

# THE EFFECTS OF WATER DEFICIT ON CONCENTRATION OF MACRO AND MICRONUTRIENTS OF COMMON BEAN (*PHASEOLUS VULGARIS* L.) CULTIVARS

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## ABSTRACT

Water deficit is one of the main restrictions to crop growth and productivity worldwide. This study was conducted to investigate the effects of different levels of water deficit ( $I_{1.00}$ :100%–control of field/pot capacity,  $I_{0.75}$ :75% of field/pot capacity and  $I_{0.50}$ :50% of field/pot capacity) on the concentration of macro- and micronutrients of four common bean (*Phaseolus vulgaris* L.) cultivars ("Sarıköz", "Sazova", "Kırk Günlük", and "Gina"). The investigation was carried out in pot experiment in a greenhouse and experiments were designed using a randomized block design with ten replications. Water stress significantly but differentially affected the growth, seed yield components and nutrients of the four common beans in our study. In the fresh pod, cv."Gina" has come to the fore in terms of macro and micro elements (P, K, Ca, Mg, B, Cu, Mn, and Se) under the maximum water stress ( $I_{0.50}$ ). Similarly, cv."Gina" was released mainly foreground in terms of growth parameters (pod width, pod length, number of pods in the plant and number of seed in the total plant) and macro- and micronutrients in terms of P, Cu, F and S under the maximum water stress ( $I_{0.50}$ ). Based on the results of this study, it can be said that cv. "Gina" is more tolerant to water stress than other bean cultivars. The use of drought-tolerant cultivar of common bean may produce more yield with less water; thereby improves water productivity for efficient use of water resources.

## KEYWORDS:

Common bean, water deficit, seed yield, yield, components, growth responses, macro- and micronutrients

## INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a crop of considerable importance in the worldwide as a grain legume and as a vegetable and is also the world's most important food legume used for direct

human consumption [1,2,3]. It is one of the important legume crops with its high protein content, rich in mineral substances compared to other plants [4,5,3]. Water deficit is one of the main restrictions to crop growth and productivity worldwide. Moreover, Food and Agriculture Organization (FAO) reported that there were 45% of agricultural land exposed to drought stress on the earth [6,7]. Extreme lack of water negatively affects physiological, biochemical and metabolic mechanisms in plant, and finally decreases crop yield and quality [8,9,10,11]. Other effects of water stress include reduction in nutrient uptake, cell growth and enlargement, leaf expansion, assimilation, translocation and transpiration. Many nutrient elements are actively taken up by plants, however the capacity of plant roots to absorb water and nutrients generally decreases in water stressed plants, presumably because of a decline in the nutrient element demand [12].

However, water stress is a serious problem especially in arid and semi-arid regions around the world [13,14,15]. The arid and semi-arid regions with water scarcity are vulnerable to several stressors such as high water demand created by agricultural activities. Hence, appropriate crop water management is critical in these regions. One of the context of crop water management is to determine the physiological responses of the plants under water deficit conditions (commonly known as drought) [16].

Common beans have a low tolerance to water stress [46]. This condition is very important considering that approximately 60 percent of the world's production is carried out under water deficit conditions [17,18]. Plants need a various macro- and micronutrients such as P, K, Ca, Mg, B, Na, Cu, Fe, Mn, Zn and Se for proper growth and the reduction in the presence of such nutrients affects their growth, development and production. These nutrients play a crucial role in sustainable agriculture worldwide. Drought intervenes the provision of substantial trace elements in the soil and an imbalance may occur in macro- and micronutrients in the plants [19,20]. It is

**TABLE 1**  
**Some features of common bean varieties studied in the experiment**

Name of Cultivars	Characteristic Features	Registrant Institution
cv. Sarıkız	Fruits are spineless, flat and pod color is slightly dark green	Transitional Zone Agricultural Research Institute, Eskisehir, Turkey
cv. Sazova	Fruits are spineless, rounded, curved, and very fleshy fruit and bean color is medium green	Transitional Zone Agricultural Research Institute, Eskisehir, Turkey
cv. Kırk Günlük	Fruits are spineless, slightly curved, medium length and flat and pod color is light green	Transitional Zone Agricultural Research Institute, Eskisehir, Turkey
cv. Gina	Fruits are spineless, flat and pod color is green	Monsanto Food Agriculture Company

important to understand the effects of drought on the availability of the nutrient elements. Although several studies carried out on the effect of water stress [2,21,22], few studies are related to morphological plant responses, macro- and micronutrients concentrations under water stress.

The main aim of the study was to determine the effects of water deficit on the concentration of macro- and micronutrients of four common bean cultivars in pot experiment in a greenhouse. The study also aims to identify the responses of seed yield and yield components of common bean cultivars to water stress.

## MATERIAL AND METHODS

**Plant materials.** Four varieties were selected for the present study: "Sarıkız", "Sazova", "Kırk Günlük" and "Gina". The first three of 4 common bean cultivars were chosen among varieties developed by the Transitional Zone Agricultural Research Institute, Eskisehir, 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. Some features of common bean varieties were presented in Table 1.

