiriciliği yapılan bölgelerde özelikle yeni dikim yapılan alanlarda su kaynaklarının durumuyla ilişkilendirmek ve nihai olarak üreticilere tavsiye etmektir. Bunlara ek olarak meyve ağaçlarının sadece vejetatif değil ürün verdiği dönemlerin yani ileriki dönemleri için de bu tip çalışmaların yapılması muhakkak önem taşımaktadır.

4. Sonuç

Armut yetiştiriciliğine olan talebin artması nedeniyle farklı gelişim özelliklerine sahip anaçların yanı sıra yeni çeşitler de üreticiler tarafından kullanılmaya başlanılmıştır. Meyve yetiştiriciliğinde anaç-su ilişkilerinin iyi irdelenmesi, hali hazırda elverişli su kaynakları bakımından sınırlı bir miktara sahip olan ülkemiz tarımsal üretimi için büyük önem taşımaktadır. Armut yetiştiriciliği yapılan bölgelerde kullanılan anacın yanında çeşitlerin özelliklerinin de yani çeşit/anaç kombinasyonunun suya karşı tepkilerinin bilinmesi su kaynakları kullanımının planlanması ve verimli kullanılması açısından önemlidir. OHFx333 anacı üzerine aşılı Deveci, Ankara ve Margarita çeşitlerinin bitki su tüketimi ve vejetatif gelişimi üzerine su stresinin etkilerinin incelendiği bu çalışmada; anaç aynı olsa dahi çeşitlerin su stresine karşı gösterdikleri tepkilerin farklı olduğu belirlenmiştir. Su stresi uygulamalarının yoğunluğuna bağlı olarak denemede ölçülen tüm parametreler olumsuz etkilenmişlerdir. Vejetatif ölçüm sonuçlarına göre OHFx333 anacına aşılı Margarita çeşidinin su stresinden en az etkilenen çeşit olduğu belirlenmiştir. Su stresine karşı göstermiş oldukları dayanıklılık bakımından OHFx333 anacı üzerine aşılı armut çeşitlerinin sıralaması Margarita, Ankara, Deveci şeklinde olmuştur. Çalışma sonucuna göre

su kısıtı olan bölgelerde sözü edilen çeşitlerden OHFx333 anacı üzerine aşılı Margarita çeşidi armut üreticilerine tavsiye edilebilir.

Bu çalışmadan elde edilen sonuçlar armut ağaçlarının ilk gelişim yıllarına ait olduğundan, benzer çalışmaların ekonomik verim çağındaki aynı çeşit/anaç kombinasyonlarında da tekrarlanması yerinde olacaktır.

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Araştırma Makalesi (Research Article)

Seed Storability and Genetic Parameters Estimation on Accelerated Aging Seed of Argomulyo Soybean (*Glycine max* (L.) Merr.) Mutant Lines

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Abstract: Seed storability of 22 selected soybean mutant lines from Argomulyo population irradiated by gamma ray were assessed by rapid aging tool, APC-IPB 77-1MM. Seed viability and vigor parameter observed due to genetic factors. The 90% ethanol was applied for 20, 40, 60 and 80 min as accelerated aging test. M100-96-53-6 was estimated that has good storability with less seed deterioration rate expressed by slow slope of germination percentage, germination speed and electrical resistance value after 20-80 min of chemical accelerated aging. Electrical resistance (ER) test could be as alternative and a substitute of electrical conductance (EC) test as alternative of vigor test. The high heritability and moderate to high genetic advance were noted on all parameters except moisture content. Germination percentage and germination speed could be reviewed for early stage selection to improve traits at the next generation based on R-square value of regresion and genetic parameters obtained.

Hızlandırılmıs Yaşlandırma Yapılan Argomulyo Soybean (*Glycine max* (L.) Merr.) Mutant Hatlarına Ait Tohumların Depolanabirliği ve Genetik Parametrelerinin Belirlenmesi**

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Anahtar Kelimeler
Etanol,
Genetik,
Baklagil,
Canlılık,
Vigor (Güç)

Özet: Gama ışını ile ışınlanmış olan Argomulyo popülasyonundan seçilen 22 soya fasulyesi mutant hatlarının tohum depolanabilirliği, APC-IPB 77-1MM olarak bilinen hızlı yaşlandırma aleti ile değerlendirilmiştir. Hızlandırılmış yaşlandırma testinde 20, 40, 60 ve 80 dakika içinde uygulanarak % 90 etanol kullanılmıştır. M100-96-53-6 'nın 20-80 dakika kimyasal hızlandırılmış yaşlandırma yapıldıktan sonra tohumun çimlenme oranı, çimlenme hızı ve elektriksel direnç değerinde yavaşlama eğilimi gösterilerek daha az tohum bozulma oranının yanı sıra iyi depolanabilirliğe sahip olduğu tahmin edilmiştir. Vigor (güç) testi için elektrik iletkenliği (EC) testi yerine bir alternatif olarak elektrik direnci (ER) testi kullanılabilmektedir. Nem içeriği hariç tüm parametrelerde bitkilerin kalıtım derecesi yüksek ve genetik ilerleme orta ila yüksek olduğu kaydedilmiştir. Regresyonun elde edilen R-kare değeri ve genetik parametreler değeri bakımından sonraki nesilde özellikleri iyileştirme amacıyla seçime (seleksiyona) ilk aşama için tohumun çimlenme oranı ve çimlenme hızı gözden geçirilebilmektedir.

** This article extracted from B.Sc. thesis of Siti MAESAROH.

1. Introduction

Soybean, as source of functional food, containing about 37% of vegetable protein is one of the important legume crops in Indonesia with 0.539 million tons in 2017 (Ministry of Agriculture, 2018). It can be used as raw material due to about 25% of its oil content (Pereira et al., 2011). The supply of soybean in Indonesia is only about 30% of national demand per annum due to low productivity with 1-1.5 ton/ha productivity. National production is reducing day after day with every increase in the national (BPS, 2015).

High production and productivity to achieve soybean self-sufficiency must be supported by supplying superior varieties with high quality seeds. Mutation breeding providing a source of genetic variation by developing and increasing genetic variability through mutation induction is necessary for improving crop yield and quality (Shu et al., 2011).

Deterioration of soybean seed is faster than cereals crop seed due to high protein and fat contents (Lisjak et al., 2009). Sofalian et al. (2015) noticed that polymorphism of storage protein on seed of soybean genotypes could be used as for selection. Soybean seed viability among cultivars showed gradual decreasing with increasing storage periods up to six months (El-Abady et al., 2012). Mbofung et al. (2013) noted that soybean seed viability expressed by germination percentage was affected by environmental factors during storage.

The Accelerated Aging (AA) test that established an injurious environmental condition (high temperature and relative humidity) for a specific period is applied in the chamber to evaluate the storability of seed lots (Gupta, 1993). The effectivity and good accuracy of accelerated aging with high temperature and RH for minimum 24 hours had been noted to predict relative storability and field emergence of soybean (TeKrony and Egli, 1997; Torres et al., 2004; Shivasharanappa et al., 2017**).** Demir and Mavi (2007) also noted the utilization of accelerated aging on melon seed lots for predicting seedling emergence.

MPC IPB 77-1, a rapid aging machine that had been introduced by Sadjad et al. (1982) is used to estimate seed storability by chemical aging of 95% ethanol. It has been developed to MPC IPB 77-1 M which provide shorter time of chemical accelerated aging test (Sadjad, 1991). The modified rapid aging tool of APC IPB 77-1MM from MPC IPB 77-1 M can be used to accelerate the deterioration of seeds with chemical or physical accelerated aging (Suhartanto, 1994). It has 60% smaller size chamber than previous model which can avoid vapor leakage lead to direct contact of seeds with vapor. The APC IPB 77-1 MM has been designed by placing the seeds in a non-stationary state and allowing for gradually seed devigoration.

Electrical conductivity (EC) test is one of tool to determine seed vigor loss (Gupta, 1993). The using conductivity meter for testing vigour seed is sometimes limited in the university's seed laboratory due to its availability. Electrical conductivity of solution can be obtained by measuring its resistance which has positive correlation with resistivity value. Electrical resistivity is described as reciprocal of conductivity (Heaney, 2003 and 2014). The use of ohmmeter as a resistance measurement tool is quite easy, practical and cheap.

The research aims are to estimate seed storability of soybean mutant lines with chemical accelerated aging by utilizing APC IPB 77-1MM, check effectivity of electrical resistance measuring for vigor test and determine genetic parameters value for supporting selection.

2. Material and Methods

The soybean line seeds of M7 population harvested at the same time were dried at 105±3 ºC for 24 h to determine seed moisture content in the beginning and after accelerated aging treatment (ISTA, 2007). The selected lines of M7 population were used in respect to M7 population which is generally used as advanced yield potential trial due to their stability and uniformity to get promising new variety.

The seeds moisturized between paper towel for 12 h were used for chemical accelerated aging with 95% ethanol vapor using Rapid Aging Tool (APC IPB 77-1MM) during different levels of treatment durations (20, 40, 60 and 80 min). Each of twenty-five treated seeds were placed between moist paper towel. The seeds rolled paper towel were germinated in growth cabinet at 24±1 ºC under dark conditions for 5 days.

Figure 1. Sample soybean seeds for accelerated aging test.

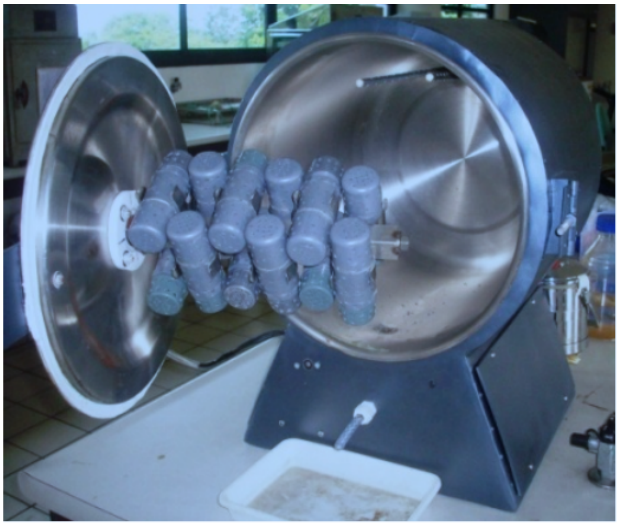

Figure 2. Rapid aging tool of APC IPB 77-1MM.

2.1. Measurement

Germination percentage (GP)

Germination percentage one of standard germination test is simple to measure seed viability. Evaluation of normal seedlings (2 mm radicle) was observed on the fifth day of standard germination test. The degree of complete germinated seed over germination period was expressed as percentage following Bewley and Black (1994):

$$GP\ (\%) = \frac{\sum ni}{N}\ x\ 100\% \quad (1)$$

With GP (%) = germination percentage, n = the number of normal germinated seeds at "i" day, N= the total number of incubated seeds per test.

Germination speed (GS)

Speed of germination, a direct measure of seed vigor can be expressed by germination index on one hundred seeds (from partial germination counts with percentages instead of counts) was calculated using Equation 2 (Gupta, 1993).

$$GI = \frac{\text{number of normal seedling}}{\text{days to first count}} + \ldots + \frac{\text{number of normal seedling}}{\text{days to final count}} \quad (2)$$

Electrical resistance

The resistivity can be found by measuring resistance and physical dimension of material. Conductivity value can be calculated by inversing resistivity value (Heaney, 2003 and 2014).

$$\rho = \frac{R\,w\,h}{l} \quad (3)$$

with ρ is resistivity, R is resistance and w (width), h (heigth) and l (length) are physical dimension

$$\sigma = \frac{1}{\rho} \quad (4)$$

with σ is conducitivity.

Measurement of the electrical resistance (R) value of seeds used an electrical resistance meter (Ohmmeter). Twenty-five (25) seeds were soaked for 24 h in 100 ml of distilled water. After 24 h the seeds were stirred to ensure mixing and electrical resistance value was measured.

2.2. Statistical analysis

The experiment was designed in a Nested Plot Design with 22 soybean lines and two control varieties (Argomulyo as *wildtype* and Tanggamus as acid-tolerant variety) nested within five period of accelerated aging in 0, 20, 40, 60 and 80 min were distributed in to 3 replications. The percentage data were transformed by Arcsine transformation (Steel and Torrie, 1980) before the analysis of variance using computer statistical software "SAS'' and difference among the means were made using t-Dunnet. Pearson Correlation coefficient and regression among germination parameters were analyzed using computer statistical software "MINITAB 14''.

Table 1. ANOVA models and estimate of variance components

Source of variation	Degrees of freedom	Mean squares	E(MS)
Duration	d-1	M5	$\sigma^2_e + g.\sigma^2\, r/_{d} + gr\,\sigma^2_g$
Rep (Duration)	d(r-1)	M4	$\sigma^2_e + g.\sigma^2\, r/_{d}$
Genotype	g-1	M3	$\sigma^2_e + r.\sigma^2_{g*d} + r.d\,\sigma^2_g$
Genotype*Duration	(g-1)(d-1)	M2	$\sigma^2_e + r.\sigma^2_{g*d}$
Error	d(g-1)(d-1)	M1	σ^2_e

Note: d (duration), g (genotype), r (replication) E (expected) (Annicchiarico, 2002).

Estimation of variance componetns were calculated by using formula (Syukur et al., 2012):

Phenotypic variance (σ^2_p) $= \sigma^2_g + \sigma^2_{g*e} / d + \sigma^2_e / rd$ (5)

Genotypic variance (σ^2_g) $= (M3-M2) / rd$ (6)

Interaction variance (σ^2_{g*e}) $= (M2-M1) / r$ (7)

Environmental variance (σ^2_e) $= M1$

With r (replication), d (duration), and M1-M3 (mean square).

Heritability (h^2) was calculated using formula described by Tinker (2008) and categorized by Stansfield (1991):

$$h^2_{bs} = \sigma^2_g / \sigma^2_p \quad (8)$$

h^2_{bs} : Broad sense heritability
σ^2_g : Genetic variance
σ^2_p : Phenotypic variance.

Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) were determined by a formula suggested by Singh and Chaudhary (1985) as:

$$PCV\ (\%) = (\sqrt{\sigma^2_p} / \bar{X}) \times 100\ \% \quad (9)$$

$$GCV\ (\%) = (\sqrt{\sigma^2_g} / \bar{X}) \times 100\ \% \quad (10)$$

with $\bar{X}$ (sample mean of character).

Genetic advance (GA) and percentage of means (GAM) was computed according to Johnson et al. (1955) and Singh and Chaudhary (1985):

$$GA = K \times \sqrt{\sigma^2_p} \times h^2_{bs} \quad (11)$$

$$GAM\ (\%) = (GA / \bar{X}) \times 100\% \quad (12)$$

Where, K = 2.06 with assumption of 5% selection intensity for the respective trait.

3. Results and Discussion

3.1. Moisture Content

The initial moisture content among soybean mutant lines were uniform with values 8-9%. These moisture content values are recommended for storing of soybean seeds that have high protein content. The uniformity of seed water content is important to get standardization and to obtain greater reliability. The results confirm that high humidity level on seeds could be influenced by accelerated aging that leads to lowering or reduction seed quality (Marcos Filho, 2015). The uniform seed moisture contents of 29-34% were noted after moisturizing and decreased between 28-31% after accelerated aging of each duration in contrast to Toledo et al. (2011) who reported uniformity of seed moisture content in each exposure duration and their increasing after time passed. Imaniar (2012) notified that decreasing moisture content after chemically accelerated aging is caused by replacement of water by ethanol which is easy-accessable in binding water molecules and lead entering ethanol into seeds. While the increasing moisture content after physical accelerated aging is caused by entering water vapor into seeds.

3.2. Seed Viability and Vigor

There was a significant ($p < 0.05$) different effect between the interaction of accelerated aging duration and genetics on seed germination of soybean mutant lines (Table 2). Performance of manually harvested soybean mutant lines seeds have high initial seed viability. They showed more than 80% of germination percentage in the beginning (0 min) without application of increased accelerated aging. However, germination percentage decreased by increasing the duration of chemical accelerated aging on soybean mutant lines in agreement with Imaniar (2012). Mohammadi et al. (2011) noted decreasing germination percentage, germination rate and the normal seedling percentage that indicate seed deterioration of soybean.

