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The Effect of Water Stress on Nutrient Elements in Soil and Leaf of Common Bean (*Phaseolus vulgaris* L.)

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Abstract: Water resources are a scarce and limiting factor for expanding cultivation and plant production in many arid and semi-arid areas. This study was conducted to investigate the effects of different water deficit levels on soil and plant (leaf) concentration of macro and micro nutrients of four common bean cultivars and was carried out in a pot in a greenhouse. The treatments consisted of three irrigation regimes to which 100% ($I_{1.00}$), 75% ($I_{0.75}$) and 50% ($I_{0.50}$) of depleted water from field capacity and four bean varieties ("Sarıkız", "Sazova", "Kırk Günlük", and "Gina"). It was determined that leaf macro and micro nutrients reduced from the full irrigation treatment ($I_{1.00}$) to the treatment exposed the highest water stress ($I_{0.50}$). The highest values of the macro and micro parameters in the soil under the highest water constraint were obtained in cv. "Gina". However, the highest values in the cv. "Sazova" were obtained in terms of micro elements in the leaf, and the highest values were obtained from the cv. "Gina" in terms of macro elements in the treatments of the highest water constraint ($I_{0.50}$). As a result, based on the data obtained in this study, it may be stated that cv. "Gina" is more tolerant to water stress in comparison to the other varieties in the pot experiment.

Keywords: Common bean, water deficit, leaf, plant nutrients, soil nutrients

Su Stresinin Fasulye (*Phaseolus vulgaris* L.) Toprakta ve Yapraklarında Besin Elementleri Üzerine Etkisi

Öz: Birçok kurak ve yarı kurak bölgelerde tarım alanlarının yayılımı ve bitki üretimi için su kaynakları kıt ve sınırlayıcı bir faktördür. Bu çalışma, farklı su kısıtı koşulları altında yetiştirilen dört fasulye çeşidinde ve toprakta makro ve mikro besin maddelerinin konsantrasyonu üzerindeki etkilerini araştırmak için yapılmış ve serada saksı denemesi olarak yürütülmüştür. Deneme konuları üç farklı sulama seviyesi (tarla kapasitesine göre tüketilen suyun %100 ($I_{1.00}$), %75 ($I_{0.75}$) ve %50 ($I_{0.50}$)'sinin uygulamıştır) ve dört fasulye çeşidinden (Sarıkız, Sazova, Kırk Günlük ve Gina) oluşmuştur. Tam sulama ($I_{1.00}$) seviyesinden en fazla su stresi etkisinde olan $I_{0.50}$ konusuna doğru yaprakta makro ve mikro besin maddelerinin azaldığı belirlenmiştir. Toprakta en yüksek makro ve mikro besin elementleri $I_{0.50}$ konusunda "Gina" çeşidinde belirlenmiştir. Bununla birlikte, su kısıtının en yüksek olduğu konularda yapraktaki mikro elementler açısından, en yüksek değerler "Sazova", makro elementler açısından da en yüksek değerler "Gina" da elde edilmiştir. Sonuç olarak, bu çalışmada elde edilen verilere dayanarak, "Gina" çeşidinin diğer çeşitlere kıyasla su stresi şartlarında makro elementleri daha iyi alabildiği söylenebilir.

Anahtar Kelimeler: Fasulye, su kısıtı, yaprak, bitki besin maddeleri, toprak besin maddeleri

1. Introduction

Water shortage is a major limiting factor regarding crop yields and productivity worldwide. It is also a vital problem which affects the growth and productivity of crops through reducing the availability of macro and micro nutrients that are necessary for photosynthesis and other metabolic phenomena's (Mahajan and Tuteja, 2005; Miletic et al., 2010; Ashraf et al., 2016). The common bean (*Phaseolus vulgaris* L.) is a major grain legume crop grown and consumed for providing food and feed all over the world because they contain considerable amount of protein, starch, oils and vitamins necessary for human growth and health (Franca et al., 2000). Legumes are grown on a wide range of soils varying in texture and fertility. They are mostly grown in arid and semi-arid regions, where availability of water for crops is limited, and yield losses due to water stress are very high (Farias-Rodriguez et al., 1998).

Mineral nutrients play an active role in minimizing the photo-oxidative damages caused by generation of reactive oxygen species (ROS) in plants growing under drought conditions (Cakmak, 2005; Wang et al., 2005; Ashraf et al., 2016). Therefore, limited supply of water adversely affects plant growth and metabolic processes of plants (Ashraf et al., 1998), and proper supply of macro and micro nutrients leads to higher plant productivity under drought/water deficit conditions (Hussain et al., 2004).

Environmental factors such as water stress may cause nutrient deficiencies, even in fertilized fields, as the physiochemical properties of soil may lead to reduced mobility and absorbance of individual nutrients (Amtmann and Blatt, 2009; Ashraf et al., 2016). Mineral nutrients are essential chemical elements for plant growth and reproduction, acquired primarily in the form of inorganic ions from the soil (Taiz and Zeiger, 2006; Barker and Pilbeam, 2007; Silva et al., 2011).

Several studies have shown that proper supply of nutrient elements to crops for plant growth and productivity is important (Mann et al. 2002; Bhadoria et al. 2003; Rashid and Ryan, 2004; Welch and Graham, 2004; Gupta, 2005; He et al. 2005; Liang et al. 2007; Waraich et al. 2011). However, studies on water deficit effects on macro and micro nutrient contents of common bean (*Phaseolus vulgaris* L.) cultivars are scarce (Abacı, 2009; Kose, 2011; Pitir, 2015). The aim of this study is to investigate the effects of water deficits on the nutrient elements in soil and leaf of the common bean (*Phaseolus vulgaris* L.).