**Experimental procedure and design.** The trial was conducted in a pot experiments under the greenhouse (Gothic type, 240 m<sup>2</sup> area) conditions at Kirsehir 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 (See Table 2) and five seeds per pot were initially sown and later thinned to one plant per pot when the first trifoliolate 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 soil level of the pot were applied to  $I_{1.00}$ ,  $I_{0.75}$  and  $I_{0.50}$ , respectively. The experiment was arranged in a randomized block design with control ( $I_{1.00}$ ) and two water stress treatments ( $I_{0.75}$  and  $I_{0.50}$ ), and ten replicates, giving a total of 120 pots. The physical and chemical properties of soil used pot experiment were given in Table 2.

Irrigation applications were carried out when the available water of soil in the pots dropped to about 60% of field capacity. To this end, each pot was filled with local field soil that mixed with 5.8 liters. All pots were weighed. Then, a pot soil sample for each pot size was brought into air-dry. Air-dry soil was weighed together with pot. The pots with air-dry soil were watered up to fully saturated, and were covered with plastic mulch to prevent evaporation [23].

**TABLE 2**  
**Some physical and chemical properties of soil used pot experiment**

Physical properties						Chemical properties							
Particle size distribution (%)			Texture	Field capacity (%w)	Wiltin g point (%w)	Bulk densit y (g cm <sup>-3</sup> )	pH	Total salt (%)	Available nutrients (kg ha <sup>-1</sup> )		Satura tion (%)	Lime (%)	
Sand	Silt	Clay							P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O			
49.3	25.6	25.1	Sandy clay loam	21.22	11.1	1.34	7.02	0.055	14.60	623.90	4.19	77.0	14.10

**TABLE 3**  
**Amounts of irrigation water applied**

Irrigation Dates	Irrigation Treatments			Irrigation Dates	Irrigation Treatments		
	I <sub>0.50</sub>	I <sub>0.75</sub>	I <sub>1.00</sub>		I <sub>0.50</sub>	I <sub>0.75</sub>	I <sub>1.00</sub>
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	<b>Total Irrigation (liter)</b>	<b>15.23</b>	<b>22.09</b>	<b>28.75</b>
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				
07/09/2017	0.63	0.94	1.25				
09/09/2017	0.60	0.90	1.20				

\*: Soil water content in soil depth of all pots was increased up to field/pot capacity.

Tap water was used as irrigation water. The class of water was C<sub>1</sub>S<sub>1</sub> [24]. 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 given to the pots based on experimental treatments. In the beginning, an equal amount of water was applied to all treatments until the moisture reached the field capacity. In the next step, the pot with full irrigation treatment (100 % of field capacity or 100% of water to replenish the soil moisture up to field capacity) was weighed and irrigation water is applied again when the available moisture decreased to 60 % level (40 % reduction in the moisture). Full irrigation was applied to the treatments in which the available moisture was brought to the field capacity. Irrigation water was ceased as soon as the first water leakage started in the pots (3 pots) with full irrigation treatments, leaking water was weighed after 15-20 minutes wait. Leaking water amount was subtracted from the amount which we applied and then irrigation water amount was determined for the full irrigation treatment. 50 and 75 percent of this amount was applied to other deficit irrigation treatments. Applied amounts of irrigation water were precisely determined since irrigation was done by the metered cap.

According to the results of experimental soil analysis, mixed of ammonium nitrate (0.452 g) and triple superphosphate (0.66 gr) were added before sowing in per pots. Before the flowering of plants, 16.71 g mixed of ammonium sulphate (21% N), potassium nitrate (13-0-46) and iron (6%) were applied for two times (27 July and 6 August 2017) at interval 10 days per pot. At flowering periods, mixed

fertilization (8 g), consist of ammonium sulphate, monopotassium phosphate (0-52-34), were applied at 7 day interval two times (19 August ve 26 August 2017) for per pots. To prevent the formation of aphids, two chemical struggles have been conducted every seven days (01 August and 08 August 2017).

**Seed yield and its components.** Dry seed, pod width, pod length, number of pods per plant, number of seed per pod, seed width, seed length, seed thickness and seed yields per plant were measured on a random sample of 3 plants from each treatment. 100-seed weight was determined according to the methods described in researchers [25,26,27].

**Nutrient analyses.** A samples of fresh pod at podding period and seed samples at harvest of four bean varieties were dried in an oven at 68 °C for 48 hours after air drying and these samples were milled into flour. Before mineral material analysis, samples were taken to microwave by inductively coupled plasma mass spectrometry (ICP-MS). For this purpose, 8 ml nitric acid and 2 ml hydrogen peroxide were added to the sample of 0.31 grams and incineration was carried out. Three replicate measurements were made for each solution. In the samples taken into the solution, related readings were made as µg L<sup>-1</sup> or ppb by ICP-MS (Inductively Paired Plasma-Mass Spectrometer). The analyzes were made at East Anatolian High Technology Application and Research Center of Ataturk University, Erzurum, Turkey.