The different responses among soybean lines during accelerated aging period in agreement with Mustika et al. (2014) who noted difference of decrease rate of germination on Anjasmoro and Wilis varieties treated by physical accelerated aging. M100-96-53-6 line had a significantly higher germination percentage of 80% than Argomulyo on 60 min and 80 min of a duration of chemical accelerated aging. Germination percentage of M100-29A-42-15 line was noted significantly higher than Argomulyo and germination percentage of M200-20-52-3 line was noted significantly less than Argomulyo and Tanggamus on 60 min of accelerated aging duration. They indicated high seed longevity of M100-96-53-6 line and low seed longevity of M200-20-52-3 line due to seed viability after

accelerated aging. It can be predicted that M100-96-53-6 line and M200-20-52-3 line have good and bad storability respectively. These differences expressed by germination percentage on soybean mutant lines might be related to genetic, structural characteristics and chemical composition, as confirmed by Sheidaei et al. (2014).

Table 2. Effect of accelerated aging duration and soybean mutant lines on germination percentage

Mutant lines	Duration of accelerated aging (min)				
	0	20	40	60	80
	Percentage (%)				
M50-97-8-12	93.3	90.0	87.3	80.7	48.0
M50-78-9-13	94.7	95.3	89.3	62.7	34.7^{t-}
M50-45-9-12	88.0	83.3	86.7	80.0	56.7
M100-96-53-7	96.7	92.0	83.3	82.0	60.0
M100-96-53-6	92.7	90.0	92.0	91.3^{a+}	87.3^{a+}
M100-46-44-6	89.3	84.0	77.3	71.3	56.7
M100-29A-42-15	95.3	89.3	92.0	92.7^{a+}	72.7
M100-29A-42-14	94.0	91.3	81.3	61.3	32.0^{t-}
M100-29A-42-10	88.7	86.0	88.7	80.0	70.0
M150-69-47-2	88.7	85.3	75.3	72.7	36.7^{t-}
M150-40-65-5	86.7	83.3	72.7	44.7	19.3^{t-}
M150-29-44-10	95.3	87.3	81.3	81.3	63.3
M150-24-48-2	92.0	86.0	80.7	58.7	18.0^{t-}
M200-93-49-13	94.0	91.3	84.0	84.7	65.3
M200-79A-50-5	88.7	84.7	84.7	77.3	62.7
M200-64-51-2	89.3	86.0	86.0	62.7	45.3
M200-62-54-4	94.7	91.3	72.0	66.0	34.0^{t-}
M200-39-69-6	82.0	67.3	64.7	45.3	24.7^{t-}
M200-20-52-3	96.0	88.7	71.3	17.3 $^{at-}$	10.0^{t-}
M200-20-52-11	98.0	96.0	86.0	85.3	65.3
M200-13-47-5	87.3	84.7	72.7	47.3	22.0^{t-}
M200-6B-58-7	85.3	84.0	76.7	66.0	36.0^{t-}
Argomulyo	**85.3**	**72.0**	**74.0**	**55.3**	**34.7**
Tanggamus	**94.0**	**90.7**	**87.3**	**78.0**	**85.3**

Means followed by the **a** letter within a column differ significantly of Argomulyo and **t** letter within a column differ significantly of Tanggamus at 5% level with Dunnet-test, (-) = less than, (+) = higher.

A significant ($p < 0.05$) different effect was noted between the interaction of accelerated aging duration and genetic on germination speed of *soybean mutant lines* (Table 3). The decline in seed vigor expressed by germination speed values was noted on all soybean mutant lines. The increasing duration of accelerated aging caused reduction of germination speed in agreement with Mohammadi et al. (2011) and Rastegar et al. (2011). Summarily, accelerated aging decreased both germination percentage and germination speed of soybean similar to Imaniar (2012) who noted the loss of germination percentage and germination speed of Anjasmoro soybean variety seeds due to chemical and physical accelerated aging.

Generally, non-significant germination speed values of soybean mutant lines were higher than Argomulyo and lower than Tanggamus in each duration of accelerated aging. M100-96-53-6 line had a higher significant germination speed value than Argomulyo and closed to Tanggamus that indicated its ability to germinate faster and higher. According to germination speed value, M100-96-53-6 line has been estimated that is more vigorous and has good storability than other lines.

There were significant electrical resistance values among soybean mutant lines which are less than Argomulyo and Tanggamus in each duration of accelerated aging (Table 4). A few soybean mutant lines had a higher electrical resistance value than Argomulyo at 20 min of accelerated aging duration. The increasing duration of accelerated aging decreased the electrical resistances value of all soybean mutant lines. Decreasing electrical resistances values might be caused by membrane damage or loss of

membrane integrity led to electrolyte leakage. The increasing ionic concentration of seed soaking solution contributed to higher conductivity. It means that decreasing electrical resistances followed by decreasing electrical resistivity led to increasing electrical conductivity on solution as confirmed by Heaney (2003 and 2014).

Table 3. Effect of accelerated aging duration and soybean mutant lines on germination speed

Mutant lines	Duration of accelerated aging (min)				
	0	20	40	60	80
M50-97-8-12	42	34	29	24	14^{t-}
M50-78-9-13	44	35	29	20	11^{t-}
M50-45-9-12	45	31	30	26	19
M100-96-53-7	42	33	28	28	20
M100-96-53-6	45	32	31	30	29^{a+}
M100-46-44-6	36	31	25	24	17
M100-29A-42-15	44	34	31	30	23
M100-29A-42-14	44	35	28	19	12^{t-}
M100-29A-42-10	44	32	31	24	24
M150-69-47-2	34	35	26	23	15^{t-}
M150-40-65-5	34	31	26	17	6^{t-}
M150-29-44-10	43	30	28	25	21
M150-24-48-2	42	32	26	18	7^{t-}
M200-93-49-13	40	34	25	28	23
M200-79A-50-5	40	29	27	25	20
M200-64-51-2	41	30	29	21	17
M200-62-54-4	50	35	25	20	9^{t-}
M200-39-69-6	36	23^{t-}	21^{t-}	14	8^{t-}
M200-20-52-3	44	31	24	4^{t-}	3^{t-}
M200-20-52-11	46	33	30	28	21
M200-13-47-5	42	30	25	15	9^{t-}
M200-6B-58-7	39	27	26	22	12^{t-}
Argomulyo	**38**	**27**	**24**	**17**	**13**
Tanggamus	**44**	**41**	**34**	**27**	**30**

Means followed by the a letter within a column differ significantly of Argomulyo and t letter within a column differ significantly of Tanggamus at 5% level, (-) = less than, (+) = higher.

The unexpected data on untreated soybeans seeds which are showing values lower than 20 min treatment seeds might be caused by seed genetic as genetic variability and purity, size and weight (physical) uniformity and purity and less environmental factor. Although used seeds of M7 were selected from same seed lot, mentioned reasons might influenced on measuring electrical resistance between untreated seeds and 20 min treatment seeds. Each lot has its own characteristics led to seeds which have a common genotype might vary in their vigor depending on the maternal environment and their harvest and handling (Finch-Savage and Bassel, 2016). Each seed of seed lot which are produced and handled at the same time might have varying in vigor due to its own characteristic (Kuswanto, 2007). These unexpected data have been also suggested due to soaking time inaccuracy. The soaking time on untreated seeds might be slightly over 24 hours led to increasing the amount of electrolyte leakage impacted to low electrical resistance value. Hartati (2019) reported that the increasing soaking time on sesame seeds caused the increasing electrical conductivity.

3.3. Effectivity of utilization electrical resistance

A significant and strong positive correlation was noted between electrical resistance and other parameters (Table 5). It indicated that value of evaluated parameters increased with increasing electrical resistance value. It is indicated that resistivity value correlated positively with resistance value on same measured solution of soybean. It is also estimated that a solution which has high resistivity will has low

conductivity in agreement with Heaney (2003 and 2014). Oktaviani (2012) verified that conductivity value had a negative correlation with germination percentage and germination speed on black soybean.

Table 4. Effect of accelerated aging duration and soybean mutant lines on electrical resistance

Mutant lines	Duration of accelerated aging (min)				
	0	20	40	60	80
	Ohm (Ω)				
M50-97-8-12	21.33^{t-}	25.50^{a+}	17.33^{t-}	16.17	12.33^{t-}
M50-78-9-13	21.00^{t-}	22.67^{t-}	17.33^{t-}	15.17^{t-}	11.33^{t-}
M50-45-9-12	20.00^{t-}	24.67	18.33	14.83^{t-}	12.50^{t-}
M100-96-53-7	21.33^{t-}	24.00^{t-}	16.00^{t-}	15.50^{t-}	12.42^{t-}
M100-96-53-6	22.33	23.17^{t-}	17.00^{t-}	17.00	15.00
M100-46-44-6	20.67^{t-}	22.00^{t-}	15.67^{t-}	15.83	12.83
M100-29A-42-15	22.33	23.67^{t-}	17.67^{t-}	16.50	13.83
M100-29A-42-14	19.83^{t-}	24.67	13.17^{t-}	13.83^{t-}	11.00^{t-}
M100-29A-42-10	21.00^{t-}	26.00^{a+}	18.67	15.67^{t-}	14.17
M150-69-47-2	20.33^{t-}	21.67^{t-}	17.00^{t-}	15.83	11.00^{t-}
M150-40-65-5	21.00^{t-}	24.33	17.00^{t-}	13.67^{t-}	10.50^{t-}
M150-29-44-10	20.33^{t-}	23.33^{t-}	16.83^{t-}	15.83	12.50^{t-}
M150-24-48-2	21.67^{t-}	24.50	16.00^{t-}	15.00^{t-}	9.67^{t-}
M200-93-49-13	20.00^{t-}	25.33	16.67^{t-}	16.00	13.00
M200-79A-50-5	20.67^{t-}	23.67^{t-}	15.83^{t-}	15.50^{t-}	12.83
M200-64-51-2	18.83^{at-}	24.33	19.00	14.83^{t-}	11.33^{t-}
M200-62-54-4	21.33^{t-}	26.00^{a+}	16.67^{t-}	14.50^{t-}	9.83^{t-}
M200-39-69-6	21.50^{t-}	22.67^{t-}	15.67^{t-}	13.67^{t-}	11.33^{t-}
M200-20-52-3	20.00^{t-}	24.00^{t-}	17.17^{t-}	13.17^{t-}	8.83^{at-}
M200-20-52-11	20.00^{t-}	24.17^{t-}	17.00^{t-}	15.17^{t-}	12.00^{t-}
M200-13-47-5	19.83^{t-}	21.50^{t-}	17.17^{t-}	13.17^{t-}	8.75^{at-}
M200-6B-58-7	20.83^{t-}	19.67^{t-}	17.83^{t-}	14.83^{t-}	11.67^{t-}
Argomulyo	**23.33**	**20.33**	**17.17**	**15.67**	**13.17**
Tanggamus	**26.67**	**29.33**	**22.67**	**18.67**	**16.17**

Means followed by the a letter within a column differ significantly of Argomulyo and t letter within a column differ significant of Tanggamus at 5% level, (-) = less than, (+) = higher.

Table 5. Correlation between electrical resistance value and other parameters

Parameters	Germination percentage	Germination speed	Moisture content
Electrical resistance	0.634 0.001**	0.729 0.000**	-0.231 0.279^{ns}

Note: ** significant at 1% level.

3.4. Regression analysis

Increasing duration of accelerated aging was inverse of reduction seed viability and seed vigor showed by negative regression coefficient on soybean mutant lines. In this condition, a high R-squared value showed a higher loss of viability and vigor. The M100-96-53-6 line had good seed viability and vigor as an indicator of good seed storability due to low R-squared value compared to other soybean mutant lines (Figure 3-5). On the contrary, high R-squared values were noted on M200-20-52-3 line that indicated bad seed storability.

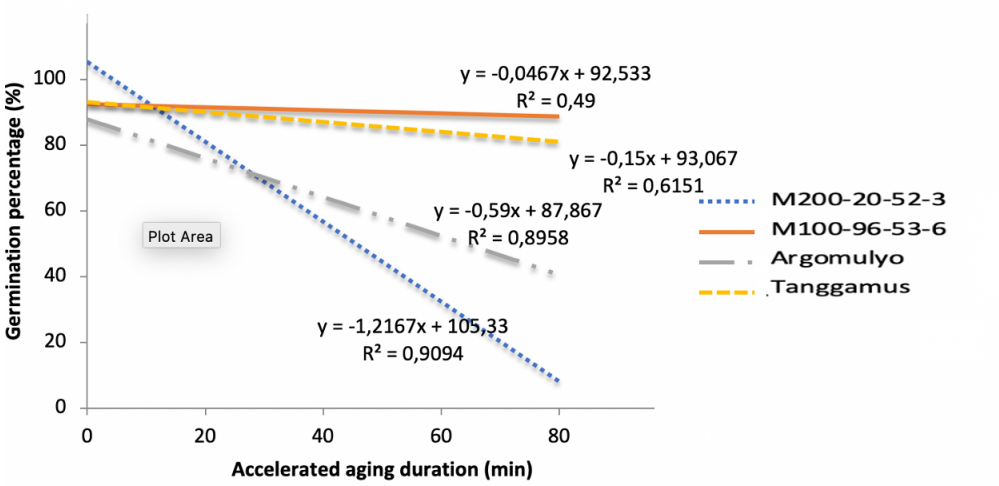

Figure 3. Relation between accelerated aging duration and germination percentage.

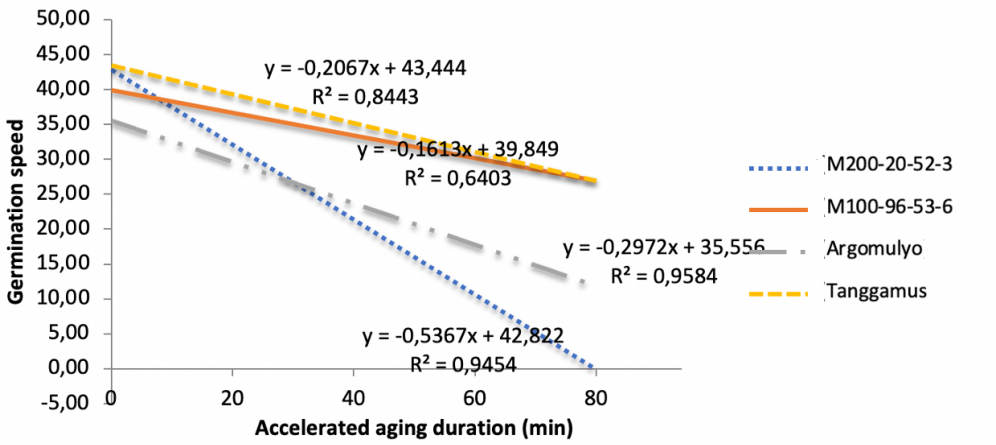

Figure 4. Relation between accelerated aging duration and germination speed.

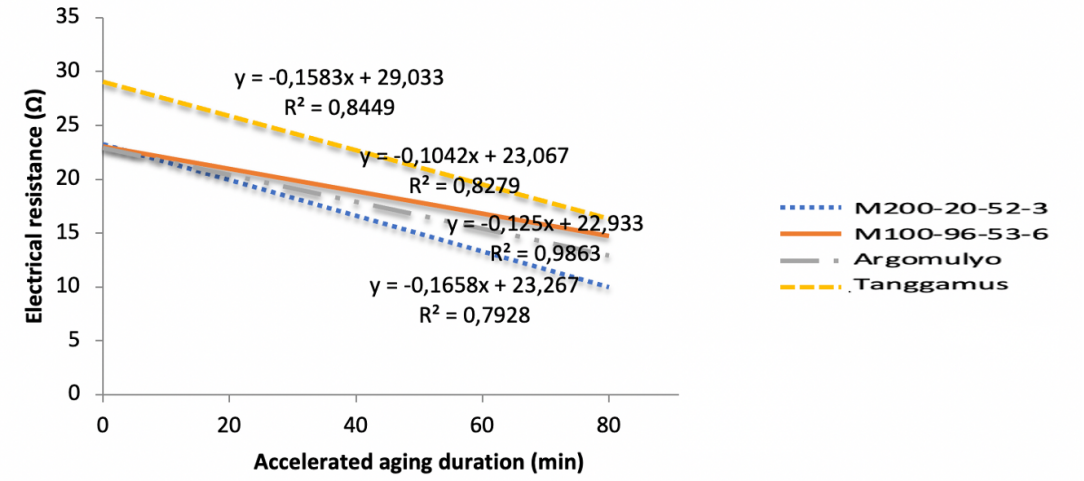

Figure 5. Relation between accelerated aging duration and electrical resistance.