2. Material and Methods

2.1. Plant materials and soil characteristics

Four bean varieties were selected for this study: "Sarıkız", "Sazova", "Kırk Günlük” and "Gina". The three most common bean cultivars were chosen from among the varieties developed by the Transitional Zone Agricultural Research Institute, Eskişehir, Turkey for wider adaptations to Central Anatolia and Transitional Zone Regions. The other is a variety of "Gina", which is widely cultivated by farmers in the region for wider adaptations to Turkey.

The soils in the pots of this study was taken from an agricultural field, in where widely grew beans. The content of the organic matter of the soil was high due to appropriate crop rotation. Soil samples taken at sowing and harvest, and leaf samples were taken at the harvest were analyzed to determine macro and micro elements and also some physico-chemical soil properties. All these analyses were carried out at the Research and Application Center laboratory of Kırşehir Ahi Evran University, Turkey.

2.2. Experimental procedure and design

The study was carried out as a pot experiments in a greenhouse (Gothic type, 240 m^2 area) Kırşehir Ahi Evran University, Turkey from July to September of 2017. The seeds were sown in 5.8 l plastic pots (25 cm diameter and 21 cm soil depth), filled with 5 kg sandy clay loam soil, and five seeds per pot were initially sown and later thinned to one plant per pot when the first trifoliate leaves were unfolded. The bean cultivars in the experiment were exposed to three irrigation regimes ($I_{1.00}$, $I_{0.75}$ and $I_{0.50}$), to which 100%, 75% and 50% of depleted water from field capacity were applied to $I_{1.00}$, $I_{0.75}$ and $I_{0.50}$, respectively. The experiment was arranged as a completely randomized block design with ten replications.

Irrigation applications were carried out whenever 40% of soil available moisture was depleted in $I_{1.00}$ treatment. To this end, each pot was filled with local field soil that was mixed with manure by 5.8 L. The pots, filled with air-dried soils, were watered until they were fully saturated and covered with plastic mulch to prevent evaporation. After providing drainage of excess water leaked from the bottom of the pots, the weight of the pots was accepted as field capacity (Camoglu, 2013; Kurunç and Ünlükara, 2009).

Tap water was used as irrigation water in the experiments. The class of water was C_1S_1 with a sodium risk and low electrical conductance (USSL, 1954). Equal amounts of irrigation water (150 ml) were applied to all pots during three weeks after the bean seeds were planted. When the seedling planting reached a certain height, irrigation water was provided to the pots based on the experimental treatments. At the beginning, an equal amount of water was applied to all treatments until the moisture level reached field capacity. In the next step, the pot with full irrigation treatment (100% of field capacity) was weighed, and irrigation water was applied at around 40% of available water depletion. Full irrigation was performed for three pots of $I_{1.00}$ treatments and then the leaked water was determined after 15-20 minutes drainage period. The leaking water amount was subtracted from the amount which we applied, and then, the irrigation water amount was determined for the full irrigation treatment. 50% and 75% of this amount was applied to other deficit irrigation treatments. The amounts of irrigation water that were applied were precisely measured by a metered cap.

Irrigation treatments were recorded for a 2 month-period (started on 29 July 2017 completed on 30 September 2017). The plants were irrigated 22 times in 3-day intervals during their growing periods. Irrigation was continued in a schedule based on intervals of 3 days.

Based on soil nutrient analysis at the beginning of the experiment, mixtures of ammonium nitrate (0.452 g) and Triple superphosphate (0.66 g) were added before sowing in the pots. Before the flowering of the plants, 16.71 g of mixtures of ammonium sulphate (21% N), potassium nitrate (13-0-46) and iron (6%) were applied two times (27 July and 6 August 2017) at intervals of 10 days. In the flowering periods, mixed fertilization (8 g), consisting of ammonium sulphate, mono potassium phosphate (0-52-34), were applied at 7-day intervals two times (19 August and 26 August 2017) per pot. To prevent formation of aphids, two chemical struggles were conducted every seven days (01 August and 08 August 2017).

2.3. Determination of nutrient elements and soil analyses

Random representative pot plant (leaf) samples of four bean varieties from each pot were selected for chemical analyses to determine the macronutrients K, Ca, Mg and Fe and micronutrients Na, Cu, Mn and Zn by the atomic absorption spectrophotometer (AAS) method following the procedures outlined by Jones and Case (1990), and the protein content of the granulated leaf samples was determined by the Kjeldahl method (Kacar, 1994). The soil samples including the Ca, Mg, Na and K elements were determined by the method described by Helmke and Sparks (1996), and the Fe, Cu, Mn and Zn contents were determined according to the methods used by Lindsay and Norvell (1978). According to the principles reported by Demiralay (1981), the percentage of saturation in the soil was determined. Soil reaction and electrical conductivity were determined by the method reported by Thomas (1996). Total lime was constructed according to method reported by Gulcur (1974). The methods reported by Nelson and Sommers (1996) were performed based on the wet digestion method for organic matter. The methods stated by Kuo (1996) as reported by Olsen et al. (1954) were carried out based on the method developed by UV-VIS spectrometry for utilizing phosphorus. Texture analyses were determined by the hydrometer method according to the principles specified by Bouyoucos (1951). Three replicated measurements were made for each parameter. For both plant leaf and soil analyses, all samples were used at the Research Center and Application laboratory of Kırşehir Ahi Evran University in Turkey.

2.4. Statistical analysis

An analysis of variance (Two-way ANOVA) was performed in a randomized block design with 10 replications and using the GLM (General Linear Model) procedure in the "MINITAB" statistical software (Version 17). 10 plants from four cultivars were exposed to three watering treatments, with a total of 120 plants used in the experiment. The mean values were separated with Tukey multiple range test at $p \leq 0.05$.

