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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determining effects of foliar boron applications on yield and fruit quality of apricot trees for reducing water stress

Su stresinin azaltılmasında yapraktan bor uygulamalarının kayısı ağaçlarında verim ve meyve kalitesi üzerine etkileri

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Ö Z E T / A B S T R A C T

Aims: The research was carried out to determine the effects of different boron doses on yield, yield components and quality on 5-6 years old apricot trees of Mogador variety, which were exposed to water stress in the Amik Plain in 2019.
Methods and Results: The factorial experimental design was conducted on apricot trees of Mogador variety, using four doses of foliar boron (ppm) (0-B0, 150-B150, 225-B225 and 300-B300 ppm) and four irrigation levels (100%-I100, 75%-I75, 50%-I50 and 25%-I25 of available water holding capacity) in four replications. Each replication consisted of two apricot trees. The quantity of irrigation water applied in the experiment ranged from 179 to 742 mm, while the evapotranspiration varied between 295 and 832 mm during the irrigation season. Irrigation water use efficiency (IWUE) and water use efficiency (WUE) varied between 3.51-5.18 kg m-3 and 2.89-4.17 kg m-3, respectively. Boron doses did not cause significant differences in WUE and IWUE values. Each unit increase in crop water use caused an average yield increase of 16.8 kg ha-1. Relative to the full irrigation (I100), fruit weight decreased by 13 and 3% in I25 and I50, respectively, but increased by 2% in I75. Relative to the control group (B0), fruit weight increased by 2, 4, and 2% with B150, B225, and B300, respectively. Average fruit size varied between 47.40 (I75) and 42.99 mm (I25); total soluble solids (TSS) between 16.13 (I100) and 12.65 (I25); and pH between 3.16 (I100) and 3.30 (I50). The increased boron dose did not cause a significant difference in fruit size and width. The leaf boron content increased up to the B225 dose and tended to decrease at the B300 dose.
Conclusions: Boron element provides an increase in yield in deficit irrigation conditions, the yield increase is higher in fully irrigated apricot trees. In full irrigation treatment (I100), the B225 treatment was more effective on the yield.
Significance and Impact of the Study: The boron element is an important element that causes an increase in photosynthesis by light adsorption. There is not a lot of research investigating the effects of nutrient elements to relieve the negative effect of water stress in orchards. This research is important in terms of revealing the effects of the element boron in water stress conditions.

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INTRODUCTION

Apricot is an important fruit widely grown, in particular, in arid semi-arid climates of the world. Globally, the total apricot yield was on average 7.941 kg ha^{-1} in 2017. It is one of the plants with high crop water consumption and requires 560 m^3 of irrigation water per hectare during the irrigation period (April to September) when 980 mm of evaporation occurs. Though varying regionally, annual crop water consumption of apricot trees is in the range of 900-1000 mm (FAO, 2019). Apricots, like most stone fruit trees, are susceptible to water deficiency throughout the fruit development period. Water scarcity causes fruits to shrink and decrease in yield. Preventive measures are needed to ensure that the plants are resistant to droughts. Although breeding and genetic studies about the modification of plants play an important role in enhancing their water stress resistance, management practices to increase drought tolerance in sensitive growth periods of plants have also become important. Proline applications on leaves to support its accumulation in the vacuole in the plant cell (Iba, 2002), silicon applications to reduce transpiration (Ahmed et al., 2011), and nutrient applications to inhibit cell degradation (Ödemiş et al., 2017, Kazgöz Candemir and Ödemiş, 2018) can be considered important research directions to reduce the detrimental effect of stress conditions.

Boron (B) is an important micronutrient whose deficiency decreases the absorption and use of photosynthetically active radiation by leaves. It plays a role in cell elongation, nucleic acid synthesis, hormone reactions, and membrane functions. It is used in the transport of photosynthetic products from leaves to meristematic organs in the root and green parts, in ensuring the structural integrity of cell membranes, nitrogen fixation, nodule formation, and in generative development (seed and fruit formation), rather than vegetative growth (leaf and shoot formation). It also plays a vital role in activities such as cell division, leaf and flower formation, glucose metabolism, hydrocarbons and their transport, root development, cell wall formation, and material transport between two cells. Although boron is naturally found in the soil, its content is prone to decrease due to leaching by heavy rainfall in some regions and some agricultural applications. Boron deficiency occurs mostly in sandy and acidic soils with low soil organic matter (Anonymous, 2016a).

Studies about boron have generally focused on the effects of boron applied from leaf, soil, or leaf + soil on yield and quality in soils with a low or insufficient boron content. Under the sufficient soil moisture with the leaf boron content of 120 ppm, the quality of pistachio was found to decrease (Onay et al., 2012). Foliar boron applications were reported not to adversely affect yield but leaf length and leaf age, soluble dry matter, titratable acid, ascorbic acid, total sugar, total phenolic, and total antioxidant significantly in mandarins (Ullah et al., 2012). Among the boron doses (0, 0.15, 0.30, 0.45 and 0.60 kg da^{-1}) applied to sugar beet leaves with the methods of soil, leaf, and soil + leaf, root yield increased by 5.7 and 7.4%, while sugar yield by 3.8 and 7.3% with 0.30 and 0.45 kg B per da are used based on the soil and soil + leaf applications, respectively (Gezgin et al., 2007). Similarly, boron increased hazelnut yield by decreasing the quantity of empty fruits when applied from the leaves (0-300-600-900 ppm) and increased the quantity of healthy fruits when applied from soil (0-5-10-15 g tree^{-1}) (Şahin et al., 2010). Foliar boron application (0, 245, 490, and 735 mg L^{-1}) when compared to soil application (1.5 and 3 kg ha^{-1}) increased the seed yield in the reproductive tissues and vegetative parts of sugar beets by 10% in the first year and 44% in the second year (Dordas et al., 2007).

It is yet clear the effect of boron applied on leaves before the flowering period on the formation of flower bud under water stress. Our study is therefore aimed to determine the effect of different boron doses in preventing the decreased photosynthesis efficiency due to water stress when carried out via foliar application.