3.5. Variance components and genetic parameters

Variance components of germination parameters showed Table 6 and were calculated by using formulas in Table 1. According to Stansfield (1991), the high heritability (> 0.5) was noted on germination percentage, germination speed and electrical resistance, while moisture content was categorized to moderate heritability (0.2-0.5) (Table 6). This high heritability implied that the heredity regressed < 30% toward the mean of previous generation and characters were mostly influenced by the genotype. Kalpande et al. (2015) also noted the high heritability estimate on germination seed, electrical conductivity and vigor index of sorghum landraces.

The high to low GA of this study were noted on germination percentage, germination speed, electrical resistance value and moisture content respectively. High genetic advance as percentage of mean (GAM) on germination percentage and germination speed (> 20%), moderate on electrical resistance value (10-20%) and low on moisture content (≤10%) were noted in accordance with Johnson et al. (1955). Additive genes action was suggested on germination percentage and germination speed expressed by high heritability with moderate to high values of GA in agreement with Naik et al. (2016) and Joshi et al. (2018) who noted additive gene and non-additive gene effects on soybean yield traits. Whereas non-additive gene action was indicated on the moisture content expressed by moderate heritability with low genetic advance. Kalpande et al. (2015) also suggested the high heritability with low genetic advance showed a non-additive effect that was most influenced by environmental than genotype on germination percentage and vigor seed of sorghum landraces. It had been notified effectivity and reliability of using a combination of heritability with genetic advance over mean (GAM) to predict the progress of selection. The combination of the high heritability and moderate to high genetic advance provide variation sources and improvement of the traits in the selection process (Jain et al., 2018). In this study, germination speed, germination percentage and electrical resistance value could be considered as criteria in sequence for selecting soybean mutant lines in consequence of the appearance of a character that is influenced by genetic and less environmental factor.

Table 6. Variance components and genetic parameters on seed viability and vigor of soybean mutants lines

Parameters	Mean	σ^2_e	σ^2_g	σ^2_{g*e}	σ^2_p	h^2_{bs}	GCV	PCV	GA	GAM
Germination Percentage (GP)	75.00	169.58	76.99	45.90	97.47	0.79	11.70	13.16	16.06	21.42
Germination speed (GS)	27.81	29.43	11.13	3.99	13.89	0.80	12.00	13.40	6.15	22.12
Moisture content (MC)	29.99	3.15	0.13	0.11	0.36	0.35	1.18	2.00	0.43	1.45
Electrical resistance	17.86	2.49	1.30	0.58	1.58	0.82	6.39	7.05	2.13	11.93

Note: σ^2_e (environmental variance), σ^2_g (genotypic variance), σ^2_{g*e} (interaction of genotypic and environmental variance), σ^2_p (phenotypic variance), h^2_{bs} (broad sense heritability), GCV (genotypic coefficient of variance), PCV (phenotypic coefficient of variance), GA (genetic advance), GAM (GA as percentage of means).

According to Deshmukh et al. (1986) classification, medium PCV and GCV of germination percentage and germination speed (10-20%) and low PCV and GCV on remaining parameters (< 10%) with smaller differences were observed in this study. The higher PCV than GCV with small differences between PCV and GCV indicated that these parameters are less influenced by the environment in phenotypic expression in agreement with Kalpande et al. (2015) and Ali et al. (2016). The parameters had medium PCV and GCV with smaller differences that might be effective for selection. Similarly, Tuhina-Khatun et al. (2015), Ali et al. (2016) and Kuswantoro et al. (2018) mentioned the effectivity of selection due to the high or medium of PCV and GCV with narrow differences.

4. Conclusion

Diversity in seed storability of soybean mutant lines was influenced by most of the genetic and some degree of environmental factors. M50-45-9-12, M100-29A-42-10, M100-29A-42-15, M100-96-53-6, M100-96-53-7, M200-93-49-13 and M200-20-52-11 lines had been estimated good seed storability and M200-13-47-5 and M200-20-52-3 lines had poor estimated seed storability compared to Argomulyo as wild type based on germination percentage, germination speed and electrical resistance

value. M100-96-53-6 and M200-20-52-3 lines deteriorated to the slowest and fastest as expressed on the slope graph. Beside using electrical conductivity value, electrical resistance value could be used as an alternative method to evaluate seed vigor test. It is also recommended to compare electrical conductivity value and electrical resistance to confirm the validity.

Germination percentage, germination speed and electrical resistance could be considered to select lines having good quality seeds with estimated storability values as a step of plant breeding purposes. To evaluate seed performances, selected good lines of accelerated aging might be compared to natural dry storage following field emergence test.

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Araştırma Makalesi (ResearchArticle)

Characterization and Haplotype Analysis of *Colletotrichum truncatum* in Greenhouse Tomato in Turkey

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Keywords

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Abstract: Anthracnose caused by *Colletotrichum truncatum* (Schwein.) Andrus and W.D. Moore, is an economically important disease of most tropical crops. In recent years, it has been reported that it is also pathogenic on tomatoes. In this study, the infected fruits were obtained from Antalya province in 2019. Isolates were purified by taking single spore. Conidia were measured as 22.5-32.5 × 3.75 µm. DNA isolation was carried out using the CTAB method. After the PCR amplification, the PCR product was run on agarose gel, visualized with a UV transilluminator, and sequenced. Phylogenetic analysis was conducted in MEGA 7. Based on morphological and phylogenetic analysis, the CT isolate was identified as *C. truncatum*. Pathogenicity tests were carried out using tomato leaves and cherry tomatoes. The inoculated leaves and tomatoes were incubated on a moist filter paper in climate chambers under 27 °C temperature and 12:12 h light-dark conditions. Acervuli were observed on infected tissues on the 7th day of inoculation. Haplotype, the number of haplotypes, and nucleotide diversity were analyzed by DnaSP 6.0 software. 8 haplotypes were determined according to the ITS sequence of 46 *C. truncatum* isolates from different countries. The median-joining network analysis of haplotypes was drawn using the NETWORK 10 program. It was determined that the CT isolate reported with this study from Turkey and the other reference isolates reported on tomatoes were in the H1 which is the most common haplotype.

Türkiye'de Sera Domatesinde *Colletotrichum truncatum'un* Karakterizasyonu ve Haplotip Analizi

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Anahtar Kelimeler

Colletotrichum,
Haplotip,
Filogenetik analiz,
Network analizi,
Domates.

Öz: *C. truncatum*'un (Schwein.) Andrus and W.D. Moore neden olduğu antraknoz çoğu tropikal ürünün ekonomik olarak önemli bir hastalığıdır. Son yıllarda domateste de patojen olduğu rapor edilmiştir. Bu çalışmada, enfekteli meyveler 2019 yılında Antalya ilinden elde edilmiştir. İzolatlar tek spor alınarak saflaştırıldı. Konidiler 22.5-32.5 × 3.75 µm olarak ölçülmüştür. DNA izolasyonu CTAB metodu kullanılarak gerçekleştirildi. PCR amplifikasyonundan sonra, PCR ürünleri agaroz jelde koşturuldu, UV cihazı ile görüntülendi ve sekanslandı. Filogenetik analiz MEGA 7'de yapılmıştır. Morfolojik ve filogenetik analizlere dayanarak CT izolatı *C. truncatum* olarak tanımlanmıştır. Patojenite testleri domates yaprakları ve çeri domatesleri kullanılarak gerçekleştirildi. İnokule edilen yapraklar ve domatesler, 27 °C sıcaklık ve 12:12 saat aydınlık-karanlık koşulları altındaki iklim odasında nemli bir filtre kağıdı üzerinde inkübe edilmiştir. İnokülasyonun 7. gününde enfekteli dokularda acervuli gözlenmiştir. Haplotip, haplotip sayısı ve nükleotid çeşitliliği DnaSP 6.0 yazılımı ile analiz edilmiştir. Farklı ülkelerden 46 *C. truncatum* izolatının ITS sekansına göre 8 haplotip belirlenmiştir. Haplotiplerin

medyan birleştirme ağı analizi NETWORK 10 programı kullanılarak çizilmiştir. Türkiye'den bu çalışma ile rapor edilen CT izolatının ve domateste rapor edilen diğer referans izolatların en yaygın haplotip olan H1'de olduğu belirlenmiştir.

1. Introduction

Tomato is used both as fresh and as a raw material for various industrial products. Turkey is among the most important countries in tomato production and exports (FAO, 2020). In 2020, most of the total tomato production of 13 204.015 tons was obtained from Antalya, Bursa, and Manisa provinces, respectively 2 570.910, 1 335.430, and 1 123.684 tons. The province, with the highest greenhouse tomato production, is Antalya with 2 465.402 tons (TUIK, 2021).

There are many fungal pathogens that cause yield and quality losses by root, stem, flower, and fruit infections on tomatoes. *Colletotrichum* species can cause significant economic losses by affecting fruit production especially under field conditions, as well as causing significant damage in warehouses (Živković et al., 2010). Although the most common species on the tomato fruit is *C. coccodes*; *C. truncatum, C. gloeosporioides*, *C. acutatum*, *C. dematium*, *C. fioriniae,* and *C. nymphaeae* also cause fruit infections (Blancard, 2012; Víchová et al., 2012; Diao et al., 2014; Saini et al., 2017; Chechi et al., 2019). Other than fruit, they can cause serious infections on leaves, stems, and roots (Isaac, 1992; He et al., 2016; Belov et al., 2017). Root infections usually occur, when the inoculum level is too high or plants are stressed especially due to infection by other pathogens such as *Pyrenochaeta lycopersici* (Anonymous, 2017).

It has been stated that *C. fioriniae* and *C. gleosporioides* are also an entomopathogenic fungus, and in these species may be biovars that have acquired the ability to infect both insects and plants (Marcelino et al., 2008; 2009). These fungi, which can be found endophytically in the plant, can be used as a biological control agent in the control of insects (Marcelino et al., 2009). It has been reported that the *C. truncatum* is found endophytically in the plant (Ranathunge and Sandani, 2016). There is no literature on the presence of entomopathogenic biovars in the species.

Anthracnose caused by *C. truncatum* (Schwein) Andrus and W.D. Moore, is an economically important disease of most tropical crops (Cannon et al., 2012). This pathogen is the main pathogen especially in countries where chili pepper is grown (Rao et al., 2018). It has been reported as a pathogen in alfalfa in Turkey (Eken and Demirci, 2000). There are studies showing that there are races of the pathogen on lentils (Tullu et al., 2006). It is one of the important seed-borne diseases of soybean and chili pepper (Begum et al., 2007; Naveen et al., 2021). In recent years, it has been reported that it is also pathogenic on tomatoes (Diao et al., 2014; Saini et al., 2017; Villafana et al., 2018; Almaraz Sánchez et al., 2019). It also causes necrotic spots on the leaves (He et al., 2016) although it causes more fruit infections.

It is seed-borne (Naveen et al., 2021) and can also be found endophytically in non-host species (Ranathunge and Sandani, 2016). As a plant pathogenic fungus, it mostly infects dicotyledonous plants but has also been detected on *Cyperus rotundus* from monocotyledonous plants (Damm et al., 2009). It has also been reported to cause eye infections in humans (Shivaprakash et al., 2011).

C. truncatum has not been reported previously on tomatoes in Turkey. Currently, there are no tomato cultivars resistant to *C. truncatum*. In order to develop resistant cultivars, it is important to determine the pathogenic and genetic variation in the population. In this study, it is aimed to identify this pathogen, to perform pathogenicity tests and haplotype analysis.

2. Materials and methods

2.1. Isolation and morphological identification of pathogen

The infected fruits were obtained from Antalya province in 2019. Infected plant tissues were taken, surface-sterilized in 1% NaOCl for 1 min, dried between sterile blotting papers, and transferred to PDA medium. After the fungal sporulation was observed, conidia were spread onto the PDA medium by means of a sterile needle. Isolates were purified by transferring a single spore into PDA medium with sterile needles under a binocular microscope (Leica M165 C). Single spore isolates were maintained in agar slants at +4°C for further studies.

The measurements of 30 conidia obtained from an 8-days culture grown on PDA were performed with a 40X magnification using a Leica DM1000 light microscope. Morphological identification of the fungus was performed according to Damm et al., 2009.

2.2. Molecular identification

The acervuli and mycelia of the pathogen from the 12-days culture grown on PDA medium were scraped with a sterile scalpel and placed in a sterilized mortar. Fungal tissues were crushed by pouring liquid nitrogen into the mortar. DNA isolation was carried out using the CTAB method according to Lefort et al. (1998). The density and purity of DNA were measured by NanoDrop 1000 Spectrophotometer (Thermo Fisher Scientific).

In the PCR reaction, 10 µM ITS4 and ITS5 primers (White et al. 1990), 50-100 ng DNA, 12.5 µl Thermo Dream Taq green mix was used, and the total volume was completed to 25 µl with PCR grade water. PCR amplification was performed using Thermocycler (Bio-Rad Thermal Cycler PTC-200). PCR conditions were 3 min at 95 °C, 35 cycles 30 s at 95 °C, annealing 30 s at 60 °C, elongation 60 s at 72 °C, and final elongation 10 min at 72 °C. PCR products were run on 1.5% agarose gel in 1X TBE buffer at 120 V current for 45 minutes and were visualized with a UV transilluminator. PCR product was purified and sequenced by BM Labs located in Ankara, Turkey. The sequence was subjected to BLAST analyze at NCBI gene bank and the accession number was taken.

2.3. Pathogenicity tests

Pathogenicity tests were performed on moist filter paper with 3 replicates of Purdue 135 tomato variety obtained from the Gene Bank of the Czech Republic (https://grinczech.vurv.cz/gringlobal/search.aspx) and 5 replicates of cherry tomatoes. The leaves and tomatoes to be used in the tests were first washed with water and then surface disinfection was carried out with 70% alcohol. Spore suspension at a density of 1.2×10^6 conidia/ml was prepared using a hemocytometer from 9 days old fungus culture. 20 µl of this suspension was injected into leaves and tomatoes. 20 µl of water was injected into the leaves and tomatoes used as control. The inoculated leaves and tomatoes were incubated on a moist filter paper in climate chambers under 27 °C temperature and 12:12 h light-dark conditions (Torres-Calzada et al., 2018). The pathogen was re-isolated from infected tissues.

2.4. Phylogenetic and network analysis

The sequences of the isolates to be used in phylogenetic and network analysis were obtained from the NCBI gene bank. *Passalora fulva* was used as an out-group. Sequences were aligned in the MEGA7 program using ClustalW. The phylogenetic tree was inferred by using the Maximum Likelihood method and Kimura 2-parameter model (Kimura 2+G) with bootstrap analysis 1500 replications (Kimura, 1980). Phylogenetic analysis was conducted in MEGA 7 (Kumar et al., 2018).

Haplotype, the number of haplotypes, and nucleotide diversity were calculated by DnaSP 6.0 software. The median-joining network analysis of haplotypes was drawn using NETWORK 10 program.

3. Results and Discussion

3.1. Morphologic identification

Conidia were hyaline, curved inward at the ends without septa. It was measured as 22.5-32.5 × 3.75 µm (x = 26.9-3.75 µm, n = 30). Brown setae were 2-5 septa. Culture, acervuli, conidia and setae of the pathogen on PDA medium are given in Figure 1.

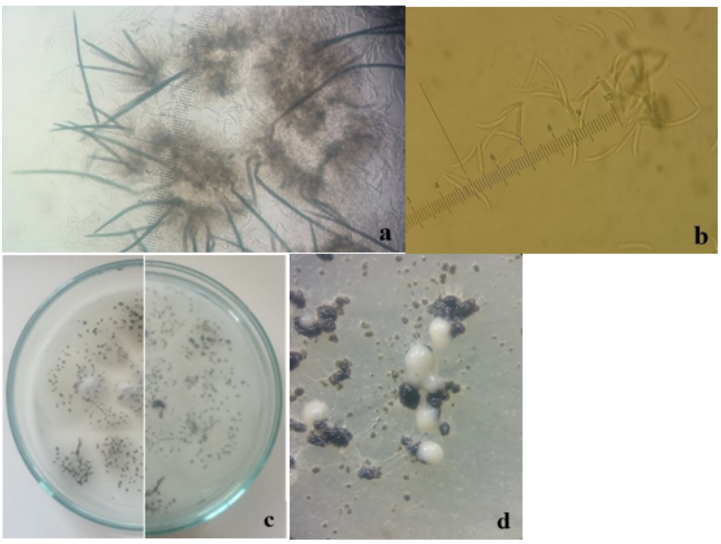

Figure 1. Setae (a), conidia (b), culture (c) and acervuli (d), of the fungus on the PDA medium.