**Statistical analysis.** The analysis of variance (Two-way-ANOVA) was performed in a completely randomized design with 10 replications and using

**TABLE 4**  
**The effects different water regimes on concentration macro- and micronutrients of common bean (*Phaseolus vulgaris* L.) cultivars in the fresh pod**

Treatments	Macro nutrients (ppm)					Micronutrients (ppm)					
	P	K	Ca	Mg	Fe	B	Na	Cu	Mn	Zn	Se
I <sub>1.00</sub> C1	4257 562 <sup>c</sup>	30371 479 <sup>de</sup>	67448 4 <sup>d</sup>	2929 518 <sup>d</sup>	1162 73 <sup>c</sup>	2274 7 <sup>a</sup>	19737 9 <sup>g</sup>	5497 ab	149 92 <sup>e</sup>	35016 b	113 <sup>a</sup>
I <sub>1.00</sub> C2	4406 388 <sup>b</sup>	32691 920 <sup>ab</sup>	73536 2 <sup>d</sup>	2659 964 <sup>ef</sup>	7636 3 <sup>g</sup>	1871 0 <sup>cd</sup>	45342 3 <sup>a</sup>	4755 c	191 49 <sup>b</sup>	67457 a	152 <sup>a</sup>
I <sub>1.00</sub> C3	4206 848 <sup>c</sup>	33147 030 <sup>a</sup>	90567 4 <sup>bc</sup>	3039 564 <sup>c</sup>	9936 7 <sup>f</sup>	2155 0 <sup>ab</sup>	27628 4 <sup>d</sup>	4904 bc	168 17 <sup>cd</sup>	31988 cdef	155 <sup>a</sup>
I <sub>1.00</sub> C4	5034 928 <sup>a</sup>	32380 009 <sup>bc</sup>	10515 86 <sup>ab</sup>	3156 623 <sup>b</sup>	9727 8 <sup>f</sup>	2068 2 <sup>abc</sup>	33585 1 <sup>c</sup>	6042 a	239 29 <sup>a</sup>	32562 bcde	331 <sup>a</sup>
<b>Mean</b>	<b>4476</b> <b>32</b>	<b>32147</b> <b>610</b>	<b>84177</b> <b>7</b>	<b>2946</b> <b>417</b>	<b>9729</b> <b>5</b>	<b>2092</b> <b>2</b>	<b>31573</b> <b>4</b>	<b>5300</b>	<b>187</b> <b>222</b>	<b>41756</b>	<b>188</b>
I <sub>0.75</sub> C1	4038 474 <sup>d</sup>	30654 672 <sup>d</sup>	63600 2 <sup>d</sup>	2653 515 <sup>ef</sup>	1107 84 <sup>d</sup>	1795 5 <sup>d</sup>	21796 1 <sup>f</sup>	4673 c	178 42 <sup>c</sup>	29356 f	197 <sup>a</sup>
I <sub>0.75</sub> C2	3492 143 <sup>e</sup>	29476 814 <sup>f</sup>	92443 0 <sup>bc</sup>	3219 802 <sup>b</sup>	1228 63 <sup>b</sup>	2061 1 <sup>abcd</sup>	27917 5 <sup>d</sup>	4476 cd	137 94 <sup>e</sup>	30020 ef	63 <sup>a</sup>
I <sub>0.75</sub> C3	3565 721 <sup>e</sup>	29715 401 <sup>ef</sup>	68639 7 <sup>d</sup>	2730 463 <sup>e</sup>	1157 67 <sup>c</sup>	2167 7 <sup>ab</sup>	35732 8 <sup>b</sup>	4591 c	170 24 <sup>cd</sup>	32881 bcd	155 <sup>a</sup>
I <sub>0.75</sub> C4	5015 667 <sup>a</sup>	32291 794 <sup>bc</sup>	10868 22 <sup>a</sup>	3504 817 <sup>a</sup>	1317 09 <sup>a</sup>	2093 9 <sup>abc</sup>	26476 9 <sup>de</sup>	5654 a	191 54 <sup>b</sup>	30261 def	303 <sup>a</sup>
<b>Mean</b>	<b>4028</b> <b>001</b>	<b>30534</b> <b>670</b>	<b>83341</b> <b>3</b>	<b>3027</b> <b>149</b>	<b>1202</b> <b>81</b>	<b>2029</b> <b>6</b>	<b>27980</b> <b>8</b>	<b>4849</b>	<b>169</b> <b>54</b>	<b>30630</b>	<b>180</b>
I <sub>0.50</sub> C1	3030 872 <sup>g</sup>	26941 032 <sup>g</sup>	72866 9 <sup>d</sup>	2600 720 <sup>f</sup>	7736 6 <sup>g</sup>	1906 1 <sup>bcd</sup>	22112 5 <sup>f</sup>	4475 cd	145 57 <sup>e</sup>	34467 bc	47 <sup>a</sup>
I <sub>0.50</sub> C2	3434 997 <sup>e</sup>	30569 149 <sup>d</sup>	67249 6 <sup>d</sup>	2855 337 <sup>d</sup>	1042 35 <sup>e</sup>	2180 7 <sup>a</sup>	27026 2 <sup>d</sup>	3872 d	177 22 <sup>c</sup>	25711 g	105 <sup>a</sup>
I <sub>0.50</sub> C3	3262 321 <sup>f</sup>	32344 135 <sup>bc</sup>	77993 2 <sup>cd</sup>	3055 579 <sup>c</sup>	1323 86 <sup>a</sup>	1845 0 <sup>cd</sup>	22116 4 <sup>f</sup>	4806 bc	164 68 <sup>d</sup>	31536 def	194 <sup>a</sup>
I <sub>0.50</sub> C4	4056 344 <sup>d</sup>	31802 695 <sup>c</sup>	10400 89 <sup>ab</sup>	3039 812 <sup>c</sup>	1126 42 <sup>cd</sup>	2016 3 <sup>abcd</sup>	25011 7 <sup>e</sup>	6014 a	176 77 <sup>cd</sup>	30774 def	220 <sup>a</sup>
<b>Mean</b>	<b>3446</b> <b>13</b>	<b>30414</b> <b>253</b>	<b>80529</b> <b>7</b>	<b>2887</b> <b>862</b>	<b>1066</b> <b>57</b>	<b>1987</b> <b>0</b>	<b>24066</b> <b>7</b>	<b>4792</b>	<b>166</b> <b>06</b>	<b>30622</b>	<b>142</b>
<b>*Rate (%)</b>	↓ <b>23.02</b>	↓ <b>5.39</b>	↓ <b>4.33</b>	↓ <b>1.99</b>	↓ <b>11.33</b>	↓ <b>5.03</b>	↓ <b>23.78</b>	↓ <b>9.58</b>	↓ <b>2.05</b>	↓ <b>26.66</b>	↓ <b>24.63</b>
<b>Water Regimes (I)</b>	**	**	**	**	**	**	**	**	**	**	ns
<b>Cultivars (C)</b>	**	**	**	**	**	**	**	**	**	**	*
<b>IxC</b>	**	**	**	**	**	**	**	**	**	**	ns