3. Results and Discussion

3.1. Some properties of the experimental soil

The physical and chemical analysis of soils before sowing were presented in Table 1. As shown in Table 1, the texture of the experimental soil was sandy clay loam, its pH was neutral (7.02) (Ergene, 1995), it had good organic matter content (4.19%), useful phosphorus content was very high (14.60 kg da^{-1} P_2O_5), and lime content was medium (14.10%) (Aydin and Sezen, 1995). The variable K content (623.90 kg da^{-1} K_2O) was sufficient for plant nutrition (Elgala et al. 1986). The total salinity of the experimental soil before the trial (0.055%) was determined as salt-free (Soil Survey Manuel, 1993). The beans' plant soil demand of the loamy body, pH 7-8 without salinity and alkalinity problems were achieved in a fertile soil, and the plant had a high demand for the element of zinc (Keles, 2015).

Table 1. Some physical and chemical properties of the pot soil
Çizelge 1.*Saksı toprağının bazı fiziksel ve kimyasal özellikleri*

Physical properties							Chemical properties						
Particle size distribution (%)			Texture	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})	pH	Total salt (%)	Available nutrients (kg da^{-1})		Organic matter (%)	Saturation (%)	Lime (%)
Sand	Silt	Clay							P_2O_5	K_2O			
49.3	25.6	25.1	SCL	21.22	11.1	1.34	7.02	0.055	14.60	623.90	4.19	77.0	14.10

3.2. Effects of water stress on soil and plant properties

The plants in their growing periods were irrigated 22 times in 3-day interval (Table 2). A total of 28.75 L, 22.09 L and 25.23 L of irrigation water was applied to the treatments of I_{100}, I_{75} and I_{50}. While more water was applied in each irrigation in July and August, water consumption decreased in September towards the end of the season and less water was applied in each irrigation. According to the I_{100} treatment, 23.1% and 47% less irrigation water was applied to the I_{75} and I_{50} treatments, respectively.

Table 2. Amounts of irrigation water applied
Çizelge 2. *Uygulanan sulama suyu miktarları*

Irrigation Dates	Irrigation Treatments			Irrigation Dates	Irrigation Treatments		
	I0.50	I0.75	I1.00		I0.50	I0.75	I1.00
29/07/2017	1.50*	1.50*	1.50*	12/09/2017	0.60	0.90	1.20
05/08/2017	0.75	1.13	1.30	15/09/2017	0.58	0.86	1.15
08/08/2017	0.70	1.05	1.40	18/09/2017	0.58	0.86	1.15
10/08/2017	0.70	1.05	1.40	21/09/2017	0.55	0.83	1.10
13/08/2017	0.68	1.01	1.35	24/09/2017	0.55	0.83	1.10
15/08/2017	0.68	1.01	1.35	27/09/2017	0.50	0.75	1.00
18/08/2017	0.68	1.01	1.35	30/09/2017	0.50	0.75	1.00
21/08/2017	0.65	0.98	1.30				
23/08/2017	0.65	0.98	1.30				
25/08/2017	0.65	0.98	1.30				
27/08/2017	0.65	0.98	1.30				
30/08/2017	0.65	0.98	1.30				
03/09/2017	0.63	0.94	1.25	Total Irrigation (L)	15.23	22.09	28.75
07/09/2017	0.63	0.94	1.25				
09/09/2017	0.60	0.90	1.20				

*Soil water content of all pots was increased up to field capacity.

Water deficit causes major changes in the physical, chemical and biological nature of soils (Table 3). As shown in Table 3, water regimes had a significant effect ($p<0.01$) on the soils' chemical properties. There was also a significant interaction between the water regimes (I) and cultivars (C). The pH, salinity, organic matter, saturation and total lime were generally decreased by increasing water stress in all cultivars. Among these parameters, based on the mean values, the highest reduction was observed in organic matter (20.03%) and salinity (17.12%) because of irrigation regime. There were significant increases in soil pH, salinity, water saturation percentage and lime ratio of the control ($I_{1.00}$) soil with respect to water stress treatments. It was observed that these values were reached in the $I_{1.00}$ irrigation regime. It was noticed that there was a significant decrease in the amount of organic matter in the soil in comparison to the control soil. The lowest organic matter value (1.33%), soil pH, salt, and more lime were reached at $I_{0.50}$ irrigation regime.

Table 3. The effect different water regimes on soil chemical characters of common bean (*Phaseolus vulgaris* L.) cultivar**s** in harvesting stage

Çizelge 3. *Farklı sulama rejimlerinin hasattaki fasulye (Phaseolus vulgaris L.) çeşitlerinin toprak kimyasal özellikleri üzerine etkisi*

Treatments	pH	Salinity (%)	Organic matter (%)	Saturation (%)	Total Lime (%)
$I_{1.00}$ C1	7.68 a	0.06 ı	1.63 b	99.01 c	32.784 a
$I_{1.00}$ C2	7.41 f	0.08 f	2.10 a	96.25 d	14.505 f
$I_{1.00}$ C3	7.56 c	0.12 b	1.43 bc	69.30 ı	19.458 c
$I_{1.00}$ C4	7.66 a	0.08 f	1.48 bc	89.10 f	18.868 cd
Mean	7.58	0.11	1.66	88.41	21.40
$I_{0.75}$ C1	5.57 c	0.08 g	0.92 e	95.15 e	28.656 b
$I_{0.75}$ C2	7.57 c	0.10 d	1.28 cd	89.10 f	16.628 e
$I_{0.75}$ C3	7.53 d	0.11 c	1.43 bcd	67.65 j	16.981 e
$I_{0.75}$ C4	7.45 e	0.11 c	2.08 a	100.65 b	17.572 de
Mean	7.53	0.10	1.43	88.13	19.96
$I_{0.50}$ C1	7.62 b	0,09 e	1.43 bcd	78.10 g	16.864 e
$I_{0.50}$ C2	7.41 f	0.19 a	0.68 f	101.20 a	14.977 f
$I_{0.50}$ C3	7.38 g	0.07 h	1.26 d	89.10 f	14.505 f
$I_{0.50}$ C4	7.57 c	0.07 h	1.94 a	70.95 h	17.572 de
Mean	7.50	0.09	1.33	84.84	15.98
*Rate (%)	↓ 1.06	↓ 17.12	↓ 20.03	↓ 4.05	↓ 25.34
Summary of ANOVA					
Water Regimes (I)	**	**	**	**	**
Cultivars (C)	**	**	**	**	**
IxC	**	**	**	**	**