3.2. Pathogenicity tests

In the pathogenicity tests were carried out on moist filter paper using tomato leaves and cherry tomatoes. Acervuli were observed on infected tissues on the 7th day of inoculation. Slightly inwardly curved conidia and setae of the pathogen were observed in the preparations made by taking the plant tissue (Figure 3). No symptoms were observed on the control fruits and leaves (Figures 2 and 3). CT isolate was evaluated as a pathogen.

Figure 2. Controls and tomatoes inoculated with *C. Truncatum*.

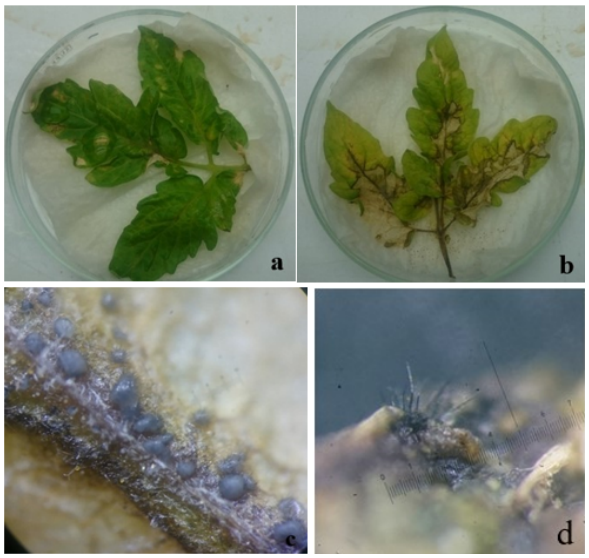

Figure 3. Control (a), symptom of *C. truncatum* on leaf on the moist filter paper (b) and acervuli on the infected leaf (c-d).

3.3. Phylogenetic and network analysis

The accession number (MW453147) of the CT isolate was taken from the NCBI gene bank. The CT isolate showed similarity with the *C. truncatum* isolates in the NCBI gene bank. In addition, in the phylogenetic analysis performed with other *Colletotrichum* species, the pathogen was clustered together with the *C. truncatum* isolate (Figure 4). Information about the *Colletotrichum* species used in the study are given in Table 1.

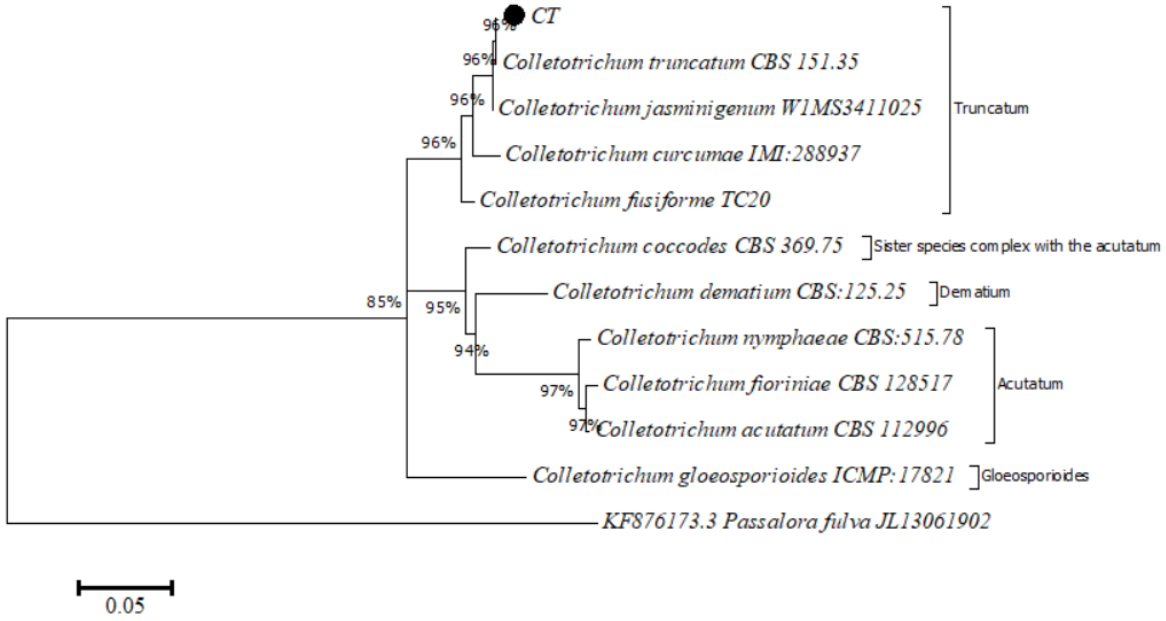

Figure 4. The evolutionary history was inferred by using the Maximum Likelihood method and Kimura 2-parameter model (G). Evolutionary analysis was conducted in MEGA 7; bootstrap values higher than 50% are shown on branches.

Table 1. Isolates used in molecular characterization studies

Species complexes	*Colletotrichum* species	Isolates	Accession numbers
Truncatum	*Colletotrichum truncatum*	CT	MW453147
	Colletotrichum truncatum	CBS_151.35	GU227862
	Colletotrichum curcumae	IMI:288937	GU227893.1
	Colletotrichum fusiforme	TC20	MT318539.1
	Colletotrichum jasminigenum	W1MS3411025	KC172075.1
Dematium	*Colletotrichum dematium*	CBS:125.25	GU227819
Sister species complex with the acutatum species complex	*Colletotrichum coccodes*	CBS_369.75	HM171679
Gloeosporioides	*Colletotrichum gloeosporioides*	ICMP:17821	JX010152
Acutatum	*Colletotrichum_fioriniae_*	CBS_128517	JQ948292
	*Colletotrichum_nymphaeae_*	CBS:515.78	JQ948197
	Colletotrichum_acutatum	CBS_112996	JQ005776

In the previous phylogenetic analysis studies (Cannon et al., 2012; Jayawardena et al., 2016), the species complexes including the *Colletotrichum* species are given in Table 1. In phylogenetic analysis, it is seen that *C. jasminigenum* is the molecularly closest species to the *C. truncatum* (Figure 4). This species is only reported on the *Jasminium sambac* in Vietnam. Its conidia are similar to the slightly inward curved conidia of the *C. truncatum*. It does not form setae in PDA medium (Wikee et

al., 2011). In this study, it was observed that CT isolate formed setae in PDA medium. It was found to be compatible with *C. truncatum* in terms of the shapes and sizes of conidia and setae (Damm et al., 2009). Based on morphological and phylogenetic analysis, the CT isolate was identified as *C. truncatum*. All of the *C. truncatum* isolates reported on tomatoes were found to be in the H1 haplotype group in the network analysis. The accession numbers of the isolates used in the analysis are given in Table 2. 65% of the isolates were in the H1 haplotype. After H1, the second most common haplotype was determined to be H2. This haplotype includes isolates from Nepal, Brazil, the USA, India, Denmark (Figure 5, Table 2). H3 Bangladesh, H4 and H5 Mexico, H6, H7, and H8 haplotypes contain unique isolates reported from Brazil. No relationship could be determined between the geographic distribution of the isolates and haplotypes.

8 haplotypes were determined in the median-joining network analysis performed according to the ITS sequence of 46 *C. truncatum* isolates from different countries (Figure 5). Haplotype diversity was Hd: 0.5440. Nucleotide diversity was Pi: 0,00136. It was determined that Fu and Li's D (FLD: -2,90185) and Fu and Li's F (FLF: -2,78932) test results were statistically significant ($P < 0.05$).

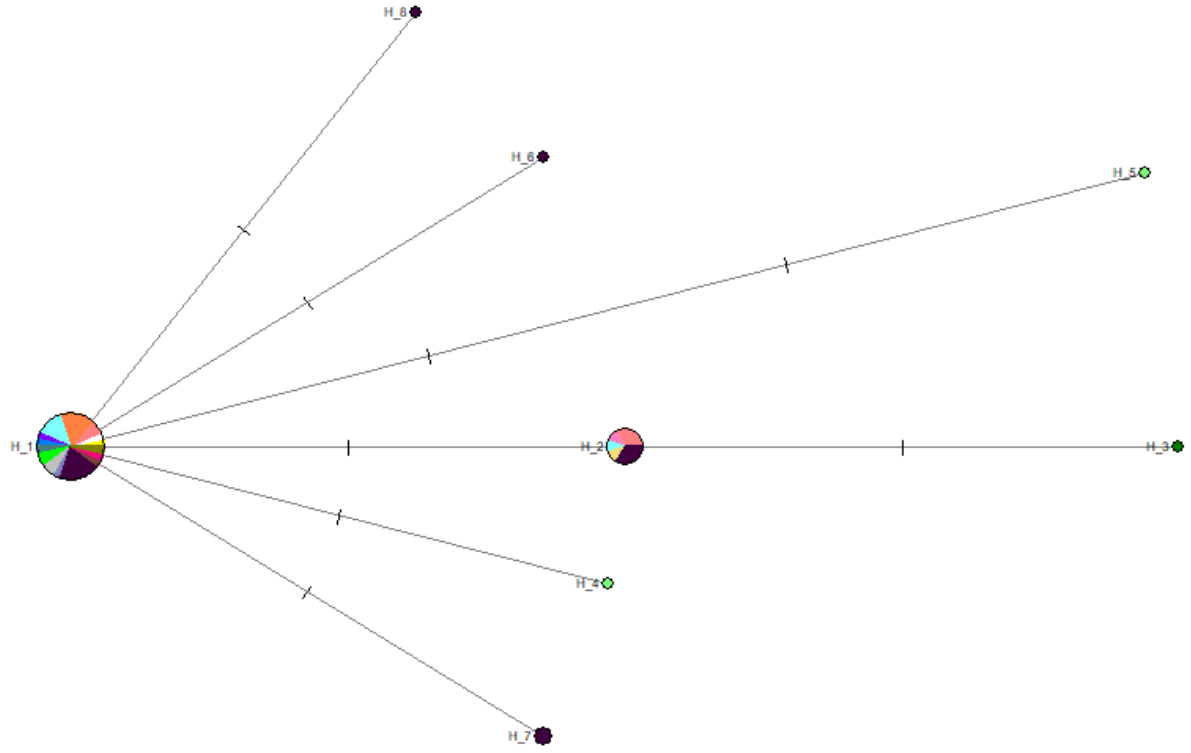

Figure 5. Network analysis of the *C. truncatum*. Each country is represented by a different colour; the size of the circle and circle slices indicates the number of isolates in the haplotype; Turkey ( ),USA ( ), Brazil ( ), China ( ), Trinidad and Tobago ( ), India ( ), Laos ( ), Indonesia ( ), Pakistan ( ), Mexico ( ), Denmark ( ), Burkina Faso ( ), Thailand ( ), Martinique ( ), Israel ( ), Sudan ( ), Nepal ( ), Bangladesh ( ).

Currently, 14 species complexes of *Colletotrichum* fungi are recognized (da Silva et al., 2020). The closest species complexes to the truncatum species complex are gloeosporioides and boninense (Cannon et al., 2012). Boninense species complex, which contains a large number of *Colletotrichum* species, which can be identified only by ITS region, is accepted as the sister species complex of the truncatum species complex (Cannon et al., 2012). The conidium morphology of the *C. truncatum* species is quite different from the gloeosporioides and boninense species complexes to which it is phylogenetically close (Damm et al., 2012).

The haplotypes found at the terminal in network analysis are new haplotypes that have recently been formed. Older haplotypes are found more inland in network analysis (Posada and Crandall, 2001).

Younger haplotypes show more limited geographic association, while older haplotypes show a wider geographic distribution (Carbone and Kohn, 2004). Accordingly, it can be said that terminal haplotypes are younger than the H1 haplotype. In network analysis, it is seen that the H3 haplotype originates from the H2 haplotype. In terms of geographical location, it can be said that the H3 haplotype originates from Nepal and India, which are included in the H2 haplotype (Katoch et al., 2016).

Table 2. *C. truncatum* isolates used in network analysis

Haplotype	Frequency	Accession numbers and country
Hap_1	30	**MW453147, Turkey; KC460308, China**; GU228254, USA; **GU227862, USA**; **MG822829, Trinidad and Tobago**; **MG822828, Trinidad and Tobago**; **MG822827, Trinidad and Tobago**; JF749808, Trinidad and Tobago; HQ287583, Trinidad and Tobago; **KY399773, India**; GU227886, India; GU227880, India; HM231266, India; GU227889, Laos; GU227891, Martinique; GU227879, Indonesia; GU227885, Mexico; HM562707, Mexico; DQ454016, Thailand; DQ454028, Thailand; GU227871, Burkina Faso; KJ614299, Brazil; KJ614302, Brazil; KJ614311, Brazil; KJ614334, Brazil; GU227864, Brazil; GU227892, Brazil; GU227868, Israel; GU227874, Sudan; GU227872, Pakistan
Hap_2	9	GU227863, USA; GU227865, USA; GU227866, USA GU227867, Denmark; GU227878, India; GU227890, Nepal; KJ614306, Brazil; KJ614321, Brazil; KJ614328, Brazil
Hap_3	1	GU227882, Bangladesh
Hap_4	1	HM439289, Mexico
Hap_5	1	HM450132, Mexico
Hap_6	1	KJ614293, Brazil
Hap_7	2	KJ614313, Brazil; KJ614314, Brazil
Hap_8	1	KJ614319, Brazil

* Isolates reported on tomato are written in bold.

Negative values in Fu and Li's F test indicate that the population is expanding. The fact that the test results are statistically significant indicates that the polymorphism in the population is not random, it occurs as a result of selection pressure.

The wide host range of the *C. turuncatum* is indicative of selection pressure on different hosts. It is thought that genetic diversity analysis of populations with limited hosts from different parts of the world will provide useful information on the evolutionary behaviour and the formation of effective management strategies based on host resistance (Katoch et al., 2016).

Phylogenetic analysis performed with *C. turuncatum* from different countries have shown that high of gene flow occur between geographically different populations of the pathogen (Katoch et al., 2016). It has been determined that the pathogen forms perithecium in sexual reproduction (Armstrong and Banniza, 2006). Gene flow and genetic diversity are higher in fungi that reproduce both sexually and asexually (Carbone and Kohn, 2004). For these reason, it can be said that the *C. turuncatum* has a high evolutionary potential.

In the network analysis of *C. truncatum* isolates from different hosts and different geographic regions, based on the ITS region, it has been reported that the H1 is more dominant among 11 haplotypes (Katoch et al., 2016). In the haplotype analysis performed using GAPDH, HIS3 and ITS regions, it was determined that *C. truncatum* has 27 haplotypes. These haplotypes formed three groups. Although there is a certain grouping in network analysis, no relationship was determined between the geographic distribution and haplotypes of this pathogen (Rogério et al., 2017). In this study, similar to the study of Katoch et al. (2016), the *C. truncatum* isolates reported on tomato were included in H1, the most dominant haplotype. Mutations in the ITS region have led to the emergence of new haplotypes. Since the gene flow is a high pathogen, a geographic relationship cannot be determined in network analysis performed based on single and multiple gene regions.

It has been stated that some wild lentil cultivars can be used in the development of resistant plants against *C. truncatum* races on Lentil (Tullu et al., 2006). Similarly, studies are needed to

determine the wild tomato variety(s) that can be used as a source of resistance against this pathogen on tomato.

In this study, it was determined that CT isolate infects tomato leaves and fruits. Conducting more extensive pathogenicity tests using other hosts of the pathogen will enable the determination of pathogenic variation in Turkey.

In cross inoculation tests with *C. truncatum* isolates obtained from papaya, pepper and physic nut, it was determined that the isolates infect the fruits and leaves of all three hosts. Although the most aggressive isolates were obtained from pepper; isolates, more aggressive on papaya and physic nut which alternative hosts, were also reported (Torres-Calzada et al., 2018). It has been hypothesized that the pathogen transitions from its main host pepper to its alternative host. The detection of more aggressive isolates of the pathogen on the alternative host shows that if the population of these aggressive isolates increases over time, the pathogen may cause significant economic losses on alternative hosts and become the main pathogen of these plants.