Water Regimes: I<sub>1.00</sub>: 100%-control of pot/field capacity, I<sub>0.75</sub>: 75% of pot/field capacity, and I<sub>0.50</sub>: 50% of pot/field capacity  
 Cultivars: C1: "Sarıköz", C2: "Sazova", C3: "Kırk Günlük", and C4: "Gina"

ns: non-significant, \*: significant at P≤0.05, \*\*: significant at P≤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<sub>1.00</sub> (100%-control of pot/field capacity) and I<sub>0.50</sub> (50% of pot/field): Increase: ↑ and decrease ↓

the GLM (General Linear Model) procedure in "MINITAB" statistical software (Version 17). 10 plantules from four cultivars were exposed to three irrigation treatment, with a total of 120 plantules

used in the experiment. The means were separated with Tukey multiple range test at P≤0.05.

## RESULTS AND DISCUSSION

**Plant water consumption (Et).** Irrigation treatments were recorded for a 2 month-period (started on July 29, 2017 completed on September 30, 2017). The plants in growth period were irrigated 22 times. The amount of water applied, and plant water consumption (Et), were presented in Table 3. The total amount of water applied for I<sub>0.50</sub>, I<sub>0.75</sub>, and I<sub>1.00</sub> treatments was 15.23 L, 22.09 L, and 28.75 L. The lowest and the highest values of irrigation water and plant water consumption (Et) were observed in the I<sub>0.50</sub> and I<sub>1.00</sub> treatments, respectively in growing periods. (Table 3). The Et values increased depend on irrigation levels.

### Some properties of the pot experimental soil.

The results of some physico-chemical analyses of soil used pot experiment given in Table 2. The texture of the experimental soil was sandy clay loam, with pH 7.02 and high available P<sub>2</sub>O<sub>5</sub>, and medium K<sub>2</sub>O were 14.60 kg ha<sup>-1</sup> and 623.90 kg ha<sup>-1</sup>, respectively.

**Plant Nutrients.** The effects of different water regimes on the concentration of macro- and micronutrients of common bean (*Phaseolus vulgaris* L.) cultivars in the fresh pod were presented in Table 4 and the concentrations of macro- and micronutrients (P, K, Ca, Mg, Fe, B, Na, Cu, Mn, Zn, and Se) generally were decreased with increasing water stress in all cultivars. The decreasing were 23.02%, 5.39%, 4.33%, 1.99%, 5.03%, 23.78%, 9.58%, 11.33%, 2.05%, 26.66% and 24.63% in P, K, Ca, Mg, B, Na, Cu, Fe, Mn, Zn, and Se, respectively. The decrease in plant nutrient content was an indicator of plant development and yield. However, the interaction between water regimes (I) and cultivars (C) were found significant (p<0.01) for all nutrients, except Se (Table 4).