MATERIALS AND METHODS

Materials

Soil, irrigation water and climate characteristics

This experimental study was carried out in an area of approximately 2 decares (146 m above sea level; 36◦ 37′ 38.77″ N latitude and 36◦ 27′ 00.20″ E longitude) in Amik Plain district of Hatay province, one of the apricot cultivation-intensive regions. Apricot trees are at distances between 5 x 3 rows and above rows and are 'Y' shaped in the wired cultivation system. The soils of the trial area carry the chalky and hard ground characteristics of arid semi-arid climates in terms of pH and lime (Solmaz, 2019). The physical and chemical properties and macro and micronutrient contents of the soil are given in Tables 1 and 2. Irrigation water electrical conductivity was found 0.682 dS m^{-1}

Table 1. Some physical and chemical properties of the soils in the experimental area

Soil depth (cm)	Fc	Wp	As	pH	ECe	OM	$CaCO_3$(%)	Texture
0-30	23.8	11.9	1.23	7.28	0.15	2.71	4.6	L
30-60	24.2	12.1	1.05	7.2	0.16	2.20	5.2	CL
60-90	24.5	12.3	1.25	7.09	0.18	1.45	4.3	CL

Fc: Field capacity (% Pw), Wp: wilting point (% Pw), As: bulk density (g cm^{-3}, ECe: Electrical conductivity of soil extraction (dS m^{-1}), OM: Organic matter (%)

Table 2. Some macro and microelement quantities of the experimental area soils (mg kg^{-1})

Soil depth (cm)	P	K	Mg	Ca	Fe	Zn	Mn	Cu
0-30	23.2	86.4	364	5860	6.4	0.4	3.0	12.3
30-60	17.6	61.2	326	5420	6.0	0.2	2.8	9.7
60-90	14.2	45.4	296	4890	5.3	0.2	2.8	5.1
Limit values	20-40	244-300	161-480	1151-3500	>4.5	0.8-2.4	>2	>0.2

Climatic characteristics of the experimental area for the study period and the long annual climate characteristics were given table 3 and table 4. The lowest temperature was determined as 10.5 °C in 2019-January and the highest temperature in August 2018 as 31.0 °C (Anonymous, 2019b).

Table 3. Climate data for the study period

Climate parameters	2018							2019				
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Mean temp.(°C)	27.9	30.4	31.0	28.2	22.2	15.1	11.9	10.5	12.6	14.7	18.11	25.6
Rainfall (mm)	14.13	3.5	3.2	2.8	58.4	76.2	192.3	233.9	155.6	92.2	52.5	1.5
Wind speed (m sn^{-1})	1.3	1.7	1.8	1.2	1.1	1.1	1.3	1.5	1.3	1.4	1.4	1.4
Relative humidity (%)	48.4	45.1	45.6	48.1	52.0	67.9	74.8	71.4	73.7	66.0	65.5	46.5

Table 4. Long-term (2015-2018) climate data for the study region

Climate parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean temp. (°C)	8.4	12.1	15	18.9	23.2	27.7	31.1	31.1	27.9	22.7	15.4	9.9
Rainfall (mm)	71.7	42.2	38	55.3	14.4	7.5	0.4	0.3	9.6	26.5	24.3	28.8
Wind speed (m sn^{-1})	1.1	1.0	1.3	1.2	1.4	1.6	1.8	1.5	1.2	1.0	1.0	1.1
Relative humidity (%)	74.0	64.1	62	52.3	51.7	45.7	43.7	48.9	49.7	50.2	53.7	68.9

Plant material

In the experiment, Mogador variety apricot (*Prunus armeniaca*) trees grafted on Mirobolan plum rootstock with a planting interval of 5 x 3 m and ages 5 to 6 were used. Mogador apricot is one of the earliest apricot (Mikado, Coloroda) varieties for Hatay and has a strong and semi-flat growing tree structure. The variety has an early flowering character and is self-fertile as a pollinator (Anonymous, 2020). Its fruit is 60% red on orange background and has a round shape, a balanced taste and flavor and a maturity date between May 1 and 11.

Irrigation system

Drip irrigation system was used to irrigate the plants. Drip irrigation laterals (diameter of 20 mm) are arranged on both sides of the tree. In-line drippers with a dripper space of 40 cm are used.

Boron fertilizer

Water soluble 11% boron ethanolamine fertilizer was used to increase flower bud and fruit set in apricot plants. Boron ethanolamine is an important micronutrient and has the ability to be taken quickly by plants.

Method

Experimental design

The study was conducted according to the factorial experimental design. The sub-treatments were composed of boron doses, while the main treatments were the irrigation levels. To create water stress, the four irrigation levels were planned in three replications with two trees in each replication.

Irrigation treatments

The first irrigation was done when 50% of the available water was consumed. The other irrigation treatments were that 75% (I_{75}), 50% (I_{50}) and 25% (I_{25}) of full irrigation (I_{100}) where the water deficit was brought to the field capacity in a period of 7 to 8 days were applied. Water quantity missing in the effective root depth (mm) was converted to a volumetric basis in Equation 1.

$$I= (d \times A \times P)/Ea \quad (1)$$

where I: irrigation water quantity to be applied to the full irrigation (L), d: irrigation water quantity required (mm), A: Parcel area (m^2), Ea: Water application efficiency (taken as 0.95), and P: percentage of wetted area (taken as 35%).

Fertilization treatments

120 kg N, 80 kg P, 160 kg K, 50 kg magnesium nitrate ($Mg(NO_3)_2$), 50 kg calcium nitrate ($Ca(NO_3)_2$), 10 kg Fe, and 15 kg organic matter were applied per decar per year (Table 5). Fertigation method was used in fertilization (Burt et al., 1995). Boron fertilizer was applied in addition to the fertilizers specified in Table 5. Boron applications were made on two different dates (February 25 and March 10) at different levels on each tree used in the experiment using a ridge sprayer. The first application was carried out on 25 February 2019 at 100% beginning flowering period. The second application was carried out on 9 March 2019 during the flower and fruit formation period

Table.5. Annual conventional fertilization quantity for apricot trees (kg ha^{-1})

Month	N	P	K	Ca	Mg	Fe	OM
Feb	20	70	5			5	5
Mar	90	5	10	45	45	5	5
Apr	6	5	100	5	5		5
May	4		40				
Jun	-	-	-	-	-	-	-
Jul			5				
Total	120	80	160	50	50	10	15

OM: Organic matter

In both application periods, there was no adverse condition that may have decreased the fertilizer efficiency after fertilization. Boron levels in the experiment were established as follows:

B_0: foliar boron fertilizer was not applied
B_{150}: 100 ppm + 50 ppm = 150 ppm foliar boron fertilizer
B_{225}: 150 ppm + 75 ppm = 225 ppm foliar boron fertilizer
B_{300}: 200 ppm + 100 ppm = 300 ppm foliar boron fertilizer

Cultivation practices

Pruning, tillage, spraying, and fertilization processes were carried out adopting the common cultivation practices of the region. Both winter and summer pruning were performed. After the apricot trees yielded, not much pruning was done. Upon the general examining of the trees, diseased, dried, broken, and overlapped branches preventing the entry of light into the crown were cut. Since the soil structure of the experimental area hardened due to the presence of excessive lime, extra attention was paid not to damage the roots near the tree during tillage, and deep plowing was avoided. Due to rainfall, fruit ripening was delayed and the harvest was carried out on May 4 and 10 while it was normally done on April 21.

Crop water use

The water use of the trees was calculated with the water balance equation below (Bos et al., 2009):

$$ET = I + R + Cr - Dp - Rf \pm \Delta S \quad (2)$$

where ET: Evapotranspiration, mm; I; amount of irrigation water, mm; R; rainfall, mm; Cr; capillary rise, mm; Dp; deep percolation, mm; Rf; Runoff, mm; and ± ΔS; moisture change (mm/90 cm) in the soil profile. Since the drip irrigation system was used, the runoff (Rf) was not calculated, while the deep percolation losses (Dp) were neglected.