Water Regimes: $I_{1.00}$: 100%-control of field capacity, $I_{0.75}$: 75% of field capacity, and $I_{0.50}$: 50% of field capacity; Cultivars: C1: "Sarıkız", C2: "Sazova", C3: "Kırk Günlük", and C4: "Gina"; ns: non-significant, *: significant at $P \leq 0.05$, **: significant at $p \leq 0.01$; Different letters at the same column show significant differences at 0.05 level; *: Decrease and/or Increase Rate of parameters between means of $I_{1.00}$ (100%-control of field capacity) and $I_{0.50}$ (50% of field capacity): Increase: ↑ and decrease: ↓

As presented in Table 4, water regimes had a significant effect ($p<0.01$) on soil macro-micro nutrients of the common bean cultivars. There was also a significant interaction between the water regimes (I) and the cultivars (C). The macro and micro nutrients (P, K, Ca, Mg, Fe, Na, Cu, Mn and Zn) were generally decreased by increasing the water stress in all cultivars. Each nutrient played a different role in crop growth and development. Among these parameters, based on the mean values, the highest reduction was observed in Mn (36.09%), Fe (19.38%), Na (13.81%) and Zn (12.10%).

Table 4. The effect different water regimes on soil macro and micro nutrients of common bean (*Phaseolus vulgaris* L.) cultivars

***Çizelge 4.** Farklı sulama rejimlerinin fasulye (Phaseolus vulgaris L.) çeşitlerinin toprak makro ve mikro besin maddeleri üzerine etkisi*

Treatments	Macro nutrients (ppm)				Micro nutrients (ppm)				
	P	K	Ca	Mg	Fe	Na	Cu	Mn	Zn
$I_{1.00}$ C1	61.79 h	1980 e	6440 a	529 l	1.311 k	562 d	0.748 de	5.333 j	0.862 ı
$I_{1.00}$ C2	78.00 e	2373 b	5870 e	870 a	2.868 a	456 e	0.700 g	12.360 d	1.331 a
$I_{1.00}$ C3	72.21 f	2320 b	6090 cd	801 c	1.692 g	417 f	0.779 b	14.486 a	1.222 c
$I_{1.00}$ C4	88.66 d	2000 e	6490 a	689 g	1.995 d	720 b	0.815 a	10.513 d	0.974 f
Mean	75.17	2168.25	6222.50	722.25	1.970	538.72	0.760	10.67	1.10
$I_{0.75}$ C1	65.86 g	1880 f	5500 f	730 f	2..111 c	754 a	0.734 e	5.226 j	1.001 e
$I_{0.75}$ C2	139.47 a	2180 c	6110 cd	781 d	1.590 ı	605 c	0.749 cd	11.933 c	1.090 d
$I_{0.75}$ C3	111.13 c	2020 de	6170 bc	633 j	1.610 h	569 d	0.719 f	7.640 g	1.025 e
$I_{0.75}$ C4	78.24 e	2180 c	6310 ab	681 h	1.823 f	178 h	0.802 a	7.953 f	1.027 e
Mean	73.68	2065.00	6022.50	706.25	1.78	526.50	0.750	8.19	1.040
$I_{0.50}$ C1	28.08 j	1513 g	5870 e	549 k	1.848 e	335 g	0.755 cd	5.552 ı	0.729 j
$I_{0.50}$ C2	55.28 ı	1807 f	5970 de	675 ı	2.207 b	164 ı	0.744 de	5.566 ı	0.908 h
$I_{0.50}$ C3	70.75 f	2087 d	5440 f	834 b	1.129 l	615 c	0.763 c	5.973 h	0.913 g
$I_{0.50}$ C4	122.04 b	2640 a	6080 cd	751 e	1.157 j	743 a	0.690 g	10.193 e	1.308 bd
Mean	69.04	2011.75	5840	702.25	1.590	464.35	0.74	6.82	0.96
Summary of ANOVA									
*Rate (%)	↓ 8.15	↓ 7.22	↓ 6.15	↓ 2.77	↓ 19.38	↓ 13.81	↓ 2.96	↓ 36.09	↓ 12.10
Water Regimes (I)	**	**	**	**	**	**	**	**	**
Cultivars (C)	**	**	**	**	**	**	**	**	**
IxC	**	**	**	**	**	**	**	**	**

Water Regimes: $I_{1.00}$: 100%-control of field capacity, $I_{0.75}$: 75% of field capacity, and $I_{0.50}$: 50% of field capacity
Cultivars: C1: "Sarıkız", C2: "Sazova", C3: "Kırk Günlük", and C4: "Gina"
ns: non-significant *: significant at $P \leq 0.05$, **: significant at $p \leq 0.01$
Different letters at the same column show significant differences at 0.05 level
*: Decrease and/or Increase Rate of parameters between means of $I_{1.00}$ (100%-control of field capacity) and $I_{0.50}$ (50% of field capacity): Increase: ↑ and decrease: ↓