Many researchers have reported different effects of water stress on nutrient concentrations of different plant species and genotypes of environments, and most studies have reported that mineral uptake can decrease when water stress intensity is increased [28,29,30,2,22,21].

Many plant nutrients, dissolved in the soil, were taken by plants, however, the capacity of plant roots to absorb water and nutrients were generally decreased in water-stressed plants, presumably because of a decline in the nutrient element receptivity. The present study agreed with the findings of the studies done by several researchers [31,32,30].

The effects of different water regimes on the concentration of macro- and micronutrients of common bean (*Phaseolus vulgaris* L.) cultivars in the dry seed presented in Table 5. According to the

results, the concentrations of P, K, Ca, Mg, B, Na, Cu, Fe, Mn, Zn, and Se generally were decreased with increasing water stress in all cultivars. The decreasing rates were 8.87%, 4.38%, 66.32%, 70.83%, 53.74%, 14.78%, 27.44%, 21.32%, 7.29%, 12.31% and 71.30% in P, K, Ca, Mg, B, Na, Cu, Fe, Mn, Zn, and Se, respectively. However, the interaction between water regimes (I) and cultivars (C) were found significant (p<0.01) for all nutrients, except Se (Table 5). The micronutrients as B, Na, Cu, Mn, Zn, and Se are essential to plant life. There are limited studies that contain drought and its effects on micronutrient uptake and metabolism. Also, little attention has been given to these nutrients due to their lower required concentration for plant growth. Our results indicated that there was a general decreasing trend in nutrients in all cultivars due to water deficit which were in agreement with findings of the studies done by several researchers [33,34,35].

**Seed yield and yield components in the dry seed.** Selection criteria for drought resistance in the common bean are crop growth and seed production parameters [36, 37]. Although these parameters reflect plant performance under water stress, many of these are difficult to measure and time-consuming.

Seed yield and its components were illustrated in Table 6. In our results, seed yield and yield components (pod width, pod length, number of pod in plants, number of seed in pods, number of seed in total plant, seed width, seed length, seed thickness, seed yields per plant and 100-seed weight) were decreased depending upon increasing water stress in all cultivars, except number of seed in pods. The decreasing rates were 6.07%, 7.33%, 29.17%, 27.07%, 8.26%, 3.87%, 7.96%, 42.21% and 23.18% in pod width, pod length, number of pod in plants, number of seed in pods, number of seed in total plant, seed width, seed length, seed thickness, seed yield per plant and 100-seed weight, respectively. Among these parameters, the seed yields per plant followed by numbers of pods in plant, number of seed in total plant and 100-seed weight were the most affected yield components under water stress conditions. Bean seed yield reduction due to drought stress are attributed to adverse effects of the stress on individual yield components (pod width, pod length, number of pod in plants, number of seed in total plant, seed width, seed length, seed thickness, seed yields per plant and 100-seed weight). On the other hand, the increasing rate (12.98%) was recorded in number of seed in pods. However, the interaction between water regimes (I) and cultivars (C) was found significant (p<0.01) for the seed yield and yield components, except seed width, seed length and pod length (Table 6). Other researchers reported similar decreases in the water deficit conditions. In a

**TABLE 5**  
**The effects different water regimes on concentrations macro- and micronutrients of common bean (*Phaseolus vulgaris* L.) cultivars in the dry seed**