Water use efficiency

The yield values obtained from each tree were converted to the yield collected from an area of one decare. The WUE and IWUE values were calculated by proportioning each to the quantity of evapotranspiration and irrigation water applied (Equation 4 and 5**)** (Howell et al., 1990):

WUE = Ey/Et (3)

IWUE = Ey/I (4)

where Ey: economic yield, kg ha^{-1}, Et: crop water use, mm, and I; amount of irrigation water (mm)

***Yield, pomological and fruit quality characteristics*: Fruit Yield (kg ha^{-1})**

The total quantity of fruits collected from a decare. Fruit weight (g): Average weight of a single apricot fruit. Fruit length (mm): The longest distance between the top surface of the fruit sepals and the stylus tip. Fruit width (mm): The largest diameter perpendicular to the fruit axis. The pH, crude fiber, water and alcohol soluble extract were determined according to Demir and Ozcan (2001).Total soluble solids (TSS, %) was determined analyzing juice obtained by squeezing 10 fruits from each replication using a hand-held refractometer.

Foliar boron (B) analysis

In order to determine the effects of the applications on the leaf boron concentration, 10 leaves were collected from each tree for each replication after harvest and passed through/washed with pure water in the laboratory. The leaves dried in the oven at 65 °C for a day were prepared for analysis by crushing with a mortar. In the analysis, 5-milligram samples prepared for each replication and measured using ICP (Kaçar and Ünal, 2008).

Statistical data analysis and evaluation

The results obtained from the irrigation treatments were evaluated using analysis of variance (ANOVA) with SPSS 14.0. The response means were compared using a Duncan test (Bek and Efe, 1988).

RESULTS AND DISCUSSION

Irrigation management and crop water use

In the experiment, 11 irrigation applications were carried out in total between June 3 and October 8 of 2018. 179, 363, 500, and 742 mm irrigation water was applied to I_{25}, I_{50}, I_{75} and I_{100}, respectively (Table 6).

Table 6. The results of irrigation water, ET and yield

Irrig. Level	Boron Doses (ppm)	I* (mm)	ET (mm)	Yield (kg ha^{-1})	WUE (kg m^{-3})	IWUE (kg m^{-3})
I_{25}	B_0	179	287	11333	39.4	63.3
	B_{150}		294	14222	48.3	79.4
	B_{225}		301	18000	59.7	100.5
	B_{300}		298	14444	48.4	80.6
	Mean	**179**	**295**	**14500**	**49.1**	**80.9**
I_{50}	B_0	363	457	14444	31.6	39.8
	B_{150}		465	17778	38.2	49.0
	B_{225}		472	22667	48.0	62.5
	B_{300}		467	19111	40.9	52.7
	Mean	**363**	**465**	**18500**	**39.8**	**51.0**
I_{75}	B_0	500	597	16889	28.3	33.8
	B_{150}		606	22667	37.4	45.3
	B_{225}		607	23111	38.1	46.2
	B_{300}		596	18444	30.9	36.9
	Mean	**500**	**602**	**20288**	**33.7**	**40.6**

Table 6 (continued). The results of irrigation water, ET and yield

I_{100}	B_0	742	828	20000	24.2	27.0
	B_{150}		832	23333	28.0	31.5
	B_{225}		838	28667	34.2	38.7
	B_{300}		832	22444	27.0	30.3
	Mean	**742**	**832**	**2361**	**28.4**	**31.8**
Boron Dose (Mean)	B_0		542	15677	28.9	35.1
	B_{150}		549	19500	35.5	43.7
	B_{225}		555	23111	41.7	51.8
	B_{300}		548	18611	33.9	41.7

*Approximately 81 mm of precipitation was measured from the beginning of the experiment until the harvest date, I: irrigation water, WUE: water use efficiency, IWUE: irrigation water use efficiency.

Irrigation water requirement for the three irrigation intervals (7, 14, and 21 days) in the same region was estimated at 141-562, 145-579, and 139-555 mm in the first year, 165-660, 147-588, and 150-599 mm in the second year, and 180 -721, 188-750, and 200-801 mm in the third year, respectively (Bozkurt et al., 2015). Perez Pastor et al. (2009) stated that sufficient irrigation water requirement of about 700 mm for apricot was reduced by 50% with deficit irrigation and by 57-78% with regulated deficit irrigation. Overall, irrigation water requirements were significantly affected by annual temperature, rainfall, soil structure, and crop type.

The irrigation levels affected ET significantly but the boron treatments (Table 7). As seen from the table 7, the highest and lowest crop water use occurred from the interactions I_{100} B_{225} with 838 mm and I_{25} B_0 with 287 mm, respectively. Annual ET of apricot trees varies regionally between 900 and 1000 mm (FAO, 2019). Our results have been confirmed by the previous studies indicating the relationship between irrigation water level and the crop water use. It is well established that the ET for apricot increases in parallel with the amount of irrigation water applied, and its highest value (661.1 mm) was measured from the treatment when 649.9 mm of irrigation water was applied (Shalhevet et al., 1979). At 7, 14, and 21-day irrigation intervals under similar climatic conditions, evapotranspiration from apricot trees was determined as 603, 621 and 585 mm in the first year, 679, 660, and 659 mm in the second year, and 852, 750, and 801 mm in the third year, respectively (Bozkurt et al., 2015). To our best knowledge, there has been no previous studies to compare our results regarding boron uses.

As seen from table 6, ET fluctuated between B_0 and B_{300}, which was not statistically significant. However, it could be speculated that the increase in Boron more than those used in this experiment would prone to yield statistically significant results.

Yield

The irrigation levels and boron treatments had separate significant effects on yields (Table 7). The mean yield increased with the increasing water treatment and therefore the highest yield, 23611 kg ha^{-1}, was obtained from the full irrigation, I_{100}.

As for Boron, increasing the boron doses did not increase the yield up to a certain level. The highest yield was obtained from B_{225} (23111 kg ha^{-1}). After that point was reached, higher boron doses reduced the increase in yields dramatically, 18611 kg ha^{-1} for B_{300}. Based on B_0, the mean yield increase was 24% for B_{150}, 48% for B_{225}, and 19% for B_{300}.

Although there seemed no interaction between irrigation and boron doses on yield, it could be noticed that increasing the boron doses with increasing irrigation level had an emphisased effect on yield. For instance, yield of $I_{100}B_{225}$ was found to be higher than the other irrigation level (28677 kg ha^{-1}).

Table 7. Variance analysis table for yield values

Variation Source	Sd	Sum of squares	Mean of squares	F
Irrigation Level	3	51694934.17	17231644.7	312.04**
Boron Doses	3	33972234.17	11324078.1	205.06**
Irrigation LevelxBoron doses	9	3815450.83	423938.9	7.68ns
Error	47	107153792.5		

**: p<0.01, ns: not significant, Sd; degree of freedom.

Water use efficiency

The highest water use efficiency (WUE) was obtained from I_{25}. Compared to I_{100}, a 30% reduction in irrigation water resulted in a 75% increase in WUE of I_{25}. No significant difference was found in WUE between I_{50} and I_{75}. As for irrigation water use efficiency (IWUE), the lowest and the highest values were obtained from I_{100} (3.18 kg m^{-3}) and I_{25} (8.09 kg m^{-3}). A significant difference (60%) was estimated between I_{25} and I_{50} while the difference between I_{50} and I_{75} was 27%.