In our study, depending on the increase in water stress, the Fe, Cu, Zn and Mn values of the soil were significantly reduced. The lowest Fe (1.59 mg kg^{-1}), Mn (6.82 mg kg^{-1}), Zn (0.96 mg kg^{-1}) and Cu (0.74 mg kg^{-1}) contents were found to be reached under the $I_{0.50}$ irrigation regime. The highest amounts of Fe and Zn in the soil were found in the area where the C2 (Sazova) plant varieties in the $I_{1.00}$ irrigation regime. In $I_{0.50}$ treatment, exposed to the highest water stress, soil available P, exchangeable K, Ca and Na elements with microelements of Mn and Zn contents reached their highest level for C4 (Gina) cultivar. Contrary, in the $I_{0.50}$ irrigation regime, it was observed that the amount of Mn and Zn micro elements and the available P, changeable K and Mg elements were the lowest for C1 (Sarıkız) cultivar. In the soil of the C2 (Sazova) cultivar, the changeable Na was the lowest, and Fe was the highest under $I_{0.50}$ irrigation treatment. It was observed that soil Ca and Fe contents were the lowest, and Mg and Cu contents were higher in the soil of C3 (Kırk Günlük) cultivar. When the effects of the water regime applications on the elemental concentrations in soils were examined, it was seen that K, P, Ca, Na and Mg concentrations were adversely affected by water treatments.

Nutrients are essential components required by living plants for growth and development. As presented in Table 5, water regimes had a significant effect ($p<0.01$) on plant leaves' macro-micro nutrients and protein content of common bean cultivars. There was also a significant interaction between water regimes (I) and cultivars (C). Plant (leaf) macro-micro nutrients (K, Ca, Mg, Fe, Na, Cu, Mn, Zn) and protein content were generally decreased by increasing water stress in all cultivars. Among these parameters, based on the mean values, the highest reductions were observed in Na (56.25%), (56.25%), Zn (30.22%), Ca (17.32%), and Fe (13.64%) and Cu (11.55%).

Table 5. The effect different water regimes on plant leaves macro and micro nutrients and protein content of common bean (*Phaseolus vulgaris* L.) cultivars
Çizelge 5. *Farklı su rejimlerinin fasulye (Phaseolus vulgaris L.) çeşitlerinin bitki yaprakları makro ve mikro besin maddeleri ve protein içeriği üzerine etkisi*

Treatments	Macro nutrients (ppm)				Micro nutrients (ppm)				Protein Content (%)
	K	Ca	Mg	Fe	Na	Cu	Mn	Zn	
$I_{1.00}$ C1	55000 cd	46333 cd	7656 a	187 f	261640 h	1978 h	42 f	36 f	34 a
$I_{1.0}$0 C2	57333 bc	58166 a	6753 c	239 b	406070 d	2671 b	50 b	42 c	28 cd
$I_{1.00}$ C3	46666 f	44166 d	5693 ı	194 d	2014423 ı	3263 a	50 b	65 b	29 cd
$I_{1.00}$ C4	65666 a	47666 c	5753 ı	194 d	431068 c	1488 j	39 g	39 e	28 cd
Mean	56166	49083	6464	204	778300	2350	45	46	30
$I_{0.75}$ C1	52166 e	52000 b	6390 f	172 g	272750 g	2333 d	33 ı	41 de	33 ab
$I_{0.75}$ C2	52666 de	48166 c	7113 b	190 e	493839 b	1706 ı	45 c	34 fg	28 cd
$I_{0.75}$ C3	66666 a	40166 e	5073 j	245 a	331078 e	2025 g	44 d	42 cd	29 cd
$I_{0.75}$ C4	57833 b	46000 cd	6310 g	157 ı	318301 f	2293 e	55 a	34 gh	28 cd
Mean	54792	46583	6222	191	353992	2089	44	38	30
$I_{0.50}$ C1	48833 f	30166 f	4602 k	189 e	253863 h	2488 c	43 e	33 h	30 bc
$I_{0.50}$ C2	48000 f	41500 e	6503 e	212 c	584941 a	2056 f	52 b	34 gh	26 d
$I_{0.50}$ C3	56833 bc	44333 d	6600 d	169 h	209979 ı	1398 k	37 h	26 ı	29 cd
$I_{0.50}$ C4	65500 a	46333 cd	6220 h	133 j	313302 f	2223 f	33 ı	34 gh	28 cd
Mean	52166	40583	5981	176	340521	2079	41	32	28
*Rate (%)	↓ 7.12	↓ 17.32	↓ 7.46	↓ 13.64	↓ 56.25	↓ 11.55	↓ 8.84	↓ 30.22	↓ 5.04
Water Regimes (I)	**	**	**	**	**	**	**	**	**
Cultivars (C)	**	**	**	*	**	**	**	**	**
IxC	**	**	**	**	**	**	**	**	**

Water Regimes: I1.00: 100%-control of field capacity, I0.75: 75% of field capacity, and I0.50: 50% of field capacity
Cultivars: C1: "Sarıkız", C2: "Sazova", C3: "Kırk Günlük", and C4: "Gina"
ns: non-significant *: significant at $P \leq 0.05$, **: significant at $p \leq 0.01$
Different letters at the same column show significant differences at 0.05 level
*: Decrease and/or Increase Rate of parameters between means of $I_{1.00}$ (100%-control of field capacity) and $I_{0.50}$ (50% of field capacity): Increase: ↑ and decrease: ↓

When the effects of different irrigation regimens on the elemental concentrations of plant leaves for different bean cultivars were examined, and K, Ca, Mg and Na concentrations were significantly affected by the treatments. It was found that the amount of the macro elements in the $I_{1.00}$ treatment was the highest, and the elements in the $I_{0.50}$ treatment were the lowest. The amount of Ca in the $I_{1.00}$ water regime was found to be higher than the other two treatments. This may have been due to the high amounts of lime in the soil under the $I_{1.00}$ irrigation regime. In the treatment of $I_{1.00}$, the amount of the elements Ca, Mg, K and Na in the plants were high due to the high organic matter content (1.66%) in the soil. In the treatment of the highest water stress, the amount of K and Ca from the macro elements and the amount of Zn from the micro elements were found to be higher in the C4 (Gina) plant leaves. Drought caused a decrease in Ca concentration in green parts of bean plants. Additionally, the lowest Fe and Mn values in the $I_{0.50}$ regime were found in the C4 (Gina) plant leaves, while Na, Cu and Zn values were found in the variety of C3 (Kırk Günlük).