Treatments	Macro nutrients (ppm)					Micronutrients (ppm)					
	P	K	Ca	Mg	Fe	B	Na	Cu	Mn	Zn	Se
I <sub>1.00</sub> C1	5014 545 <sup>ab</sup>	15222 687 <sup>a</sup>	65159 ac	1710 469 <sup>b</sup>	7414 5 <sup>d</sup>	2350 9 <sup>a</sup>	18139 2 <sup>cd</sup>	8537 a	118 13 <sup>cd</sup>	40109 c	1214 a
74145 <sup>d</sup>	4569 870 <sup>d</sup>	14443 599 <sup>bc</sup>	14081 1 <sup>a</sup>	1579 090 <sup>ef</sup>	5119 8 <sup>h</sup>	1600 9 <sup>b</sup>	24270 9 <sup>a</sup>	6041 c	119 46 <sup>cd</sup>	40393 c	595 <sup>ab</sup>
51198 <sup>h</sup>	3804 868 <sup>f</sup>	15242 295 <sup>a</sup>	11018 7 <sup>ab</sup>	1620 935 <sup>de</sup>	5646 5 <sup>g</sup>	1113 8 <sup>c</sup>	16935 6 <sup>d</sup>	5585 cd	108 97 <sup>efg</sup>	38705 cd	632 <sup>ab</sup>
56465 <sup>g</sup>	4984 648 <sup>b</sup>	14609 707 <sup>b</sup>	81758 ab	1476 812 <sup>g</sup>	1614 46 <sup>a</sup>	9739 cd	22556 2 <sup>ab</sup>	7313 b	139 92 <sup>a</sup>	47047 ab	456 <sup>b</sup>
16144 6 <sup>a</sup>	<b>4593</b> <b>483</b>	<b>14879</b> <b>572</b>	<b>99479</b>	<b>5445</b> <b>383</b>	<b>8581</b> <b>4</b>	<b>1509</b> <b>9</b>	<b>20475</b> <b>5</b>	<b>6869</b>	<b>121</b> <b>62</b>	<b>41563</b>	<b>724</b>
I <sub>0.75</sub> C1	4025 690 <sup>c</sup>	14210 81 <sup>cd</sup>	86461 ab	1873 847 <sup>a</sup>	7648 2 <sup>cd</sup>	9047 de	18023 6 <sup>cd</sup>	4875 f	107 35 <sup>fg</sup>	35504 de	374 <sup>b</sup>
I <sub>0.75</sub> C2	5068 044 <sup>ab</sup>	15324 880 <sup>a</sup>	94207 ab	1579 090 <sup>ef</sup>	6162 3 <sup>f</sup>	9856 cd	21693 9 <sup>b</sup>	4757 f	124 22 <sup>bc</sup>	32925 ef	237 <sup>b</sup>
I <sub>0.75</sub> C3	3924 107 <sup>ef</sup>	14792 259 <sup>b</sup>	13928 3 <sup>a</sup>	1470 947 <sup>g</sup>	7678 0 <sup>cd</sup>	7442 ef	18257 5 <sup>cd</sup>	4953 f	117 11 <sup>ede</sup>	35375 de	800 <sup>b</sup>
I <sub>0.75</sub> C4	5107 699 <sup>ab</sup>	13959 169 <sup>d</sup>	59621 ac	1709 541 <sup>bc</sup>	9720 6 <sup>b</sup>	6189 f	17053 1 <sup>d</sup>	8341 a	128 00 <sup>b</sup>	50046 a	152 <sup>b</sup>
<b>Mean</b>	<b>4531</b> <b>385</b>	<b>14571</b> <b>787</b>	<b>94893</b>	<b>1656</b> <b>599</b>	<b>7802</b> <b>3</b>	<b>8134</b>	<b>18757</b> <b>0</b>	<b>5732</b>	<b>119</b> <b>17</b>	<b>38462</b>	<b>211</b>
I <sub>0.50</sub> C1	4801 248 <sup>c</sup>	15378 697 <sup>a</sup>	25647 bc	1545 131 <sup>f</sup>	6534 7 <sup>e</sup>	7489 ef	18957 3 <sup>c</sup>	5235 def	128 11 <sup>b</sup>	31400 f	168 <sup>b</sup>
I <sub>0.50</sub> C2	3385 833 <sup>g</sup>	13292 659 <sup>e</sup>	15335 c	1655 310 <sup>cd</sup>	6631 5 <sup>e</sup>	7180 f	17395 9 <sup>cd</sup>	3774 g	113 21 <sup>def</sup>	31237 f	296 <sup>b</sup>
I <sub>0.50</sub> C3	3460 164 <sup>g</sup>	14090 151 <sup>cd</sup>	53575 abc	1705 154 <sup>bc</sup>	5948 5 <sup>fg</sup>	7266 f	16811 2 <sup>d</sup>	5377 de	100 77 <sup>g</sup>	46425 b	80 <sup>b</sup>
I <sub>0.50</sub> C4	5133 114 <sup>a</sup>	14146 739 <sup>cd</sup>	39442 bc	1446 567 <sup>g</sup>	7891 3 <sup>c</sup>	5999 f	16631 2 <sup>d</sup>	5549 cd	108 92 <sup>efg</sup>	36714 d	288 <sup>b</sup>
<b>Mean</b>	<b>4195</b> <b>090</b>	<b>14227</b> <b>062</b>	<b>33500</b>	<b>1588</b> <b>036</b>	<b>6751</b> <b>5</b>	<b>6983</b>	<b>17448</b> <b>9</b>	<b>4984</b>	<b>112</b> <b>75</b>	<b>36444</b>	<b>208</b>
<b>*Rate (%)</b>	↓ <b>8.87</b>	↓ <b>4.38</b>	↓ <b>66.32</b>	↓ <b>70.8</b>	↓ <b>32</b>	↓ <b>53.7</b>	↓ <b>14.78</b>	↓ <b>27.4</b>	↓ <b>7.29</b>	↓ <b>12.31</b>	↓ <b>71.3</b>
<b>Water Regimes (I)</b>	**	**	**	**	**	**	**	**	**	**	**
<b>Cultivars (C)</b>	**	**	**	**	**	**	**	**	**	**	*
<b>IxC</b>	**	**	**	**	**	**	**	**	**	**	ns

Water Regimes: I<sub>1.00</sub>: 100%-control of pot/field capacity, I<sub>0.75</sub>: 75% of pot/field capacity, and I<sub>0.50</sub>: 50% of pot/field capacity

Cultivars: C1: "Sarıköz", C2: "Sazova", C3: "Kırk Günlük", and C4: "Gina"

ns: non-significant, \*: significant at P<0.05, \*\*: significant at P<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<sub>1.00</sub> (100%-control of pot/field capacity) and I<sub>0.50</sub> (50% of pot/field capacity): Increase: ↑ and decrease: ↓