In terms of boron doses, the WUE and IWUE estimates showed a regular increase up to a certain extent (B_{225}) and a decrease afterwards with (B_{300}). Increasing boron doses caused a 45% increase in WUE up to B_{225}. Both WUE and IWUE were higher than those with the other boron treatments in B_{225}, where the highest efficiency was obtained. In terms of the irrigation level-boron dose interaction, the highest WUE and IWUE were estimated at 5.97 kgm^{-3} and 10.05 kgm^{-3} for $I_{25}B_{225}$.

The deficit irrigation strategy increased the WUE while the boron applications caused a lower difference in WUE. In the arid conditions, WUE seems to be affected particularly by different strategies in water use (Hassan and Seif, 1999, Mitchell et al., 1989). Similar results for WUE were reported when boron applications for cotton under deficient irrigation was applied (Ödemiş and Delice, 2018).

The combine effect of irrigation water and boron doses on yield

The relationship between irrigation and yield was calculated using the following equation : Yield = *-0.001x²+2.56x+1033; r² = 0.99** (n=16).* Based on this equation, the amount of optimum irrigation water should be 960 mm for maximum yield. It is well known that irrigation during flowering and fruit formation periods are more important than in other periods (Perez et al., 2009), and post-harvest and autumn irrigation improves flower bud formation and tree structure before winter (Matuskovic et al., 2002) and therefore yield.

In our study, several observations were made as follows. Firstly, it is clear that increasing the boron dose up to a certain level (B_{225}) increased the yield at every irrigation level, then a decrease was monitored after that point (B_{300}). The biggest increase determined for I_{25}, I_{50}, I_{75} and I_{100} at B_0 level were about 58.8%, 56.9%, 36.8% and 43.4%, respectively. These results clearly indicated that boron has a positive effect on apricot yield up to a certain level.

Secondly, this effect of boron became stronger when the irrigation level is increased. The highest mean yield (23611 kg ha^{-1}) of all irrigation levels were recorded for I_{100}. The effect of boron appeared to be depending on irrigation water level. This mechanism is yet to be explained.

Thirdly, based on the mean yield obtained from I_{25}, there were a 27.6% for I_{50}, 39.9% for I_{75}, and 62.8% for I_{100}. This means the higher the irrigation water and boron (up to a certain level) the higher the yield is obtained. In other words, boron exerted an increasing effect on yield as soil moisture increases.

Lastly, the highest yield arising from the combine effect of boron and irrigation level was obtained at $I_{100}B_{225}$ amongst all the treatments. This combination currently appear to be the optimum for the highest yield.

A significant relationship was determined between ET and yield as *Yield = 16.9x + 9959.9 r² = 0.59 ** (n = 16)*. Each unit increase in ET resulted in an average increase of 16.9 kg ha^{-1} in yield. Boron doses were found to have a significant effect on the linear relationship between evapotranspiration and yield. Significant but low regression coefficients were calculated for B_{150} and B_{300} in the relationship between evapotranspiration and yield while higher regression coefficients were found with B_0 and B_{225}. According to the equations, a one-unit increase in crop water use caused an increase by 16.0 kg ha^{-1} in B_0, 17.7 kg ha^{-1} in B_{150}, 18.9 kg ha^{-1} in B_{225}, and 13.7 kg ha^{-1} in B_{300}.

Boron dose-yield relationships

Boron doses appeared to increase the apricot yield, but this increase was not statistically significant ($p > 0.05$). The effect of the boron doses on yield at each irrigation level occurred differently (Figure 1). The boron application significantly increased yield with all the irrigation levels.

Based on 11333 kg ha^{-1} with B_0 of I_{25} (Table 6), the yield increased by 25% with B_{150}, by 59% with B_{225}, and by 27% with B_{300}. With B_{225}, the yield increased from 11333 to 18000 kg ha^{-1}. A similar increase rate was observed with I_{50}. While the yield with B_0 of I_{50} was measured at 14444 kg ha^{-1}, it increased by 23% with B_{150}, 57% with B_{225}, and 32% with B_{300}. At I_{75}, B_{150} and B_{225} caused almost the same increase in yield (34 and 37%). The least effect of the boron applications on the yield was realized with B_{300} under I_{75}. While the yield per decare of I_{75} B_0 was 16889 kg ha^{-1}, it increased only 9% with $I_{75}B_{300}$ (18444 kg ha^{-1}). The boron doses increased the yield between 12% (B_{300}) and 43% (B_{225}) with the full irrigation treatment (I_{100}). Yield for B_{150} increased by 17% relative to B_0. The boron applications caused an increase by 9% to 59% in yield when compared to B_0. Among the boron applications, the highest contribution to the yield increase was obtained from B_{225}.