Drought stress affected soil properties as like organic matter, macro and micro elements. Some studies demonstrated that water stress tends to reduce mineralization of organic matter in soils (Sardans et al. 2008). Changes in the chemical properties of soils might affect plant growth and crop production due to reduced release of essential plant nutrients for plant uptake. Soil organic matter (SOM) is known to play a major role in soil fertility due to its effects on the physical, chemical and biological properties of soils (Quiroga et al., 2006). Soil organic matter increases soil nutrient status, structure and water holding capacity (Sparkling, 1992; Von Lützow et al., 2002). Badiane et al. (2012) at the National Center for Agricultural Research Bambey in Senegal under water stress, in their study in the field of vegetable production, found water restriction to decrease by soil organic matter, and it was stated that the risk was important for farmers. Soil organic matter is very important for the effects of soil retention and water use of plants (Ankenbauer and Loheide, 2017). Dostal (2002) stated that the balance of organic matter is an important indicator of sustainability in agriculture.

The macro and micro nutrients (P, K, Ca, Mg, Fe, Na, Cu, Mn and Zn) were generally decreased by increasing the water stress in all plants. Each nutrient played a different role in crop growth and development. The phosphorus uptake decreased by decreasing the soil moisture in various crops such as pepper (Turner, 1985) and wheat (Ashraf et al., 1998; Abu-Muriefah, 2013). It was determined that soil organic matter increases the amount of phosphorus that is present by delaying the reactions of the available phosphorus with Al, Fe and Ca (Tomer et al., 1984). In this study, the effects of water restriction on the macro and micro nutrients in soils varied depending on the common bean species or varieties. Most previous studies have reported that nutrient uptake is mostly affected by low soil moisture (Marschner, 1997; Raynaud and Leadley 2004; Sardans et al., 2008). Alam (1999) also illustrated that drought (water stress) reduces both nutrient uptake by roots and transport from the roots to shoots, due to decreased transpiration rates and impaired active transport and membrane permeability. The decrease in the K concentration in bean genotypes exposed to drought stress, decrease in turgor pressure with water deficiency and inhibition of K intake cause a decrease in K concentration in dry conditions in plant conditions (Kaya, 2011; Özpay, 2008). Similar results were reported to be valid in Ca concentrations. Kaya and Daşgan (2013) stated that the green components' K concentrations increased in salt-stressed plants and decreased in drought stress. The root K concentration was decreased by both types of stress. As a result of salt and drought stress, the green components' Ca concentrations showed a decrease in average percentages (%) in comparison to the control plants. The root Ca concentration showed an increase in the plants under salt stress, while the average percentage (%) changes in the plants under drought stress decreased in comparison to the control plants. Abdalla and El-Khoshiban (2007), in their drought trial on wheat, reported that lack of water caused a decrease in the Ca concentration in root and green parts, and this decrease was more pronounced in sensitive genotypes. With the increase of stress in the rest of the plant that is subjected to drought in a pumpkin implementation, it was stated that there was a reduction in the uptake of Fe (Kose, 2011). Moreover, the K amount was lower in the C2 (Sazova) plant leaves, but the Na, Mn and Zn amounts were high. Similarly, the amounts of K, Ca and Mg were found to be the lowest, while the amount of Cu was the highest in the variety of C1 plant leaves. In another study on coriander plants, with an increase in drought severity, there was a decrease in the content of the Na element in the plant with an increase in the elements Mg, K and Ca (Gozuacik, 2013). The gongronema latifolium plant was grown under the drought conditions described by Osuagwu and Edeoga (2012), the mineral contents were examined, and as a result of water stress, a significant decrease in potassium and calcium content ($p < 0.05$) was observed in the leaves of the plant. Khalid (2006) applied different water stress levels on two different basil species, and N, P, K and protein ratios were decreased in both basil species under stress conditions. When the micro elements of Fe, Cu, Zn and Mn in the plant leaves were examined, the highest values were found in the plant leaves grown in calcareous soils, and the lowest values were found in the plant leaves grown in soils with low lime and organic matter. Similar findings were also found in cherry drought stress. It was reported that reductions in the amounts of K, Ca, Fe and Mn occur in these conditions (Sivritepe et al., 2008). According to Nasri et al. (2008), under 4 different irrigation conditions exposed to drought in watermelon, as the severity of drought increased in the plant, N, P and K contents were reduced. The findings above showed similarity with the results of our study.

4. Conclusions

This study showed that different water regimens had a significant effect on soils' chemical properties, and soil and plant (leaf) macro and micro nutrients. The highest values of the macro and micro parameters in the soil under the highest water constraint were obtained in cv. "Gina". However, the highest values in the cv. "Sazova" were obtained in terms of micro elements in the leaf, and the highest values were obtained from the cv. "Gina" in terms of macro elements in the treatments of the highest water constraint ($I_{0.50}$). As a result, based on the data obtained in this study, it may be stated that cv. "Gina" is more tolerant to water stress in comparison to the other varieties in the pot experiment.

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References

Abaci AA (2009). Comparison of The Ecophysiologıcal Properties of C_4 Haloxylon Persicum and C_3 Tamarix Parviflora By Eczotic Specıes Kahramanmaraş Sütçü İmam Unıversıty Graduate School of Natural And Applied Scıences Master Of Science Thesis pp:72.

Abu-Muriefah SS (2013). Effect of chitosan on common bean (*Phaseolus vulgaris* L.) plants grown under water stress conditions. International Research Journal of Agricultural Science and Soil Science, 3(6): 192-199.