4. Conclusion

In this study, the CT isolate obtained from greenhouse tomato was identified as *C. truncatum* based on morphological and phylogenetic analysis. This isolate caused leaf and fruit infection on tomato. With this study, *C. truncatum* is reported for the first time on tomato in Turkey. Phylogenetic analysis and haplotype analysis were carried out using ITS region. Phylogenetic analysis showed that the closest species to *C. truncatum* was to be the *C. jasminigenum*. In the haplotype analysis a total of 8 haplotypes were identified. It has been determined that Turkish and other reference isolates reported on tomato were in the H1 which the most common haplotype. Isolates of the pathogen that may be more aggressive on alternative hosts have been reported. This pathogen can migrate to alternative hosts in Turkey, and the dominance of more aggressive isolates in the population may cause significant yield losses.

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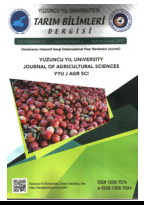

Derleme Makalesi (Review Article)

Türkiye'de Tarımsal Mekanizasyona Bir Bakış

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Tarım Makinaları,
Tarımsal Mekanizasyon.

Öz: Tarihsel süreci içerisinde tarımsal mekanizasyon, kas gücüyle başlayıp teknolojinin de yardımıyla gelişmiş sensör uygulamaları, dronlar ve otonom traktöre kadar evrilmiştir. Temel gıda ihtiyacının sağlanması, maliyetin düşürülmesi, işçilik sorunlarının ortadan kaldırması ve birim alandan daha yüksek verim elde edilmesi gibi nedenlerden dolayı tarımsal mekanizasyonun önemi gün geçtikçe artmaktadır. Bu çalışmanın amacı; Ülkemizdeki tarımsal mekanizasyonun mevcut durumunu değerlendirmektir. Bu değerlendirmede traktör sayıları, biçerdöver sayıları ve yaş grupları, tarım makinalarının yıllara göre değişimi, ithalat ve ihracat değerleri ile önemli tarımsal mekanizasyon göstergelerinin yıllara göre değişimi incelenmiştir. Ülkemizde 1988 yılında 654 636 adet traktör bulunurken, 2018 yılına gelindiğinde bu rakam 1 332 139'a ulaşmıştır. 2000 yılında 12 578 adet biçerdöver bulunurken bu değer 2018 yılında 17 266 olarak yaklaşık % 37 artmıştır. Yıllara göre tarımsal mekanizasyonda, meyve hasat makinaları, pamuk toplama makinası, motorlu tırpan ve yem dağıtıcı römorklarda artış görülürken, hayvanla çekilen hububat ekim makinası, tarımsal mücadele uçağı, döven, karasaban ve hayvan pulluğu sayılarında ciddi azalmalar meydana gelmiştir. 2001 – 2018 yılları arasında tarımsal mekanizasyon ekipmanlarındaki ithalat ve ihracat değerleri göz önüne alındığında, 2001 yılında ithalat değeri ihracat değerinin yaklaşık 2 katı iken 2016 yılında bu değer neredeyse eşitlenmiş, 2018 yılında ise ihracat değeri ithalat değerinin yaklaşık 1.4 katına çıkmıştır.

Agricultural Mechanization to Turkey at a Glance

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Abstract: In its historical process, agricultural mechanization has evolved from muscle power to advanced sensor applications, drones and autonomous tractors with the help of technology. The importance of agricultural mechanization increases due to reasons such as providing basic food need, reducing costs, eliminating labor problems and obtaining higher yields per unit area. The aim of this study is to evaluate the current situation of agricultural mechanization in Turkey. In this evaluation, the number of tractors, the number of combine harvesters and age groups, the change of agricultural machinery by years, import and export values, and the change of agricultural mechanization indicators by years were examined. While there were 654 636 tractors in 1988, this figure reached to 1 332 139 in 2018 in Turkey. While there were 12 578 combine harvesters in 2000, this value increased by approximately 37% in 2018 to 17 266. Over the years, there has been an increase in agricultural mechanization, fruit harvesters, cotton harvesters, motor scythes and feed spreading trailers, while there has been a serious decrease in the number of animal-borne grain planting

machines, agricultural protection aircraft, threshing sled, primitive plough and livestock plows. Considering the import and export values of agricultural mechanization equipment between 2001 and 2018, the import value was approximately 2 times of the export value in 2001, while this value almost equalized in 2016, and the export value increased approximately 1.4 times the import value in 2018.

1. Giriş

Mekanizasyon basit bir ifade ile makinalaşma, mekanik düzeni sağlama anlamlarına gelmektedir. Tarımsal mekanizasyon ise; işletmeler için gerekli enerji ve kuvvet kaynaklarının motorizasyon ve elektrifikasyon ile karşılanmasıdır. Daha geniş bir ifade ile tarımsal mekanizasyon, tarımsal alanların geliştirilmesi, her türlü tarımsal üretimin yapılması ve ürünlerin değerlendirilmesi amacıyla ileri üretim teknolojilerinin gereği olarak kullanılan her türlü enerji kaynağı ve mekanik güç kullanılarak çalıştırılan çok farklı tipteki tarımsal alet ve makinanın tasarımı, yapımı, geliştirilmesi, pazarlanması, yayımı, eğitimi, seçimi, işletilmesi, kullanımı, tamir-bakımı ve korunmalarına yönelik tüm faaliyetleri kapsayan bir bilim dalıdır. Tarımsal mekanizasyon, kas gücü ile başlamış bunu hayvanların gücü takip ederken, basit aletlerden yararlanma ve ardından makina kullanımı ile devam etmiştir. Ağızan ve ark. (2020), yaptıkları çalışmada mekanizasyon kullanımının, başta verimlilik olmak üzere birçok alanda belirleyicilikte önemli rol oynadığını belirtmiştir. Son dönemde ise; motorlar, hidrolik ve pnömatik sistemler, traktörler, toprak işleme makinaları, ekim-dikim makinaları, ilaçlama makinaları, gübre dağıtma makinaları, hasat makinaları yaygın olarak kullanılmakla birlikte artık tarımsal üretimin her kolunda otomasyona geçiş başlamış, bilgisayarlı sistemler, dronlarla ürün, hastalık takibi, sulama sistemlerindeki teknolojik yenilikler, tarım makinalarında gelişmiş sensör uygulamaları görülmeye başlanmıştır (Uulu ve ark., 2018).

Bilindiği gibi dünyada ve ülkemizde artan gıda ihtiyacının sağlanmasının temel gereklerinden biri birim alandan niteliksel ve niceliksel olarak verimin artırılmasıdır. Tarımsal mekanizasyon uygulamaları, tarımda verimin artırılmasının yanı sıra üretim maliyetinin düşürülmesini ve işçilik sorununun ortadan kaldırılmasını sağlayacaktır. Mekanizasyon; toprak, su, gübre, ilaç vb. girdilerin daha etkin kullanımını sağlayarak tarımda verimi artıran önemli bir üretim aracıdır (Evcim ve ark., 2005; Saral ve ark., 2005; Altuntaş, 2016). Tarımsal üretimde kullanılan alet ve makinaların ürün verimini artırmadaki etkisi; kullanılan alet ve makinaların kapasitesine, bunları tahrik edecek traktörün iş makinaları ile olan uyumuna, arazi varlığına, parsel büyüklüğüne, toprak ve iklim özelliklerine, ürün desenine, üretim tekniklerine ve tüm bunları uygun şekilde işleyebilecek yetişmiş insan gücüne bağlıdır (Yıldız ve Erkmen, 2004).

Genel olarak tarımsal mekanizasyonun faydaları;

- Üretimde yeni teknoloji uygulamalarına imkân sağlamak, bunların etkinlik ve ekonomikliğini artırmak,
- Üretimi doğa koşullarına bağımlı olmaktan mümkün olduğunca kurtarmak ve daha nitelikli ürün elde etmek,
- Üretim işlemlerini en uygun süre içerisinde tamamlayarak, gecikmeden doğan ürün kaybını önlemek,
- Kırsal kesimde teknik bilgi ve beceriyi geliştirerek çalışma koşullarını daha rahat, çekici ve güvenli bir duruma getirmek ve tarım işçilerinin iş verimini yükseltmek,
- Bir yandan tarımsal ürün artışı, diğer yandan tarım araçları sanayiindeki gelişmeler ile yeni iş alanlarının açılmasına imkân sağlamak,
- İnsan ve hayvan gücü ile başarılamayan tarımsal işlemleri makina gücü ile başarmak ve yeni alanların tarıma açılmasını sağlamak, olarak sıralanabilir (Evcim ve ark., 2005).

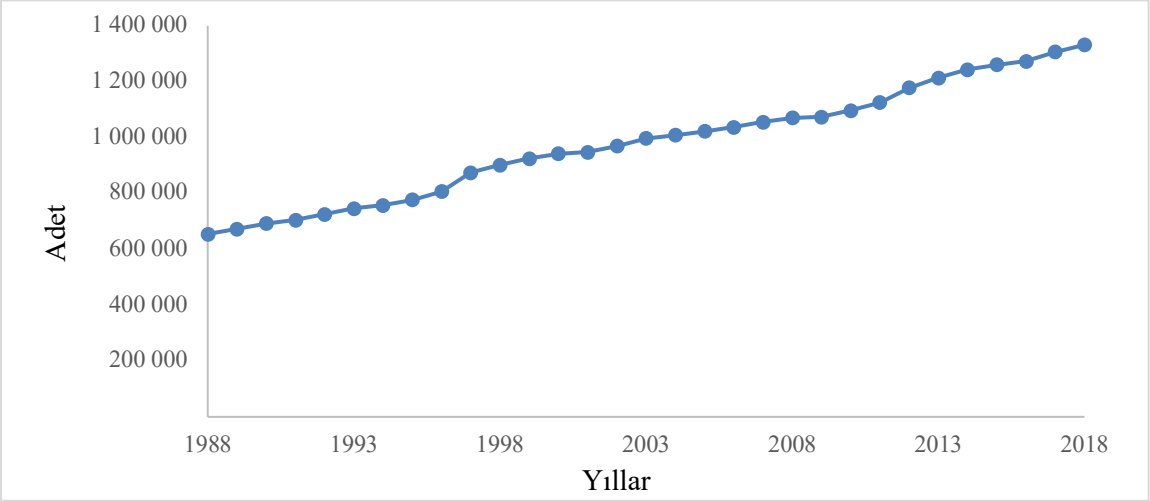
Tarımda makina kullanımı, diğer tarım teknolojisi uygulamalarından farklı olarak, verim artışını dolaylı etkilemekte; kırsal kesimde yeni üretim yöntemlerinin uygulanmasını sağlamaktadır. Bu yönüyle diğer teknolojik uygulamaların etkinliğini ve ekonomikliğini artırmanın yanı sıra çalışma koşullarını da iyileştirmektedir. Böylece, uygun teknolojilerin kullanımına olanak sağlayarak belirli büyüklüğe sahip üretim alanlarından daha fazla verimin alınmasına yardımcı olmaktadır. Mekanizasyon yüksek maliyetli bir üretim girdisidir. Doğru seçilmemesi ve uygulanmaması durumunda işletme ölçeğinde üretimin

kârlılığını olumsuz etkileyebilmekte, plansız mekanizasyon sonucu tarım ve sanayi kesimleri arasındaki denge tarım aleyhine bozulabilmekte ve kırsal kesimdeki işsizliğin artmasına neden olabilmektedir. Bu girdinin en ekonomik kullanımı ancak yöresel koşullara uygun planlama modelleri ile mümkün olabileceği için, tarımsal mekanizasyonun artırılabilmesi ancak tarımsal mekanizasyon planlamasının doğru bir şekilde yapılması ile sağlanabilir (Özgüven ve ark., 2010).

2. Mevcut Durum

Tarımsal mekanizasyon düzeyinin belirlenmesi, tarımsal üretimde verimliliğin ve karlılığın bir göstergesi olmakta birlikte, belli ülkeler, bölgeler ve hatta işletmeler arasında tarımda gelişmişlik göstergesi olarak değerlendirilmektedir. Bu düzeyin belirlenmesinde traktör ve traktörle kullanılan alet ve makinaların sayısal yoğunluğu ile işletme alan büyüklükleri temel olmaktadır. Mekanizasyon düzeyini belirlemede kullanılan en yaygın kriterler 1 000 ha işlenen alana düşen traktör sayısı, birim alan için traktör gücü, traktör başına düşen işlenen alan, traktör başına düşen alet-ekipman sayısıdır (Evcim ve ark., 2015; Gökdoğan, 2012; Uulu ve ark., 2018).

Ülkemizde yıllara göre traktör sayıları incelendiğinde 1988 yılında toplamda 654 636 adet iken, 1998, 2008 ve 2018 yıllarında sırasıyla 902 513, 1 070 746 ve 1 332 139 adet olmuştur (Şekil 1 ve Çizelge 1). 2018 yılı TÜİK verilerine göre traktörlerin % 5.85'i tek akslı, % 0.01'i paletli ve % 94.14'ü iki akslı olarak kullanılmaktadır. Her biri kendi içerisinde değerlendirildiğinde ise, tek akslı traktörlerde % 78.0'lik kısmın 5 BG'den daha yüksek seviyelerde olduğu görülmektedir. İki akslı traktörlerde ise % 39.3'lük payın 35-50 BG, % 40.3'lük payın 51-70 BG ve %13'lük payın da 70 BG'den daha büyük güçlü traktörler olduğu izlenmektedir (TÜİK, 2021).



Şekil 1. Yıllara göre toplam traktör sayılarındaki değişim, 1988-2018.

Yapılan bir başka çalışmada 2018 yılı itibariyle 1 882 077 adet traktör bulunduğu, bunların yaş ortalamasının 24 olduğu belirtilmiştir. Bu traktörlerin 600 bininin 35, 870 bininin ise 25 yaşın üzerinde olduğu vurgulanmıştır. Traktör ömrünün yıllık 500 saatlik kullanım koşullarında 20 yıl olduğu düşünüldüğünde, 2017 yılı itibariyle traktör parkının sadece % 33'ünün tarımsal faaliyetlerde ekonomik olarak kullanıldığı bildirilmiştir. Geriye kalan yaşı büyük traktörlerin daha yüksek yakıt tüketimi ve tamir-bakım masraflarının yanı sıra daha düşük teknolojiye sahip oldukları da göz önünde bulundurulmalıdır. Aynı zamanda bu traktörler iş ve zaman kayıplarına neden olmakta, kaza yapma ve can güvenliği açısından yüksek risk taşımaktadırlar. Yenilenen bir traktörün kullanılması ile 80 kg daha az NO_x (azotoksit), 27 kg daha az kurum, 56 kg daha az CO, 82 kg daha az HC yayılımı gerçekleşeceği, gürültü açısından da 7 dbA'lik bir azalma oluşacağı bildirilmektedir (İleri, 2019). Ayrıca mekanik ömrünü doldurmuş bir traktörün yenilerine oranla % 30 oranında daha fazla yakıt tükettiği ve yılda 150 saatlik iş kaybına neden olduğu da belirtilmektedir (Evcim, 2008).