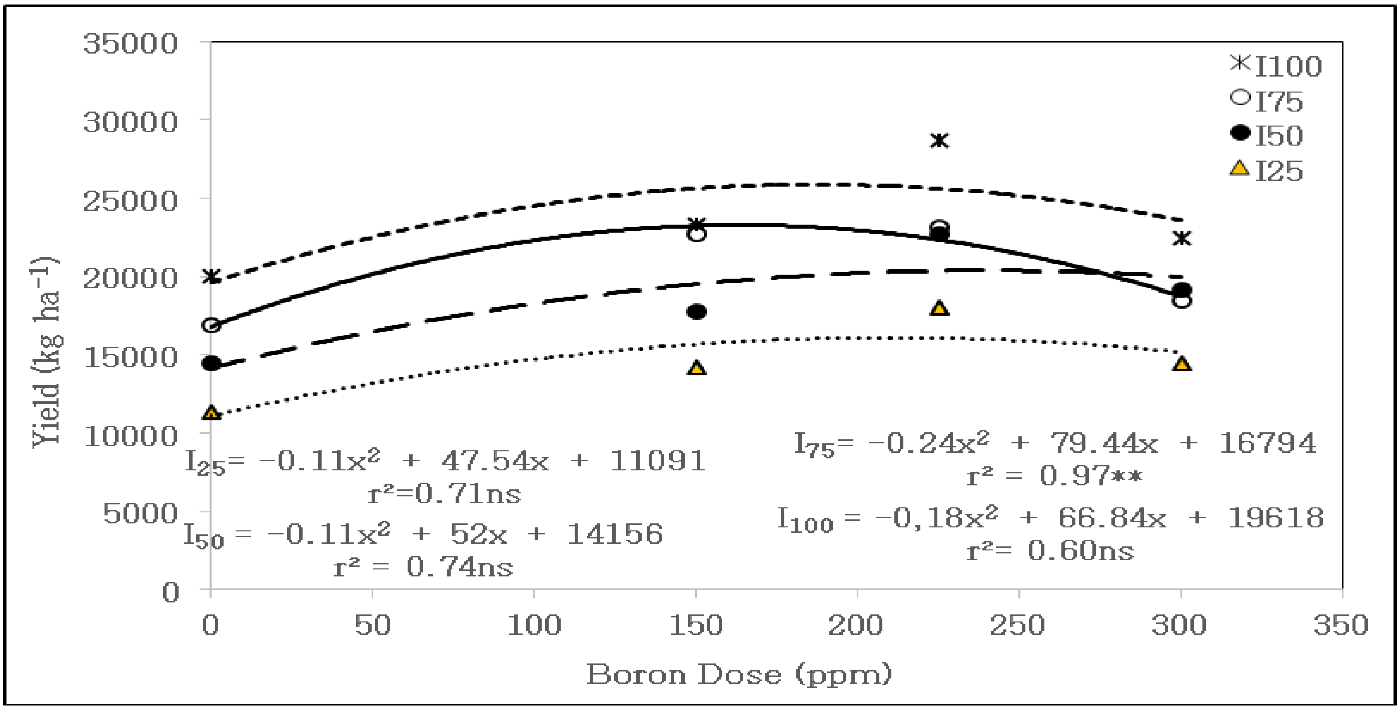

Figure 1. Change in yield as a function of boron and irrigation treatments.

Many studies have been conducted to determine the relative contributions of plant nutrients to their drought tolerance as well as to eliminate or mitigate the effects of stress during drought through nutrients (Hu et al., 2008; Garg et al., 2004; Kazgöz Candemir and Ödemiş, 2018; Li-Na et al., 2005). In the aforementioned studies, it was aimed to eliminate or mitigate the effects of stress occurring during drought by means of nutrients. Foliar-based boron treatments increased the number of flowers and fruit yield in olive trees (Gündeşli, 2005) and plant height, spike length, grain number in the spike, grain weight in the spike, and grain yield in wheat (Bilir, 2020). They caused the protein and fatty acid content of the plant seed to change in soybean (Bellaloui et al., 2013). Doğan et al. (2013) found that boron application under drought stress increased the amount of chlorophyll and proline but did not significantly change the amount of MDA. Also, some studies indicated that the application of boron 30 days after germination had no effect on yield (Seidel et al., 2015).

Pomological and fruit quality characteristics

Fruit weight increased depending on irrigation levels. The highest fruit weight was measured on I_{75} treatment (62.11 g) (Table 8). Based on I_{100} treatment, fruit weight decreased by 13% for I_{25} and 3% for I_{50}, while it increased by 2% for I_{75}. Increasing boron doses differed slightly in fruit weight ($p>0.05$). Fruit weight at B_0, B_{150}, B_{225} and B_{300} doses was determined as 57.19 g, 58.26 g, 60.33 g and 59.31 g, respectively. Based on B_0, fruit weight increased by 2%, 4% and 2% in B_{150}, B_{225} and B_{300} treatments, respectively. As the irrigation levels increased, the effect of boron doses on fruit weight decreased.

Irrigation levels and boron doses do not have significant effect on fruit width (p>0.05) (Table 9). Fruit width varied between 44.06 mm (I_{100}) and 41.98 mm (I_{25}) and these values were approximately the same in I_{50} and I_{75} treatment (42.88 mm and 42.44 mm).

Fruit size were affected by *irrigation levels* and *irrigation levels x boron dose* interaction. The highest and lowest fruit size were measured from I_{75} (47.40 mm) and I_{25} (42.99 mm) treatments and it increased up to 48.92 mm in I_{75}. Boron doses did not affect fruit size. While fruit sizes were at the same level in $I_{25}B_{150}$ and $I_{50}B_{150}$ treatment, it increased 20% and 15% in $I_{75}B_{150}$ and I_{100} B_{150} treatment, respectively.

Total soluable solids (TSS) were affected statistically at p <0.01 level from both applications and interactions. TSS ranged from 12.65 (I_{25}) to 16.13 (I_{75}). Based on I_{25} treatment, TSS increased by about 35% in I_{75}. In the B_{150} and B_{225} (13.87-13.97) and the B_0 and B_{300} doses, TSS were measured at approximately the same level (15.95-15.21). When the interaction effect was examined, the highest TSS was found in I_{25} B_0 (15.60%). TSS increased

Table 8. Fruit quality and pomological properties of apricots fruits

Irr. Level	Bor Dose (ppm)	Fruit weight	Fruit width	Fruit Lenght	TSS %	pH	Leaf Boron Conc. mg kg^{-1}
I_{25}	B_0	47.51	43.30	46.31	15.60	3.15	41.54
	B_{150}	56.33	41.29	40.96	11.02	3.28	38.27
	B_{225}	59.91	43.18	42.17	11.80	3.22	41.25
	B_{300}	50.54	40.18	42.53	12.20	3.35	38.91
	Mean	53.57	41.98	42.99	12.66	3.25	39.99
I_{50}	B_0	50.53	44.00	46.41	16.00	3.29	38.98
	B_{150}	59.63	40.80	40.29	12.42	3.33	41.16
	B_{225}	60.50	41.38	45.57	12.93	3.24	45.36
	B_{300}	64.17	45.36	47.91	16.27	3.35	43.61
	Mean	58.71	42.89	45.05	14.41	3.30	42.28
I_{75}	B_0	68.19	38.55	46.49	15.40	3.29	40.06
	B_{150}	58.25	46.13	49.63	16.27	3.27	43.37
	B_{225}	60.16	43.46	46.24	16.29	3.25	41.54
	B_{300}	61.85	41.62	47.25	16.56	3.18	43.59
	Mean	62.11	42.44	47.40	16.13	3.25	42.14
I_{100}	B_0	62.55	44.27	46.39	16.80	3.18	39.85
	B_{150}	58.86	44.68	47.02	15.80	3.17	40.90
	B_{225}	60.78	43.60	45.72	14.87	3.10	48.00
	B_{300}	60.67	43.70	46.82	15.83	3.18	48.09
	Mean	60.72	44.06	46.49	15.82	3.16	44.21
Mean	B_0	57.20	42.53	46.40	15.95	3.23	40.11
	B_{150}	58.27	43.22	44.48	13.88	3.26	40.93
	B_{225}	60.34	42.91	44.93	13.97	3.20	44.04
	B_{300}	59.31	42.72	46.13	15.21	3.27	43.55
	Mean	58.78	42.84	45.48	14.75	3.24	42.15

TSS: Total soluable solids until I_{75} treatment at irrigation levels at all boron doses except irrigation levels of B_0 dose and decreased relatively in I_{100}.

It is shown that, fruit juice acidity (pH) and sugar content increase and fruit quality deteriorates as the amount of irrigation water applied decreases (Chartzoulakis, 1999). In our experiment, the pH varied between 3.16 (I_{100}) 3.30

(I_{50}) at irrigation levels and 3.20 (B_{225}) and 3.27 (B_{300}) at boron doses. The pH in I_{25} and I_{75} and B_0 and B_{150} was measured at approximately the same level. When interacting effects were examined, pH values increased relatively with increasing boron doses. While pH increased at I_{50} irrigation level in B_{150} dose, it was measured at the lowest value in I_{100}.