Abdalla, MM and El-Khoshiban, NH (2007). The Influence of Water Stress on Growth, Relative Water Content, Photosynthetic Pigments, Some Metabolic and Hormonal Contents of Two Triticium aestivum Cultivars. Journal of Applied Sciences Research, 3 (12): 2062-2074.

Alam SM (1999). Nutrient uptake by plants unders stress conditions. In: Pessaraki M (ed) Handbook of plant and crop stress. Marcel Dekker, New York, pp: 285-314.

Amtmann A and Blatt MR (2009). Regulation of macronutrient transport. New Phytologist, 181: 35 MR-32.

Ankenbauer, KJ and Loheide SP (2017). The effects of soil organic matter on soil water retention and plant water use in a meadow of the Sierra Nevada, CA. Hydrological Processes, 31: 891-901.

Ashraf MY, Ala SA and Bhatti AS (1998). Nutritional imbalance in wheat (*Triticum aestivum* L.) genotypes grown under soil water deficit. Acta physiologiae plantarum, 20: 307-311.

Ashraf MY, Mahmood K, Ashraf M, Akhter J and Hussain F (2016). Optimal Supply of Micronutrients Improves Drought Tolerance in Legumes, 25: 637-657.

Badiane A, Ndour NYB, Guèye F, Faye S, Ndoye I and Masse D (2012). Effects of different inputs of organic matter on the response of plant production to a soil water stress in Sahelian region. Natural Science, 4(12): 969-975.

Barker AV and Pilbeam DV (2007). Handbook of Plant Nutrition (1nd Edn), CRC Taylor and Francis, NY, pp: 636.

Bhadoria PBS, Prakash YS and Rakshit A (2003). Relative efficacy of organic manures on rice production in lateritic soil. Soil Use and Management, 19: 80-82.

Bouyocous GL (1951). A Recalibration of Hydrometer Method for Making Mechanical Analysis of soils. Agronomy Journal, 43: 434-438.

Cakmak I (2005). Role of potassium in alleviating the detrimental effects of abiotic stress plants. Journal of Soil Science and Plant Nutrition, 168: 521-530.

Camoglu G (2013). The effects of water stress on evapotranspiration and leaf temperatures of two olive cultivars. Zemdirbyste, 100(1): 91-98.

Demiralay İ (1981). Some Physical Analysis Methods in Soil. Atatürk University Faculty of Agriculture, Department of Soil Science, Erzurum.

Dostal J (2002). Results of the Long-Term Organic Matter Balance Investigations in Usti Nad Orlici District and the Trends in the Whole Czech Republic. Archives Agronomy Soil Science, 48(2): 155-160.

Farias-Rodriguez R, Robert BM, Carlos A and Pena-Cabriales JJ (1998). The accumulation of trehalose in nodules of several cultivars of common bean (Phaseolus vulgaris) and its correlation with resistance to drought stress. Acta Physiologiae Plantarum, 102: 353-359.

Franca MGC, Pham-Thi CAT, Pimentel ROP, Rossiello Y, Fodil Z and Laffray D (2000). Differences in growth and water relations among Phaseolus vulgaris cultivars in response to induced drought stress. Environmental and Experimental Botany, 43: 227-237.

Gozuacik HG (2013). Investigation of the Effect of Water Stress on Coriander (Coriandrum Sativum L.) Plant Growth and Fatty Acid and Nutrient Content in Fruits. Kilis 7 Aralık University Graduate School of Natural and Applied Sciences M.Sc. Thesis Department of Biology September 2013 pp:56.

Gulcur F (1974). Physical and Chemical Analysis Methods of Soil, Istanbul University Faculty of Forestry Publications, Istanbul University Publishing No: 1970, Kutulmus Matbaası, İstanbul.

Gupta AP (2005). Micronutrient status and fertilizer use scenario in India. J Trace Element Med Biol., 18:325-331.

He ZL, Yang EE and Stoffella PJ (2005). Trace elements in agroecosystems and impacts on the environment. J Trace Element Med Biol., 19:125-140.

Helmke PA, Sparks DL (1996). Lithium, Sodium, Potassium, Rubidium, and Calcium, in Sparks, D.L., (Ed) Methods of Soil Analysis, Part 3, Chemical Methods, SSSA Book Series Number 5, SSSA., Madison,WI, pp:551-574.

Hussain A, Chaudhry MR, Wajad A, Ahmed A, Rafiq M, Ibrahim G and Goheer AR (2004). In fluence of water stress on growth, yield and radiation use efficiency of various wheat cultivars. International Journal Agriculture and Biology, 6:1074-1079.

Jones JJB and Case WW (1990). "Sampling, Handling, and Analyzing Plant Tissue Samples," In: R.L. Westerman, Ed., Soil Testing and Plant Analysis, Book Series 3, Soil Science Society of America, Madison, pp. 389-427.

Kacar B (1994). Chemical Analysis of Plant and Soil: III, Soil Analysis, Ankara University, Faculty of Agriculture, Education, Research and Development Foundation Publications No: 3, Ankara.

Kaya E and Daşgan HY (2013). Screening Bean Genotypes for Tolerance to Drought and Salinity Stresses in Early Plant Development. Cukurova University Journal of Science and Engineering Sciences: 29-2, pp: 39-48.

Kaya E (2011). Screening of Bean Genotypes for Tolerance to Drought and Salinity Stresses in Early Plant Development Phase. Master Thesis, Cukurova University Graduate School of Natural and Applied Sciences, Department of Horticulture, Adana.213.

Khalid KA (2006). Influence of water stress on growth, essential oil, and chemical composition of herbs (Ocimum sp.). International Agrophysics, 20: 289-296.