Çizelge 1. Traktör sayısı, 1988-2019 (TÜİK, 2021)

		Tek akslı		İki akslı						Paletli
		BG		BG						(Tırtıllı)
	Toplam	1-5	5 +	1-10	11-24	25-34	35-50	50+	51-70	70+	
1988	654 636	623	1 311	2 655	16 741	62 230	351 210	219 545	-	-	321
1989	672 845	1 169	1 326	3 623	17 704	64 494	358 620	225 556	-	-	353
1990	692 454	1 234	1 570	3 175	17 841	66 696	364 052	237 579	-	-	307
1991	704 373	968	2 334	3 200	20 194	66 288	366 159	244 910	-	-	320
1992	725 933	951	2 432	3 352	20 595	68 540	373 162	256 601	-	-	300
1993	746 283	1 047	2 714	3 321	20 539	69 239	379 835	269 253	-	-	335
1994	757 505	1 033	2 946	2 770	19 499	68 945	384 160	277 850	-	-	302
1995	776 863	1 022	3 445	2 841	19 960	72 535	389 023	287 616	-	-	421
1996	807 303	1 075	4 620	2 960	19 838	75 116	401 360	301 935	-	-	399
1997	874 995	2 370	4 501	2 631	19 967	78 240	424 128	342 709	-	-	449
1998	902 513	1 449	5 826	3 271	20 371	78 796	434 018	358 456	-	-	326
1999	924 471	1 323	6 783	3 439	20 311	78 094	437 928	376 092	-	-	501
2000	941 835	2 049	7 882	3 776	20 409	77 364	446 541	383 424	-	-	390
2001	948 416	2 048	8 727	4 243	19 955	74 533	450 452	388 098	-	-	360
2002	970 083	2 994	15 689	4 149	19 962	75 359	449 139	-	356 943	45 668	180
2003	997 620	3 098	10 896	4 104	21 155	78 621	459 383	-	368 549	51 668	146
2004	1 009 065	3 220	11 784	3 904	21 075	77 747	458 677	-	376 108	56 349	201
2005	1 022 365	2 848	13 321	3 495	20 264	77 205	460 336	-	382 448	62 237	211
2006	1 037 383	3 094	11 743	3 480	19 716	76 340	465 926	-	390 904	65 972	208
2007	1 056 128	3 852	13 156	4 352	19 260	76 514	469 201	-	399 528	70 029	236
2008	1 070 746	4 096	13 675	6 027	19 635	76 670	471 817	-	401 791	76 817	218
2009	1 073 538	4 403	16 422	4 853	20 494	76 507	465 237	-	404 032	81 386	204
2010	1 096 683	5 235	20 176	5 344	19 997	72 411	471 531	-	414 977	86 813	199
2011	1 125 001	8 212	27 283	5 578	21 244	72 668	476 010	-	422 389	91 411	206
2012	1 178 253	9 450	36 188	5 696	20 704	71 989	488 877	-	438 623	106 522	204
2013	1 213 560	10 889	42 476	5 937	20 153	71 165	493 462	-	451 292	118 000	186
2014	1 243 300	14 383	51 492	6 247	20 906	69 223	493 914	-	461 399	125 536	200
2015	1 260 358	14 856	54 604	6 252	21 181	68 074	491 828	-	468 060	135 297	206
2016	1 273 531	15 736	57 131	6 448	21 274	66 825	489 621	-	475 665	140 699	132
2017	1 306 736	16 589	59 061	6 432	20 527	65 866	492 343	-	493 660	152 133	125
2018	1 332 139	17 129	60 707	6 554	20 886	66 104	493 134	-	505 087	162 425	113
2019	1 354 912	17 512	62 178	6 589	20 513	65 496	495 375	-	513 035	174 105	109

Ülkemizde traktör imalatı değerlendirildiğinde ise, 1992 yılında 22 011 adet iken 2017 yılında 72 032 adete çıktığı, ancak son iki yılda önemli bir düşüş gerçekleştiği görülmektedir (Çizelge 2). Üretimde Ocak-Eylül döneminde ise 2017-2019'da % 60.4, 2018-2019'da % 49.7'lik, aynı şekilde trafik tescilinde de Ocak-Temmuz döneminde 2017-2019'da % 67.9, 2018-2019'da % 58.8 orannda bir azalma olduğu bildirilmiştir. Bununla beraber traktör ihracatımız 2001 yılında 3 791 adet iken, 2018 yılında 19 256 adete çıkmıştır. Ancak artış hızı Ocak-Eylül dönemi değerlendirildiğinde, 2017-2019'da % 24.6, 2018-2019'da bir miktar düşerek % 17.2 seviyesinde gerçekleşmiştir. 2018 yılı rakamlarına göre traktör ihracatının değeri 423.6 milyon ABD doları iken, ithalat 162.4 milyon ABD doları olmuştur (Çizelge 2) (İleri, 2019; TARMAKBİR, 2019). Parkta bulunan traktör sayılarına dair kurumlar arasında farklı bilgiler mevcuttur. Bunun temel iki nedeni TÜİK'in trafik tescili devam eden bütün traktörleri (tarımda kullanılsın veya kullanılmasın) değerlendirmesi, buna karşılık Tarım ve Orman Bakanlığı'nın tarımda kullanılan traktörleri (sahada) sayım yoluyla raporlaştırmasıdır (TARMAKBİR, 2020). Ülkemizde meydana gelen ekonomik dalgalanmalar yıllara bağlı imalat rakamlarındaki değişken oranda artış ve azalışlara sebep olmuştur.

Çizelge 2. Traktör imalatı, ihracat ve ithalat değerleri, 1992-2018 (İleri, 2019; TARMAKBİR, 2020)

Yıllar	Traktör imalatı (adet)	Traktör ihracatı (adet)	İhracat değeri (milyon ABD doları)	Traktör ithalatı (adet)	İthalat değeri (milyon ABD doları)
1992	22 011	-	-	-	-
1993	33 601	-	-	-	-
1994	25 817	-	-	-	-
1995	44 482	-	-	-	-
1996	54 819	-	-	-	-
1997	58 736	-	-	-	-
1998	61 868	-	-	-	-
1999	27 867	-	-	-	-
2000	37 938	-	-	-	-
2001	15 052	3 791	30.62	137	1.88
2002	10 840	4 554	38.77	279	6.14
2003	29 761	12 664	156.74	988	11.05
2004	42 511	10 376	147.13	4 207	115.90
2005	41 502	8 361	123.94	5 977	163.81
2006	44 386	9 871	147.90	7 345	210.55
2007	37 623	9 376	159.50	4 925	148.99
2008	28 751	10 766	221.54	5 441	161.92
2009	17 762	9 337	178.70	3 803	90.80
2010	39 134	10 000	195.43	8 896	200.09
2011	62 250	10 719	219.41	14 961	345.23
2012	53 982	16 191	324.85	11 699	259.30
2013	56 407	15 372	340.68	11 166	244.49
2014	64 342	17 739	434.24	13 634	276.70
2015	66 615	17 533	374.47	20 659	396.61
2016	66 915	15 767	338.70	21 634	390.22
2017	72 032	14 565	320.94	18 107	343.57
2018	47 689	19 256	423.60	8.044	162.39
2019	29.539	23.32	479.87	6.472	81.52

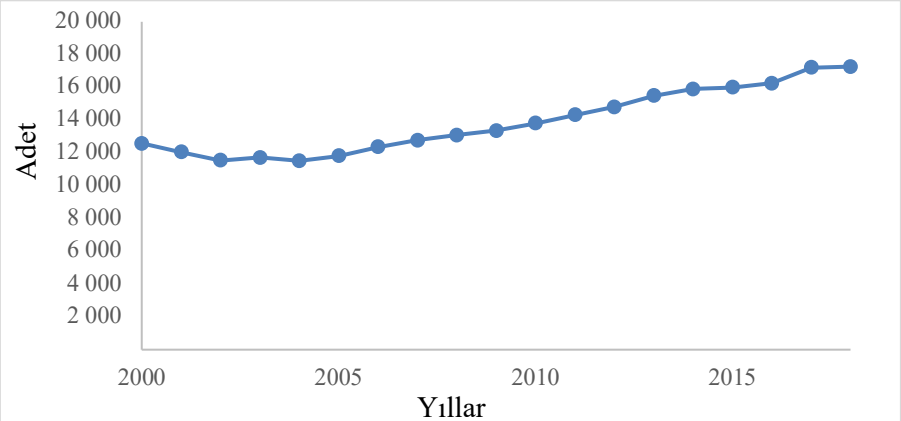
Traktör pazarı değerlendirildiğinde ise, Türkiye'de 30 firma ve 40 markanın olduğu, dünyanın en büyük 4. pazarı haline geldiği, yıllara göre farklılıklarla beraber özellikle kriz dönemlerinde çok düşük düzeylere düştüğü görülmektedir. 2017 yılı için 72 909 adet traktör iken, 2018 yılında 48 356 olarak gerçekleştiği belirtilmiştir.

Ülkemizde biçerdöverler iklimin uygunluğu nedeniyle müteahhitlik yoluyla kullanılmaktadır (Şekil 2). Güneydoğu Anadolu Bölgesi'nde hasada başlayan biçerdöverler tüm ülkeyi dolaşmakta, daha sonra yurt dışında hasada devam etmektedirler. 2000 yılında 12 578 adet olan biçerdöver sayısı, 2018 yılında 17 266 adede ulaşmıştır (Çizelge 3, Şekil 3). Ancak yaş gruplarına göre yapılan değerlendirmeye göre biçerdöver parkının % 52.9'u 10, % 29.9'u ise 20 yaşın üzerindedir (Şekil 4). Dolayısı ile bu parkın tamamının aynı hassasiyette çalışmadığı, bu biçerdöverlerde kayıpların çok daha yüksek olduğu düşünülmektedir.

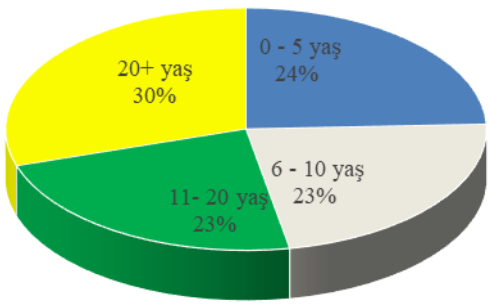
Şekil 2. Ülkemizde biçerdöverlerle yapılan hasat.

Çizelge 3. Biçerdöver sayısı ve yaş grupları dağılımı, 2000-2018 (TÜİK, 2019)

		Yaş grubu			
	Toplam	0 - 5	6 - 10	11- 20	20+
2000	12 578	-	-	-	-
2001	12 053	-	-	-	-
2002	11 539	1 213	2 125	3 526	4 675
2003	11 721	1 352	2 214	3 545	4 610
2004	11 519	1 430	2 298	3 489	4 302
2005	11 811	1 659	2 405	3 551	4 196
2006	12 359	2 036	2 598	3 596	4 129
2007	12 775	2 338	2 739	3 652	4 046
2008	13 084	2 558	2 873	3 657	3 996
2009	13 360	2 643	2 950	3 669	4 098
2010	13 799	2 820	3 116	3 721	4 142
2011	14 313	3 038	3 293	3 834	4 148
2012	14 813	3 160	3 483	3 960	4 210
2013	15 486	3 431	3 722	3 882	4 451
2014	15 899	3 604	3 812	3 852	4 631
2015	15 998	3 815	3 750	3 780	4 653
2016	16 247	3 985	3 790	3 813	4 659
2017	17 199	4 167	3 907	4 062	5 063
2018	17 266	4 207	3 924	3 969	5 166



Şekil 3. Biçerdöver sayısındaki değişim, 2000-2018 (TÜİK, 2019).



Şekil 4. 2018 yılında biçerdöverlerin yaş grupları (TÜİK, 2019).

Biçerdöverlerin mekanik ömrü 3 000 saat olarak kabul edilmektedir ve yıllık çalışma saatlerinin 300-350 saat olduğu varsayımıyla ömürlerinin 9-10 yıl olacağı kestirilmektedir. Ancak ülkemizde

biçerdöver kullanımı müteahhitlik sistemi ile yapıldığından biçerdöverler ülkemizi dolaşmakta ve aynı zamanda farklı ürünler için de kullanılmaktadır. Dolayısı ile yıllık kullanım süresi 1 200 saate kadar çıkmaktadır. Bu şekilde düşünüldüğünde mekanik ömrünün 3-4 yıl içerisinde dolacağı, bunun sonucu olarak da biçerdöver parkında bulunan mekanik ömrünü tamamlamış araçların bakım, onarım, yakıt ve işçilik giderlerinin yüksek, ayrıca ürün ve kalite kayıplarına da neden olacağı açıktır. Bu kaybın büyüklüğünü insan beslenmesi açısından çok önemli bir kaynak olan buğday üretimini değerlendirerek incelediğimizde, 2018 yılı için 20 milyon ton buğday üretildiği görülmektedir. Bu miktar ürünün yaşlı biçerdöverlerle 10 milyon ton'luk kısmının hasat edildiği varsayıldığında, yaklaşık % 8'lik kayba neden olduğu düşünülürse 700 bin ton buğday, dolayısı ile 2018 fiyatlarına göre 800 milyon TL'lik bir zarar oluşacağı belirtilmelidir. Bu kayıp değerinin her bir birim artması, bu kaybın katlanması ile sonuçlanacaktır. Aynı şekilde yakıt tüketimi açısından yapılan değerlendirmede de ömrünü doldurmuş ve modern biçerdöverlerle yapılan hasat sırasındaki yıllık yakıt tüketimi farkının yaklaşık 13 bin ton olduğu ifade edilmiştir (İleri, 2019). Bunun yanı sıra ömrünü doldurmuş biçerdöverlerin kullanılması, yüksek yakıt tüketimi, birim zamanda daha az hasat, yüksek arıza sıklığı ile hasat döneminde yaşanan zaman kayıpları ve düşük tarla etkinliği, düşük operatör verimi, aşırı işletme giderleri, çevre kirliliği sonucunda gelir ve kalite kaybına neden olmaktadır.

Türkiye'de tarım makinaları sektöründe faaliyet gösteren firma sayısı TÜİK kayıtlarına göre 2017 yılı için 1 161 imalatçı firma olarak belirtilmiştir. Sektörde çalışan sayısı ise 18 747 kişidir. Firma sayısı oldukça fazla görülmesine rağmen, önemli bir kısmının birkaç kişi çalıştıran torna/kaynak atölyesi niteliğinde olan son derece küçük işletmeler olduğu tahmin edilmektedir (Profi, 2019). Tarımsal üretimin birçok aşamasında kullanılan çok farklı makinaların sayılarındaki değişim 2003-2018 yılları için Çizelge 4'te verilmiştir. Burada toprak işleme, ekim-dikim-gübreleme, bakım, ilaçlama, sulama, hasat, hayvancılık ve içsel tarımda kullanılan makinaların sayılarındaki değişim incelenebilir. Görüleceği gibi en büyük artış, meyve hasat makinaları, pamuk toplama makinası, motorlu tırpan ve yem dağıtıcı römork sayılarında olmuştur. Bunun yanı sıra, hayvanla çekilen hububat ekim makinası, tarımsal mücadele uçağı, döven, karasaban ve hayvan pulluğu sayılarında önemli düzeyde azalma meydana gelmiştir (TÜİK, 2019).

Tarım makinaları ihracat ve ithalat değerleri incelendiğinde, 2001 yılında 26.4 milyon ABD doları olan ihracatımız hemen her yıl artarak 2018 yılında 406.4 milyon ABD dolarına yükselirken, ithalatımız aynı yıllar için 42.0 ve 298.2 milyon ABD doları olarak gerçekleşmiştir (Çizelge 5). 2017 yılı için dış ticaretimizde farklı tarım makinaları gruplarına göre dağılım yapıldığında, ihracatta en önemli pay % 32 ile toprak işleme, ekim, gübreleme ve bitki bakım ekipmanları, % 24.5 ile tohum ilaçlama, budama, yem hazırlama, ormancılık, kümes ve arıcılık makinalarını kapsamaktadır (Çizelge 6). İthalatta ise en büyük pay % 54.5 ile hasat-harman, biçme, balya ve sınıflandırma ekipmanlarına aittir. Benzer durum 2018 yılı için de ufak miktardaki değişikliklerle beraber aynı şekilde gerçekleşmiştir (Çizelge 7). Bununla beraber 2018 yılında 120 ülkeye ihracatın olduğunu, karşılığının ise 830 milyon ABD doları ile ekipman, 150 milyon ABD doları ile traktör aksam ve parçalarını kapsadığını belirtmek gerekmektedir. En çok ihracat yapılan ülkeler ise ABD, İtalya, Azerbaycan, Irak, Özbekistan, Sudan, Bulgaristan, Cezayir, Avustralya ve Sırbistan'dır (İleri, 2019). Dünya toplam traktör ihracatı 2016 yılında 16.6 milyar ABD doları, ekipman ihracatı ise 34.1 milyar ABD doları olarak gerçekleşmiştir. Hem traktör hem de ekipman ihracatının ilk sırasında Almanya (% 19 ve % 17) gelmekte, Türkiye ise 12. (% 2) ve 24. (% 0.8) sırada yer almaktadır. Dünya ithalatında ise aynı yıl için traktörde 15.5 milyar ABD doları, ekipmanda 26.2 milyar ABD doları kullanılmıştır. Dünya traktör ve ekipman ithalatının ilk sırasında ABD (% 19 ve % 14) gelirken, Türkiye % 3 ve % 1 payla 10. ve 31. sıradadır (TAGEM, 2018).