Table 9. Variance analysis results of fruit quality and pomological properties of apricots fruits

Fruit Charac.	Source of Variation	Sd	SS	MS	F
Fruit Weight (g)	I	3	503.72	167.91	6.126**
	B	3	65.72	21.91	0.799 öd
	IxB	9	705.37	78.37	2.859**
	Error	47	2151.94		
Fruit Width (mm)	I	3	28.58	9.53	1.086 öd
	B	3	3.15	1.05	0.120 öd
	IxB	9	153.19	17.02	1.940 öd
	Error	47	465.66		
Fruit Lenght (mm)	I	3	133.13	44.38	6.658**
	B	3	30.99	10.33	1.550 öd
	IxB	9	140.47	15.61	2.342*
	Error	47	517.87		
TSS (%)	I	3	90.77	30.26	54.909**
	B	3	36.25	12.08	21.926**
	IxB	9	44.85	4.98	9.044**
	Error	47	189.51		
pH	I	3	0.13	0.04	10.725***
	B	3	0.03	0.01	2.770 öd
	IxB	9	0.09	0.01	2.500*
	Error	47	0.37		
Leaf Boron Conc. (mg kg^{-1})	I	3	106.99	35.66	4.807**
	B	3	134.40	44.80	6.038**
	IxB	9	163.06	18.12	2.442*
	Error	47	641.87		

I: Irrigation Level, B, Boron doses, **: $p<0.05$ significant level, ns: non significant, df: degree of freedom SS: Sum of squares, MS: Mean square, TSS: Total soluable solids.

The most stable change in *irrigation level x boron dose interaction* was observed at I_{75} irrigation level. The highest and lowest pH of I_{75} irrigation level was measured between B_0- B_{300}. In I_{100}, it was observed that the pH values followed a decreasing trend in the B_0-B_{225} range, but increased again in the B_{300} dose. When evaluated in general, the pH values were not significantly affected by the boron doses of irrigation treatments, except for I_{75}.

When the flowering rate of the apricot reaches 80% and the petal fall stage, foliar boron was applied to the canopy. In leaf samples taken 15-20 days after harvest, the boron content in the leaves was determined depending on the irrigation levels and the applied boron doses. The effects of the foliar application of boron were found to be statistically significant.

As the amount of irrigation water increased during the flowering period, the efficiency of boron fertilizer increased (Figure 1). The lowest and highest leaf boron contents in irrigation treatment were measured in I_{25} (39.99 mg kg-1) and I_{100} (44.20 mg kg^{-1}). In I_{50} and I_{75}, the leaf boron content was approximately the same (42.28 mg kg^{-1}-42.14 mg kg^{-1}). When compared with the B_0 dose, it was determined that the leaf boron content increased approximately 10% in the B_{225}.

In *irrigation level x boron dose* interactions, leaf boron contents were determined at the same level in $I_{25}B_0$ and $I_{25}B_{225}$ and $I_{25}B_{150}$ and $I_{25}B_{300}$ treatment. Leaf boron content increased from $I_{50}B_0$ to $I_{50}B_{225}$ at the I_{50} irrigation

level and decreased again for $I_{50}B_{300}$. Boron doses were not cause a significant difference in leaf boron content in I_{75}, but resutlted in a linear increase in I_{100}. The lowest and highest leaf boron content was measured as 39.84 and 48.09 mg kg^{-1} in $I_{100}B_0$-$I_{100}B_{300}$ treatment. Compared to other irrigation levels, the most unstable trend was in the boron treatments of the I_{25} irrigation level. It was observed that the leaf boron contents increased with boron application in all treatment except $I_{25}B_0$.
In conclusion, in this study, it was determined that although the boron element provides an increase in yield in deficit irrigation conditions, the yield increase is higher in fully irrigated apricot trees. In full irrigation treatment (I_{100}), the B_{225} treatment was more effective on the yield. Polynomial trend was determined between the yield and the boron dose in the fully irrigated treatment, and it was determined that the application of boron more than 225 ppm did not increase the yield, but decreased it. Considering that the soil boron content was insufficient in the area where the experiment was conducted, it could be expected that it would have an effect on increasing light adsorption even slightly below the field capacity (at low water stress). Since the reliability of one-year results in fruit trees is controversial, such studies should be at least three years old and one-year studies should be evaluated as a preliminary data.

ÖZET

Amaç: Araştırma, 2019 yılında Amik Ovasında su stresine maruz bırakılan 5-6 yaşlı Mogador çeşidi kayısı ağaçlarında farklı bor dozu uygulamalarının verim, verim bileşenleri ve kalite üzerine olan etkileri belirlemek amacıyla yürütülmüştür.
Yöntem ve Bulgular: Araştırma Mogador çeşidi kayısı ağaçlarında, yapraktan uygulanacak tanık konusu (B0) dışında 3 farklı dozda yapraktan bor B150 (150 ppm), B225 (225 ppm) B300 (300 ppm), elverişli kapasitenin 4 farklı sulama düzeyinde I100, I75, I50 ve I25, 4 tekerrürlü olarak yürütülmüştür. Her tekerrür 6 sıradan oluşturulmuştur. Denemede uygulanan sulama suyu miktarı 179 mm ile 742 mm, bitki su tüketimleri 295 mm ile 832 mm arasında gerçekleşmiştir. Sulama ve su kullanma randımanları 3.51-5.18 kg m-3 ile 2.89-4.17 kg m-3 arasında değişmiştir. Bor dozları WUE ve IWUE değerlerinde anlamlı farklara neden olmamıştır. Bitki su tüketimindeki her birim artış verimde ağaç başına ortalama 16.8 kg ha-1'lık artışa neden olmuştur. Tam sulama konusu I100 esas alındığında meyve ağırlığı I25 ve I50 konularında sırasıyla %13 ve %3 azalırken, I75 konusunda %2 artmıştır. B0 konusu esas alındığında ise meyve ağırlığı B150, B225, B300 konularında %2, %4 ve %2 oranında arttığı gözlenmiştir. Sulama düzeylerinde ortalama meyve boyu değeri 47.40 mm (I75) ve 42.99 mm (I25); suda çözünebilir kuru madde miktarı (TSS) değerleri 16.13 (I100) ve 12.65 (I25) ile; pH değerleri ise 3.16 (I100) ve 3.30 (I50) arasında gerçekleşmiştir. Bor dozlarındaki artış meyve boyunda ve meyve eninde anlamlı bir farklılığa neden olmamıştır. Yaprak bor içeriği B225 dozuna kadar artmış B300 dozunda ise azalma eğilimi göstermiştir.
Genel Yorum: Bor elementi kısıtlı sulama koşullarında verim artışı sağlarken, tam sulanan kayısı ağaçlarında verim artışı daha fazladır. Tam sulama uygulamasında (I100), B225 uygulaması verim üzerinde daha etkili olmuştur.
Çalışmanın Önemi ve Etkisi: Bor elementi ışık adsorpsiyonu ile fotosentezin artmasına neden olan önemli bir elementtir. Meyve bahçelerinde su stresinin olumsuz etkisini gidermek için besin elementlerinin etkilerini araştıran çok fazla araştırma bulunmamaktdır. Bu araştırma bor elementinin su stresi koşullarında etkilerini ortaya koyması açısından önemlidir.