Kose S (2011). Turkey also grown in some type of pumpkin (Cucurbita sp.) Drought Stress Tolerance Respect Determination of genotypic variation. Master Thesis, Department of Horticulture, Graduate School of Natural and Applied Sciences, Van. pp:87

Kuo S (1996). Phosphorus in D.L. Sparks (Ed) Methods of Soil Analysis, Part 3, Chemical Methods, SSSA Book Series Number 5, SSSA., Madison,WI, pp: 869-921.

Kurunç A and Ünlükara A., 2009. Growth, yield, and water use of okra (*Abelmoschus esculentus)* 422 and eggplant (*Solanum melongena*) as influenced by rooting volume. RSZN New Zealand 423 Journal of Crop and Horticultural Science, 37: 201-210.

Liang YC, Sun WC, Zhu YG and Christie P (2007). Mechanisms of silicon-mediated alleviation of abiotic stresses in higher plants, a review. Environmental Pollution 147: 422-428.

Lindsay WL and Norvel WA (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Science Society of America Journal 42(3): 421-28.

Mahajan S and Tuteja N (2005). Cold, salinity and drought stresses. Archives of biochemistry and biophysics, 444: 139-158.

Mann EN, Resende PM, Mann RS, De Carvalho JG and Von Pinho EVD (2002). Effect of manganese application on yield and seed quality of soybean. Pesquisa Agropecuaria Brasileira, 37: 1757-1764.

Miletic RPR, Dodig D, Milutinovic S, Mihajlovic I and Nikodijevic SM (2010). Strategies for solving the problem of drought in Eastern Serbia. http://www.wgcrop.icidonline.org/40doc.pdf

Marschner H (1997). Mineral Nutrition of Higher Plants (second ed.). Academic Press Limited Publishing. London-San Diego ISBN: 0-12-473542-8 (HB), 0-12-473543-6

Nasri M, Khalatbari M, Zahedi H, Paknejad F and Moghadam HR (2008). Evaluation of micro and macro elements in drought stress condition in cultivars of rapeseed watermelon (*Brassica napus* L.). American journal of agricultural and biological sciences3(3): 579-583.

Nelson DW and Sommers LE (1996). Total Carbon, Organic Carbon, and Organic Matter. P: 9611011. In D.L. Sparks (ed) Method of Soil Analysis: Chemical Methods. Part 3. SSSA, Madison, WI.

Olsen SR, Cole V, Watanabe FS, Dean LA (1954). Estimation of Available Phosphorus in Soils by Extraction With Sodium Bicarbonate, U.S.A.

Osuagwu, GGE and Edeoga, HO (2012). Th inflence of ater stress (drought) on the mineral and vitamin content of the leaves of Gongronema latifolium (Benth). International Journal Aromatic Plants, 2 (2): 301-309.

Quiroga, A, Funaro, D, Noellemeyer, E and Peinemann N (2006). Barley yield response to soil organic matter and texture in the Pampas of Argentina. Soil and Tillage Research, 90 (1-2): 63-68.

Özpay T (2008). Determination of Reactions of Fresh Bean (Phaseolus vulgaris L.) Genotypes to Drought Stress. Master Thesis, Department of Horticulture, Graduate School of Natural and Applied Sciences, Van. pp:54.

Pitir M (2015). Determination of physiological, morphological and chemical changes caused by different water constraints in pepper cultivation. Master Thesis Namık Kemal University Science Institute Tekirdağ, Turkey.

Rashid A and Ryan J (2004). Micronutrient constraints to crop production in soils with Mediterranean type characteristics: a review. J Plant Nutrition, 27:959-975.

Raynaud X and Leadley PW (2004). Soil characteristics play a key role in modelling nutrient competition in plant communities, Ecology, 85:2200-2214.

Sardans J, Penuelas J and Ogaya R (2008). Drought-induced changes C and N stoichiometry in a Quercus

ilex Mediterranean Forest. Forest Science, 54:513-522.
Silva EC, Nogueina RJMC, Silva MA and Albuquerque MB (2011). Drought stress and plant nutrition. Plant Stress. (Special Issue 1): 32-41.
Sivritepe N, Erturk U, Yerlıkaya C, Türkan İ, Bor M and Özdemir F (2008). Response of the cherry root stock to water stress induced *in vitro*. Biology Plant, 52 (3): 573-576.
Taiz L and Zelger E (2006). Plant physiology (4th Edn), Sinauer Associates, Massachusetts, pp:69.
Thomas GW (1996). Soil pH and Acidity. In D.L. Sparks (ed) Method of Soil Analysis: Chemical Methods. Part 3. SSSA, Madison, WI. pp:475-491.
Tomer NK, Khanna SS and Gupta AF (1984). Transformation of Mixture of Missouri Rock Phosphate and TSP in Calcareous Soil Applied after Incubation with Organic Matter. Hayrana Agriculture University Journal of Reseach, 14: 324-333.
Turner LB (1985). Changes in the phosphorous content of Capsicum annuam L) leaves during water stress. Journal of Plant Physiology, 121: 429.
USSL (1954). Diagnosis and Improvement of Salina and Alkali Soils. Agriculture Hand-book No: 60, USA. pp. 160.
Von Lützow M, Leifeld J, Kainz M, Kogel-Knabner I and Munch JC (2002). Indications for soil organic matter quality in soils under different management. Geoderma, 105: 243-258.
Wang ZY, Ge YX, Main R and Baker J (2005). Development of highly tissue culture responsive lines of Lolium temulentum by another culture. Plant Science, 168:203-211.
Waraich EA, Amad R, Ashraf MY and Saifullah AM (2011). Improving agricultural water use efficiency by nutrient management. Acta Agriculturae Scandinavica-Soil and Plant Science, 61(4): 291-304.
Welch RM and Graham RD (2004). Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal Experimental Botany, 55: 353-3