Çizelge 4. Tarım makinaları sayılarındaki değişim, 2003-2018 (TÜİK, 2019)

Tarım alet ve makinalar	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Anıza ekim makinası	2 154	2 140	2 186	637	690	743	814	633	736	860	1 046	1 209	1 257	1 292	1 320	1 422
Ark açma pulluğu	54 421	56 212	58 076	58 626	60 475	61 198	61 456	63 926	64 402	66 664	66 791	66 150	66 879	68 117	68 654	69 080
Atomizör	103 812	100 823	100 758	103 125	103 324	103 490	105 036	112 738	113 641	114 435	116 789	115 995	116 883	120 402	121 448	123 790
Balya makinası	8 999	9 072	9 431	10 185	10 998	11 839	12 613	13 303	14 524	15 887	18 024	19 459	20 446	21 520	23 015	24 682
Biçer bağlar makinası	5 072	4 557	4 558	4 950	5 039	6 107	6 139	6 451	6 987	7 409	8 468	8 882	9 210	9 305	9 478	9 492
Biçerdöver	11 721	11 519	11 811	12 359	12 775	13 084	13 360	13 799	14 313	14 813	15 486	15 899	15 998	16 247	17 199	17 266
Civciv ana makinası	1 511	1 487	1 592	1 695	1 644	1 582	1 520	1 390	1 384	852	853	978	968	1 005	981	971
Çiftlik gübresi dağıtma makinası	1 717	1 671	1 916	1 950	1 938	1 967	2 223	2 282	2 508	2 519	2 915	3 628	4 090	4 382	4 795	5 246
Damla sulama tesisi	124 036	142 350	149 792	160 629	182 991	206 307	219 052	245 823	264 639	293 967	318 413	362 033	389 831	412 468	441 366	475 141
Derin kuyu pompa	95 604	99 623	103 540	106 627	115 875	122 622	122 831	131 009	134 734	142 540	148 675	163 275	168 502	172 923	179 659	185 708
Dipkazan (Subsoiler)	15 993	18 494	19 238	22 205	23 708	24 654	26 150	27 688	27 541	29 054	30 401	32 568	35 132	36 515	38 127	39 277
Diskli anız pulluğu (Vanvey)	37 960	38 223	39 210	41 745	41 725	41 964	42 280	43 642	43 251	44 220	44 387	45 405	45 002	45 365	46 540	47 036
Diskli tırmık (Diskarolar)	190 739	191 789	192 700	191 360	198 548	204 665	205 804	213 909	221 884	229 761	232 278	235 594	240 303	243 310	247 121	251 439
Diskli traktör pulluğu	64 076	63 149	64 965	66 801	66 491	66 933	67 838	67 954	67 452	68 332	68 773	70 701	71 829	72 448	73 139	74 054
Dişli tırmık	348 911	350 640	351 327	353 205	355 991	353 128	348 587	351 866	350 406	350 968	343 906	341 050	343 954	345 533	350 126	353 932
Döven	46 417	39 440	36 452	30 477	28 855	27 582	22 015	18 875	17 305	15 612	14 874	13 543	12 407	12 168	11 749	10 337
Elektropomp	147 909	155 474	157 873	159 603	167 050	172 022	170 459	174 294	180 399	186 503	192 378	203 614	210 045	214 407	221 016	228 524
Fındık harman makinası	5 603	5 749	5 851	6 035	5 315	5 409	5 276	5 309	5 362	5 474	5 621	5 616	5 687	5 861	5 878	5 752
Fide dikim makinası	10 727	10 621	12 631	12 852	12 900	12 960	13 016	13 270	13 036	13 391	13 894	14 145	14 188	13 939	13 820	13 793
Hayvan pulluğu	233 708	215 322	207 033	196 278	181 974	170 797	155 196	137 526	129 153	121 320	110 903	89 155	82 732	78 344	70 471	64 827
Hayvanla çekilen çayır biçme makinası	2 155	2 128	2 092	2 071	2 048	1 830	1 701	1 564	1 561	1 535	1 521	1 546	1 588	1 601	1 639	1 451
Hayvanla çekilen hububat ekim makinası	1 619	1 515	1 234	1 197	806	750	582	506	460	346	289	194	159	159	133	69
Hayvanla ve traktörle çekilen ara çapa makinası	141 315	141 443	141 961	144 308	146 408	146 615	141 939	138 413	137 838	135 428	133 608	132 603	135 684	136 942	139 385	139 774
Karasaban	125 335	110 486	103 578	91 213	84 304	77 175	68 463	58 695	51 889	49 453	45 965	40 695	37 455	34 643	31 330	27 313
Kepçe (Tarımda kullanılan)	21 441	23 433	26 363	29 798	32 314	33 403	34 750	38 867	41 163	41 620	42 470	45 727	48 559	50 304	53 996	56 860
Kimyevi gübre dağıtma makinası	314 660	320 609	326 599	334 461	339 461	346 471	354 973	366 781	371 771	385 149	389 918	392 908	399 451	408 737	419 388	428 545
Kombikürüm (Karma tırmık)	20 604	22 621	22 169	22 374	24 891	24 984	24 600	25 971	26 029	24 840	24 495	23 555	23 881	24 352	24 786	26 096
Kombine hububat ekim makinası	162 763	166 897	163 577	164 524	169 695	173 654	179 048	187 459	196 147	199 640	202 915	205 286	208 403	211 348	217 642	221 782
Kombine pancar hasat makinası	3 056	3 521	3 928	4 029	3 593	3 716	3 932	4 271	4 590	4 921	5 288	5 448	5 593	5 807	6 256	6 733
Kombine patates hasat makinası	515	520	574	591	608	612	630	766	811	839	902	993	924	980	574	804
Krema makinası	253 086	246 482	239 836	240 295	234 050	230 138	222 470	214 482	210 047	200 922	197 520	182 920	178 535	177 268	174 176	173 871
Kulaklı Anız pulluğu	26 536	26 285	26 871	27 045	28 304	29 411	33 791	36 797	37 752	39 834	39 909	42 483	44 151	44 579	45 450	44 592
Kulaklı traktör pulluğu	930 943	947 416	958 228	983 275	986 291	996 013	1 002 734	1 014 188	1 025 892	1041 903	1 045 122	1 046 048	1 050 237	1 057 870	1 071 553	1 079 396
Kuluçka makinası	978	1 008	962	1 062	1 114	1 025	1 075	1 000	1 147	1 140	1 146	1 206	1 247	1 285	1 410	1 507
Kuyruk milinden haraketli pülverizatör	229 497	239 126	241 753	245 311	255 582	259 475	264 421	278 761	291 505	305 295	312 651	322 174	329 768	338 625	350 272	358 407
Kültüvatör	421 455	430 074	430 981	443 776	451 214	457 711	466 727	479 972	488 802	500 126	503 786	508 218	515 172	520 970	532 508	540 795

Çizelge 4. Tarım makinaları sayılarındaki değişim, 2003-2018 (TÜİK, 2019) (devam)

Tarımsal alet ve makinalar	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Merdane	64 195	66 503	67 322	72 371	75 682	77 445	77 294	81 094	82 100	83 033	83 487	84 819	86 138	87 374	91 011	93 266
Meyve hasat makinası	122	171	190	265	320	510	647	1 535	2 522	4 119	6 565	8 117	10 556	13 243	16 220	17 831
Mısır daneleme makinası	5 766	5 715	6 262	5 621	5 447	5 433	5 343	5 350	4 388	4 336	4 352	4 268	4 195	4 170	4 175	4 164
Mısır hasat makinası	542	506	534	588	677	726	749	863	915	987	1 019	1 030	1 043	1 142	1 211	1 292
Mısır silaj makinası	6 327	7 416	8 717	9 734	11 998	14 000	15 287	16 627	18 507	19 988	21 887	24 486	25 370	26 347	27 998	29 247
Motopomp (Termik)	197 888	198 407	196 687	197 395	198 735	197 514	193 698	193 032	193 898	194 776	194 154	191 855	192 827	192 871	192 841	192 238
Motorlu pülverizatör	72 618	72 868	72 838	73 015	71 015	72 171	72 494	73 745	75 905	78 151	80 457	84 093	85 974	87 486	90 832	95 143
Motorlu tırpan	6 134	7 942	9 974	14 034	17 400	18 785	21 167	32 608	47 985	56 693	65 013	76 236	84 307	91 865	101 664	111 544
Orak makinası	64 434	64 489	64 549	64 972	65 977	69 430	71 415	69 411	66 768	63 092	61 954	60 645	58 271	57 234	53 972	52 172
Ot silaj makinası	1 984	2 017	2 225	2 585	2 853	3 087	3 156	3 471	3 778	3 917	4 248	4 674	4 908	5 227	5 541	5 783
Ot tırmığı	63 944	64 824	68 132	68 566	70 335	101 958	98 383	99 729	101 452	103 940	106 668	110 030	113 405	115 169	115 809	119 760
Pamuk toplama makinası	31	56	128	349	500	520	508	595	730	910	950	1 050	1 080	1 155	1 245	1 285
Pancar sökme makinası	9 606	10 087	10 757	10 400	10 845	12 927	13 332	13 750	14 306	14 752	15 125	15 059	15 172	15 319	15 134	15 474
Patates dikim makinası	11 830	11 875	12 217	12 761	13 183	13 632	13 698	14 006	14 413	14 970	15 152	15 421	15 769	16 087	16 717	16 993
Patates sökme makinası	15 794	15 637	15 974	16 243	16 802	16 932	16 938	18 679	19 274	20 176	19 756	20 229	20 462	20 353	21 250	21 477
Pnömatik ekim makinası	15 908	20 668	18 633	19 874	22 048	22 919	23 165	25 390	27 153	29 377	30 921	32 048	34 589	35 850	39 024	40 376
Rototiller	7 187	7 820	8 666	9 097	9 584	9 807	10 297	10 760	11 080	11 640	11 942	12 870	13 443	13 978	15 092	15 737
Römork (Tarım arabası)	966 596	986 313	995 523	1 011 577	1 026 389	1 036 613	1 041 239	1 061 656	1 074 764	1 098 995	1 109 917	1 121 371	1 126 166	1 137 709	1 165 873	1 184 193
Saman aktarma boşaltma makinası	9 218	10 021	10 474	11 687	11 520	11 366	11 995	13 347	13 955	14 175	14 009	14 348	15 328	15 621	16 431	16 789
Santrifüj pompa	92 359	92 821	96 572	97 622	98 762	104 141	104 898	109 155	110 450	108 665	108 872	111 593	111 682	113 075	114 159	115 046
Sap döver ve harman makinası (Batöz)	193 963	193 930	197 017	196 346	194 847	192 440	190 856	187 978	188 153	185 327	181 320	173 555	170 836	167 581	160 121	155 600
Sap parçalama makinası	12 170	12 876	13 571	13 881	14 933	15 075	15 243	16 685	17 288	17 968	17 889	17 864	18 239	18 533	19 014	19 241
Sap toplamalı saman yapma makinası	10 084	11 902	12 563	12 942	12 980	11 966	12 513	13 662	14 062	15 062	16 445	17 338	17 711	17 978	18 542	19 106
Sedyeli, motorlu pülverizatör tozlayıcı kombine atomizör	16 281	16 212	16 411	15 828	14 993	15 084	13 955	14 188	14 020	14 303	14 325	13 811	12 731	12 802	13 832	13 997
Selektör (Sabit veya seyyar)	4 092	4 156	4 310	4 258	4 387	4 390	4 378	4 347	4 388	4 481	4 455	4 394	4 321	4 443	4 400	4 516
Set yapma makinası	11 582	12 303	12 957	13 434	14 146	14 095	13 967	15 032	15 734	15 892	16 004	15 796	16 131	16 639	16 650	16 912
Sırt pülverizatörü	580 927	580 547	582 618	586 685	587 821	590 590	588 556	591 373	597 460	606 366	612 626	623 190	628 059	633 598	641 819	647 442
Su tankeri (Tarımda kullanılan)	171 469	176 576	180 208	184 195	187 727	191 309	194 573	198 031	200 350	206 078	208 544	208 538	209 372	210 697	213 393	216 276
Süt sağım makinası (Seyyar)	109 728	121 534	130 087	150 049	164 051	177 630	187 123	208 457	225 937	254 348	268 164	282 433	292 405	301 795	319 885	332 595
Süt sağım tesisi	5 618	5 637	5 571	5 763	5 749	6 216	6 714	7 280	7 959	7 336	8 182	9 279	9 744	10 057	12 226	12 856
Tarımsal mücadele uçağı	57	58	62	60	61	49	33	20	22	10	8	8	8	5	5	5
Taş toplama makinası	330	356	373	410	416	422	471	530	653	806	990	1 240	1 356	1 448	1 571	1 657
Tınaz makinası	16 627	15 910	15 703	14 082	13 634	13 368	12 167	12 015	11 523	11 201	10 710	8 405	8 111	7 739	7 440	6 924
Toprak burgusu	2 388	2 630	2 894	3 575	4 148	4 340	4 682	4 920	5 047	5 502	5 561	5 917	6 277	6 470	6 550	6 809
Toprak frezesi (Rotovatör)	33 413	33 771	34 895	36 601	37 604	38 937	40 739	41 685	42 649	43 972	46 716	50 100	51 860	53 301	54 960	56 306
Toprak tesviye makinası	13 177	14 106	14 843	15 515	16 471	16 502	16 906	17 301	17 602	17 943	17 657	17 919	18 238	18 873	19 182	19 328
Tozlayıcı	34 671	30 924	27 729	24 773	24 522	23 694	22 996	22 800	21 543	19 509	19 307	17 827	17 855	17 749	16 762	16 268

Çizelge 4. Tarım makinaları sayılarındaki değişim, 2003-2018 (TÜİK, 2019) (devam)

Tarımsal alet ve makinalar	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Traktörle çekilen çayır biçme makinası	39 682	40 684	42 690	46 213	50 669	54072	55 762	61 248	66 193	68 579	73 314	79 115	81 480	82 899	87 233	90 020
Traktörle çekilen hububat ekim makinası	89 441	90 171	94 588	101 776	101 633	106 533	111 049	117 276	119 889	128 675	131 471	134 786	136 846	140 329	142 258	144 927
Üniversal ekim makinası (Pancar mibzeri dahil)	66 216	63 073	62 982	63 392	62 979	62 892	61 634	61 487	62 015	61 702	61 922	61 337	61 353	61 018	61 660	61 509
Ürün kurutma makinası	303	392	478	525	587	621	629	675	739	826	862	927	974	1 006	1 069	1 113
Ürün sınıflandırma makinası (Selektör hariç)	5 972	6 100	6 396	6 772	7 163	8 059	9 295	13 215	13 601	13 763	14 371	14 577	14 785	14 928	15 119	15 276
Yağmurlama tesisi	188 258	194 055	197 908	200 780	206 014	216 130	219 868	229 691	235 104	236 078	240 253	247 520	248 039	252 215	259 838	267 022
Yayık	234 950	256 621	257 466	265 131	268 237	265 658	259 800	261 161	254 791	249 449	252 104	248 815	248 720	249 297	256 123	256 902
Yem dağıtıcı römork	354	508	545	463	605	849	1 219	1 483	1 711	1 844	2 052	2 484	2 874	3 356	4 066	4 894
Yem hazırlama makinası	18 508	18 604	18 753	19 957	21 435	21 419	21 497	22 140	23 397	24 478	25 891	26 924	27 747	28 979	31 962	35 957
Yerfıstığı harman makinası	174	156	159	161	210	214	220	249	231	238	245	265	282	300	323	365
Yerfıstığı hasat makinası	164	179	186	193	206	217	237	282	295	330	295	320	318	373	400	462

Çizelge 5. Ekipman ihracat ve ithalat değerleri, 2001-2018 (İleri, 2019)

Yıllar	Ekipman ihracatı değeri (milyon ABD doları)	Ekipman ithalatı değeri (milyon ABD doları)
2001	26.44	41.98
2002	22.70	35.18
2003	32.24	47.08
2004	52.27	121.98
2005	71.50	218.14
2006	93.98	278.63
2007	135.72	263.22
2008	178.16	216.84
2009	140.60	144.67
2010	165.59	255.52
2011	204.17	407.62
2012	234.47	408.72
2013	263.93	473.28
2014	299.91	352.22
2015	287.11	312.94
2016	277.47	300.21
2017	333.46	313.93
2018	406.43	298.17

Çizelge 6. Türkiye traktör ve ekipman dış ticareti, 2017 (İleri, 2019)