Anahtar Kelimeler: Kayısı, su kısıtı, yapraktan bor uygulaması, bitki su tüketimi, su kullanma randımanı.

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CONFLICT OF INTEREST
The author declares that there is no conflict of interest in the study

AUTHOR'S CONTRIBUTIONS
The contribution of the authors is equal.

REFERENCES

Ahmed M, Hassen UF, Khursıd Y (2011) Does silicon and ırrigation have impact on drought tolerance mechanism of sorghum. Agricultural Water Management 98(12): 1808-1812.

Anonymous (2016a) Ulusal Bor Araştırma Enstitüsü El Kitabı, https://www.boren.gov.tr. Erişim tarihi: Ocak 2019.

Anonymous (2019b) Meteoroloji Genel Müdürlüğü. https://www.mgm.gov.tr/ FILES/ arastirma/ yagis-degerlendirme/ 2016alansal.pdf. Erişim tarihi: Ocak 2020.

Anonymous (2020) https://www.parlarfidan.com Erişim tarihi: Ocak 2020.

Bek Y and Efe E (1988) Araştırma ve Deneme Medotları I. Çukurova Üniversitesi, Ziraat Fakültesi, Ders Kitabı No:71, 395 s.

Bellaloui N, Yanbo H, Mengistu A, Kassem MA, Abel, CA (2013) Effects of foliar boron application on seed composition, cell wall boron and seed 15N and 13C iso-topes in water - stressed soybean plants. Frontiers in Plant Science https://doi.org/10.3389/fpls, 00270.

Bilir R (2020) Yapraktan uygulanan bor gübresinin bazı makarnalık buğday çeşitlerinin verim ve verim unsurları üzerine etkisi. Kahramanmaraş Sütçü İmam Üniversitesi, Tarla Bitkileri Anabilim Dalı, 45 s.

Burt CM, O'connor K, Ruehr T (1995) Fertigation. 295 pp.

Bos MG, Richard K, Allen G, Molden DJ (2009) Evapotranspiration: Water requirements for irrigation and the environment. 10.1007/978.

Bozkurt S, Ödemiş B, Durgaç C (2015) Effects of deficit irrigation treatments on yield and plant growth of young apricot trees. New Zealand Journal of Crop and Horticultural Science 1-12.

Chartzoulakis K, Michelakis H, Stefanoudaki E (1999) Water use, growth, yield and fruit quality of 'Bonanza'oranges under different soil water regimes. Adv Hortic. Sci. 13: 6-11.

Demir F and Ozcan M (2001) Chemical and technological properties of rose (*Rosa canina* L.) fruits grown wild in Turkey. Journal of Food Engineering 47: 333-336.

Doğan M, Avu A (2013) Kuraklık stresine karşı bor bileşiklerinin soyada (*Glycine max.* L.) büyüme parametrelerine etkisi. Nevşehir Bilim ve Teknoloji Dergisi 2(2): 1-13.

Dordas C, Apostolides GE, Goundra O (2007) Boron application affects seed yield and seed quality of sugar beets. Journal of Agricultural Science 145: 377-384.

FAO (2019) FAOSTAT online database, available at link http://faostat.fao.org

Garg BK, Burman U, Kathju S (2004) The influence of phosphorus nutrition on the physiological response of moth bean genotypes to drought. J. Plant Nutr. Soil Sci. 167: 503-508.

Gezgin S, Hamurcu M, Dursun N, Gökmen F (2007) Değişik bor dozları ve uygulama şekillerinin farklı lokasyonlarda yetiştirilen şeker pancarının yaprak bor içeriği, verim ve kalite üzerine etkisi. Selçuk Tarım ve Gıda Bilimleri Dergisi 21(42): 25-35.

Gündeşli M (2005) İlkbaharda yapraktan bor uygulamasının gemlik zeytin çeşidinde meyve tutumu üzerine etkisi. Sütçü İmam Üniversitesi Bahçe Bitkileri Anabilim Dalı, 38 s.

Hassan MM and Seif SA (1999) Water use of apricot trees. Egyptian Journal of Horticulture 26(1): 77-83.

Howell TA, Davis KR, Mc-Cormick RL, Yamada H, To-Walhood V, Meek DW (1990) Water use efficiency of narrow row cotton. Irrig. Sci. 5: 195-214.

Hu Y, Burucs Z, Schmıdhalter U (2008) Effect of foliar fertilization application on the growth and mineral nutrient content of maize seedlings under drought and salinity. Soil Science and Plant Nutrition 54: 133-141.

Iba K (2002) Aclimative response to temperature stres in higher plants: Approaches of gene engineering for temperature tolerance. Annu. Rev. Plant. 3: 32-55.

Kaçar B and Ünal A (2008) Bitki Analizleri. Nobel Yayınları. Ankara

Kazgöz Candemir D and Ödemiş B (2018) Yapraktan uygulanan farklı kükürt dozlarının pamuk bitkisinin (*Gossypium hirsutum* L.) değişik gelişme dönemlerindeki su stresinin azaltılması üzerine etkileri. Derim 35(2): 161-172.

Li-Na Z, Dong Q, Li-Li S, Wei-Jie Y (2005) Effects of sulfur fertilization on the contents of photosynthetic pigments and mda under drought stress. Acta Botanica Boreali-Occidentalia Sinica 2005-08.

Mitchell PD, Van Den Ende B, Jerie PH, Chalmers DJ (1989) Response of 'Bartlett'pear to withholding irrigation regulated deficit irrigation and tree spacing. American Soc. Hort. Sci. 114: 15-19.

Matuskovic J, Owais S, Hribik J (2002) The course of soil moisture content and the irrigation regime in apricot growing. Acta Horticulturae et Regiotecturae 5(2): 36-39.

Onay A, Tilkat E, Ersalı Y, Ayaz TE, Süzerer V (2012) Antepfıstığının (*Pistacia vera* L.) morfolojik ve biyolojik özellikleri ile verimini etkileyen faktörler. Batman Üniversitesi Yaşam Bilimleri Dergisi 2(1): 116-131.

Ödemiş B, Akışcan Y, Akgöl B, Can D, Demirel E, Karazincir K (2017) Kısıtlı su koşullarında yapraktan uygulanan farklı kükürt dozlarının pamuk bitkisinin kuraklık toleransına etkileri. TÜBİTAK sonuç raporu. 2017/8/1 133 sayfa.