**TABLE 6**  
**The effect different water regimes on seed yield and yield components of common bean**  
**(*Phaseolus vulgaris* L.) cultivars in the dry seed**

Treatments	Seed yield and its components									
	Pod width (mm)	Pod length (cm)	Number of pod in plant (Number)	Number of seed in pods (Number)	Number of seed in total plant (Number)	Seed width (mm)	Seed length (mm)	Seed thickness (mm)	Seed yields per plant (g)	100-seed weight (g)
I <sub>1.00</sub> C1	9.84 <sup>abc</sup>	9.17 <sup>ab</sup>	15.00 <sup>ab</sup>	5.00 <sup>a</sup>	46.00 <sup>a</sup>	7.72 <sup>ab</sup>	13.40 <sup>a</sup>	5.35 <sup>cde</sup>	24.24 <sup>g</sup>	10.16 <sup>c</sup>
I <sub>1.00</sub> C2	6.96 <sup>bc</sup>	10.98 <sup>a</sup>	8.00 <sup>ef</sup>	3.33 <sup>ab</sup>	29.00 <sup>d</sup>	7.69 <sup>ab</sup>	12.73 <sup>a</sup>	6.52 <sup>bcd</sup>	49.03 <sup>b</sup>	8.44 <sup>e</sup>
I <sub>1.00</sub> C3	10.29 <sup>abc</sup>	9.78 <sup>ab</sup>	8.00 <sup>ef</sup>	3.00 <sup>ab</sup>	26.00 <sup>e</sup>	8.04 <sup>a</sup>	12.15 <sup>a</sup>	8.76 <sup>a</sup>	95.61 <sup>a</sup>	9.26 <sup>d</sup>
I <sub>1.00</sub> C4	12.76 <sup>a</sup>	9.51 <sup>ab</sup>	17.00 <sup>a</sup>	4.00 <sup>ab</sup>	32.00 <sup>c</sup>	7.77 <sup>a</sup>	11.31 <sup>a</sup>	5.12 <sup>de</sup>	21.33 <sup>h</sup>	13.51 <sup>a</sup>
<b>Mean</b>	<b>9.96</b>	<b>9.86</b>	<b>12.00</b>	<b>3.83</b>	<b>33.25</b>	<b>7.81</b>	<b>12.40</b>	<b>6.44</b>	<b>47.55</b>	<b>10.34</b>
I <sub>0.75</sub> C1	9.97 <sup>abc</sup>	10.80 <sup>a</sup>	13.00 <sup>bc</sup>	5.33 <sup>a</sup>	48.00 <sup>a</sup>	7.18 <sup>ab</sup>	11.19 <sup>a</sup>	5.19 <sup>de</sup>	22.09 <sup>h</sup>	7.20 <sup>h</sup>
I <sub>0.75</sub> C2	9.67 <sup>abc</sup>	9.46 <sup>ab</sup>	11.00 <sup>cd</sup>	3.66 <sup>ab</sup>	15.00 <sup>f</sup>	6.50 <sup>b</sup>	12.82 <sup>a</sup>	7.83 <sup>ab</sup>	29.11 <sup>e</sup>	6.19 <sup>i</sup>
I <sub>0.75</sub> C3	9.39 <sup>abc</sup>	8.20 <sup>ab</sup>	7.00 <sup>efg</sup>	4.66 <sup>a</sup>	25.00 <sup>e</sup>	8.05 <sup>a</sup>	12.30 <sup>a</sup>	5.78 <sup>cde</sup>	35.62 <sup>d</sup>	7.47 <sup>g</sup>
I <sub>0.75</sub> C4	10.57 <sup>ab</sup>	9.55 <sup>ab</sup>	11.00 <sup>cd</sup>	3.00 <sup>ab</sup>	41.00 <sup>b</sup>	7.45 <sup>ab</sup>	12.70 <sup>a</sup>	5.92 <sup>cde</sup>	42.22 <sup>c</sup>	11.22 <sup>b</sup>
<b>Mean</b>	<b>9.90</b>	<b>9.50</b>	<b>10.50</b>	<b>4.16</b>	<b>32.25</b>	<b>7.30</b>	<b>12.25</b>	<b>6.18</b>	<b>32.26</b>	<b>8.02</b>
I <sub>0.50</sub> C1	6.45 <sup>c</sup>	10.23 <sup>ab</sup>	6.00 <sup>fg</sup>	5.33 <sup>a</sup>	25.00 <sup>e</sup>	6.69 <sup>ab</sup>	11.34 <sup>a</sup>	5.53 <sup>cde</sup>	15.00 <sup>i</sup>	6.06 <sup>i</sup>
I <sub>0.50</sub> C2	12.71 <sup>a</sup>	8.76 <sup>ab</sup>	5.00 <sup>g</sup>	4.33 <sup>a</sup>	16.00 <sup>f</sup>	7.61 <sup>ab</sup>	12.23 <sup>a</sup>	6.79 <sup>bc</sup>	41.29 <sup>c</sup>	7.84 <sup>f</sup>
I <sub>0.50</sub> C3	9.95 <sup>abc</sup>	7.64 <sup>b</sup>	9.00 <sup>de</sup>	4.66 <sup>a</sup>	8.00 <sup>g</sup>	7.56 <sup>ab</sup>	12.43 <sup>a</sup>	6.61 <sup>bcd</sup>	29.91 <sup>e</sup>	7.64 <sup>g</sup>
I <sub>0.50</sub> C4	8.32 <sup>a</sup>	9.92 <sup>ab</sup>	14.00 <sup>b</sup>	3.00 <sup>ab</sup>	48.00 <sup>a</sup>	6.78 <sup>ab</sup>	11.67 <sup>a</sup>	4.77 <sup>e</sup>	27.37 <sup>f</sup>	10.24 <sup>c</sup>
<b>Mean</b>	<b>9.36</b>	<b>9.14</b>	<b>8.50</b>	<b>4.33</b>	<b>24.25</b>	<b>7.16</b>	<b>11.92</b>	<b>5.93</b>	<b>27.48</b>	<b>7.95</b>
<b>*Rate (%)</b>	<b>↓ 6.07</b>	<b>↓ 7.33</b>	<b>↓ 29.17</b>	<b>↑ 12.98</b>	<b>↓ 27.07</b>	<b>↓ 8.26</b>	<b>↓ 3.87</b>	<b>↓ 7.96</b>	<b>↓ 42.21</b>	<b>↓ 23.18</b>
<b>Summary of ANOVA</b>										
<b>Water Regimes (I)</b>	ns	ns	**	ns	**	*	ns	ns	**	**
<b>Cultivars (C)</b>	ns	*	**	*	**	*	ns	**	**	**
<b>IxC</b>	**	*	**	**	**	ns	ns	**	**	**