Sınıflandırma, tanımlama		İhracat değeri (bin $)	%	Traktör hariç %	İthalat değeri (bin $)	%	Traktör hariç %
Sulama ekipmanları	8424.8210	18 501	2.8	5.5	23 969	3.6	7.6
İlaçlama ekipmanları	8424.41 8724.49	15 484	2.4	4.6	8 733	1.3	2.8
Diğer	8424.8290	4 196	0.6	1.3	386	0.1	0.1
Sulama & İlaçlama Aksam-Parça	8424.90.11	11 483	1.8	3.4	27 558	4.2	8.8
Yükleyiciler	8428.9071 8428.9079	926	0.1	0.3	6 320	1.0	2.0
Toprak işleme, Ekim, Gübreleme ve Bitki Bakım Ekipmanları	8432	106 669	16.3	32.0	19 847	3.0	6.3
Hasat, Harman, Biçme, Balya ve Sınıflandırma Ekipmanları	8433	57 921	8.9	17.4	171 054	26.0	54.5
Süt Sağım ekipmanları	8434.10 8434.90	21 082	3.2	6.3	4 018	0.6	1.3
Diğer tarım makinaları (Tohum İlaçlama, Çit Budama, Yem Hazırlama, Ormancılık, Kümes ve Arıcılık Makinaları)	8436	81 859	12.5	24.5	49 050	7.5	15.6
Tarımsal römork	8716.20	14 487	2.2	4.3	48	0.0	0.0
Traktör	8701.90	320 497	49.0		344 405	52.3	
El traktörü	8701.10	849	0.1	0.3	2 942	0.4	0.0
TOPLAM		653 954			658 330		

Çizelge 7. Türkiye traktör ve ekipman dış ticareti, 2018 (İleri, 2019)

Sınıflandırma, tanımlama		İhracat değeri (bin $)	%	Traktör hariç %	İthalat değeri (bin $)	%	Traktör hariç %
Sulama ekipmanları	8424.8210	32 522	3.9	8.0	20 357	4.4	6.8
İlaçlama ekipmanları	8424.41 8724.49	19 228	2.3	4.7	8 012	1.7	2.7
Diğer	8424.8290	7 200	0.9	1.8	304	0.1	0.1
Sulama & İlaçlama Aksam-Parça	8424.90.11	11 309	1.4	2.8	17 838	3.9	6.0
Yükleyiciler	8428.9071 8428.9079	1 277	0.2	0.3	6 826	1.5	2.3
Toprak işleme, Ekim, Gübreleme ve Bitki Bakım Ekipmanları	8432	121 869	14.7	30.0	14 662	3.2	4.9
Hasat, Harman, Biçme, Balya ve Sınıflandırma Ekipmanları	8433	71 438	8.6	17.6	195 883	42.5	65.7
Süt Sağım ekipmanları	8434.10 8434.90	27 238	3.3	6.7	5 891	1.3	2.0
Diğer tarım makinaları (Tohum İlaçlama, Çit Budama, Yem Hazırlama, Ormancılık, Kümes ve Arıcılık Makinaları)	8436	103 882	12.5	25.6	25 234	5.5	8.5
Tarımsal römork	8716.20	9 023	1.1	2.2	44	0.0	0.0
Traktör	8701.90	423 603	51.0	0.0	162 391	35.3	0.0
El traktörü	8701.10	1 443	0.2	0.4	3 123	0.7	1.0
TOPLAM		830 032			460 565		

Tarımsal mekanizasyon düzeyi incelenirken; ülkemizin tarım alanlarındaki değişimin yanı sıra bu alana düşen traktör sayısı ve traktör gücü, traktör başına işlenen alan büyüklüğü ve alet-makina sayısı değerlerindeki değişim Çizelge 8'de verilmiştir. Görüldüğü gibi tarım alanlarının gün geçtikçe azaldığı, bununla beraber traktör başına düşen alanın da düştüğü, 1000 ha alana düşen traktör sayısının arttığı açıktır. Aynı zamanda işlenen alan başına düşen traktör gücü de artmış, 1990 yılında 1.10 kW/ha iken, 2018 yılında 2.10 kW/ha'a yükselmiştir. Traktör ortalama gücünün ise 2018 yılında 40.2 kW düzeyine ulaştığı bildirilmiştir (Evcim ve ark., 2010 ve 2015; İleri, Ağustos 2019).

Çizelge 8. Tarımsal mekanizasyon göstergelerinin değişimi (Evcim ve ark., 2010 ve 2015; İleri, 2019)

Yıllar	Tarım alanı (1000 ha)	Traktör sayısı (adet)	Traktör başına düşen alet /makine sayısı (traktör / alet - makine)	1000 ha işlenen alana düşen traktör sayısı (traktör/ 1000 ha)	Traktör başına işlenen alan (ha / traktör)	İşlenen alana düşen traktör gücü (kW/ha)	Ort. traktör gücü (kW)	1000 işletme başına traktör sayısı (traktör/ 1000 işletme)	B.döver başına düşen hasat edilen alan (b.döver/ 1000 ha)
1970	27 338	105 865	-	-	-	0.10	27.4	-	-
1980	28 175	436 369	-	-	-	0.96	36.3	-	-
1990	27 856	692 454	-	28.00	36.00	1.10	39.8	189.00	-
2000	26 379	941 835	-	44.00	22.76	1.85	42.0	377.00	-
2005	26 606	1 022 365	4.9	47.00	21.32	1.97	42.0	466.00	0.84
2010	24 395	1 096 683	5.0	58.00	17.36	2.48	43.0	606.00	1.11
2015	23 934	1 260 358	4.7	52.66	18.99	2.37	45.0	573.59	1.33
2018	23 375	1 332 139	4.6	52.50	19.00	2.10	40.2	633.45	1.54

3. Sonuçlar

Türkiye'de tarımsal mekanizasyonun başladığı zamandan günümüze kadar hem traktör hem de traktörle çalıştırılan tarım alet ve ekipmanları varlığında önemli düzeyde gelişmeler görülmüştür. Ancak buna rağmen; enerji tüketimi (kWh/ha), yakıt tüketimi (l/ha), zaman gereksinimi (h/ha) ve insan işgücü gereksinimini azaltmak (BGh/ha), tarla trafiğini azaltarak toprak sıkışmasını önlemek, optimum gübreleme, sulama ve ilaçlama sağlamak ve uzaktan algılama ve kontrol yöntemlerinin geliştirilmesi (GPS, GIS) konularında teknolojik beklentiler vardır. Bu beklentilerin karşılanması için Ar & Ge, inovasyon, üniversite-sanayi iş birliğinin geliştirilmesi, akıllı tarım makinalarının gelişerek yaygın kullanım alanı bulmaları, malzeme teknolojisinin üretime yansıması, meyve ve sebze hasat ve hasat sonu teknolojilerinin gelişmesi, çiftçi eğitimlerinde yenilikçi yaklaşımlar kullanarak gelişimlerine katkı sağlanması gerekmektedir. Türkiye'de imalat sanayi hem traktör hem de alet-ekipman bazında son yıllarda büyük gelişme göstermiştir. Traktör imalat sektöründe 2010-2017 döneminde % 111'lik, alet-ekipman imalatında ise aynı dönemde % 103'lük bir büyüme gerçekleşmiştir (Evcim ve ark., 2005; Profi, 2019).

Bununla beraber traktör gücünün düşük olması nedeniyle yüksek üretim teknolojilerine sahip makinaların kullanılamayacağı, sebebinin ise işletme yapılarının ve büyüklüklerinin elverişsiz olduğu unutulmamalıdır. Bunun yanı sıra yeteri kadar ekipmana sahip olmayan traktörlerle de gereken etkinlikte çalışmak mümkün değildir. Hem traktör sayısının hem de güç düzeyinin hiçbir anlamı kalmamaktadır. Tarımsal mekanizasyon kriterleri açısından ise, aynı gelişmişlik düzeyinde olduğu gibi ülkemiz bölgeleri arasında da farklılıklar vardır. Genel olarak mekanizasyon düzeyi kuru tarımın yapıldığı bölge ve illerde, sulu tarım yapılan bölgelere göre daha düşüktür. Aynı şekilde dağlık kesimlerde de düzey düşüktür, hatta kuvvet kaynağı olarak hala hayvan kullanımı söz konusudur. Çiftçilerin alım gücündeki dalgalanma ve düşüşler, tarımsal girdilerin içerisinde en esnek girdi olan tarım makinaları sektörünü olumsuz yönde etkilemektedir. Tarımsal mekanizasyon üretim girdilerinin % 35'ini kapsamasına rağmen, tohum, ilaç, gübre ve yakıttan daha az önemli görülmektedir. Mekanizasyon araçlarının eski teknolojiye sahip olmaları ürün verimini düşürmektedir. Mekanizasyona gerekli kaynağın aktarılmaması;

- Birim alandan elde edilen verimin ve ürün kalitesinin düşmesi,
- Tarlaya fazla gübre, ilaç ve egzoz emisyonu gibi insan, çevre ve canlıları etkileyecek olumsuz ortamın oluşması,
- Bakım-onarım masraflarının yanı sıra mazot ve yağ gibi işletme masraflarını artırması,

- Arıza ve kaza yapma riski olasılığının artması ile sonuçlanır (Koçtürk ve Avcıoğlu, 2007; Özgüven ve ark., 2010).

10 yaş üzerindeki biçerdöverler yapılacak desteklerle yenilenmeli, 20 yaşın üzerindekilerin kullanımına dahi izin verilmemelidir. Ancak bunların yenilenmesi için çeşitli teşvik mekanizmaları devreye sokulmalıdır. Bunun yanı sıra biçerdöverlerin uydu ile takibi gerçekleştirilmeli, kayıpların önlenmesi konusunda dikkat edilmelidir. Modern üretim teknolojilerinin kullanımını sağlayacak en önemli yollardan biri, ortak makina kullanımı gibi organizasyonların artırılmasıdır. Ayrıca ileri teknoloji, otomasyon ve yeni tasarımlardan beklentiler; daha kolay kullanılır ve yönetilir olmaları, işlevsel özellikleri iyileştirilmeli ve birleştirilmeli, edinme maliyeti getirisiyle karşılanabilmeli ve çiftçilerin ihtiyaçlarına cevap verebilmeleridir (Evcim ve ark., 2010).

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YÜZÜNCÜ YIL ÜNİVERSİTESİ TARIM BİLİMLERİ DERGİSİ
YAYIN İLKELERİ*

1. Van Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 1995 yılında yayın hayatına başlamış bir bilimsel araştırma dergisidir Dergide, tarım bilimleri (Bahçe Bitkileri, Bitki Koruma, Biyosistem Mühendisliği, Gıda Mühendisliği, Peyzaj Mimarlığı, Su Ürünleri Mühendisliği, Tarla Bitkileri, Tarımsal Biyoteknoloji, Tarım Ekonomisi, Toprak Bilimi ve Bitki Besleme, Zootekni) alanında düzenli olarak Mart, Haziran, Eylül ve Aralık aylarında yılda dört sayı yayımlanan uluslararası hakemli bir dergidir.
2. Dergimizde Türkçe ve İngilizce yazılmış Araştırma Makalesi, Teknik Not ve Derlemeler yayımlanır.
3. Yayımlanmak üzere gönderilen makalelerin herhangi bir yerde yayımlanmamış veya yayımlanmak üzere herhangi bir dergiye gönderilmemiş olması zorunludur. On yıldan eski çalışmalar değerlendirmeye alınmaz.
4. Dergiye yayınlanmak üzere gönderilen bir araştırma makalesi; Başlık, Türkçe ve İngilizce Özet, Giriş, Materyal ve Yöntem, Bulgular, Tartışma ve Sonuç ve Kaynaklar ana başlıkları altında hazırlanmalıdır. Bulgular ve Tartışma kısmı birlikte de yazılabilir.
5. Araştırma Makalesi 2500-5000, Derleme 4.000-7000 ve Teknik Not 1000-2500 kelime sayısı sınırları içerisinde olmalıdır.
6. Derlemeler bilimsel dergilerde yayınlanmış bilimsel yazıların, çalışmaların veya güncel gelişmelerin belirtilen konuda yoğun çalışmaları bulunan deneyimli yazarlarca (sorumlu yazarın derleme konusu ile ilgili Uluslararası hakemli dergilerde en az 5 özgün makaleye sahip olması şartı aranır) yapılan bir sentezi, yorumu ve durum değerlendirmesi şeklinde olmalıdır. Her sayıda basılan makale sayısının en fazla % 10'u kadar derlemeye yer verilir.
7. Araştırma makalesi olarak dergimize gönderilen çalışmalar lisansüstü tezlerden üretilmiş ise bu durum ilk sayfada dipnot olarak verilmelidir.
8. Dergimiz **Açık Kaynak Yayın Politikasını** benimsemektedir.
9. Dergimizde yayınlanacak makalelerin bilimsel etik kuralları içerisinde olması gerekmektedir. Makaleler, uluslararası kabul görmüş bilim etik kurallarına uygun olarak hazırlanmalıdır.
10. Etik Kurul Raporu gerekli hallerde (doğrudan/dolaylı olarak hayvan ile ilişkili olan çalışmalar) raporun bir kopyası metin ile birlikte gönderilmelidir.
11. Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisine gönderilen makaleler intihal raporu iThenticate yazılımı aracılığıyla kontrol edilir. Makalenin Benzerlik İndeksi (SI) < % 20; Her bir benzerlik oranı (alıntı yapılan her bir kaynak) ise ≤ % 5 olmalıdır. Benzerlik indeksi belirtilen düzeylerin üzerinde ise ilgili yazar/yazarlara makale iade edilir (Bir makale için en fazla 3 benzerlik taraması yapılır). Bu konuda yeterli düzeltmelerin 10 gün içerisinde yapılmaması halinde makale reddedilir. İntihal, makalenin yayınlanmasından sonra ispatlanırsa, o makale derhal web sitesinden çekilecek ve kaldırılacaktır ve ilgili yazar/yazarlar, Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisine beş yıl süre ile makale gönderemeyeceklerdir.
12. Makalede yer alan tüm yazarlar, çalışmalarının yayın haklarını Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi'ne verdiklerine dair Telif Hakları Formu'nu imzalamalıdırlar. Telif Hakkı Formu yazarlar tarafından gönderilmediği sürece çalışma değerlendirmeye alınmaz.
13. Değerlendirme süreci tamamlanan makaleler, geliş tarihi dikkate alınarak yayımlanır. Makaleler yayına hazır hale geldikleri andan itibaren yayınlanması planlanan ilk sayıya eklenirler; ancak tüm makaleler tamamlandıktan sonra ilgili sayı toplu halde yayınlanır.
14. Mizanpaj çalışması sırasında yazar(lar)a gönderilecek olan kontrol ve düzeltme amaçlı gönderilere (matbaa provası), en geç 15 gün içerisinde cevap verilmelidir. Belirtilen sürede cevap vermeyen yazar(lar)ın makaleleri daha sonraki sayıda değerlendirilmek üzere ötelenir.
15. Basımına karar verilen eserde ekleme ve çıkarma yapılamaz. Bir yazarın aynı sayıda sorumlu yazar olarak bir (1), sorumlu yazar olmadan da bir (1) eseri olmak üzere en fazla iki eseri basılabilir. Yayınlanan eserin tüm sorumluluğu yazar(lar)ına aittir.
16. Basım masrafları olarak eser başına 300 TL ya da 60 $ alınır.

ESER BAŞVURUSU

Makale Hazırlama

1. Dergimizde yayımlanmak üzere gönderilen eserler dergi yazım kurallarına göre hazırlanmalıdır. Yazım ilkelerine uygun olmayan çalışmalar hakem değerlendirme sürecine alınmadan yazarlara iade edilir. **YAZIM KURALLARI VE İLGİLİ ŞABLON için "https://dergipark.org.tr/yyutbd/writing-rules"** web adresine gidiniz.
2. Dergimizde yazım dili Türkçe ve/veya İngilizce olup makale metni anlaşılabilir, yalın ve akıcı bir tarzda ilgili alandaki teknik ifadelerle kaleme alınmalıdır. Gereksiz ve çok bilinen bilgilerden ve gereksiz kaynaklardan kaçınılmalıdır ve daha önce yayınlanmış veri, formül ve sonuçlara atıf yapılarak alıntı yapılmalıdır. Zorunlu ya da istisnai haller dışında 15 yıldan eski kaynak kullanılmamalıdır. **Kaynak sayısı her 1000 kelime için 6 adetten fazla olmamalıdır.**
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