Ödemiş B and Delice H (2018) The Effect of different boron levels on the yield and some physiological properties of cotton plant under deficit ırrigation cond. XIX. World Cong. of CIGR 1(1): 28-36.

Perez-Pastor A, Domingo R, Torrecillas A, Ruiz-Sanchez MC (2009) Response of apricot trees to deficit irrigation strategies. Irrig. Sci. 27: 231-242.

Seidel EP, Egewarth WA, Piano JT, Egewarth J (2015) The effect of foliar application rates of calcium and boron on yield and yield attributes of soybean (*Glycine max*). African Journal of Agricultural 10(4): 170-173.

Shalhevet J, Mantell A, Bielorai H, Shimshi D (1979) Irrigation of field and orchard crops under semi - arid conditions. III C No 1 (Revised Version), 124 pp, Israel.

Solmaz B and Saltalı K (2019) Yüksek pH ve kireçli topraklara kükürt (S) uygulamasının bazı toprak özelliklerine etkisi. Kahramanmaraş Sütçü İmam Üniversitesi, Fen Bilimleri Enstitüsü, Toprak Bilimi ve Bitki Besleme Anabilim Dalı, 32 s.

Şahin M, Tarakçıoğlu C, Aşkın TB (2010) Gübrelemenin fındık bitkisinin verim ve yapraklarının bazı bitki besin maddesi içerikleri üzerine etkisi. Ege Üniversitesi, Ziraat Fakültesi Dergisi, Özel Sayısı 5, Ulusal Bitki Besleme ve Gübre Kongresi Bildiriler Kitabı, 15 - 17 Eylül 2010, Bornova, İZMİR.

Ullah S, Khan A, Malik U, Afzal I, Shahid M, Razzaq K (2012) Foliar applicatıon of boron infuences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of ‘Kinnow’mandarin (*Citrus reticulata* Blanco). Journal of Plant Nutrition 35: 2067-2079.

ASABE (2012) Moisture Measurement-Forages. American Society of Agricultural and Biological Engineers, ANSI/ASAE Standarts, St Joseph, MI, S358.3, USA.

CAST (2019) Reducing the impacts of agricultural nutrients on water quality across a changing landscape. CAST Issue Paper Number 64. Council for Agricultural Science and Technology (CAST) 20 p.

Caturegli L, Corniglia M, Gaetani M, Grossi N, Magni S, Migliazzi M, Angelini L, Mazzoncini M, Silvestri N, Fontanelli M, Raffaelli M, Peruzzi A, Volterrani M (2016) Unmanned aerial vehicle to estimate nitrogen status of turfgrasses. PLoS ONE 11(6): e0158268.

EPA (2012) Frequently asked questions about nitrate and drinking water. United States Environmental Protection Agency (EPA) 2 p.

Esbensen KH (2009) Multivariate Data Analysis In Practice: An Introduction to Multivariate Data Analysis and Experimental Design. 5th edition. CAMO Inc. Corvallis, Oregon/USA.

Frank JH (2008) Detection of turfgrass stress using ground based remote sensing. MSc Thesis, University of Florida, Florida, US. 96 p.

Guillard K, Fitzpatrick RJM, Burdett H (2016) Can frequent measurement of normalized difference vegetative index and soil nitrate guide nitrogen fertilization of Kentucky Bluegrass. Crop Sci. 56: 827-836.

Inguagiato JC, Guillard K (2016) Foliar N concentration and reflectance meters to guide N fertilization for anthracnose management of Annual Bluegrass putting green turf. Crop Sci. 56: 3328-3337.

Hocaoglu T (2010) Evaluation of planning and design principles of golf courses in the context of landscape architecture: Gloria Golf Resort case. PhD Thesis, Ankara University, Ankara, Turkey. 151 p.

Jiang Y, Liu H, Cline V (2009) Correlations of leaf relative water content, canopy temperature, and spectral reflectance in Perennial Ryegrass under water deficit conditions. HortSci. 44(2): 459-462.

Kacar B (1994) Chemical analysis of plant and soil: III. Soil Analysis (In Turkish). Ankara Uni. Agric. Fac. Publ. No: 3, 735 p. Ankara

Kacar B, Inal A (2010) Bitki Analizleri (Plant Analysis – in Turkish). Nobel Publication Number: 1241, Ankara. pp 171-212.

Keskin M, Dodd RB, Han YJ, Khalilian A (2004) Assessing nitrogen content of golf course turfgrass clippings using spectral reflectance. Appl. Eng. Agric. 20: 851-860.

Keskin M, Han YJ, Dodd RB, Khalilian A (2008) Reflectance-based sensor to predict visual quality ratings of turfgrass plots. Appl. Eng. Agric. 24: 855-860.

Keskin M, Karanlik S, Gorucu Keskin S, Soysal Y (2013) Utilization of color parameters to estimate moisture content and nutrient levels of peanut leaves. Turk. J. Agric. For. 37: 604-612.

Keskin M, Sekerli YE, Gunduz K (2016) Relationship between water content and color properties of chlorotic and non-chlorotic detached crop leaves. J. Agric. Fac. Uludag Univ. 30: 319-324.

Keskin M, Setlek P, Demir S (2017) Use of color measurement systems in food science and agriculture (in Turkish with abstract in English). International Advanced Researches and Engineering Congress, 16-18 November 2017, Osmaniye. pp 2350-2359. (in Turkish with abstract in English).

Keskin M, Sekerli YE, Gunduz K (2018) Influence of leaf water content on the prediction of nutrient stress in strawberry leaves using chromameter. Int. J. Agric. Biol. 20: 2103-2109.

Knudsen DG, Peterson A, Pratt PF (1982) Lithium, Sodium and Potassium. Methods of Soil Analysis, Part 2. Chemical and Migrobiological Properties. Agronomy Monograph No:9 (2 nd Ed.) ASA-SSSA, Madison, Wisconsin. USA.

Konica Minolta (2007) Colorimetry: How to Measure Color Differences. Konica Minolta Photo Imaging Inc., USA.

Mangiafico SS, Guillard K (2007) Cool-Season turfgrass color and growth calibrated to leaf nitrogen. Crop Sci. 47: 1217-1224.

Moss JQ, Bell GE (2010) Indirect Measurement of Creeping Bentgrass N, Chlorophyll, and Color for Precision Golf Green Management. 10th International Conference on Precision Agriculture Proceedings [CD-ROM], Denver, CO.

Olsen SR, Cole V, Watanabe FS, Dean LA (1954). Estimations of available phosphorus in soils by extractions with sodium bicarbonate. U.S. Dept. Of Agric. Cric. 939, USDA, Washington, DC.

Richards LA (1954) Diagnosis and Improvement of Saline and Alkaline Soils. Handbook. 60. US. Dept. of Agriculture.

Rodriguez IR, Miller GL (2000) Using near-infrared reflectance spectroscopy to schedule nitrogen applications on dwarf-type bermudagrasses. Agron. J. 92: 423-427.

Turkish Official Gazette (2004) Regulation on protection of waters against agricultural nitrate pollution (in Turkish). 18 February 2004, Number: 25377.