Water Regimes: I<sub>1.00</sub>: 100%-control of pot/field capacity, I<sub>0.75</sub>: 75% of pot/field capacity, and I<sub>0.50</sub>: 50% of pot/field capacity

Cultivars: C1: "Sarıköz", C2: "Sazova", C3: "Kırk Günlük", and C4: "Gina"

ns: non-significant, \*: significant at P≤0.05, \*\*: significant at P≤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<sub>1.00</sub> (100%-control of pot/field capacity) and I<sub>0.50</sub> (50% of pot/field capacity): Increase: ↑ and decrease: ↓

study in two bean cultivars under drought stress conditions, parameters such as height, number of leaves, leaf area, number of pods, pod dry matter and total plant weights of both cultivars were significantly decreased [38]. Overall when considered seed yield components, all parameters decreased with the increasing water deficit. Also, plant response to water stress depends mainly on the severity and duration of the stress and the growth

stage of the plant [39]. In addition to this, the drought stress can reduce biomass, number of seeds and pods, days to maturity, harvest index, seed yield, and seed weight in a bean [40]. These findings of our study are in agreement with the results of the studies done by several researchers [41,42,37,43,38], who reported that bean seed yield reduction due to drought stress is attributed to the adverse effects of stress on individual yield components (number of

Pods per plant, number of seeds per pod, seed weight and harvest index).

Also, the relative importance of individual components as determinants of seed yield varies from experiment to experiment. In parallel with these findings, water stress significantly but differentially affected in different plant growth stages and yield components of the four common bean cultivars in our study. In another studies also reported that the plant response under water limiting conditions generally varies from species to species depending on plant growth stage and other environmental factors [44,45].

## CONCLUSIONS

This study was conducted to determine the effects of water deficit on the concentrations of macro- and micronutrients of common bean cultivars in pot experiment in a greenhouse and to identify seed yield and yield components responses of common bean cultivars to water stress. In our study, it was found that water stress significantly but differently affected the growth, seed yield components and the concentrations of macro- and micronutrients of the four different bean cultivars. Although the seed yield and yield components of the varieties and the concentration of macro- and micronutrient elements varied depending on the increasing water stress level, it was determined that cv. "Gina" gave better results in terms of growth parameters. However; the highest values were obtained in the cv. "Sazova" variety in terms of seed yield components in the dry seed parameters under the maximum water stress ( $I_{0.50}$ ). In fresh pod, cv."Gina" has come to the fore in terms of macro and micro elements (P, K, Ca, Mg, B, Cu, Mn and Se) under the maximum water stress ( $I_{0.50}$ ). Similarly, cv."Gina" was released mainly foreground in terms of growth parameters (pod width, pod length, number of pods in the plant and number of seed in total plant) and macro- and micronutrients in terms of (P, Cu, F, and S) under the maximum water stress ( $I_{0.50}$ ). Based on the data of this study, it can be said that cv."Gina" is more tolerant to water stress. The use of drought-tolerant cultivar of common bean can produce more yield with less water; thereby improves water productivity for efficient use of water resources.

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